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Investigating the Effects of Modularization in Business Process Models on the Cognitive Complexity of Humans

Master's thesis at Ulm University

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Abstract

Process models enable a better understanding of processes in enterprises as the processes are visualized step by step. This is due to the fact that process models provide precise knowledge with respect to the process through sequential linking of activities. Understanding of the process model is essential for both modelers and readers of a process. The complexity of process models has a direct effect on how comprehensible they are. Modularization is an approach for reducing the complexity. It can be applied in three different ways. Depending on the intended purpose, the design varies. Furthermore, the various modularization approaches for business process models can have implications on the cognitive complexity for humans as individuals. This thesis is based on psychological and neuroscientific cognitive concepts to gather findings through studies.

A survey and an eye tracking study were designed and conducted to obtain insights in terms of the cognitive load when individuals with little experience read different modularized business process models. The survey focuses on the cognitive load and understandability while reading business process models. As a single factor between subject study design was applied, a subdivision into three groups (one group for each modularization approach) was utilized. In contrast to the survey, the eye tracking study, with its 3x3 within subject design, provides insights into the performance success (number of correct answers, required time). Further, design variants of the single modularization approach are comparable.

The results of the survey and the eye tracking study indicate one significant difference. This difference is based on the intrinsic cognitive load measured in the survey. Vertical modularization provides a significantly higher intrinsic cognitive load compared to the other approaches in business process modeling. However, as no further differences arose, the utilization of modularization approaches in business process modeling has no impact in terms of understandability of the process model.

Acknowledgment

At this point I would like to thank all the persons that helped me in creating this thesis.

First, I want to thank the reviewers Prof. Dr. Manfred Reichert and Dr. Rüdiger Pryss, through whose consent the realization of this thesis was possible.

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Finally, I would like to thank all participants of the survey and study.

Contents

1

Introduction

Section 1.1 addresses the motivation that led to the preparation of this thesis. Further, the problem is stated. In Section 1.2, the objectives of this thesis are explained. Finally, the structure of this thesis is described in Section 1.3.

1.1 Motivation and Problem Statement

Business process models, e.g. in terms of incident management, can be complex [1, 2, 3], even more complex than their underlying business processes [4]. As stated by [4], *'Complexity has undesirable effects on, among others, the correctness, maintainability, and understandability of business process models'*. Furthermore, the size of the process model and its understandability are related [5, 6]. A large process model in terms of size causes difficulties in reading. This is, for example, caused by errors that appear more frequently in larger business process models [6]. Minimizing the size shouldn't be realized through omission of relevant process parts [7, 6]. Therefore, the creation of process models that are understandable, complete with respect to the relevant parts, and maintainable, has to be covered by modularization. Modularization exists to decompose an element into smaller units. It provides flexibility in terms of its parts as each unit is intrinsically complete [8] and interchangeable [9]. Most research regarding modularization of business process models has a conceptual nature [10, 11]. By contrast, the objective of this thesis is to obtain insights through eye tracking with respect to the resulting cognitive load while reading business process models based on different modularization approaches. Measuring cognitive load of business process models using eye tracking technology is a research subject of the DBIS (Databases and

Information Systems Department) at Ulm University. In their research, business process models were, for example, compared with regard to their basic activities. However, modularization was not considered under this aspect. Even though a lot of research about modularization of business process models is already established [11], various problems still exist. On the one hand, business process modelers and/or users aren't inevitably experienced in modularization. On the other hand, a lot of scientific research is missing in certain research fields. As an example, different activities can be applied to model the same matters; however, extensive research in terms of their impact on the models' understandability is missing. In terms of modularizing business process models, a paper from [1] compares the usability of three different modularization approaches. The participants that assessed the usability were experts. Consequently, novices were not included in the evaluation. Therefore, basic understandability of the subdivision and statement quality aren't given, as it requires the inclusion of novices. Hence, instead of usability, the cognitive load is measured in this thesis.

1.2 Objective

The objective of this thesis is to compare horizontal, vertical, and orthogonal modularization, the three modularization approaches extracted from [1]. Therefore, the graphical representation, predominantly based on the examples of business process models available in [1], will be discussed. Additionally, representations that are stated in [1] will be part of the discussion. The representation differs regarding the activities that can be applied for modularization in business process models. As an example, different events that vary with respect to the icons can be utilized. The various representations could cause effects on the understandability and the cognitive load. Instead of evaluating the usability of modularized business process models, cognitive load will be measured through a survey and an eye tracking study. Both times the participant has to answer questionnaires about the cognitive load while reading BPMN 2.0 process models. Through the study, insights are given that offer evidence indicating the difficulties and challenges of each modularization approach. Furthermore, hints advising the modeler and reader of process models could be prepared based on these results. Further, possible icon changes are prepared that could cause an easier understandability and navigation in modularization, next to linking.

1.3 Structure of the Thesis

Chapter 2 focuses on modularization in business process models. An explanation regarding business process models is provided. Besides, it specifies how complexity, redundancy, and further aspects can be handled. Therefore, different modularization approaches are presented. In **Chapter 3**, insights into the cognition with respect to complexity are provided. Thereby, the cognitive complexity and cognitive load theory are described. Further, the relation between eye behavior and cognitive load is given. Superficially these factors are part of the measurements in the studies. With respect to the survey and the eye tracking study, the studies are planned and designed properly in **Chapter 4**. The goal of this chapter is the acquisition of insights based on measurements that were gathered while participants read modularized business process models. Moreover, the formulating of hypotheses, setup and design of the study, risk analysis, and the avoidance of risks are addressed. Afterwards, the study operation is presented in **Chapter 5**. First, the study preparation is reported. It includes pilot studies and the recruitment process of participants. Then, the structure for running the studies is described. Finally, this chapter provides first insights regarding the evaluated data. This data is comprised of independent variables and attributes of the participant like the age. In **Chapter 6**, the study is analyzed and interpreted. First, the used data set reduction is provided. Then, the explained hypotheses are tested with reference to the results received from the studies. A discussion based on the obtained results is carried out. Thereby, the reasons that led to the results are discussed. **Chapter 7** examined related work. Finally, **Chapter 8** presents further research and summarizes this thesis.

2

Modularization of Business Process Models

The thesis considers modularization in business process models. Therefore, it is necessary to examine modularization and business process models theoretically and through exemplifications. Section 2.1 introduces business process models. Its modularization is described in Section 2.2.

2.1 Business Process Models

A process is a set of activities [12, 13]. Activities are elements like events, gateways, and tasks with a defined design and function. Further, they are composite units executed in a workflow. Each process has a beginning and an end. In addition, it includes a structure related to the 'how' an organization accomplishes [13] and a defined goal [14]. This shows that the management of operations and the structuring of work is necessary [15]. Therefore, concepts [16], methods, tools, and principles [15, 17] are applied.
Through optimized business processes, organizations can save time, money, and increase customer satisfaction [18]. An approach for optimizing business processes can be the BPM life-cycle [2]. Through its steps, process models are analyzed, designed, implemented/reconfigured, enacted, and monitored [2, 19]. This shows the need of business process models which are the *'lion's share of bpm (..) literature'* regarding to [15].

In literature, thematic areas like similarity, complexity, and design are researched. Superficially business process models are, for example, useful for the design and inspection of Process Aware Information Systems (PAIS) [20, 21], process automation [16], and Service Oriented Architectures (SOA) [22, 23, 24]. PAIS are software systems that handle processes through process models [25]. SOA support a unit composition of interacting services with reference to the restructuring in infrastructures and applications of software [26]. A business process model is a graphical representation of a process. It provides insights into the process by linking single activities. Thereby, the text is reduced to a minimum. Instead, a narrative text that is more difficult to understand [27] can be utilized. Hence, it serves the purpose to be understood by different involved stakeholders [2, 28], and it offers an extensive understanding of a process [12, 29]. Based on a study, [30] discussed, among other things, the above mentioned benefits regarding the targets of design and inspection, next to the understandability. However, they also refer to the improvement and communication of process modeling.

While business process models are only useful if they are understood by people, an explanation of the basic elements is provided in the business process modeling notation BPMN 2.0 [31].

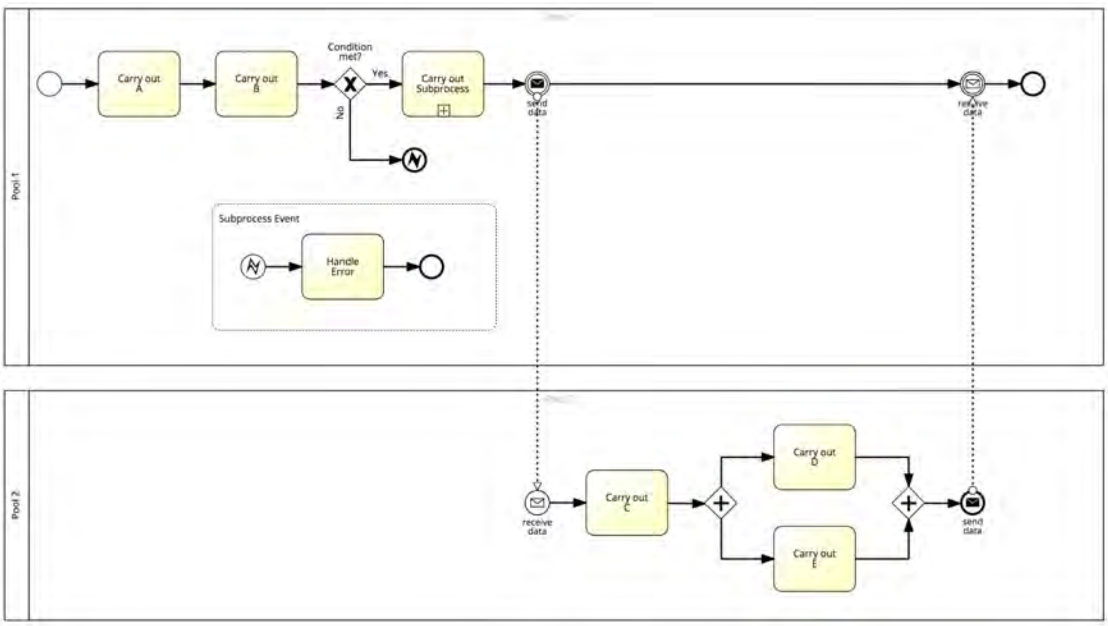

Figure 2.1: Basic Elements of BPMN 2.0 Models

Figure 2.1 shows a BPMN 2.0 business process model that is split up into two pools (Pool 1 and Pool 2). A pool represents a responsible process-participant that handles the process in its progress [32]. A process-participant can be a role, an organization, or a system [33]. In a pool, a process model is displayed horizontally, and has a process flow direction represented by arrows. Each process has a start event that triggers the process. The start event is followed by an activity, in this case the task *Carry out A*. A task is an element that includes the 'to do' at this point. After task *Carry out A*, *Carry out B* has to be executed. Afterwards, a decision has to be made. It is represented by the rhombus that includes the 'X'. Based on the decision, it is possible to run the path *yes* or *no*. If *no* occurs, the process leads to an error end event that throws an error. However, a crossover to the *Subprocess Event* is executed. The *Subprocess Event* is situated in the dotted lined edging (located in Pool 1), and indicated by its name. After running the subprocess, the whole process is completed. If instead of *no*, *yes* occurs, the process runs a subprocess task. A subprocess task is represented by the '+' icon in the bottom center of the task. Underneath this task, a further complete process is given. After running the underlying process, the intermediate message event *Sent data* is executed. Using a sequence flow (the dotted arrow), this event calls the message start event *receive data* located in Pool 2, so that the process in Pool 2 is triggered. After the message event, the task *Carry Out C* is executed. After that, a gateway is given. A gateway refers to a decision. Different gateways exist. The gateway in the process model is an AND-Gateway represented by a rhombus with a '+' inside. The AND-Gateway requires the execution of both paths; however, the execution does not have to run in parallel. Hence, next to *Carry out D*, *Carry out E* has to occur, before the process of Pool 2 is finished and the data can be sent to Pool 1. Back in Pool 1, the process is finished after receiving the data. This is visualized through the end event.

Even though further business process modeling notations like EPC [34] and FlowChart [35] exist, merely the BPMN 2.0 notation will be mentioned and presented in this thesis. BPMN 2.0 is selected because it is the leading standard due to its frequent utilization in business [36]. Therefore, it is suitable for this survey and eye tracking study. Independent of the business process modeling notation, criteria for a good process model exist. These criteria are comprised of, for example, the correctness [37, 38, 39] and design.

In terms of design, [40] focuses on the modeling of business processes. They defined guidelines to achieve a process model that is well structured, understandable, and correct. Therefore, the focus is, for example, given in decomposing models with more than 50 elements. Decomposition means dividing a unit into subdivisions. As a large model can be decomposed into single modules, the ensuing section provides insights into the subject of modularization.

2.2 Modularization

Modularization is covered in literature since 1960 [41], and represents the decomposition of a larger unit (e.g. a process model) into individual modules (e.g. multiple small process models) [8]. Each module is an element that is independently manageable [11], interchangeable [9], and intrinsically complete [8]. It interacts at particular interfaces with other modules [42]. The concept of modularization can be found in different fields. Next to products, programming, and systems, it is used in business processes [1, 43]. In Figure 2.2 a modular subdivision extended by modules is described. At the beginning, the modular approach with four tiles is extended by three modules. This leads to eight variants. Each variant stands for a possible usage. If the modular approach is extended by another module (module four), eight additional variants can be generated. Therefore, totally sixteen variants are possible. Through this example, it becomes clear that modules can interact with each other, even though they are independent. Additionally, changes in a module or the replacement of a module can be handled easily.

This thesis is focused on the utilization of modularization techniques in terms of business process modeling. Modularization is utilized to handle complexity [45]. As stated by [46], *'the degree of complexity management varies according to the ability of a notation to represent information without overloading the human mind'*. Next to complexity, modularization is used to minimize the size [47], and to handle flexibility [48] of process models. Therefore, modularized process models tend to be less error prone and more

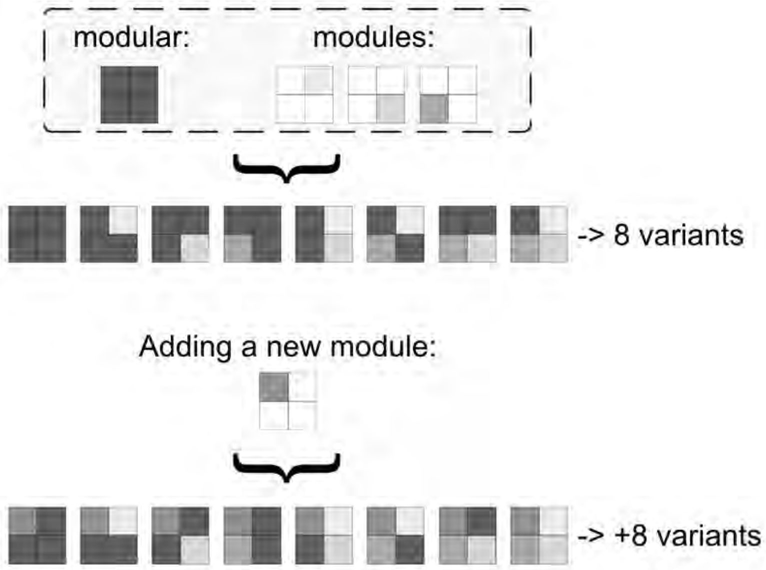

Figure 2.2: Modular Subdivision [44]

understandable [4]. Further, modularization supports reusability and maintainability [1]. All these items require successful modularization. Different aspects have to be considered in realizing a successful modularization. These aspects are operations, selections, and prerequisites [11]. While [11] refer to the 'when' (e.g. number of elements) and 'what' (e.g. selection of parts of a model that can be modularized), models have to be modularized through modularization selection and prerequisites. [11] mentions that basic operators lead to a syntactical correctness with reference to operations. Syntactical correctness bases on notational rules and, hence, the modeling syntax is understood [14].

Next to the 'when' and the 'what' has to be modularized, additionally the 'how' is of interest. With respect to the 'how', different possibilities of modularization exist. These possibilities fulfill various purposes and can be combined in process models. In scientific research, only vertical and horizontal modularization are mentioned. Therefore an example is provided in the paper [46]. [1] states another approach of modularization: the orthogonal modularization.

The three modularization approaches are presented below.

2.2.1 Vertical Modularization

Vertical modularization, also called *hierarchical structuring* [49], is the decomposition of a process model into subprocesses. Corresponding to this foundation of modularization, a hierarchical structure is given [1]. While the main process has a high abstraction level, the underlying subprocesses are more refined [50]. This leads to the benefit that a single module in form of a subprocess can be maintained [1, 51], as well as continuously and separately proved. Additionally, the possibility of reusage is given. Hence, redundancies are improved [1]. By changing the activities of one subprocess, the change will be addressed by all processes that call the subprocess. However, the reusage depends on how the overlying process is subdivided. In scientific research, the differentiation between embedded and independent subprocesses is considered [52, 53, 54]. An embedded subprocess is part of the overlying process [52, 53, 55] and not reusable [55]. In contrast, the independent approach can be called by diverse processes [53, 54] and is self-contained to the overlying process [52]. The realization of vertical modularization can be handled in BPMN 2.0 through collapsed and expanded subprocesses [1, 47]. An example is shown in Figures 2.3 and 2.4. In both figures, a process model is divided up into detailed processes. Figure 2.3 represents modularization through collapsed subprocesses. Collapsed subprocesses are realized in a self-contained model and have an information hiding quality. The calling task has an icon in the form of a '+' to address a process given in another level. In the representation of collapsed subprocesses the suggested number of levels by [56] is between three and seven, and should be observed.

In contrast to collapsed subprocesses, expanded subprocesses are groups in a process model. Hence, they are positioned on the same level, as presented in Figure 2.4. [47] compared the two forms, and reported that expanded subprocesses (with a solid line between the parent and subprocess) provide a better understandability.

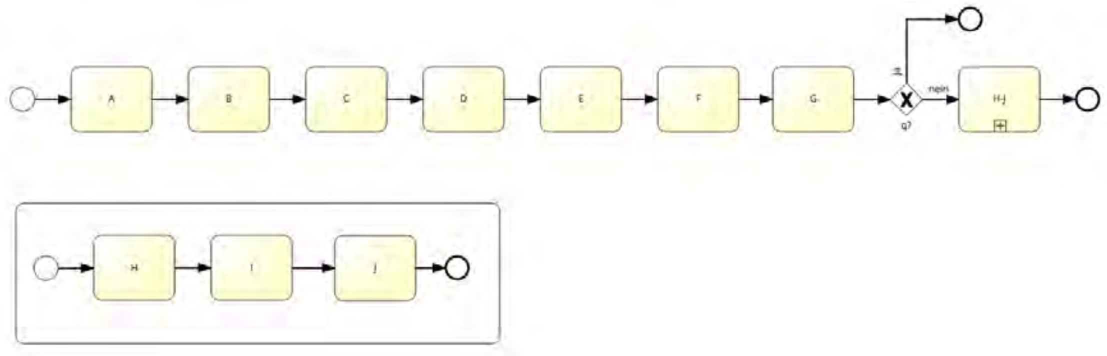

Figure 2.3: Collapsed Subprocesses in Vertical Modularization

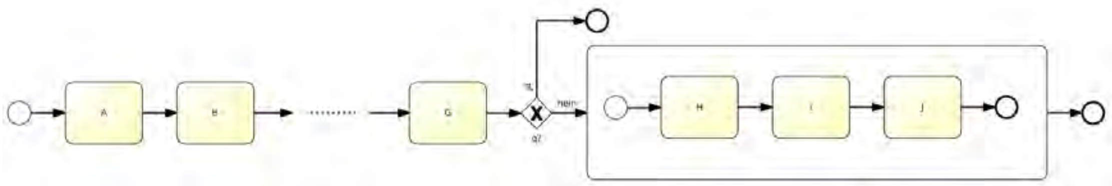

Figure 2.4: Expanded Subprocesses in Vertical Modularization

2.2.2 Horizontal Modularization

Horizontal modularization (i.e. *horizontal segmentation* [57]) has the objective to deduct a model into various small models [1] with the same abstraction level [58]. It is utilized to address benefits like reusability, and to decrease complexity by building models with almost the same size [1]. Reusage is given when different processes interact with the same process using the same interfaces.

In BPMN 2.0 it is realized through pools. The interaction between individual pools is given by activities. An end or intermediate event of one pool calls a start or intermediate event in another pool. Message, link, and signal events find use in horizontal modularization [1]. The message event is presented in Figure 2.5, and the link event is depicted in Figure 2.6. A message event is the sending of messages [33]. This is shown in Figure 2.5, and clarifies that an interaction between two pools occurs through a message flow. The message end event of Pool 1 calls the message start event of Pool 2.

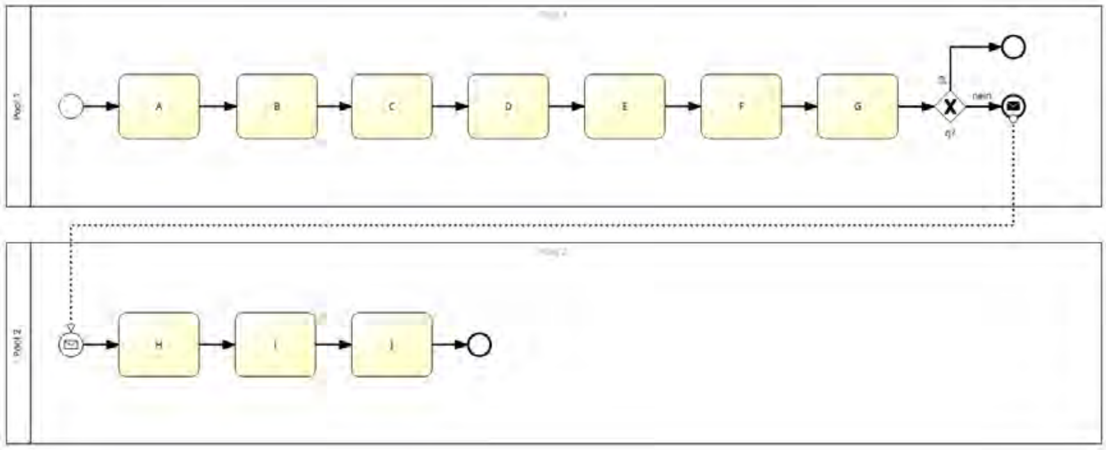

Figure 2.5: Message Event in Horizontal Modularization

In Figure 2.6, the link event is given multiple times, as each link event refers to a subprocess. In this figure, link event *2* is focused because it refers from Pool 1 to Pool 2.

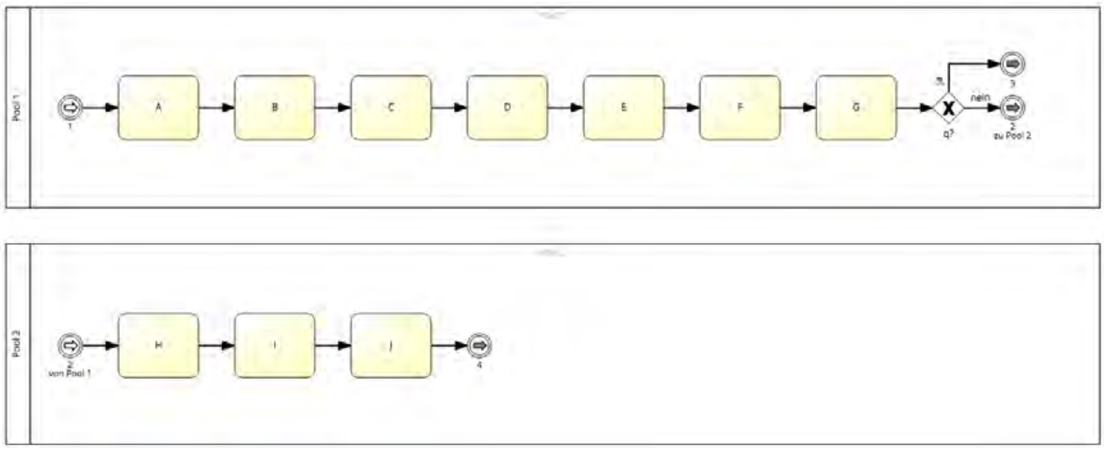

Figure 2.6: Link Event in Horizontal Modularization

2.2.3 Orthogonal Modularization

The orthogonal modularization is based on exceptions and further crosscutting concerns [1]. At crosscutting concerns, such as security aspects [1], the modular process-structure can not be observed. Hence, the elements placed on (different) processes have to be cut across the structure [59]. Efficient modularization through other approaches would be difficult [43]. To handle orthogonal modularization, various realization opportunities exist. On the one hand, exceptions can be realized through event subprocesses [1]. As stated by [52], they can be classified into:

- An event inside the subprocess that triggers an event (e.g. end error event) of the overlying process after reaching a special element
- An exception triggered at any point in time caused by an external event (e.g. timeout)

For exception handling, [60] lists end events such as: *error*, *cancel*, and *compensate*. The mentioned events trigger a start event in another pool. An example is presented in Figure 2.7. At the beginning, the process in Figure 2.7 is sequentially executed. Then, the XOR-Gateway, referring to a decision between two paths, is executed. When *q?* is *ja* the process is finished. Otherwise, when *q?* is *nein*, an exception has to be handled. The error end event triggers the process that is necessary for exception handling. This process is placed in an event subprocess called *Event* in Figure 2.7. An event subprocess is represented by a rectangle with a dashed border. The process that has to be executed starts with an error start event process, as it is called by an error event. Thereafter, the process is executed and finishes through the end event given in the event subprocess.

A further form of presentation of exception exists. [60] refers to the fact that exceptions can be thrown from a subprocess to the overlying process. As presented in Figure 2.8, elements of the vertical modularization are given. First, the overlying process triggers the subprocess. The activities of the subprocess are executed. When *q?* is *ja*, both processes are finished. Otherwise, when *q?* is *nein* the error end event triggers the intermediate error event that is attached onto the edge of the subprocess task. Then, the following process is executed according to the workflow.

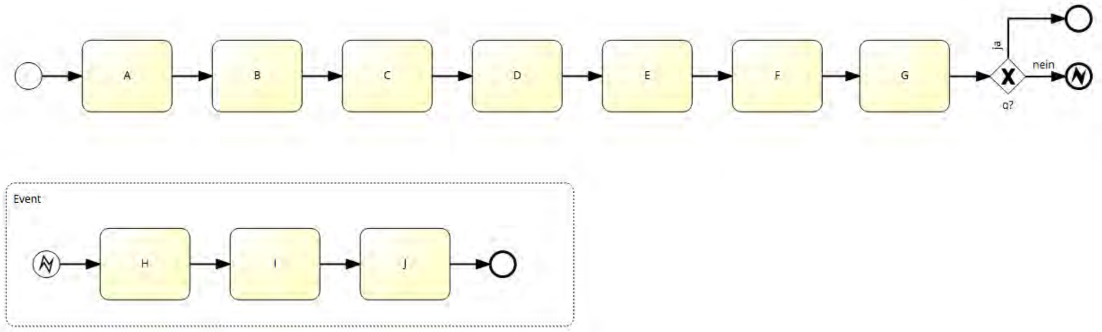

Figure 2.7: Exception Handling through Interrupting Event I in Orthogonal Modularization

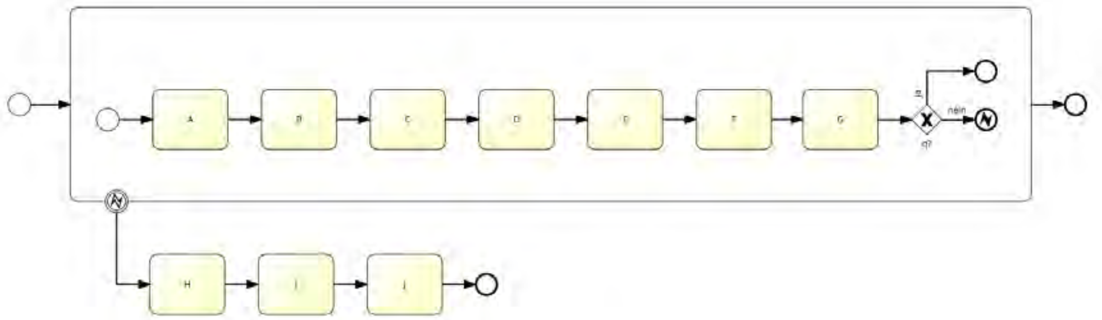

Figure 2.8: Exception Handling through Interrupting Event II in Orthogonal Modularization

Exceptions can be handled through interrupting or non-interrupting event subprocesses [1]. In both examples, the interrupting event subprocess is shown.

On the other hand, it can be realized by aspect-oriented paradigms [1]. This approach is based on the fundamentals of aspect-oriented programming [1, 43]. It provides the benefits such as handling security aspects [1, 61].

[59] utilize the term *aspect oriented process modeling language* that has a strategy where all concerns are processed in the same way. Differences in processing only occur in the relationships. As stated by [43], business processes can be divided, through aspect-oriented modularization, into:

- The basic BP (core process) which contains the essence of the BP
- The aspect process which captures the crosscutting information cutting across the core process

In BPMN 2.0 the composition of the aspect-oriented process modeling language is by '*a process model described using any language for modeling processes*' [59].

The process in executing aspect-oriented paradigm is explained to the example of Figure 2.9.
The process is executed and reaches the activity *H* that includes a pointcut, after selecting the path *nein* of the XOR-Gateway *q?*. A pointcut provides the possibility to select one or more join points [61]. In Figure 2.9 only one join point is referenced by *H*. This join point is in the advice (a module that captures the crosscutting concern [61]) *Event*. The join point in the advice is the start event *Trenn Punkt*. After the join point *Trenn Punkt* is triggered, the process inside the advice is executed. At the end of the modularized process, a join point *Zusammenführungs Punkt* is given that leads to the activity *J* of the main process. The representation is in the modeling notation BPMN 2.0. Contrary to the example, no symbols are given to represent the aspect-oriented modularization.

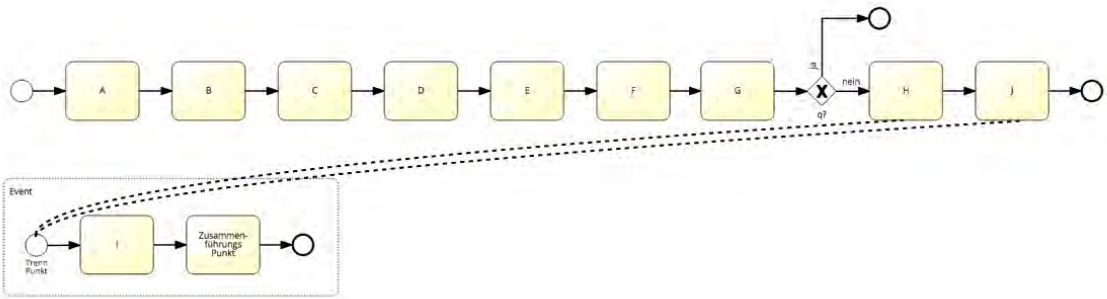

Figure 2.9: Aspect-Oriented Approach in Orthogonal Modularization

3

Fundamentals of Cognitive Complexity

Understandability as well as an easy and efficient coping of the information presented are important in dealing with business process models. Hence, an introduction of human cognitive complexity is presented in Section 3.1. In Section 3.2, the cognitive load and the sources of impact are given. Finally, cognitive load by the pupil, with reference to eye tracking, is addressed in Section 3.3.

3.1 Human Cognitive Complexity

[62] stated the term *cognitive complexity* in 1955. Cognitive complexity has different meanings, as there is no clear theoretical definition given [63]. Further, it is adopted in many research fields. Descriptions of cognitive complexity exist, such as this definition from 1962:

'Cognitive complexity is defined as the number of independent dimensions-worth of concepts the individual brings to bear in describing a particular domain of phenomena; it is assessed with a measure of information-yield based on an object-sorting task' [64].

As stated by [65], the main factor of cognitive complexity is the information processing through individual personality structures, that are based on experiences [66] of individuals, for example. Human information processing is based on external input. Therefore, different models with respect to information processing exist. One of the first models is from [67]. They designed a model with interacting items. These items are: *sensory register*, *short-term store*, and *long-term store*.

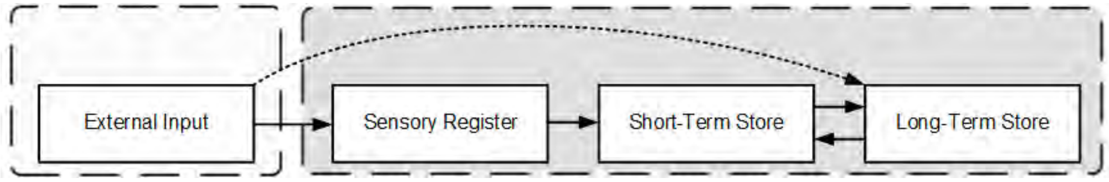

Figure 3.1: Structure of the Memory System [67] (simplified)

As shown in Figure 3.1, external input is recorded by a human. This is realized by attentioning, recognizing, and searching [68]. After acquisition of the external input, the acquired information is transferred to the short-term store in form of code or the interpretation of external input [69]. The information may be forgotten after a while since the capacities of the short-term store are limited [70]. This limitation is not necessarily given [71]. However, information is temporarily stored [72]. Furthermore, the information from short-term store can be transferred in form of a copy to the long-term store. The likelihood that information will be transferred increases with its longer presence in the short-term store [69].

So far, the 'how' in information processing was presented. Further, the complexity is relevant in cognitive complexity. The complexity is distinguished through three items [73]. These items are *integrity*, *sophistication*, and *discrimination*. [73] argues that discrimination and sophistication are based on the capacity regarding the areas of assessment and distinction. On the other hand, [73] shows that the integrity picks out an overall evaluation on the basis of isolated information as a central theme. To measure the complexity, metrics in form of cognitive weights can find use [74]. They capture the efforts that are necessary for successful performance. An example is offered in Table 3.1. The table contains weightings that relate to the understandability of business process modeling elements. A low weighting shows that the pattern is easily understandable and less complex while a high weighting points out less comprehension. While a sequence in the business process modeling notation YAWL is well understood, an OR-split leads to a reduction of comprehension. Therefore, the authors of [74] argue that AND/XOR are significantly higher in comprehension than OR. To measure cognitive complexity, inter alia, complex units are used with regard to cognitive weighting, difficulty

Workflow Pattern [3]	**BPM control structure**	**corresponding software control structure**	**W**
Sequence	consecutive steps in a workflow	sequence	1
Exclusive Choice	XOR-split (exactly one of two branches is chosen) with corresponding XOR-join ...	branching if-then ...	2
	XOR-split (exactly one of >= 3 branches is chosen) with corresponding XOR-join	branching with case (with an arbitrary number of selectable cases)	3
Parallel Split and Synchronization	An AND-split activates all outgoing links in parallel, a corresponding AND-join synchronizes the lows of control	execution of control flows in parallel	4
Multiple choice and Synchronizing Merge	OR-split (a number of branches is chosen from 2 or more possible branches) with corresponding OR-join	branching with case, followed by parallel execution	7
(none)	Composite task (subtask, can be used for decomposing a BPM into modules)	call of a user-defined function	2
Multiple Instances Patterns	Multiple Instance Activity (allows multiple instances of an activity to run concurrently	branching, followed by parallel execution	6

Table 3.1: Cognitive Weights W for BPM Elements [74]

of understanding, or the load that is a result of the limited capacities in information processing. This is, for example, given in the paper [3]. The authors argue that high cognitive effort is necessary to understand the elements of, and their relation in, process models. Additionally, they point out that they set up business process modeling metrics to determine the understandability for measuring necessary factors of cognitive load. Further, they show why the cognitive load theory is suitable in this context. Therefore, they argue *'that understanding of a fact in a BPM becomes more difficult if the number of model elements that need to be attended to increases. This is backed by the work on Cognitive Load Theory'* [3]. Even [75] points out that the cognitive load theory deals with understanding, learning, and complexity.

Next, the cognitive load theory is presented below, as this thesis deals with the cognitive capacity in terms of comprehensibility while reading business process models.

3.2 Cognitive Load Theory (CLT)

A requirement for coping with business process models is that they are understandable and easy to process. In this context, the human working memory system has to handle the perceived information. Hence, the cognitive load theory of [76] can be applied. This theory was generated to support the activities in learning through guidelines on how information can be presented in order to support a better intellectual effort [77].

'Cognitive load theory (CLT) is a learning and instruction theory that describes instructional design implications of a model of human cognitive architecture based on a permanent knowledge base in long-term memory (LTM) and a temporary conscious processor of information in working memory' [78].

The capacity of the human memory system is limited [79]. This is one of the assumptions on which the CLT is based. [80] generated a graphical representation that is provided in Figure 3.2. This representation includes the scheme construction of central learning processes, next to the already mentioned limited capacity of the working memory.

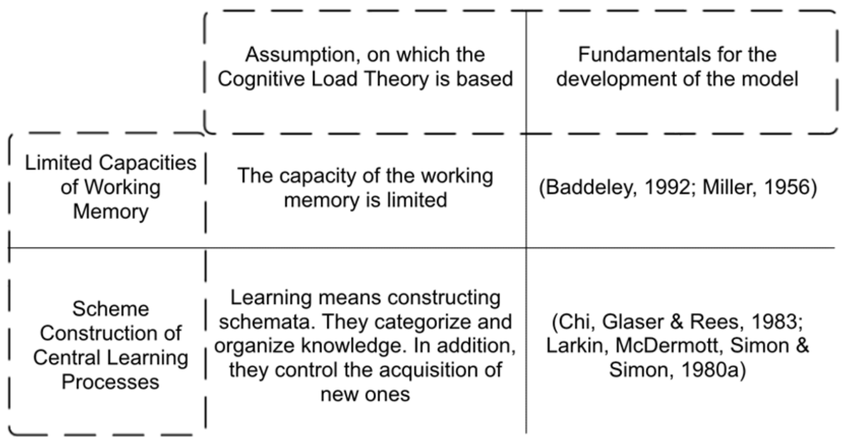

Figure 3.2: Theoretical basis of the Cognitive Load Theory of [80]

The CLT addresses the topic cognitive load, which can be divided into the mental sources of impact: *intrinsic*, *extraneous*, and *germane cognitive load*, according to [77]. They are discussed in detail below.

- Intrinsic Cognitive Load (ICL)
  This source of impact deals with the intrinsic information complexity [81]. Their focus is on the complexity, difficulty, and scope of a task [80]. In literature, two factors with an effect on intrinsic cognitive load are mentioned: element interactivity and the prior knowledge of the learner. An example for element interactivity exists

in language learning. [82] points out that low element interactivity is given when a person has to repeat single vocabularies. Therefore, they argue that element interactivity is higher by using the right grammar in generating sentences. It becomes obvious that element interactivity should be low. Low element interactivity is better understandable and separately learnable [83], as the learners don't have to link all of the elements with other elements [84]. However, high element interactivity causes high cognitive load [84]. In the following, an example in context of business process models is presented. Single parts of a process can be independently understood.
Prior knowledge of learning is the experience that a learner has during the interaction with materials that have to be learned. As an example, an expert in business process modeling and reading can construct chunks. Hence, there's no need to memorize the single elements.

- Extraneous Cognitive Load (ECL)
  This source of impact deals with the design of materials provided to the learner [82, 85]. It is reduced when progresses are simplified by the design. In business process models it is dealt with using symbols of the modeling notation, the execution direction, and the complexity.

- Germane Cognitive Load (GCL)
  This source of impact deals with knowledge acquirement [80] and the necessary consumption of cognitive resources for appropriation of learning content [86]. To receive high germane cognitive load, learners have to be dedicated, and lead their mental model to the progress of learning [82]. Therefore, the behavior while learning is necessary to receive good results while reading a business process model.

The composite load of the three mentioned types can't transcend the memory resources, because they are additive [87]. This means that the loads relate to each other and that a load capacity exists. [88] points out that there is a need to know the level of the learners knowledge. Hence, the intrinsic, germane, and extrinsic cognitive load can lead to the right learning outcomes. Further, the germane cognitive load should be high, as it is the only load that has positive effects on learning.

It is obvious that the design of business process models and modularization can have an impact on the cognitive load. In the next section, the relation of eye behavior and cognitive load is presented. The neural behavior of the eye is influenced, among other things, by cognitive load. Further, the eye can provide insights regarding the occurrence of problems in evaluating the presented learning materials.

3.3 Relation of Eye Behavior and Cognitive Load

The eye has a complex structure [89] and behavior. It's behavior depends, on the one hand, on two muscles that control changes in pupil size. According to [89] these muscles are, as presented in Figure 3.3, the dilator and sphincter pupillae muscle. The change in size is caused by stimuli, impulses [90], cognitive processes/control [91], and emotions [92]. On the other hand, eye movement is present. It is caused by switching between different points of interest. Further, it provides input about attention and demands while processing [93].

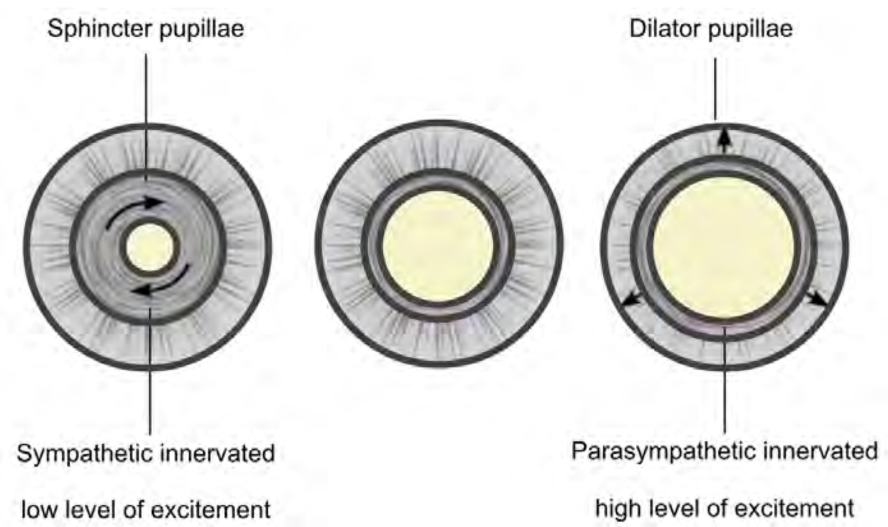

Figure 3.3: Cognitive Pupillometry [90]

A well known approach to measure cognitive load, based on certain cognitive processes is given by eye tracking [93]. For this purpose, the following behaviors are recorded:

- Pupil dilation
  Pupil size is influenced by mental effort [91, 94]. Next to mental effort, [94] refers to the subjective difficulty of the task and neural gain. Due to high parasympathetic activity (i.e. mental effort), an innervation of pupil results (see Figure 3.3). An example in reading business process models is the innervation of the pupil when the learner has difficulties in understanding the shown circumstances.
- Fixation
  The eye is looking at a stable point [95] of a visual stimuli for a period of 200-300 ms [96]. The level of experience in a task has an impact on the duration of fixation [97]. Therefore, duration is a reference of information processing. When a reader of a business process model fixates a process activity, the duration is measured by the eye tracker. This duration gives information about the necessary time to process the information presented. If the learner needs a long time, then the cognitive load is high.
- Saccades
  Between individual fixations, eye movement occurs. The time of eye movement is a saccade [95] and executed rapidly [98, 96]. A reduction of saccades is good for efficiency [94], because no information is recorded during eye movement [96]. An example for a saccade is the movement of the eye from fixating one activity to fixating another.

In case of measuring understandability in business process models, diverse research exists. Eye tracking is also utilized by [99]. They set up an eye tracking study to receive information about fixation time, etc. Hence, it becomes obvious whether the participant only refers to a single section of the process model, and how cognitive capacities are investigated. In the next section, a study is planned and defined.

4

Study Planning and Definition

The goal of the study is defined in Section 4.1. Section 4.2 considers the formalized hypotheses. Section 4.3 refers to the setup, Section 4.4 picks up the study design. Finally, the risks of analysis and migrations are discussed in Section 4.5.

All of these aspects are necessary to answer a research question. In order to receive meaningful findings, attention must be paid to the methodology of the monitoring procedure. This requires detailed planning and definition.

4.1 Goal Definition and Context Selection

In regard to process modeling, a high amount of research represented by metrics [100], guidelines [40], etc. exists. It provides the opportunity to generate adequate process models of high quality. Next to the completeness and modeling quality, process models have to be understood by all stakeholders. In this case, complexity caused by the limited capacities in human information processing, is a main factor. To handle the complexity of process models, three modularization approaches exist: horizontal, vertical, and orthogonal [1]. They reference on 'how' to modularize. Each modularization approach takes up different subdivision approaches which differ in terms of design and the intended use.
So far, a great amount of scientific research in terms of modularization was not addressed. While the usability of the modularization approaches were compared, comparisons in terms of the offered complexity are missing. This leads to the research question:

RQ1: *Do different modularization approaches in business process modeling have an impact on cognitive complexity of process readers?*

Next to the cognitive complexity, it is of interest which modularization approach provides a better overall produced result after performing the task. Hence, items that refer to the performance success like the time needed for execution and accuracy measured by tasks are of interest. This leads to the research question:

RQ2: *Do different modularization approaches in business process modeling have an impact with respect to a successful performance of process readers?*

Finally, activities used in process modeling have a firmly defined syntactical meaning for each business process modeling notation. Items could be misunderstood by the stakeholders. Further, differences in the single modularization approach exist. For vertical modularization, [47] points out that expanded subprocess provide a better understandability than collapsed subprocesses. To receive insights whether the design of a single modularization approach affects the cognitive complexity, the following research question is placed:

RQ3: *Do variations in representation of different modularization approaches in business process modeling have an impact with respect to cognitive complexity of process readers?*

This results in the goal:
Obtaining insights in terms of the cognitive load when stakeholders read different modularized business process models.

To address the research questions, a survey and an eye tracking study are applied. *Surveys* provide the benefit to obtain the opinion and attitude of a participant with little expenditure [101]. Through *studies*, profound insights can be considered. This can be realized through technical realizations such as *eye tracking*. With *eye tracking* cognitive processes of the human can be measured. Such a measurement is based on visual stimuli [102]. Hence, participants can read a business process model, and it becomes obvious where problems in processing the model exist. An evaluation is comprised of, for example, fixations and saccades.

4.2 Hypotheses Formulation

The hypothesis is an unequivocal assumption concerning the studies' result [103]. Two types of hypotheses have to be taken into account. These are the *null hypothesis*, and the *alternative hypothesis*.

The *null hypothesis* $\mathcal{H}_0$ points out that no difference or effect between the considered conditions exists [104]. Therefore, the goal of studies is to refute it.

The *alternative hypothesis* $\mathcal{H}_1$ argues that a difference or effect between the considered conditions occurs [104]. The goal of the studies is to prove it.

RQ1 is subdivided into the cognitive load and understandability. RQ2 addresses the performance success, and RQ3 the design. Subsequently, hypotheses and their related questions, that are utilized in this topic, are shown.

Cognitive Load

In Section 4.1, the main research question of the thesis is presented. It utilizes the cognitive load - a composite formed by the intrinsic, germane, and extraneous cognitive load - as the topic. Therefore, subquestions can be applied:

Q1.1: *Do different modularization approaches influence the intrinsic cognitive load by executing the task?*

All conditions provide the same complexity in the studies with respect to their tasks. Further, the study design (Section 4.4) was designed in a way to evade effects, such as learning effects. Further, for data evaluation it is ensured that only slight deviations in prior knowledge emerge.

H1.1 (a): No significant difference is given between the different modularization approaches in terms of the intrinsic cognitive load.
$\mathcal{H}_0$: $\mu_{\mathcal{V}} = \mu_{\mathcal{H}} = \mu_{\mathcal{O}}$

Next to complexity and prior knowledge, the intrinsic cognitive load depends on element interactivity. Therefore, the functionality of different activities has to be understood.

Caused by the differences in the modularization schema, for example, in terms of icons, a difference in intrinsic cognitive complexity could result.

H1.1 (b): A significant difference between the modularization approaches is given in terms of the intrinsic cognitive load.

$\mathcal{H}_{1.1(b)}$: $\mu_{\mathcal{O}} > \mu_{\mathcal{H}} > \mu_{\mathcal{V}}$

Q1.2: *Do different modularization approaches influence the germane cognitive load by executing the task?*

A good design has positive effects on the efforts by executing the tasks. The performance in carrying out the task could vary regarding differences in representation, for instance by selecting different icons. Therefore, a difference between the modularization approaches is expected.

H1.2 (a): A significant difference is given between the modularization approaches in terms of the germane cognitive load.

$\mathcal{H}_{1.2(a)}$: $\mu_{\mathcal{O}} > \mu_{\mathcal{H}} > \mu_{\mathcal{V}}$

If no difference between the modularization approaches is obtained, the alternative hypothesis has to be rejected and the null hypothesis occurs. Therefore, no modularization approach leads to higher effort by executing the task.

H1.2 (b): No significant difference is given between the modularization approaches in terms of the germane cognitive load.

$\mathcal{H}_0$: $\mu_{\mathcal{O}} = \mu_{\mathcal{H}} = \mu_{\mathcal{V}}$

Q1.3: *Do different modularization approaches influence the extraneous cognitive load by executing the task?*

Because of the different representations of the modularization approaches, for example through icons, a difference in the extraneous cognitive load is expected.

H1.3 (a): A significant difference is given between the modularization approaches in terms of the extraneous cognitive load.

$\mathcal{H}_{1.3(a)}$: $\mu_{\mathcal{O}} > \mu_{\mathcal{H}} > \mu_{\mathcal{V}}$

However, the basic activities are the same, and only small differences between icons exists. This could cause that no measurable difference is given and the null hypothesis occurs.

H1.3 (b): No significant difference between the modularization approaches in terms of the extraneous cognitive load occurs.
$\mathcal{H}_0$: $\mu_{\mathcal{O}} = \mu_{\mathcal{H}} = \mu_{\mathcal{V}}$

Understandability
Next to the cognitive load, the understandability of process models is of interest. It leads to the answer whether the represented modularization approaches in business process models could be, for example, reproduced by the participants, or not.

Q2.1: *Do different modularization approaches influence the perceived usefulness for understandability?*

An effect, caused by the different representations, in extraneous and germane cognitive load is expected. The deviations in representation could have an impact regarding the understandability. Hence, a difference between the modularization approaches, in terms of the perceived usefulness for understandability, is expected. This leads to the hypothesis:

H2.1 (a): A significant difference between the modularization approaches in terms of the perceived usefulness for understandability is given.
$\mathcal{H}_{2.1(a)}$: $\mu_{\mathcal{O}} > \mu_{\mathcal{H}} > \mu_{\mathcal{V}}$

In case of little deviations in terms of the representation exist, it could be that no significant difference will be observed and no effect is measurable. This would cause the null hypothesis:

H2.1 (b): A significant difference between the modularization approaches in terms of the perceived usefulness for understandability is given.
$\mathcal{H}_0$: $\mu_{\mathcal{O}} = \mu_{\mathcal{H}} = \mu_{\mathcal{V}}$

Q2.2: *Do different modularization approaches influence the perceived ease of understanding?*

Perceived ease of understanding focuses on the reproduction and understandability of the process models. The different modularization approaches could lead to different results because of the deviations in representation. Therefore, the following hypothesis is given:

H2.2 (a): A significant difference is given between the modularization approach in terms of the perceived ease of understanding.

$\mathcal{H}_{2.2(a)}$: $\mu_{\mathcal{O}} > \mu_{\mathcal{H}} > \mu_{\mathcal{V}}$

In cases of minor deviations in representation, no difference in the perceived ease of understanding is obtained. This would lead to the occurrence of the null hypothesis:

H2.2 (b): No significant difference between the modularization approach in terms of the perceived ease of understanding occurs.

$\mathcal{H}_0$: $\mu_{\mathcal{O}} = \mu_{\mathcal{H}} = \mu_{\mathcal{V}}$

Performance Success

So far, the cognitive load and understandability were considered. Further, the performance success can be measured. The performance success is based on the achieved performance while executing the task.

Q3: *Do different modularization approaches influence the performance success?*

Because of the expected differences in perceived usefulness for understandability, perceived ease of understanding, and cognitive load, a further difference in terms of the performance success is expected. Therefore, the following hypothesis is given:

H3 (a): A significant difference between the modularization approaches in terms of the performance success is given.

$\mathcal{H}_{3(a)}$: $\mu_{\mathcal{O}} > \mu_{\mathcal{H}} > \mu_{\mathcal{V}}$

If the other measured objects would not provide a significant difference, no significant difference for the performance success is expected. This would lead to the null hypothesis:

H3 (b): No significant difference between the modularization approaches in terms of the performance success occurs.
$\mathcal{H}_0$: $\mu_{\mathcal{O}} = \mu_{\mathcal{H}} = \mu_{\mathcal{V}}$

Design

Next to the differences regarding the modularization approaches, a difference with respect to the single modularization approach is given. Therefore, next to the existing designs, further icons were designed for each modularization approach. Hence, the quality between the activities of a modularization approach can be compared with the self designed icon.

Q4.1: *Does the design of referencing the modularized area influence the performance in horizontal modularization?*

In horizontal modularization, only small differences with respect to the design are given. Hence, no difference in cognitive load is expected.

H4.1 (a): No significant difference with respect to the horizontal modularization in terms of design and performance success occurs.
$\mathcal{H}_0$: $\mu_{\mathcal{M}} = \mu_{\mathcal{L}} = \mu_{\mathcal{SD}}$

As differences in the representation exist and additionally the complexity varies, the alternative hypothesis could occur:

H4.1 (b): A significant difference with respect to the horizontal modularization in terms of design and performance success exists.
$\mathcal{H}_{4.2(2b)}$: $\mu_{\mathcal{M}} > \mu_{\mathcal{M}} > \mu_{\mathcal{SD}}$

Q4.2: *Does the design of referencing the modularized area influence the performance in vertical modularization?*

In vertical modularization, only small differences with respect to the design are given. Therefore, no difference in cognitive load and performance success is expected.

H4.2 (a): No significant difference with respect to the vertical modularization in terms of design and performance success is given.
$\mathcal{H}_0$: $\mu_{\mathcal{C}} = \mu_{\mathcal{E}} = \mu_{\mathcal{SD}}$

[47] points out that differences for vertical modularization with respect to the understandability exist. Therefore, a significant difference regarding the hypothesis is expected.

H4.2 (b): A significant difference is given with respect to the vertical modularization in terms of design and performance success.
$\mathcal{H}_{4.2(2b)}$: $\mu_{\mathcal{C}} > \mu_{\mathcal{SD}} > \mu_{\mathcal{E}}$

Q4.3: *Does the design of referencing the modularized area influence the performance in orthogonal modularization?*

In orthogonal modularization, differences regarding the design exist. Partially, symbols exist that reference to modularization. Therefore, a difference in cognitive load and performance success is expected.

H4.3 (a): A significant difference with respect to the orthogonal modularization in terms of design and performance success exists.
$\mathcal{H}_{4.3(2a)}$: $\mu_{\mathcal{AO}} > \mu_{\mathcal{SD}} > \mu_{\mathcal{E}}$

The differences could be realized at least equivalently. This would lead to the null hypothesis:

H4.3 (b): No significant difference with respect to the orthogonal modularization in terms of design and performance success exists.
$\mathcal{H}_0$: $\mu_{\mathcal{AO}} = \mu_{\mathcal{SD}} = \mu_{\mathcal{E}}$

4.3 Study Setup

Studies are the realization for measuring effects on dependent variables by variating independent variables [101].
This section refers to the studies' setups, subdivided into the research variants *survey* and *study*. Both are part of this thesis. This leads to the first subject-matter 'Selection of

Studies'. As the fundamentals of studies are attributed by the knowledge of response variables, they are subsequently considered. Further, the selection of participants, objects, questionnaires, and instrumentations are additional subject-matter.

Selection of Studies

Different types of studies exist. Survey and study are only two of them.

Survey: A survey is applied to acquire findings such as opinions and attitudes [101]. If the survey is executed online, a large participatory number can be acquired with little expenditure [101]. Hence, the participant is neither spacially bound, nor bound by time (until the data collection has been completed). Summarized, a survey is useful for superficial and fundamental considerations.

Study: A study is chosen when profound insights have to be considered [101]. It provides the benefit that confounding and environmental variables can be controlled, depending on the study design [105]. Furthermore, the researcher is able to obtain data from the participant, for instance by thinking aloud [106]. However, the recruitment process of participants can be difficult [107].

In this thesis both study and survey are considered. The survey is applied to provide insights in terms of the differences between modularization approaches. The data collected should answer the research question RQ1 through measurements on the following aspects: cognitive load, perceived usefulness for understandability, and perceived ease of understanding. In addition, alternative representational designs can be questioned. Hence, a utilization of design changes is possible in further research.

In the study, profound insights about the cognitive complexity - independent of the intrinsic, extraneous, and germane cognitive load - can be measured. Therefore, the utilization of eye tracking technologies is possible. Using an eye tracker, neuroscientific information is measured providing insights regarding cognitive processing. It becomes obvious where the differences in understanding come from, and where difficulties occur. Hence, the study answers the research questions RQ2 and RQ3.

Definition of Response Variables

The studies that are utilized in this thesis were presented, so far. Next, the responsible variables with respect to the single studies have to be defined. They are the basis for each of the studies, and are important to reach their goal. Therefore, a differentiation between the response variable types has to be considered. These types are:

- Independent Response Variable
  The independent response variable is manipulated through the researcher in studies [108]. Except of this variable, an equal treatment is of need [109].

- Dependent Response Variable
  The dependent variables are measured [108] on participants [109] in studies. It is measured to receive insights regarding the influence through the independent variable on the dependent variable [109]. Hence, they provide a dependency to the independent ones that exist.

The variables selected for survey and study are presented in detail below.

Survey: The independent response variable is the modularization approach with the levels: horizontal, vertical, and orthogonal. Further, prior knowledge and education relate to the independent response variables. Cognitive load, perceived ease of understanding, and perceived usefulness for understandability are chosen as dependent response variables.

Study: Independent response variables comprise of the prior knowledge, the education, and the items of cognitive complexity. However, the independent response variable contains the modularization approach with the levels: horizontal, vertical, and orthogonal. Further, the designs of the modularization approach levels are measured. These are:

- Horizontal: link events, message events, self designed

- Vertical: collapsed subprocess, expanded subprocess, self designed

- Orthogonal: aspect-oriented, exception event, self designed

Dependent response variables in the study are: cognitive load, perceived ease of understanding, perceived usefulness for understandability, and the performance success (time, reached score). Further, dependent response variables exist. They result from the measurement of the eye tracker. These are, for example: average fixation, fixation duration, and fixation counts.

Next to the dependent response variables, control variables like the age, gender, and knowledge are measured in both studies - survey and study.

Selection of Participants

A sample regarding the population is selected in studies. This is reasonable because participants should reflect the population's required characteristics [110].

Readers of business process models are not necessarily experienced in business process models [28]. This is also the case for other stakeholders. Therefore, persons - in form of students, research assistants, and alumni - that are not necessarily experienced in modularized business process models will be selected as participants.

Survey: In the survey, the mentioned representative group is selected as participants.

Study: In the study, the restriction that only the mentioned research group will take part is observed.

The acquisition of participants is represented in Section 5.1.

Selection of Materials

The materials are generated. The focus in preparing the objects is the knowledge and expertise of the participants. Hence, process models were prepared with a simple and understandable content, such as baking a pizza. Further, an adequate business process modeling notation has to be selected. Not every process modeling notation supports each modularization approach. Therefore, the widespread business process modeling notation BPMN 2.0 [31] is applied. It is often utilized as an object of study in scientific papers regarding business process models. In addition to its frequent use, it is also selected due to the extensive scope of functions. Furthermore, it enables the utilization of all three modularization approaches that have to be considered. The materials are realized in German, as it is the common language in which the studies are executed. The business process models were realized using the modeling tool 'Signavio' [111].

Survey: The survey is comprised of twelve process models as presented in Table 4.1. For each modularization approach, four process models are prepared. Every process model of the four can be mapped to a process model of the other approaches. Hence, they are comparable.

With respect to the first process model 'Order', modularization was represented by message events, expanded subprocesses, and exceptions. In the process models 'Refuel', 'Pizza', and 'Loan', the modularization was realized through link events, collapsed subprocesses, and aspect-oriented paradigm. The representation of the process models is illustrated in Appendix A.

Process Model	**Horizontal Modularization**	**Vertical Modularization**	**Orthogonal Modularization**
Order	Message event	Expanded subprocess	Exception
Refuel	Link event	Collapsed subprocess	Aspect-oriented
Pizza	Link event	Collapsed subprocess	Aspect-oriented
Loan	Link event	Collapsed subprocess	Aspect-oriented

Table 4.1: Process Models in the Survey and their Realization

Study: The study picks up 81 process models, 9x9 as shown in Figure 4.1. While nine processes differ regarding the content (P1 - P9), nine process models vary in the realization of modularization. The realization of modularization is subdivided into three modularization approaches. These are the orthogonal (O1 - O3), vertical (V1 - V3), and horizontal (H1 - H3) modularization. Each approach is divided into three weightings: changed by self designed (light gray), not changed (gray), and self designed (white). Changed by self designed involves the modularization subdivisions presented in light gray. These are: *aspect-oriented*, *collapsed subprocesses*, and *link events*. They are not changed so far. The change is first utilized in the weighting self designed. In the self designed weighting, items that refer to modularization were changed/supplemented. However, the subdivisions represented in gray (*exception events*, *expanded subprocesses*, *message events*) were utilized unchanged. Further, they were not changed in successive subdivisions. As exemplified in Figure 4.1, the orthogonal modularization is subdivided into aspect-oriented, exception event, and self designed. The aspect-oriented and exception event are represented according to the figures in Section 2.2.3. In contrast, self designed is based on small icon changes on the aspect-oriented approach. Hence, for each of the presented modularization approaches, the self designed process model (in Figure 4.1 represented through the 3) is based on the first weighting in Figure 4.1, and provides minor adjustments of the icons.

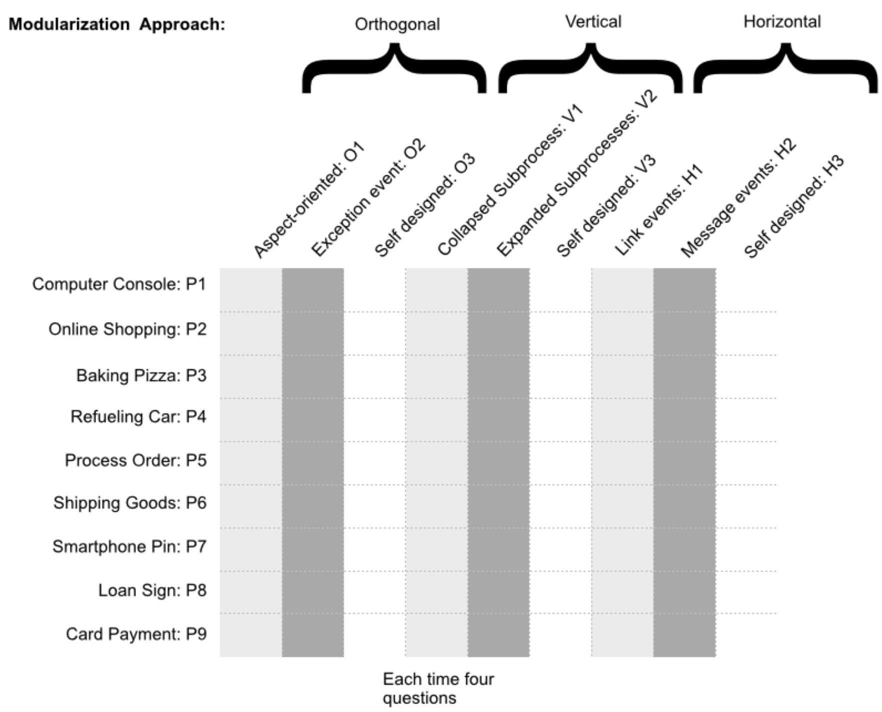

Figure 4.1: Graphics in the Study and its Realization

Furthermore, the content of process model one (P1) is realized analogically for each modularization approach and their subdivisions. Each graphic is comprised of four self generated statements. The single statement can be answered with true or false. In addition, the weighting between true and false is predominantly balanced. The process models and the questions can be extracted from Appendix B.2 up to B.10. The design of the eye tracking materials, created using the program 'Keynote' [112], is presented in Figure 4.2.

Gray is selected for the background because of the lower brightness reducing strain on the eyes. Next, the positioning of the elements inside the material is explained. The placement of the process model (yellow sector) is positioned in the upper center for each image. The statement is placed bottom center. This statement has to be assessed with true or false. Hence, the possibilities are presented to the participants. Underneath the statement, true is placed on the left, while false is presented on the right. Arrangement

Figure 4.2: Structure of Eye Tracking Material

and presentation of the possibilities is decided by the input method of the assessment: on a German standardized keyboard layout (QWERTZ). The character 'F' has to be selected for true, and 'J' for false. For each correct answer the participant receives one point. However, for an incorrect answer the participant won't receive a point. All together, 36 points can be obtained.

Selection of Questionnaires

Cognitive load and the understandability are of relevance in cognitive complexity. This leads to the usage of questionnaires that address these themes.

For cognitive load, a reliable questionnaire of the Department of Learning and Instruction of the Ulm University is used [113]. It's composed of three items to measure the extraneous, two items to measure the intrinsic, and three items to measure the germane cognitive load. In addition to the cognitive load, items that measure the motivation are utilized. At each of these items, an initial- and endpointscore seven-point likert-scale is applied. Table 4.2 show the items of the questionnaire.

Next to the cognitive load, understandability is of relevance. Therefore, two aspects will be measured: perceived usefulness for understandability (PUU) and perceived ease of

Typ	Original Question English	Question German
ICL	For this task, many things needed to be kept in mind simultaneously.	Bei der Aufgabe musste man viele Dinge gleichzeitig im Kopf bearbeiten.
ICL	This task was very komplex.	Diese Aufgabe war sehr komplex.
GCL	I made an effort, not only to understand several details, but to understand everything correct.	Sie haben sich angestrengt, sich nicht nur einzelne Dinge zu merken, sondern auch den Gesamtzusammenhang zu verstehen.
GCL	My point while dealing with the task consisted of elements supporting my comprehension of the task.	Es ging Ihnen beim Bearbeiten der Lerneinheiten darum, alles richtig zu verstehen.
GCL*	The learning task consisted of elements supporting my comprehension of the task.	Die Lerneinheit enthielt Elemente, die Sie unterstützten, den Lernstoff besser zu verstehen.
ECL	During this task, it was exhausting to find the important information.	Bei dieser Aufgabe ist es mühsam, die wichtigsten Informationen zu erkennen.
ECL	The design of this task was very inconvenient for learning.	Die Darstellung bei dieser Aufgabe ist ungünstig, um wirklich etwas zu lernen.
ECL	During this task, it was difficult to recognize and link the crucial information.	Bei dieser Aufgabe ist es schwer, die zentralen Inhalte miteinander in Verbindung zu bringen.

Table 4.2: Items to measure Cognitive Load

understanding (PEU). Both include four items. Each item utilizes a seven-point likert-scale with initial- and endpointscore labeling. The questions are withdrawn by [114] and find application with respect to papers from the Eindhoven University of Technology. For this thesis, the questions were translated into German as the survey and study are conducted in German. The items and their translation are presented in Table 4.3.

Next to the cognitive complexity, a questionnaire is of need for comparing the participants. These comparisons can be handled through control variables. Hence, a demographic questionnaire is utilized [115].

Survey: Next to the demographic questionnaire that is extended by the item 'design', two questionnaires are used.

- Cognitive Load Theory
  Changes in the survey: Terms, for example 'Aufgabe' (task), were changed to terms such as 'Prozessmodell' (process model).
- Perceived Usefulness for Understandability and Perceived Ease of Understanding

The questionnaire is integrated into the survey and can be extracted from Appendix A.
Study: Next to the demographic questionnaire, two questionnaires are utilized.

Typ	Question English	Question German
PUU	Business process models represented in this way would be difficult for users to understand.	Auf diese Weise repräsentierte Geschäftsprozessmodelle wären für die Benutzer schwer zu verstehen.
PUU	I think this presentation approach provides an effective solution to the problem of representing business process models.	Sie denken, dass dieser Präsentationsansatz eine effektive Lösung für das Problem der Darstellung von Geschäftsprozessmodellen bietet.
PUU	Using this type of process models would make it more difficult to communicate business processes to end-users.	Die Verwendung von Prozessmodellen dieser Art würde die Kommunikation von Geschäftsprozessen an den Endbenutzer erschweren.
PUU	Overall, I found the business process model in this experiment to be useful.	Insgesamt haben Sie das Geschäftsprozessmodell in diesem Experiment als nützlich erachtet.
PEU	Learning to use this way of modelling business processes would be easy for me.	Diese Art der Modellierung von Geschäftsprozessen zu erlernen, wäre für Sie einfach.
PEU	I found the way the process is represented as unclear and difficult to understand.	Sie halten die Darstellung des Prozesses für unklar und schwer verständlich.
PEU	It would be easy for me to become skilful at using this way of modelling business processes.	Es wäre leicht für Sie, diese Art der Modellierung von Geschäftsprozessen zu beherrschen.
PEU	Overall, I found this way of modelling business processes difficult to use.	Insgesamt hat sich diese Art der Modellierung von Geschäftsprozessen als schwierig erwiesen.

Table 4.3: Items to measure Perceived Usefulness for Understandability and Perceived Ease of Understanding

- Cognitive Load Theory

  Further questions are applied. These questions comprise the mental effort, difficulty of executing the task, as well as motivation and enjoyment.

- Perceived Usefulness for Understandability and Perceived Ease of Understanding

All questionnaires are demonstrated in Appendix B.11.

Selection of Technical Instrumentation

The instrumentation engages technologies used in the studies.

Survey: As an online survey is utilized, a computer with access to the internet is necessary to participate in the survey. The online survey was developed using the tool 'Google Formulare' [116]. It is appropriate, as it is an open source tool, and easy to use.

Study: In the study, an eye tracker is utilized (Section 4.5). The eye tracker used is a stationary tower mounted eye tracking system, of the type SMI iView X Hi-Speed, from SensoMotoric Instruments. It has a sampling rate of 240Hz. The benefits of such a system are that changes in pupil size and fixation are measured frequently. Further, the eye is focused on the visual stimuli presented. As the head of the participant is stabilized through the chin tray and the cranial is leaning against the headrest of the eye tracker only little head movements are possible. The data measured during the study is analyzed through the SMI BeGaze software.

4.4 Study Design

The study design relates to the structure given while running the study. The usage of an inadequate structure could cause problems regarding the progress of the study and also leads to its failure. Therefore, three things are considered:

1. First, the subject design. It includes two different approaches.

   Between Subject Design
   One group executes exactly one condition. For comparison, more participants are of need. But no learning effects exist, as no participant can map the content of one condition to the content of another condition.

   Within Subject Design
   Every participant has to conduct every condition. This leads to a better comparison and the need of less participants. However, an impact of learning effects can occur, because the participant can map the acquired knowledge from the first condition to the ensuing conditions. This leads to a more successful performance in the subsequent conditions. The eradication of learning effects can be realized as good as possible through latin square. Based on latin square, after every accomplishment the conditions are shifted by the factor one. Hence, a systematically change in the experiment is executed.

2. In addition to the different subject designs, four principles have to be considered: *balancing*, *randomizing*, *matching*, *blocking*.

   Balancing
   Through balancing, (random) sequence effects like the intern validity and test effects are controlled [117].

Randomizing

Through randomizing, differences between participants and the thereby arising interferences are randomly distributed [118].

Matching

Through matching, differences between participants are obviate. This is realized through distributing persons with similar characteristics to the different groups [119].

Blocking

Through blocking, less participants are necessary. Blocks based on a characteristic are selected and participants are assigned to the different units along this characteristic [120].

3. Next to the items mentioned, the number of factors is of interest in the experiment design.

Single Factor

A single factor design is given when an experiment has exactly one independent variable [121]. The number of levels is not of interest.

Multifactorial

A multifactorial design is given when an experiment has more than one independent variable. If a representation like 2x4 is stated, two independent variables exist. One of them has two and the other one four levels.

Survey: In the survey, a single factor between subject design finds use. Therefore, three online surveys, differentiated by the modularization approach, are designed. The structure of the study is presented in Section 5, Figure 5.1.

Study: In the study, a 3x3 within subject design finds use. The structure of the study is represented in Figure 5.2.

4.5 Risk Analysis and Migrations

In studies, different factors have to be taken into account to receive a reliable result. This can be caused by the main quality criteria.

Reliability
It is missing when subsequent measurements have differences in their findings [122]. Hence, the research results are refuted as they do not correspond to the actual circumstances.

Objectivity
It is missing, when the research results are caused by aspects such as feelings and beliefs [123] while executing the studies.

Validity
It is missing when the measurement doesn't lead to the research result that has to be investigated [122]. Types that have to be taken into account are, for example, the internal (caused effects of treatment ($A \rightarrow B$)), external (information about generalizing elicited results), conclusion (relation of treatment and outcome), and construct (quality of measurement) validity. In Figure 4.3, the relation between the mentioned validity types is shown. In the following, the validities of the studies are considered.

- Internal Validity
  Internal validity can be negative effected by the materials, technical instrumentations, and participation, next to further aspects. All of these aspects are given by the reconciliation from the independent to the dependent variable.

  The designed materials can lead to negative effects on internal validity. Therefore, an extensive research with respect to modeling modularized business process was executed. Furthermore, the designed business process models were kept simple for the studies. This provides an adequate understanding. As an extension of the eye tracking study, the position of the question was of interest. The details represented on the particular unit of the study were carefully located.

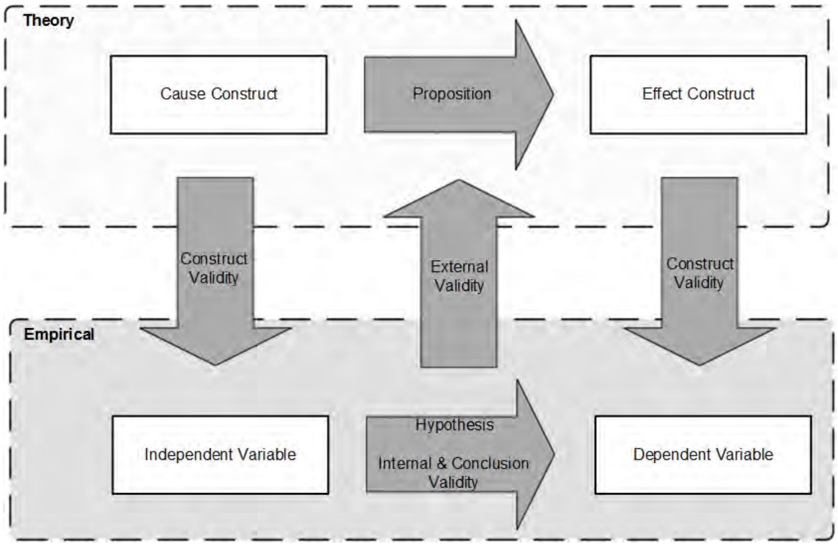

Figure 4.3: Different types of Validity [124] adapted

Next to the designed materials, questionnaires could effect the internal validity. For both studies, reliable, multiple tested questionnaires were selected. Further, they consist of items that measure the necessary attributes to answer the research question. Besides, they were inserted at well selected positions.

For both studies, the technical instrumentation can lead to negative effects on internal validity. As the survey is executed online, the technical instrumentation is of interest. A survey tool with a simple application was utilized. Therefore, the necessary actions are obvious at each point in time. Further, the material was subdivided into logical units. The technical instrumentation in the study is given by using an eye tracker. For each participant the eye tracker is adapted accordingly. To receive adequate data, a stationary eye tracker was utilized. This eye tracker ensures only little head movements and has a high sampling rate. Therefore, data loss is low. However, with respect to the eye tracker, problems could be caused by pupil feedback. There are three problems according to [125]: data loss, big amounts of data, and pupil diameter at baseline registration. All three problems are known and considered accordingly in the evaluation.

Finally, negative effects on internal validity can be caused by participants. Divergence of experience, such as environmental variables should be as little as possible. In the survey, environmental variables and an equal distribution of participants can't be controlled. Furthermore, the experience of participants can effect the internal validity. Hence, the experience should vary as little as possible through equal distribution of the participants. Further, the design of the survey is crucial for the impact of the experience. As a between subject design is utilized, a high number of participants has to be selected for randomization. As an alternative, matching would be an opportunity. In the study, the environmental variables such as place and time are controlled. Further, a within subject design is utilized. Hence, the individual divergences with respect to experience have little impact, as every participant passes each condition. A possible effect is caused by the experience of the individual participant, as he could be experienced in one modularization approach. That would impact the other approaches. Therefore, a high number of participants have to be selected.

- External Validity
  External validity can be negatively effected by aspects such as the surroundings, participants, and temporal aspects.

  First, the surroundings can lead to negative effects on the external validity. Hence environmental variables like loudness and light invasions are considered. During data collection, these variables can't be influenced as the participant can execute the survey at any point in time and place. In the study, a labor study enables the controlling of environmental variables. Therefore, each participant carries out the study under the same conditions. Further, the study is carried out during the day. Hence, temporal aspects are controlled.

  Finally, the selection of participant is of interest. Business process model stakeholders are not necessarily experienced. Especially the usage of all three modularization approaches is not implicitly given. Therefore, participants with little to no knowledge regarding modularization can be utilized to avoid differences based on prior knowledge of individual approaches. Further, process models are realized in the modeling notation BPMN 2.0. This is a well known modeling language that supports all three modularization approaches.

- Conclusion Validity
  Conclusion validity can be negatively affected by low statistical power, violated assumptions, and non-normalized procedures.

  The statistical power can lead to negative effects on the conclusion validity. Therefore, the level of significance was kept by $p <$ .05. Hence, the probability regarding the null hypotheses was kept high.

  Further, a violated assumption can lead to negative effects on the conclusion validity. It is caused by the tests chosen for evaluation. Hence, the selection of evaluational tests has to be done carefully and considering the obtained results.

  Finally, a procedure that is not normalized could have negative effects on the conclusion validity. Therefore, the procedure is normalized throughout all participants.

- Construct Validity
  The construct validity can have negative effects caused by the participant behavior and measurement. Further, the study leaders can have an influence.

  The construct validity can be negatively affected by participants. As the participant is in a test situation, he could behave in a different way than normally. In the survey, the participant is anonymous. This leads to the benefit that the participant does not feel observed. Hence, he answers the questions honestly. In the eye tracking study an interaction between the participant and the study leaders is present. As an example, it is previously defined what information the participant receives in the introduction. To avoid different behaviors towards the participants, the study leaders have defined habits. Hence, no difference should arise. Furthermore, the participants should be encouraged to behave as normally as possible with the help of the study leaders' behavior. Further, no indications in terms of the measured response variables were provided to the participant. This is especially taken into account in the introduction.

Measurements were carefully selected. Further, the questionnaires were already utilized in other empirical studies.

5 Study Operation

This chapter is subdivided into three sections. Sections 5.1 describes the preparation of the study. Afterwards, Section 5.2 discusses the execution of the study. The last section in this chapter, Section 5.3, entails data validation.

5.1 Study Preparation

After creating the materials and setting up the study, its preparation is required. In this section, pilot studies and the recruitment process of participants are considered.

Survey: Before starting the survey, two pilot studies were executed to obviate errors, to increase quality, and to test technical functions such as data collection. Based on these results the survey is adjusted.
The recruitment of participants was carried out during lectures of the Institute of Databases and Information Systems (DBIS). As remuneration, participants of the survey gained a bonus point of an exercise sheet in the lecture *Business Process Management*.

Study: Two pilot studies were performed before executing the study. Hence, it was possible to eliminate problems and mistakes. Further, the opportunity was given for increasing the quality of the study.
Friends and acquaintances were acquired for participation through lettering. Further, students and research assistants were asked to participate. As only one participant can perform the study at a point in time, participants have to select a date via 'Doodle' [126] to avoid collision. Each participant receives chocolate for participating in the study.

5.2 Study Execution

The study execution addresses the structure that a participant carries out in the respective study. Participating in one of the studies, as well as the participation at a pilot progress, excludes the individual from further participation.

Survey: After acquiring the participants through the lecture *Business Process Management*, the participants have to progress the survey, as represented in Figure 5.1. For execution, an internet-enabled terminal, such as a mobile phone or computer, is of need. This is because participants access the studies via the learning management system 'Moodle' [127]. After a participant clicks on the link provided in Moodle, he is randomly assigned to one of the groups. The random assignment process is possible as it is supported by the learning management system.

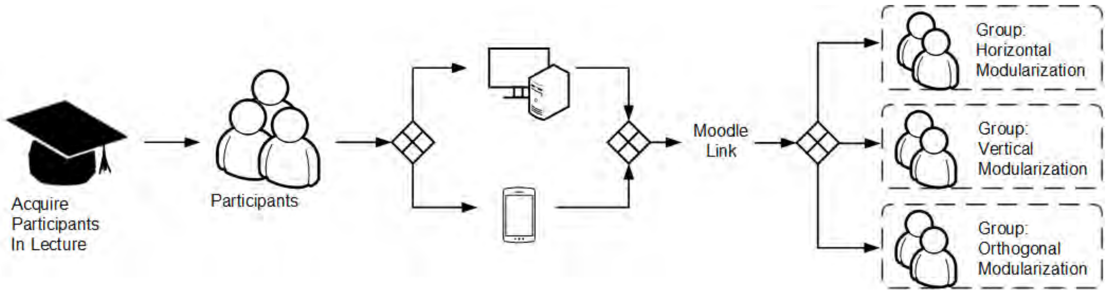

Figure 5.1: Survey Procedure

Next, the survey design is shown, as presented in Figure 5.2. After the participant is assigned to one of the groups, the introduction is presented. The introduction covers entities that contains information like the procedure, the note on voluntary, and the declaration of substitution. Afterwards, a demographic questionnaire [115], as presented in Section 4.4, is given. In the process model evaluation, the participant has to evaluate a process model, before he has to answer questions regarding the cognitive load. This is executed four times. Each time a different process model is shown as depicted in Table 4.1. All three modularization approaches follow this repeated procedure. Further, each group receives the same process models and in the same order of representation. After the execution is carried out four times, the evaluation of the modularization approach, to which the participant is assigned to, ensues. The modularization approach is graphically and textually exemplified. With further steps, the usefulness is questioned using three self designed questions. Then, questionnaires regarding the cognitive load, perceived usefulness for understandability, and perceived ease of understanding are utilized. After measuring the items, the design of the single modularization approach is considered. This is applied, as the design effects the understandability and cognitive load. Questions regarding the quality of the basic element, such as the link event in horizontal modularization, are asked, next to the icon design.

In the next step, all three modularization approaches are presented. For each approach a designation is placed above the process model. The participant has to decide which approach and combined approaches are adequate for the use in practice. In the next step, he has to provide an assessment regarding the cognitive complexity that would come up by reading all three approaches represented in one model. Before the survey ends, the participant has the opportunity to provide feedback. Then, the participants were evinced the study leaders gratitude. Finally, the used scientific literature was shown to reference the sources of information. The materials that are submitted to the participants can be obtained from Appendix A.

Study: After contacting possible participants, they can choose a time and date in Doodle.

The following procedure is given for each participant:
The study is executed in an office room in the Ulm University - the same for each iteration. Hence, the conditions during data collection remain equivalent. Before the study begins, the participant is welcomed in the staircase of the DBIS and then led into the study room. Then the experiment is executed. At the beginning of the experiment, an introduction is given. The user receives an overview about the necessary basics regarding the experiment. This is comprised of the study procedure and risks. Further, the user is referred to the fact that he can stop the experiment at any point in time. Then, the participant has to sign a declaration of consent. The signature entitles him to take part in the study. Afterwards, the participant has to fill out the components of a demographic questionnaire that is presented in Section 4.4. Next, the user is introduced to the topic. As the study scrutinizes modularization, the introduction focuses on this

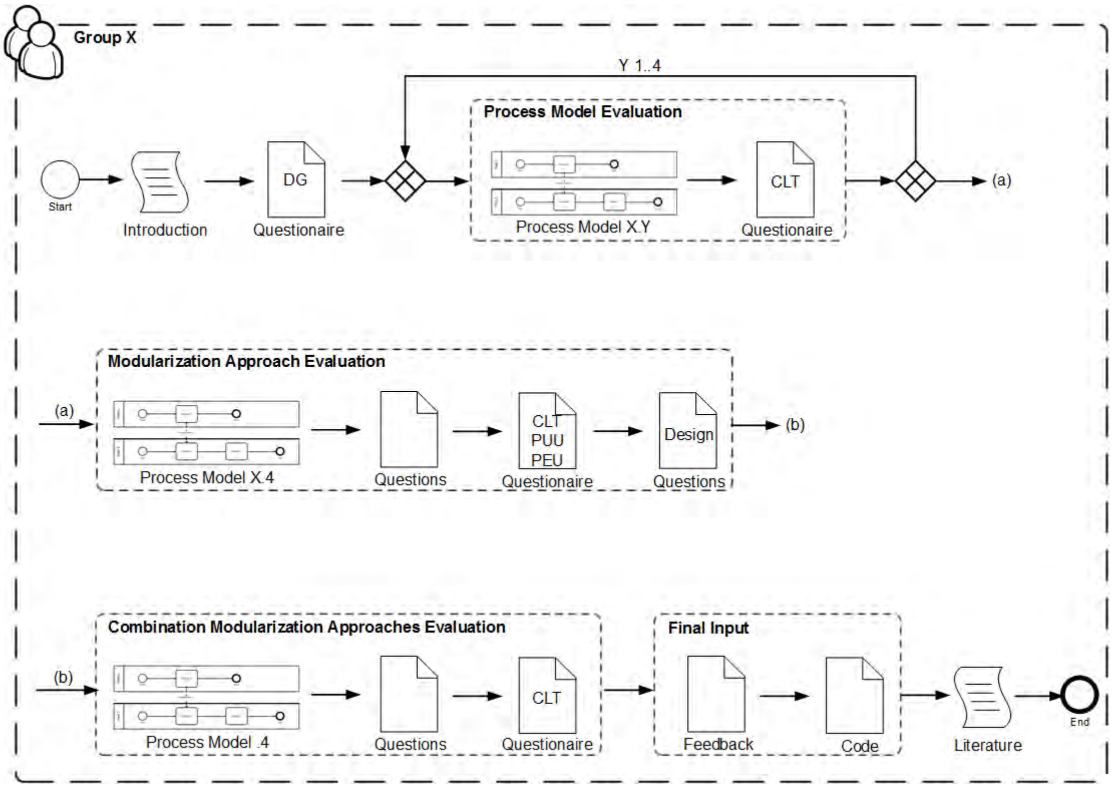

Figure 5.2: Survey Design

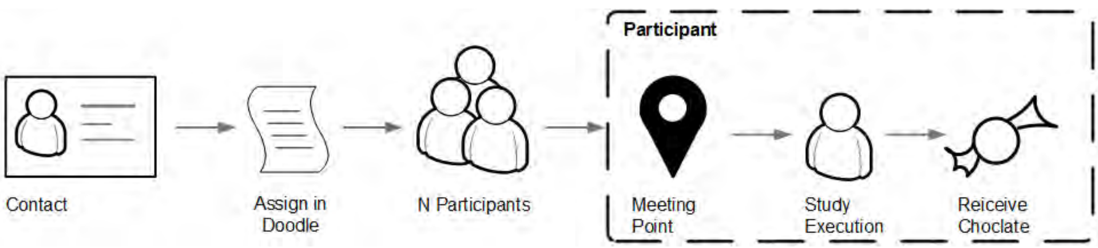

Figure 5.3: Study Procedure

topic. Further, an explanation about modularization and subareas with respect to the experiment is provided. Then an example with regard to the study materials is presented to the participant. Based on this example, a first insight in participation is provided. The eye tracker is adapted to the participant. This is necessary because feedback from the eye such as pupil size and corneal reflections have to be measured. In addition, the eye tracker is calibrated. Then, the eye tracking study is executed. It is split into three units, these are: modularization approach one, two, and three. They are executed in a balanced manner as Figure 5.4 demonstrates.

The construction of the survey is as follows:
Each unit has a trial. A trial includes one process model. This process model is differentiated four times regarding the presented questions. The procedure is executed three times blocked in one unit. It is blocked through the weighting of the representations in a modularization approach. In the example of Figure 5.5, a process model (P) is given

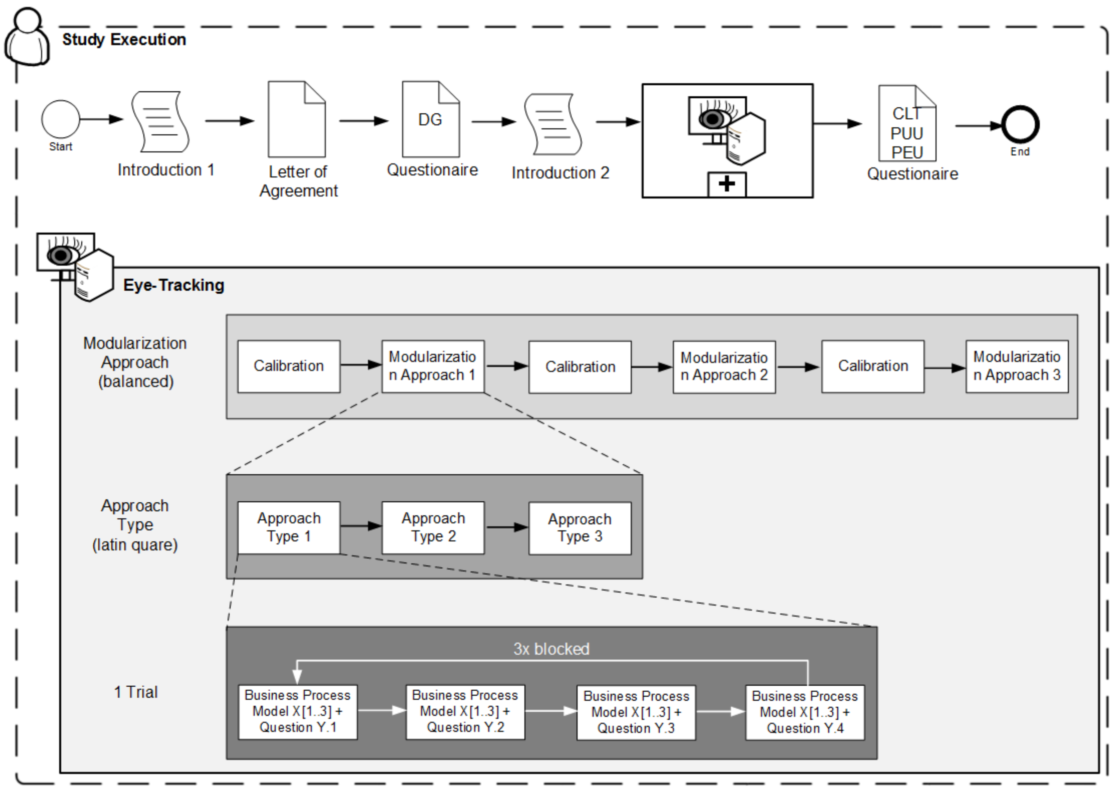

Figure 5.4: Study Design

for each column. Every process model varies with respect to the content. Regarding the row, defined variants are used. These variants are composited in a set of three modularization approaches. Each modularization approach includes: a later changed through self designed (1), a not changed (2), and a self designed (3) representation form.

Variants:

P1	P2	P3	P4	P5	P6	P7	P8	P9
O1	O2	O3	V1	V2	V3	H1	H2	H3
O2	O3	O1	V2	V3	V1	H2	H3	H1
O3	O1	O2	V3	V1	V2	H3	H1	H2
O1	O2	O3	H1	H2	H3	V1	V2	V3
O2	O3	O1	H2	H3	H1	V2	V3	V1
O3	O1	O2	H3	H1	H2	V3	V1	V2
V1	V2	V3	H1	H2	H3	O1	O2	O3
V2	V3	V1	H2	H3	H1	O2	O3	O1
V3	V1	V2	H3	H1	H2	O3	O1	O2
V1	V2	V3	O1	O2	O3	H1	H2	H3
V2	V3	V1	O2	O3	O1	H2	H3	H1
V3	V1	V2	O3	O1	O2	H3	H1	H2
H1	H2	H3	O1	O2	O3	V1	V2	V3
H2	H3	H1	O2	O3	O1	V2	V3	V1
H3	H1	H2	O3	O1	O2	V3	V1	V2
H1	H2	H3	V1	V2	V3	O1	O2	O3
H2	H3	H1	V2	V3	V1	O2	O3	O1
H3	H1	H2	V3	V1	V2	O3	O1	O2

Figure 5.5: Trials

The gap between ’O’, ’V’, and ’H’ is given by a calibration. It is necessary because participants make small head movements. They can lead to failures regarding the measurements and the evaluated results. Hence, a good tracking of the eye is possible. This progress is done twice. After completion of the eye tracking study, the participant is taken aside to answer the questionnaires regarding the cognitive load, perceived usefulness for understandability, and ease of understanding.
The materials that are given to the participant are demonstrated in Appendix B.

5.3 Data Validation

Data validation gives an overview about the period of time the data was collected. Next, collected data is considered in terms of the independent variables. For each independent variable the mean (M), standard deviation (SD), and number of participants (N) is presented.

Survey: The data was collected from November the 19th to November the 26th.

95 persons participated in the survey. 48 were male, 45 female, and two participants gave no information regarding their gender. The participants that indicated their age were between 25 and 35, and younger. All participants were academics or trainees/students, with an average year of apprenticeship of 17.34 years. The distribution in the examination variants can be taken from Table 5.1.

Independent Variable	**Horizontal Modularization**			**Vertical Modularization**			**Orthogonal Modularization**		
	M	**SD**	**N**	**M**	**SD**	**N**	**N**	**SD**	**N**
Educational years	17.32	1.95	34	16.93	1.18	28	17.72	1.57	32
Modelling experience	0.80	0.40	35	0.571	0.50	28	0.59	0.49	32
BPMN knowledge	1.00	0.00	34	1.00	0.00	28	1.00	0.00	32
Prior BPMN knowledge	0.57	0.50	35	0.57	0.50	28	0.62	0.49	32
Design knowledge	0.80	0.40	35	0.57	0.50	28	0.53	0.49	32

Table 5.1: Independent Variables in the Survey

Study: The execution of the study was carried out from November the 27th to December the 5th.

In this period of time, 22 persons participated in the study. 21 were male and one was female. After reducing the data set, as given in Section 6.1, only 19 participants remained. All of them were male, and their age was between 25 and 35, and younger. Most participants were academics or trainees/students. Only one participant has completed his apprenticeship. The average year of apprenticeship was 19.79 years. Further results of the independent variables can be taken from Table 5.2.

Independent Variable	Study		
	M	SD	N
Educational years	19.79	2.44	19
Modelling experience	0.84	0.37	19
BPMN knowledge	0.68	0.47	19
Prior BPMN knowledge	0.42	0.50	19
ICL	2.97	1.17	19
GCL	2.57	0.98	19
ECL	3.85	1.01	19
PEU	4.43	0.98	19
PUU	4.81	0.73	19

Table 5.2: Independent Variables in the Study

6

Study Analysis and Interpretation

The evaluation of the data and the related discussion are presented in this chapter. Its structure is given in the following. In the beginning, the criteria of data set reduction are presented in Section 6.1. The hypotheses are tested in Section 6.2. Finally, a summary and discussion is presented in Section 6.3.

Data is evaluated with SPSS. The ANOVA is applied for testing the control variables and the hypotheses. Significant differences ($p <$ .05) are visually marked by an '$*$' and highly significant differences ($p <$ .01) by '$**$'. The results are represented with numbers with up to two decimals after the comma. Remaining decimal numbers are cut off.

p represents the probability that the *null hypothesis* $H0$ is reported. When a significant difference with $p = .049$ is obtained, the probability for the occurrence of the null hypothesis is 4.9%. The probability for the *alternative hypothesis* $H1$ increases with a lower p value. Further, the mean (M), standard deviation (SD), and number of participants (N) is presented for hypotheses testing.

Furthermore, when the sphericity of data is not given ($p <$ .05 in a Mauchly Test) the degree of freedom has to be corrected. When $\varepsilon >$ .75 the Huynh-Feldt-Correction is selected, otherwise Greenhouse-Geisser.

The spelling for Modularization is abbreviated to *M.* in the table.

6.1 Data Set Reduction

When the following conditions are met, the data is excluded from evaluation.

Survey:

- no data in terms of assessing process models is measured

In the survey, no data set reduction exists. Hence, the complete data set was considered in the evaluation.

Study:

- it was not possible to track the eye
- divergence in environmental variables exists

Therefore, three data sets were removed in evaluation. Two times the data collection with the eye tracker was not possible. One failure was caused by the glasses of a participant. The pupil could not be captured. The second failure occurred, as it was not possible to detect a coronal reflex of the pupil. The third data set reduction was caused by environmental conditions. As the influence of light led to problems in data collection, longer breaks between eye tracking occurred. As it could have an effect on answering the statements, exclusion results. After the data set reduction, 19 data sets were included in the evaluation. Next to the complete omission of data sets, single values were removed for evaluation. This is caused by the values measured by the eye tracker. As small head movements occurred while tracking, the data quality of single tasks was sometimes too low to state the situation. Hence, when less then 50 % of the data was measured for a process model, the data regarding the KPI was excluded in the evaluation.

6.2 Hypotheses Testing

In this section, the hypotheses formalized in Section 4.3 are tested for significance.

Survey: In the following, hypotheses in terms of cognitive load and understandability, the items of RQ1, are tested.

Cognitive Load

Eight items were measured to receive insights into the cognitive load when reading modularized business process models. These items can be differentiated through the intrinsic, germane, and extraneous cognitive load. For each load, the four presented process models are considered. Further, the mean of the four process models is calculated. Finally, the load after acquiring knowledge based on the description of the single modularization approach is outlined.

Q1.1: Intrinsic cognitive load
The results can be extracted from Table 6.1 and Table 6.2. Table 6.1 provides insights in terms of the significance between all modularization approaches. Fuhrer, the means, standard deviations, and number of participants are presented. Table 6.2 compares the multiple comparisons among the single modularization approaches by the significances.

The ICL exhibits a significant difference ($F(2, 92) =$ 4.10, $p =$ .02) among the three modularization approaches after merging the results of the four presented process models. Significant differences ($p <$ .05), obtained using the Bonferroni revealed that vertical modularization increases the intrinsic cognitive load compared to horizontal modularization ($p =$ .04). Further, orthogonal modularization showed a significantly lower intrinsic cognitive load than vertical modularization ($p =$ .03).

ICL		**Horizontal M.**			**Vertical M.**			**Orthogonal M.**		
	p	**M**	**SD**	**N**	**M**	**SD**	**N**	**M**	**SD**	**N**
ICL P1	.13	1.82	0.82	35	2.19	0.89	28	1.79	0.81	32
ICL P2	.21	2.40	0.92	35	2.78	1.24	28	2.31	1.14	32
ICL P3 *	.02	3.82	1.21	35	4.57	1.37	28	3.71	1.22	32
ICL P4 *	.04	3.22	1.19	35	3.98	1.34	28	3.32	1.20	32
ICL P1-P4 *	.02	2.82	0.80	35	3.37	0.95	28	2.78	0.90	32
ICL Described	.29	3.70	1.22	35	4.00	1.29	28	3.50	1.18	32

Table 6.1: Intrinsic Cognitive Load in the Survey

ICL		**Horizontal M.**	**Vertical M.**	**Orthogonal M.**
ICL P1-P4	**Horizontal M.**	1.00	.04	1.00
	Vertical M.	-	1.00	.03
	Orthogonal M.	-	-	1.00
ICL Described	**Horizontal M.**	1.00	1.00	1.00
	Vertical M.	-	1.00	.36
	Orthogonal M.	-	-	1.00

Table 6.2: Multiple Comparisons on Intrinsic Cognitive Load in the Survey

Furthermore, two significant differences are set out in Table 6.1 for the single process models. One significant difference with respect to process model three ($F(2,92) =$ 3.96, $p =$ .02), and another for process model four ($F(2,92) =$ 3.22, $p =$ .04). Process model three showed a significant higher intrinsic cognitive load for vertical modularization than for orthogonal modularization ($p =$ .03). In process model four, no significant difference was measured for the intrinsic cognitive load among the modularization approaches ($p >$ .05).

This leads to the conclusion that hypothesis H1.1 (a), with reference to the fact that no significant differences exist, has to be rejected for the vertical modularization. In addition, the assumption in hypothesis H1.1 (b) that the vertical modularization achieves the lowest intrinsic cognitive load, does not agree with the statistical results. In summary, the intrinsic cognitive load indicates: $Vertical > (Orthogonal = Horizontal)$. Vertical modularization is significantly higher than the horizontal and orthogonal modularization. Furthermore, no significant difference between orthogonal and horizontal modularization is reported.

Q1.2: Germane Cognitive Load

No significant differences ($F(2,92) =$ 2.02, $p =$ .23) can be reported for the four summarized process models.

GCL		**Horizontal M.**			**Vertical M.**			**Orthogonal M.**		
	p	**M**	**SD**	**N**	**M**	**SD**	**N**	**M**	**SD**	**N**
GCL P1	.14	4.12	1.24	35	4.66	1.29	28	4.37	0.92	32
GCL P2	.46	4.30	1.35	35	4.66	1.29	28	4.34	0.98	32
GCL P3	.12	4.51	1.04	35	5.02	1.03	28	4.56	1.07	32
GCL P4	.19	4.39	1.20	35	4.88	1.01	28	4.66	0.95	32
GCL P1-P4	.23	4.34	1.06	35	4.81	1.00	28	4.48	0.71	32
GCL Described	.48	4.59	1.04	35	4.86	1.02	28	4.83	0.95	32

Table 6.3: Germane Cognitive Load in the Survey

Further, no significant difference ($F(2,92) =$ 0.74, $p =$ .48) was measured between the modularization approaches for the GCL after their description. As presented in Table 6.3 and 6.4, no significant difference was measured on GCL. Neither through comparing all, nor comparing the single modularization approaches a significant difference could be

GCL		Horizontal M.	Vertical M.	Orthogonal M.
GCL P1-P4	Horizontal M.	1.00	.15	1.00
	Vertical M.	-	1.00	.53
	Orthogonal M.	-	-	1.00
GCL Described	Horizontal M.	1.00	.83	.98
	Vertical M.	-	1.00	1.00
	Orthogonal M.	-	-	1.00

Table 6.4: Multiple Comparisons on Germane Cognitive Load in the Survey

observed. This leads to discarding the alternative hypothesis that significant differences are given. Hence, the null hypothesis can be reported.

Q1.3: Extraneous Cognitive Load

Regarding the extraneous cognitive load, the mean of process models one through four reports no significant difference ($F(2, 92) =$ 1.50, $p =$ .22) among the three modularization approaches.

ECL		Horizontal M.			Vertical M.			Orthogonal M.		
	p	M	SD	N	M	SD	N	M	SD	N
ECL P1	.58	1.99	0.84	35	2.16	0.83	28	1.93	0.96	32
ECL P2	.39	2.35	1.32	35	2.60	1.43	28	2.81	1.35	32
ECL P3	.37	3.59	1.34	35	4.07	1.53	28	3.75	1.22	32
ECL P4	.16	2.85	1.23	35	3.48	1.48	28	3.22	1.22	32
ECL P1-P4	.22	2.70	0.89	35	3.08	0.85	28	2.93	0.91	32
ECL Described	.07	2.97	1.02	35	3.55	1.34	28	2.94	1.13	32

Table 6.5: Extraneous Cognitive Load in the Survey

Furthermore, no significant difference ($F(2, 92) =$ 2.62, $p =$ .07) was measured for the ECL of the modularization approaches, after the description was given to the participants.

Further, no significant difference was reported as presented in Table 6.4 and 6.5. This leads to the rejection of the alternative hypothesis. Hence, no difference between the modularization approaches exists in terms of the ECL.

Understandability

Understandability is relevant for a successful utilization of modularization. Therefore, two content areas were evaluated: perceived usefulness for understandability, and perceived

ECL		Horizontal M.	Vertical M.	Orthogonal M.
ECL P1-P4	Horizontal M.	1.00	.27	.86
	Vertical M.	-	1.00	1.00
	Orthogonal M.	-	-	1.00
ECL Described	Horizontal M.	1.00	.14	1.00
	Vertical M.	-	1.00	.13
	Orthogonal M.	-	-	1.00

Table 6.6: Multiple Comparisons on Extraneous Cognitive Load in the Survey

ease of understanding. The data of both areas was measured after the process model evaluation and measuring the cognitive load in the modularization approach evaluation (see Figure 5.2). Next, for each content area the individual items are considered. Further, the mean of the items is presented for the individual content areas.

Q2.1: Perceived Usefulness for Understandability
The perceived usefulness for understandability is composed of four items. No item reported a significant difference ($p >$ .05). This is also given in the end result for perceived usefulness for understandability ($F(2, 92) =$ 0.83, $p =$ .43).

As no significant difference can be seen in Table 6.7 (for all modularization approaches) and 6.8 (between the single approaches), the null hypothesis is reported.

	PUU		Horizontal M.			Vertical M.			Orthogonal M.		
		p	M	SD	N	M	SD	N	M	SD	N
1	Business process models represented in this way would be difficult for users to understand.	.05	2.69	1.23	35	3.46	1.42	28	2.78	1.43	32
2	I think this presentation approach provides an effective solution to the problem of representing business process models.	.72	4.74	1.33	35	4.71	1.24	28	4.50	1.41	32
3	Using this type of process models would make it more difficult to communicate business processes to end-users.	.24	2.83	1.09	35	3.39	1.49	28	3.03	1.40	32
4	Overall, I found the business process model in this experiment to be useful.	.97	5.03	1.36	35	5.04	1.20	28	4.97	1.22	31
PUU sum	codified: 1, 3	.43	4.56	1.02	35	4.22	1.11	28	4.40	1.00	32

Table 6.7: Perceived Usefulness for Understandability in the Survey

PUU		Horizontal M.	Vertical M.	Orthogonal M.
PUU sum	Horizontal M.	1.00	.60	1.00
	Vertical M.	-	1.00	1.00
	Orthogonal M.	-	-	1.00

Table 6.8: Multiple Comparisons on PUU in the Survey

Q2.2: Perceived Ease of Understanding

As no significant difference ($F(2.92) =$ 0.43, $p =$ .65) for perceived ease of understanding occurs regarding the modularization approaches (see Table 6.9 and 6.10), the null hypothesis can be reported.

	PEU		Horizontal M.			Vertical M.			Orthogonal M.		
		p	M	SD	N	M	SD	N	M	SD	N
1	Learning to use this way of modelling business processes would be easy for me.	.89	4.77	1.51	35	4.86	1.32	28	4.69	1.23	32
2	I found the way the process is represented as unclear and difficult to understand.	.31	2.46	1.22	35	2.96	1.50	28	2.59	1.29	32
3	It would be easy for me to become skilful at using this way of modelling business processes.	.56	4.77	1.23	35	4.50	1.34	28	4.84	1.29	32
4	Overall, I found this way of modelling business processes difficult to use.	.70	2.83	1.17	35	3.07	1.35	28	3.03	1.25	31
PEU sum	codified: 2, 4	.65	4.56	1.00	35	4.33	1.03	28	4.48	0.97	32

Table 6.9: Perceived Ease of Understanding in the Survey

PEU		Horizontal M.	Vertical M.	Orthogonal M.
PEU sum	Horizontal M.	1.00	1.00	1.00
	Vertical M.	-	1.00	1.00
	Orthogonal M.	-	-	1.00

Table 6.10: Multiple Comparisons on PEU in the Survey

Study: While the survey discusses the issue of RQ1, the study deals with RQ2 and RQ3. Time units were adjusted. Times such as 01:12:23.01 were changed to 01:12:23.10, as SPSS was not able to capture the original time.

Performance Success

The performance success is composed of the number of a correct answer and the time required for eye tracking. Further, the results received from the eye tracker such as average fixation are utilized. A comparison with respect to different modularization approaches is considered.

First, the correct answer is considered. It was measured using points. Each right answer led to a point. Totally, 36 points were possible, twelve points for each modularization approach. As Table 6.11 shows, the scores obtained show only little difference. This is also supported by the results, analyzed through repeated measures. No measurable difference ($F(2, 34) = 0.85$, $p = .43$) occurred.
Second, the time measured while executing the task is of interest. A measurable difference ($F(2, 34) = 3.93$, $p = .02$) with an observed power of 66.8% between the modularization approaches exists when using repeated measures. However, further evaluation as presented in Table 6.12 reported no difference between the conditions ($p > .05$).

Performance Success		**Horizontal M.**			**Vertical M.**			**Orthogonal M.**		
	p	**M**	**SD**	**N**	**M**	**SD**	**N**	**M**	**SD**	**N**
Total score	.43	10.33	1.57	18	10.94	1.16	18	10.61	1.33	18
Total time*	.02	03:37.39	00:55.14	18	03:18.04	01:05.20	18	04:00.62	01:26.01	18

Table 6.11: Performance Success in the Study

Performance Success		**Horizontal M.**	**Vertical M.**	**Orthogonal M.**
Total Score	**Horizontal M.**	1.00	.39	1.00
	Vertical M.	-	1.00	1.00
	Orthogonal M.	-	-	1.00
Total Time	**Horizontal M.**	1.00	.27	.93
	Vertical M.	-	1.00	1.00
	Orthogonal M.	-	-	1.00

Table 6.12: Multiple Comparisons on Performance Success in the Study

Finally, the key performance indicators (KPI) that were observed through the eye tracker are analyzed via repeated measures. The evaluated results are presented in Table 6.13. As most items of the KPI indicate no appreciable difference ($p > .05$), the number of fixations varies ($F(1.41, 23.97) = 5.39$, $p = .01$) in terms of the modularization approach. Next, it was verified which modularization approaches attribute to the difference. This ensues through a One-Way ANOVA. With reference to the Bonferroni post-hoc analysis, as presented in Table 6.14, no difference ($p >$ .05) between the single modularization approaches occurs.

KPI		Horizontal M.			Vertical M.			Orthogonal M.		
	p	M	SD	N	M	SD	N	M	SD	N
Dwell Time	.49	92.96	7.28	18	94.49	2.91	18	91.82	9.87	18
Revisit	.50	0.80	1.67	18	0.44	0.48	18	0.93	1.52	18
Revisits	.89	0.35	0.32	18	0.33	0.32	18	0.37	0.40	18
Average Fixation	.87	219.70	22.44	18	218.57	29.03	18	221.09	27.09	18
First Fixation	.22	288.06	86.70	18	315.04	73.57	18	322.05	65.57	18
Fixation Count*	.01	71.92	28.56	18	57.13	15.66	18	60.20	15.60	18

Table 6.13: Key Performance Indicator (KPI) in the Study

KPI		Horizontal M.	Vertical M.	Orthogonal M.
Dwell Time	**Horizontal M.**	1.00	1.00	1.00
	Vertical M.	-	1.00	.71
	Orthogonal M.	-	-	1.00
Revisit	**Horizontal M.**	1.00	1.00	1.00
	Vertical M.	-	1.00	.96
	Orthogonal M.	-	-	1.00
Revisits	**Horizontal M.**	1.00	1.00	1.00
	Vertical M.	-	1.00	1.00
	Orthogonal M.	-	-	1.00
Average Fixation	**Horizontal M.**	1.00	1.00	1.00
	Vertical M.	-	1.00	1.00
	Orthogonal M.	-	-	1.00
First Fixation	**Horizontal M.**	1.00	.78	.61
	Vertical M.	-	1.00	1.00
	Orthogonal M.	-	-	1.00
Fixation Count	**Horizontal M.**	1.00	.10	.28
	Vertical M.	-	1.00	1.00
	Orthogonal M.	-	-	1.00

Table 6.14: Multiple Comparisons on KPI in the Study

As no meaningful difference in terms of the performance success occurs, the modularization approaches don't provide varieties. Therefore, the alternative hypothesis has to be rejected. The null hypothesis is given.

Design

The design refers to the research question RQ3. Therefore, the different presentations in the individual modularization approaches are compared. The comparison is comprised of measuring variables like the time, scores, and the KPI. Hence, it becomes obvious which design of the single modularization approaches gain better performance success. First, Q4.1 is considered. It points out how the representation influences horizontal modularization.

Q4.1: Horizontal Modularization
Horizontal modularization was divided into: *link events*, *message events*, and *self designed*.

Horizontal M.		Message Events			Link Events			Self Designed		
	p	M	SD	N	M	SD	N	M	SD	N
Scores	.91	3.47	0.77	19	3.42	0.76	19	3.37	0.89	19
Time	.12	01:11.61	00:30.43	19	01:22.73	00:37.08	19	01:23.18	00:28:84	19
Dwell Time	.06	94.53	3.59	16	95.87	2.12	16	93.97	3.78	16
Revisit	.61	0.40	0.42	16	0.32	0.39	16	0.34	0.47	16
Revisits	.54	0.32	0.29	16	0.26	0.29	16	0.26	0.33	16
Average Fixation	.42	222.27	25.33	16	225.69	22.00	16	228.07	24.79	16
First Fixation	.30	312.49	93.44	16	292.35	85.10	16	325.62	75.56	16
Fixation Count	.24	62.48	28.83	16	20.25	32.41	16	70.13	29.14	16

Table 6.15: Horizontal Modularization in the Study

Horizontal M.		Message Events	Link Events	Self Designed
Scores	**Message Events**	1.00	1.00	1.00
	Link Events	-	1.00	1.00
	Self Designed	-	-	1.00
Time	**Message Events**	1.00	.88	.82
	Link Events	-	1.00	1.00
	Self Designed	-	-	1.00
Dwell Time	**Message Events**	1.00	1.00	.54
	Link Events	-	1.00	.63
	Self Designed	-	-	1.00
Revisit	**Message Events**	1.00	.92	1.00
	Link Events	-	1.00	1.00
	Self Designed	-	-	1.00
Revisits	**Message Events**	1.00	1.00	1.00
	Link Events	-	1.00	1.00

	Self Designed	-	-	1.00
Average Fixation	**Message Events**	1.00	1.00	1.00
	Link Events	-	1.00	1.00
	Self Designed	-	-	1.00
First Fixation	**Message Events**	1.00	.88	1.00
	Link Events	-	1.00	.92
	Self Designed	-	-	1.00
Fixation Count	**Message Events**	1.00	.49	1.00
	Link Events	-	1.00	1.00
	Self Designed	-	-	1.00

Table 6.16: Multiple Comparisons on Horizontal Modularization in the Study

As presented in Table 6.15 and 6.16, no difference occurred ($p >$ .05). Hence, the null hypothesis is reported.

Q4.2: Vertical Modularization

The effects of representation are considered in terms of vertical modularization. Vertical modularization is composed of: *expanded subprocesses*, *collapsed subprocesses*, and *self designed.* With reference to Table 6.17 and 6.18, no recognizable difference ($p >$ .05) between the vertical modularization representations can be reported. Hence, the alternative hypothesis has to be discarded.

Vertical M.		**Expanded Subprocess**			**Collapsed Subprocess**			**Self Designed**		
	p	**M**	**SD**	**N**	**M**	**SD**	**N**	**M**	**SD**	**N**
Scores	.95	3.67	0.59	18	3.61	0.77	18	3.67	0.48	18
Time	.94	01:04.79	00:34.10	18	01:06.76	00:25.22	18	01:06.85	00:20:69	18
Dwell Time	.10	95.07	2.61	17	95.64	2.16	17	92.61	6.95	17
Revisit	.14	0.33	0.38	17	0.48	0.59	17	0.50	0.60	17
Revisits	.34	0.30	0.34	17	0.28	0.32	17	0.36	0.39	17
Average Fixation	.29	217.47	33.48	17	213.17	31.60	17	220.84	29.19	17
First Fixation	.51	219.36	73.38	17	318.13	139.53	17	321.71	87.84	17
Fixation Count	.93	56.26	22.36	17	58.18	20.09	17	56.92	18.55	17

Table 6.17: Vertical Modularization in the Study

Q4.3: Orthogonal Modularization

The different representation approaches regarding to orthogonal modularization are

Vertical M.		Expanded Sub-process	Collapsed Sub-process	Self Designed
Scores	**Expanded Sub-process**	1.00	1.00	1.00
	Collapsed Sub-process	-	1.00	1.00
	Self Designed	-	-	1.00
Time	**Expanded Sub-process**	1.00	1.00	1.00
	Collapsed Sub-process	-	1.00	1.00
	Self Designed	-	-	1.00
Dwell Time	**Expanded Sub-process**	1.00	1.00	.38
	Collapsed Sub-process	-	1.00	.17
	Self Designed	-	-	1.00
Revisit	**Expanded Sub-process**	1.00	1.00	1.00
	Collapsed Sub-process	-	1.00	1.00
	Self Designed	-	-	1.00
Revisits	**Expanded Sub-process**	1.00	1.00	1.00
	Collapsed Sub-process	-	1.00	1.00
	Self Designed	-	-	1.00
Average Fixation	**Expanded Sub-process**	1.00	1.00	1.00
	Collapsed Sub-process	-	1.00	1.00
	Self Designed	-	-	1.00
First Fixation	**Expanded Sub-process**	1.00	1.00	1.00
	Collapsed Sub-process	-	1.00	1.00
	Self Designed	-	-	1.00
Fixation Count	**Expanded Sub-process**	1.00	1.00	1.00
	Collapsed Sub-process	-	1.00	1.00
	Self Designed	-	-	1.00

Table 6.18: Multiple Comparisons on Vertical Modularization in the Study

evaluated. As shown in Table 6.19, two differences with regard to repeated measures occur. Difference one ($F(1.65, 29.76)$ = 3.59, p = .04) refers to the dwell time (time spent on fixating the graphic) and was corrected through the Huynh-Feldt correction. The second one showed a difference ($F(2, 36) =$ 3.62, $p =$ .03) regarding the average fixation. By evaluating the two measured differences through a One-Way ANOVA, no difference between the groups ($p >$ .05) was measurable. This is presented in Table 6.20.

Hence, the null hypothesis occurs.

Orthogonal M.		**Error Events**			**Aspect-Oriented**			**Self Designed**		
	p	**M**	**SD**	**N**	**M**	**SD**	**N**	**M**	**SD**	**N**
Scores	.64	3.42	1.07	19	3.68	0.67	19	3.53	0.69	19
Time	.41	01:07.06	00:15.95	19	01:16.15	00:31.44	19	01:11.27	00:25:05	19
Dwell Time*	.04	90.31	11.81	19	92.01	9.67	19	92.72	7.75	19
Revisit	.42	0.88	1.47	19	0.81	1.41	19	0.95	1.65	19
Revisits	.57	0.35	0.41	19	0.32	0.40	19	0.38	0.43	19
Average Fixation*	.03	216.42	29.30	19	219.94	29.44	19	227.75	26.63	19
First Fixation	.65	309.44	77.95	19	325.10	76.50	19	320.31	82.54	19
Fixation Count	.35	56.13	14.57	19	64.03	26.38	19	61.57	19.38	19

Table 6.19: Orthogonal Modularization in the Study

Orthogonal M.		**Error Events**	**Aspect-Oriented**	**Self Designed**
Scores	**Error Events**	1.00	1.00	1.00
	Aspect-Oriented	-	1.00	1.00
	Self Designed	-	-	1.00
Time	**Error Events**	1.00	.81	1.00
	Aspect-Oriented	-	1.00	1.00
	Self Designed	-	-	1.00
Dwell Time	**Error Events**	1.00	1.00	1.00
	Aspect-Oriented	-	1.00	1.00
	Self Designed	-	-	1.00
Revisit	**Error Events**	1.00	1.00	1.00
	Aspect-Oriented	-	1.00	1.00
	Self Designed	-	-	1.00
Revisits	**Error Events**	1.00	1.00	1.00
	Aspect-Oriented	-	1.00	1.00

	Self Designed	-	-	1.00
Average Fixation	**Error Events**	1.00	1.00	.67
	Aspect-Oriented	-	1.00	1.00
	Self Designed	-	-	1.00
First Fixation	**Error Events**	1.00	1.00	1.00
	Aspect-Oriented	-	1.00	1.00
	Self Designed	-	-	1.00
Fixation Count	**Error Events**	1.00	.73	1.00
	Aspect-Oriented	-	1.00	1.00
	Self Designed	-	-	1.00

Table 6.20: Multiple Comparisons on Orthogonal Modularization in the Study

Based on these results, the null hypothesis is given for each question regarding the design. Some differences were measured in terms of the representations of single modularization approaches. By comparing these representations through a One-Way ANOVA, with reference to the Bonferroni post-hoc analysis, no differences were measured. Hence, the various modularization approaches in business process modeling have no impact with respect to cognitive complexity of process model readers.

6.3 Summary and Discussion

In this section the results of Section 6.2 are discussed.

Cognitive Load

Intrinsic Cognitive Load:

A significant difference between vertical and the other modularization approaches is shown. This could be caused by the different representations of the three modularization approaches. The representation refers to activities like icons.

Intrinsic cognitive load has the factors element interactivity and prior knowledge of the learner. Hence, these items have to be considered. No significant differences regarding prior knowledge exists. This leads to the assumption that the significant difference is caused by element interactivity.

The significant difference of process model three and four could be caused by the growth in complexity and the need of a subprocess. Hence, a further activity, the subprocess activity, is required. It includes an icon in form of a plus. This icon can be misunderstood by novices. In contexts like applets, a plus represents the adding of further content. Hence, the participant could expect that he can add further content to the activity instead of linking to an underlying process model.

Germane Cognitive Load:
In the survey, no significant difference was measured. This can be caused by the motivation and the enjoyment while preparing the task. However, it can't be assumed that a difference between the groups in the survey exists, as only slight deviations are caused. Next, the understandability doesn't show a significant difference. The result in GCL can be caused by the little differences, such as the quality and the realization of the single modularization approaches.

Extraneous Cognitive Load:
No significant difference in ECL is shown. As the participants had to read the process models and haven't had to perform a task, it wasn't measured if the participant understood the process model. Further, it was not guaranteed that they dealt with the process model. Participants, that did not deal with the process model, required less capacities of the working memory. As no significant difference between the groups exists regarding the prior knowledge and educational background, the same behavior was expected. Therefore, it is assumed that no difference between the groups is given. Hence, the difference in ECL can be caused by the quality or difficulty in representation of the individual modularization approaches. As these are nearly identical, participants had to apply the same capacities in information processing.

Understandability
Perceived Usefulness for Understandability:
In the survey, no significant difference was obtained regarding the perceived usefulness for understandability. This leads to two assumptions:

- the representation of the three modularization approaches is analogical. Hence, no differences in understandability were possible.

- the representation of the three modularization approaches isn't analogical, but the quality in representation and understandability is the same.

With reference to the significant difference in intrinsic cognitive load that is caused by element interactivity the representation of the three approaches is not analogical. This is also supported by the different symbols caused by the modularization approaches.
Thus, assumption two that 'the representation of the three modularization approaches isn't analogical, but the quality in representation and understandability is the same' turns out to be correct. This assumption is supported by the results that were measured regarding the extraneous and germane cognitive load. With respect to these observed measurement variables, no significant difference occurred. The design and representation quality, such as the information processing, seems to be equivalent. Hence, the perceived usefulness for understandability is also equivalent.

Perceived Ease of Understanding:
No significant difference regarding the perceived ease of understanding was reported. This leads to the assumption that the process models provide an almost equivalent understandability and reproducibility. This assumption is supported by the results regarding the germane and extraneous cognitive load. Therefore, the representation exhibit the same quality and leads to the need of analogical mental resources of the individuals.
The element interactivity measured through the intrinsic cognitive load leads to two possibilities:

- Element interactivity exists without implication on perceived ease of understanding
- Element interactivity exists and has implications on perceived ease of understanding

If the first assumption occurs, the intrinsic cognitive load has no implications on the perceived ease of understanding. Hence, elements such as the selected icons would not have an effect. However, element interactivity is necessary for good understanding of the content. Therefore, the second assumption seems to be possible. Element interactivity points out that good results can be achieved when learners don't have to link other elements [84]. After linking the elements and receiving insights into the design and topic, the approaches can be understood by the participants without a measurable difference.

Performance Success

In the study, the performance success was measured without perceived differences. This can be caused by different factors.

- Quality of materials
- Difficulty of materials
- Complexity of materials
- Little number of participants

The participants received in mean 31.26 points from 36 points. Hence, 86.83% of the answers were correct. Therefore, the difficulty of materials could cause the effect. The assessed contents and statements could be too simple for receiving meaningful results. Further, the quality of materials could lead to the result. On the one hand, the chosen examples could be self-descriptive and an understanding of the process model is redundant. This assumption can be discarded as questions with respect to the usage of modules and the need of activities in modularization were questioned. On the other hand, the representation of the modularization approaches can cause effects regarding the performance. In organizations, the representation of the process models varies in terms of the presented process models. For example, in collapsed modularization, the underlying process isn't represented on the same page (except when it is opened) as the overlying process. Hence, the actual difficulties aren't necessarily eliminated.

Next, the complexity of the materials is quite low as this thesis focuses on the individual elements' modularization and the understandability of the modularization approaches. The experimental design was presented in a way to receive meaningful results regarding to the focus.

Finally, the small amount of participants could cause the effect. As only 19 persons participated in the study, significant reporting was impossible. Further, the observed power was quite often low. Hence, the study should be executed with a higher number of participants to receive adequate results.

Design

No difference caused by the design occurred with respect to the single modularization approaches.

Possible effects on the design can be caused by:

- Process model complexity
- Items in the process model

In horizontal modularization, no measurable differences resulted. The design has only slight variations, as merely changes regarding events/activities and sequenceflows exist. The single process model designs don't seem to provide higher complexity. Therefore, the performance success can almost be equivalent.

In vertical modularization, no difference regarding to the design is provided. This is in contrast to the results of [47]. [47] showed that collapsed subprocesses provide a decrease in comprehension. As the focus of this research question was on the performance success and not understandability, a different result can be obtained. However, the understandability has effects on the performance success. Further, the fixation count and the average fixation would differ through differences in understandability. Therefore, the variation in representation and the process model complexity could cause the difference. Next, the complexity of the individual representations varies. As one representation approach is given in a sequence, the ensuing approach is composed of further activities, next to subdivision. This could cause further cognitive load. As already discussed, the complexity of the presented process model and the number of modularization representations could lead to the result.

No difference in terms of the design in orthogonal modularization is reported. In orthogonal modularization, the activities and representations vary. In the aspect-oriented approach, activities were chosen to reference the join point of the modularized section through point cuts. With respect to exceptions, an interaction through events is given. Hence, the similarity doesn't lead to the missing difference. The similarity received in the results of the eye tracker confirmed this assumption.

Summary

In summary, the significant difference in intrinsic cognitive load seems to be caused by misunderstanding the plus icon utilized in vertical modularization. As no further significant difference occurred, a lot of intersection points exist, these are for example based on:

- same quality/ realization of modularization approaches
- same capacities in information processing
- element interactivity

However, different factors can lead to effects regarding the results. The study was executed with a low number of participants. As a result, the observed power was quite low. Hence, the results of replicated studies may lead to different assumptions. Further, a higher amount of participants would have effects on the validity. First of all validity, in particular regarding the external validity, as the results would provide better generalization. Therefore, more research is necessary to provide significant results and clear statements. This can be realized through experimental reproduction and/or additional studies. How further research could be realized is given in Section 8. Scientific research, utilized in this thesis, is presented in the following section.

7 Related Work

The related work is comprised of two aspects. Aspect one is in terms of the differentiation of the modularization approaches, next to their differences, while aspect two deals with the selected materials.

In [46], vertical and horizontal modularization are mentioned regarding to modularization. While many papers only refer to the horizontal and vertical modularization, [1] is cited when all modularization approaches of business process models are object of interest. The modularization approaches are comprised of horizontal, vertical, and orthogonal modularization. Furthermore, [1] provides first insights in terms of the usability and thus understandability of the single modularization approaches regarding to experts. The authors point out, that orthogonal modularization provides a lower ease of use and usefulness compared to the other two approaches. Further, [1] outlines the options of the design regarding the single approaches.

The differences in a single modularization approach are object of investigation. With respect to the vertical modularization, discerns exist. Expanded subprocesses provide better understandability as opposed to collapsed subprocesses. This finding is due to [47]. They point out that fully-flattened process models influence the understandability positively. Thus they are better understandable than collapsed and expanded subprocesses. Further, the authors argue that expanded subprocesses should preferably be used in terms of understandability.

However, the design of the single modularization approach was considered. For vertical modularization the design of expanded and collapsed subprocesses was researched. The design of expanded subprocesses is based on the presentation in [33]. This poster presents an open subprocess task in a collaboration diagram. Inside this task a self-contained process model is shown. For collapsed subprocess two different designs were considered. For the survey the representation of [1] is selected and the illustration from [47] is utilized for the study. While [1] uses dashed lines that open from the subprocess task to the underlying process, [47] illustrated the subprocess outside the pool (indicating the parent process) with a border around the subprocess.

The design of horizontal modularization contains message and link events. Both representations were illustrated in [1].

In orthogonal modularization exceptions and aspect-oriented paradigm were considered. First, activities to visualize exceptions had to be selected. Therefore, [60] referred to different events and provided insights into the possibilities in representation. Hence, [60] showed that exceptions can be handled in an event-subprocess or outside a subprocess. For the aspect-oriented paradigm the illustration of [1] was utilized. Additional research was applied to acquire knowledge regarding the procedure. In [61] single aspects and the fundamentals of aspect-oriented paradigms were considered. Further they provide insights into a possible implementation and tooling of aspect-oriented paradigms for BPMN.

Next, the presentation medium makes no difference with respect to the understandability [47]. Hence, computer or paper based materials can be selected for empirical research.

Materials of the eye tracking studies regarding business process models exist. Such materials are given in diverse pre-studies of the Institute of Databases and Information Systems (DBIS). In these pre-studies the main constructs of different business process modeling notations are differentiated. This representation provides prospects of success related to the previous findings, as significant differences are shown in the results. Measuring variables that lead to the findings are, for example, the KPI and the performance success.

Next to the materials that were prepared for measuring, the variables for comparison were of interest. [74] set up cognitive weightings for BPM elements. The weightings refer to the efforts that are necessary for understandability. An OR provides a lower comprehension than an XOR. Furthermore, [74] pointed out that the understandability is lower when the number of activities is low. The cognitive load theory supports this result. Further, [75] addresses the fact that understandability and cognitive load theory are related, as the cognitive load theory deals e.g. with understanding.

The presented related work focuses on the basic foundations on which this thesis is based. Next, further research possibilities and a conclusion are provided.

8 Future Work and Conclusion

This chapter provides further insights regarding this thesis, such as additional research possibilities. Section 8.1 presents a conclusion. Further, future work is discussed in Section 8.2.

8.1 Conclusion

This thesis investigates the effects of modularization in business process models on the cognitive complexity of humans. For this purpose, the developed research goal was to obtain insights in terms of the cognitive load when individuals read different modularized business process models. Based on further research, materials for two studies were designed. Hence, a survey with 95 participants and a study with 18 participants were executed.

In the survey, information regarding the cognitive complexity of the participants were measured. The focus lied on answering questionnaires with respect to the cognitive load, the PUU, and PEU after reading business process models. Each group (horizontal, vertical, and orthogonal) received the same process models. Process models differing in the representation were presented to the respective groups. These differences were realized through changes in terms of the process model modularization approaches. Hence, a participant of the group 'orthogonal modularization' only received orthogonal modularized process models. Then the participant had to answer questions according to the CLT. Next, the participant had to answer questionnaires after looking at all three modularization approaches. The results acquired using the survey showed a difference regarding the intrinsic cognitive load. Following, the vertical modularization leads to a significantly higher ICL caused by element interactivity.

In addition to the survey, an eye tracking study was executed. Each participant had to execute each approach. The focus was on the performance success. Therefore, the participant had to assess statements with true or false while executing the eye tracking study. Next to the accuracy of assessment, the time for executing the tasks was measured. A further point of interest was the design variations in a modularization approach. Therefore, the performance success of an individual approach was compared with the others. No difference was reported in the results.

In conclusion, the results based on the survey and the eye tracking study reported no difference. Hence, it is regardless which modularization approach is chosen. Only the vertical modularization leads to higher intrinsic cognitive load. The understandability reported, next to the germane and extraneous cognitive load, no significant difference. However, more data has to be collected through analogical/further research. Based on further results, guidelines for modularizing business process models and training documents could be designed. This would lead to the benefit that a well understandable modularization approach for process readers can be selected in process modeling. Consequently, an optimal distribution of the cognitive capacities of readers is possible.

8.2 Future Work

Modularization is a comprehensive topic. The amount of further research possibilities is enormous. Through the preliminary empirical results of this thesis it has been shown, that it makes no difference which modularization approach is chosen. However, further research is necessary to confirm these results, through replications and/or additional studies.

Next, higher complexity of process models could be used for data evaluation. As the survey results demonstrated, a small number of activities (little complexity) could contribute to the fact that only small differences are given. Hence, more complexity provides the opportunity for receiving significant differences between the modularization approaches. This assumption is supported by the results of the intrinsic cognitive load, where process models with a higher number of elements led to a significantly higher intrinsic cognitive load when reading vertical modularized business process models. In addition to the results achieved, the usage of a higher complexity is also based on the fact that business process models applied in practice have higher complexity than the process models shown in the studies.

Further, the combination of modularization approaches can be considered, as the various approaches are applicable in a business process model. The survey pointed out that 61.1% of the participants would prefer a combination of the horizontal and vertical modularization, 28.4% the combination of horizontal and orthogonal modularization, and 9.5% the combination of vertical and orthogonal modularization. No participant preferred the combination of all three modularization approaches. A study could be, inter alia, realized using an eye tracking study where insights, regarding the performance success will become obvious, for example. Further, the participant could identify the modularized parts by drawing into a process model. Hence, intuitive understanding about modularization could be captured. Further, it becomes obvious if the participant is aware of the term modularization and can transfer it into practice.

As the number of participants that would prefer a different design regarding the single modularization approaches were less than 50%, a change of elements in modularization is not of need.

However, the different representations of a single modularization approach can be measured. With respect to vertical modularization, [47] compared collapsed and expanded subprocesses, such as the usage of non-modularized process models. They received insights in terms of the understandability and therefore the usefulness when using the modularization approach. Such findings could also be recorded for the horizontal and orthogonal modularization. With respect to the horizontal approach, the utilization of signal, message, and link events can be compared. The orthogonal modularization includes the comparable elements: exceptions and aspect-oriented modularization. In terms of exception handling, various design possibilities can be compared. For aspect-oriented modularization, different possibilities in representation could be evaluated, as no clear modeling representation exists. This would lead to the benefit that a standardization of representation could be established for BPMN. Hence, literature and documentations would have a unique and understandable design for representation.

Finally, further notations of business process modeling could be used for subsequent studies. Furthermore, the different business process modeling notations could be compared with respect to their modularization.

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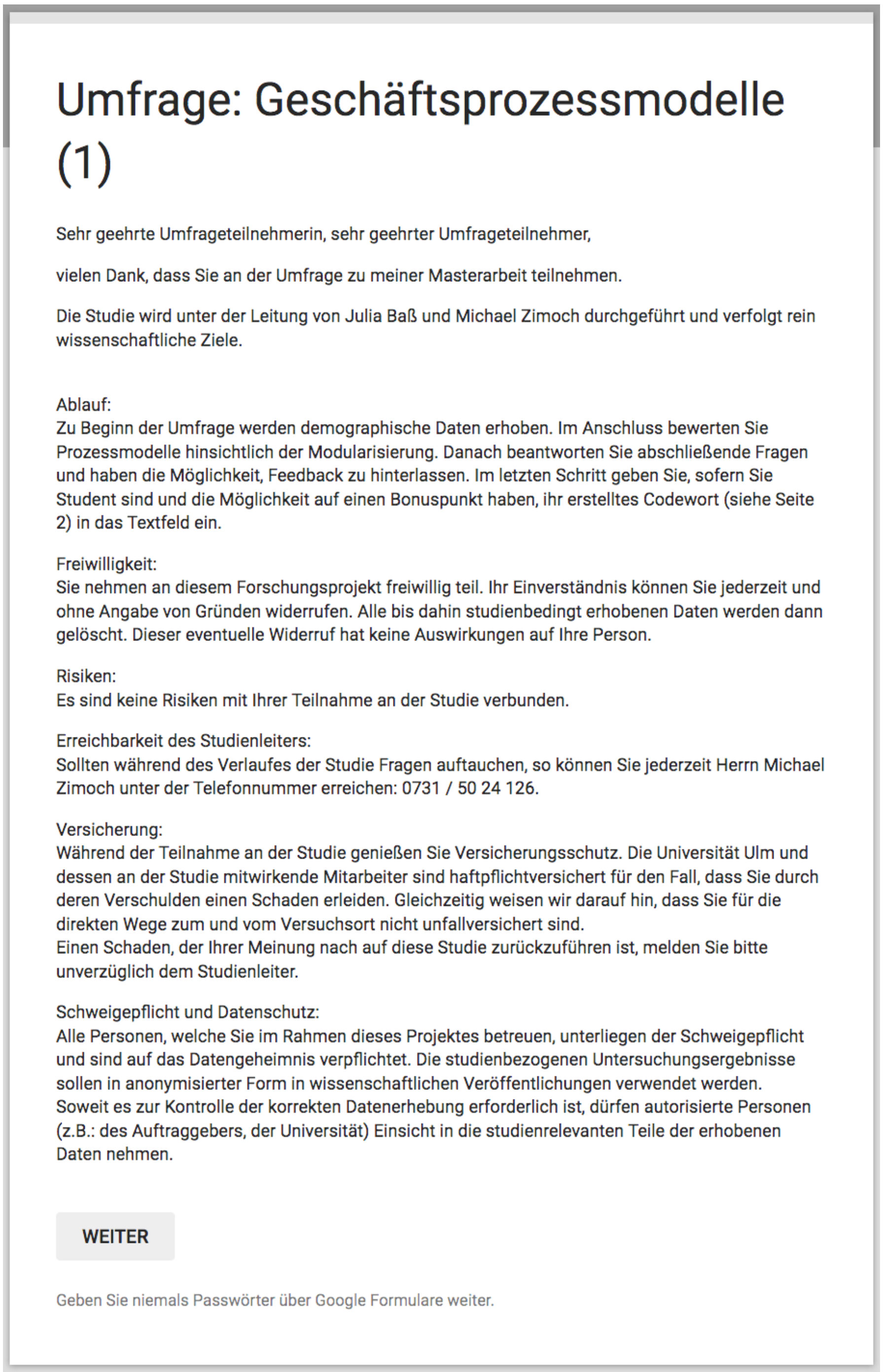
A

Survey

This appendix contains the materials presented to the participants of the survey. The participants were randomly assigned to one of the three groups. In the following, the content of the questionnaires of the groups horizontal, vertical, and orthogonal modularization are displayed.

Section 1 - Introduction



Umfrage: Geschäftsprozessmodelle (1)

Sehr geehrte Umfrageteilnehmerin, sehr geehrter Umfrageteilnehmer,

vielen Dank, dass Sie an der Umfrage zu meiner Masterarbeit teilnehmen.

Die Studie wird unter der Leitung von Julia Baß und Michael Zimoch durchgeführt und verfolgt rein wissenschaftliche Ziele.

Ablauf:
Zu Beginn der Umfrage werden demographische Daten erhoben. Im Anschluss bewerten Sie Prozessmodelle hinsichtlich der Modularisierung. Danach beantworten Sie abschließende Fragen und haben die Möglichkeit, Feedback zu hinterlassen. Im letzten Schritt geben Sie, sofern Sie Student sind und die Möglichkeit auf einen Bonuspunkt haben, ihr erstelltes Codewort (siehe Seite 2) in das Textfeld ein.

Freiwilligkeit:
Sie nehmen an diesem Forschungsprojekt freiwillig teil. Ihr Einverständnis können Sie jederzeit und ohne Angabe von Gründen widerrufen. Alle bis dahin studienbedingt erhobenen Daten werden dann gelöscht. Dieser eventuelle Widerruf hat keine Auswirkungen auf Ihre Person.

Risiken:
Es sind keine Risiken mit Ihrer Teilnahme an der Studie verbunden.

Erreichbarkeit des Studienleiters:
Sollten während des Verlaufes der Studie Fragen auftauchen, so können Sie jederzeit Herrn Michael Zimoch unter der Telefonnummer erreichen: 0731 / 50 24 126.

Versicherung:
Während der Teilnahme an der Studie genießen Sie Versicherungsschutz. Die Universität Ulm und dessen an der Studie mitwirkende Mitarbeiter sind haftpflichtversichert für den Fall, dass Sie durch deren Verschulden einen Schaden erleiden. Gleichzeitig weisen wir darauf hin, dass Sie für die direkten Wege zum und vom Versuchsort nicht unfallversichert sind.
Einen Schaden, der Ihrer Meinung nach auf diese Studie zurückzuführen ist, melden Sie bitte unverzüglich dem Studienleiter.

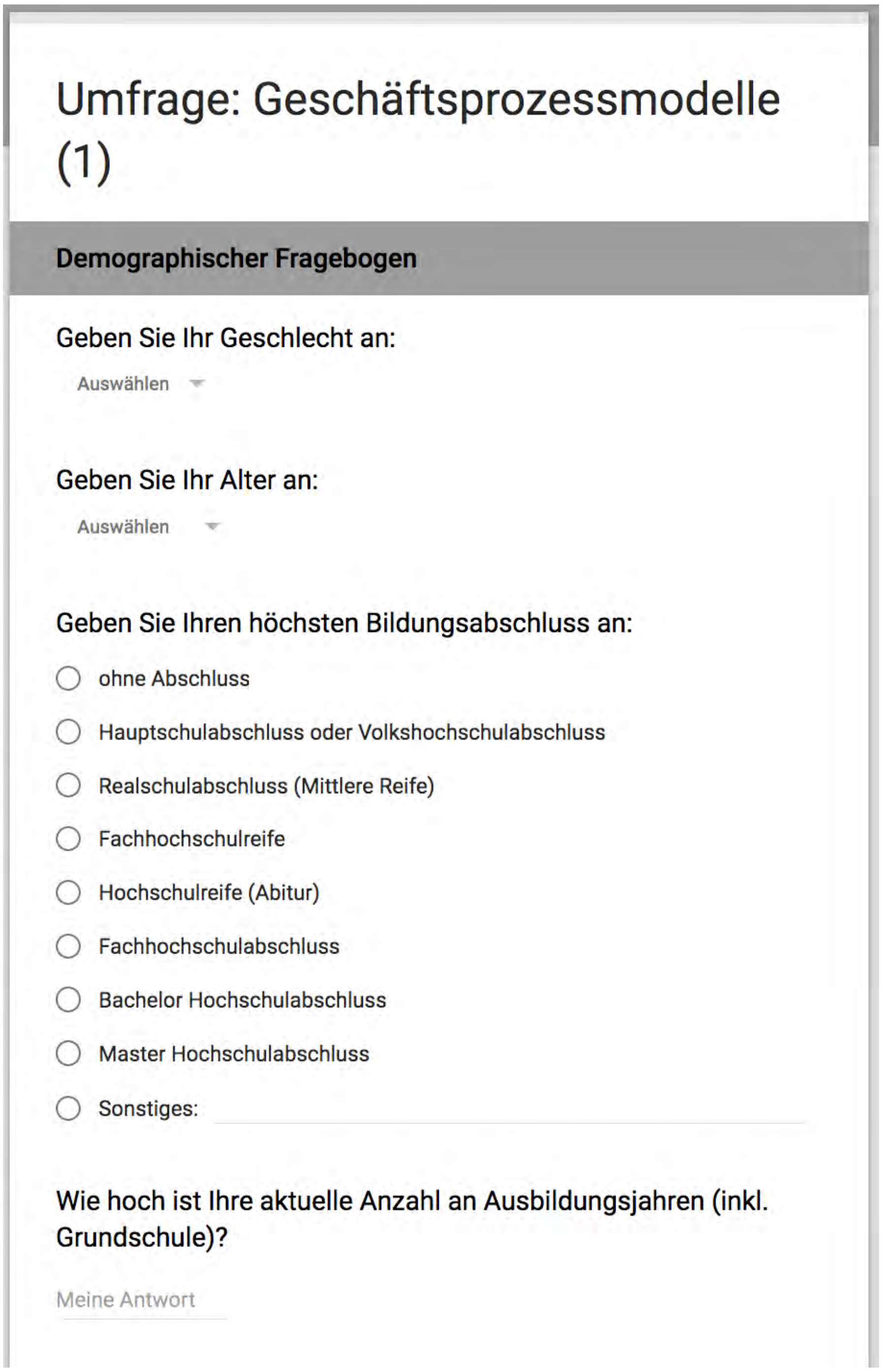
Schweigepflicht und Datenschutz:
Alle Personen, welche Sie im Rahmen dieses Projektes betreuen, unterliegen der Schweigepflicht und sind auf das Datengeheimnis verpflichtet. Die studienbezogenen Untersuchungsergebnisse sollen in anonymisierter Form in wissenschaftlichen Veröffentlichungen verwendet werden. Soweit es zur Kontrolle der korrekten Datenerhebung erforderlich ist, dürfen autorisierte Personen (z.B.: des Auftraggebers, der Universität) Einsicht in die studienrelevanten Teile der erhobenen Daten nehmen.

WEITER

Geben Sie niemals Passwörter über Google Formulare weiter.

Figure A.1: Introduction

Section 2 - Demographic Questionnaire



Umfrage: Geschäftsprozessmodelle (1)

Demographischer Fragebogen

Geben Sie Ihr Geschlecht an:

Auswählen

Geben Sie Ihr Alter an:

Auswählen

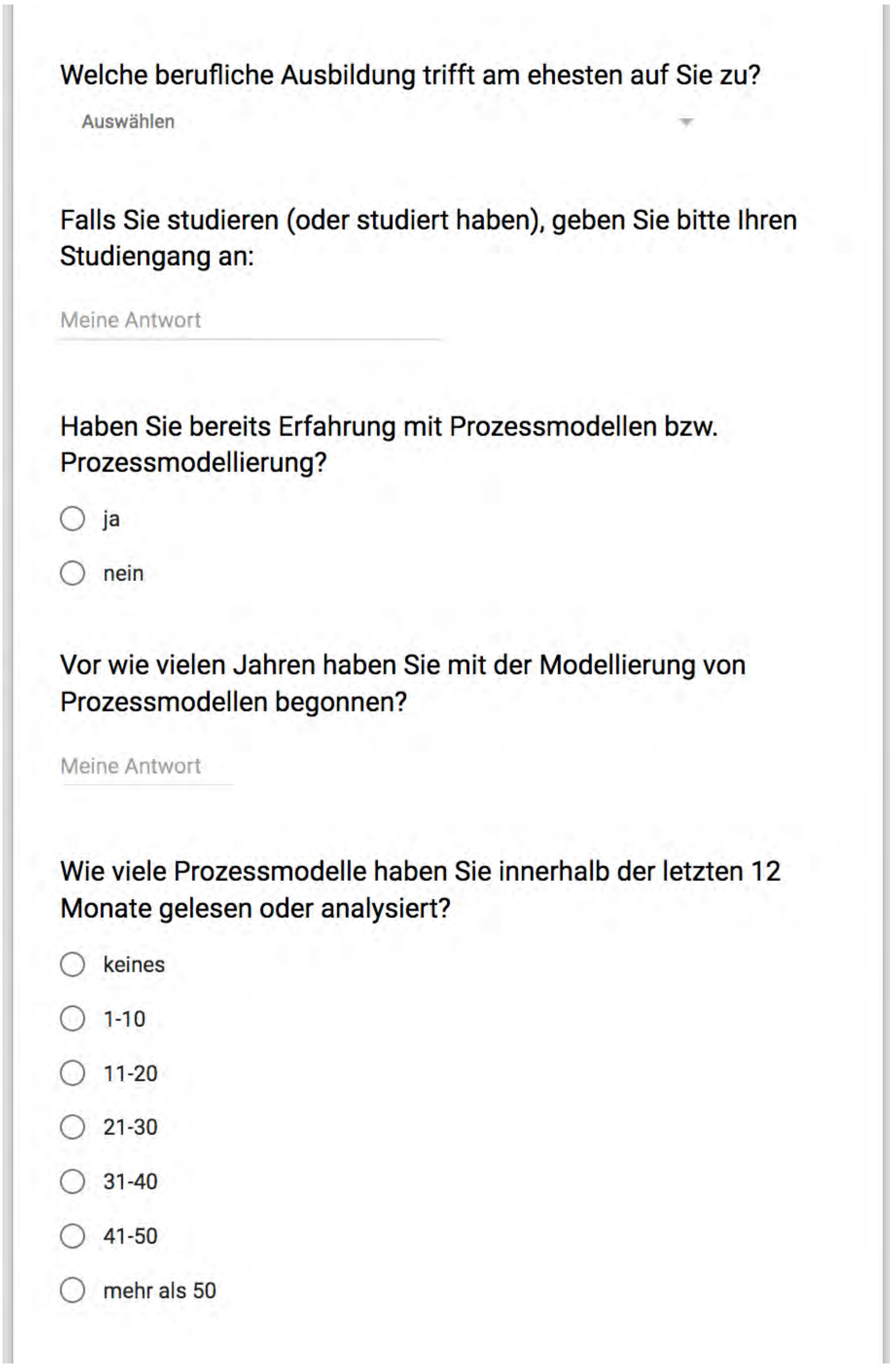
Geben Sie Ihren höchsten Bildungsabschluss an:

- ohne Abschluss
- Hauptschulabschluss oder Volkshochschulabschluss
- Realschulabschluss (Mittlere Reife)
- Fachhochschulreife
- Hochschulreife (Abitur)
- Fachhochschulabschluss
- Bachelor Hochschulabschluss
- Master Hochschulabschluss
- Sonstiges:

Wie hoch ist Ihre aktuelle Anzahl an Ausbildungsjahren (inkl. Grundschule)?

Meine Antwort

Figure A.2: Section 2-1 of Demographic Questionnaire



Welche berufliche Ausbildung trifft am ehesten auf Sie zu?

Auswählen

Falls Sie studieren (oder studiert haben), geben Sie bitte Ihren Studiengang an:

Meine Antwort

Haben Sie bereits Erfahrung mit Prozessmodellen bzw. Prozessmodellierung?

- ja
- nein

Vor wie vielen Jahren haben Sie mit der Modellierung von Prozessmodellen begonnen?

Meine Antwort

Wie viele Prozessmodelle haben Sie innerhalb der letzten 12 Monate gelesen oder analysiert?

- keines
- 1-10
- 11-20
- 21-30
- 31-40
- 41-50
- mehr als 50

Figure A.3: Section 2-2 of Demographic Questionnaire

Wie viele Prozessmodelle haben Sie innerhalb der letzten 12 Monate erstellt oder bearbeitet?

- ◯ keines
- ◯ 1-10
- ◯ 11-20
- ◯ 21-30
- ◯ 31-40
- ◯ 41-50
- ◯ mehr als 50

Wie viele Aktivitäten hatten diese Modelle im Durchschnitt?

- ◯ weniger als 10
- ◯ 10-20
- ◯ 21-30
- ◯ 31-40
- ◯ 41-50
- ◯ mehr als 50

Figure A.4: Section 2-3 of Demographic Questionnaire

Wie viele Tage formale Ausbildung zum Thema „Prozessmodellierung" haben Sie in den letzten 12 Monaten erhalten?

Eine Vorlesung mit 2 Stunden / Woche ergibt ca. 8 Stunden Ausbildung pro Monat. Das entspricht einem Arbeitstag pro Monat. Eine Vorlesung inkl. Übungen ergibt folglich 2 Arbeitstage pro Monat.

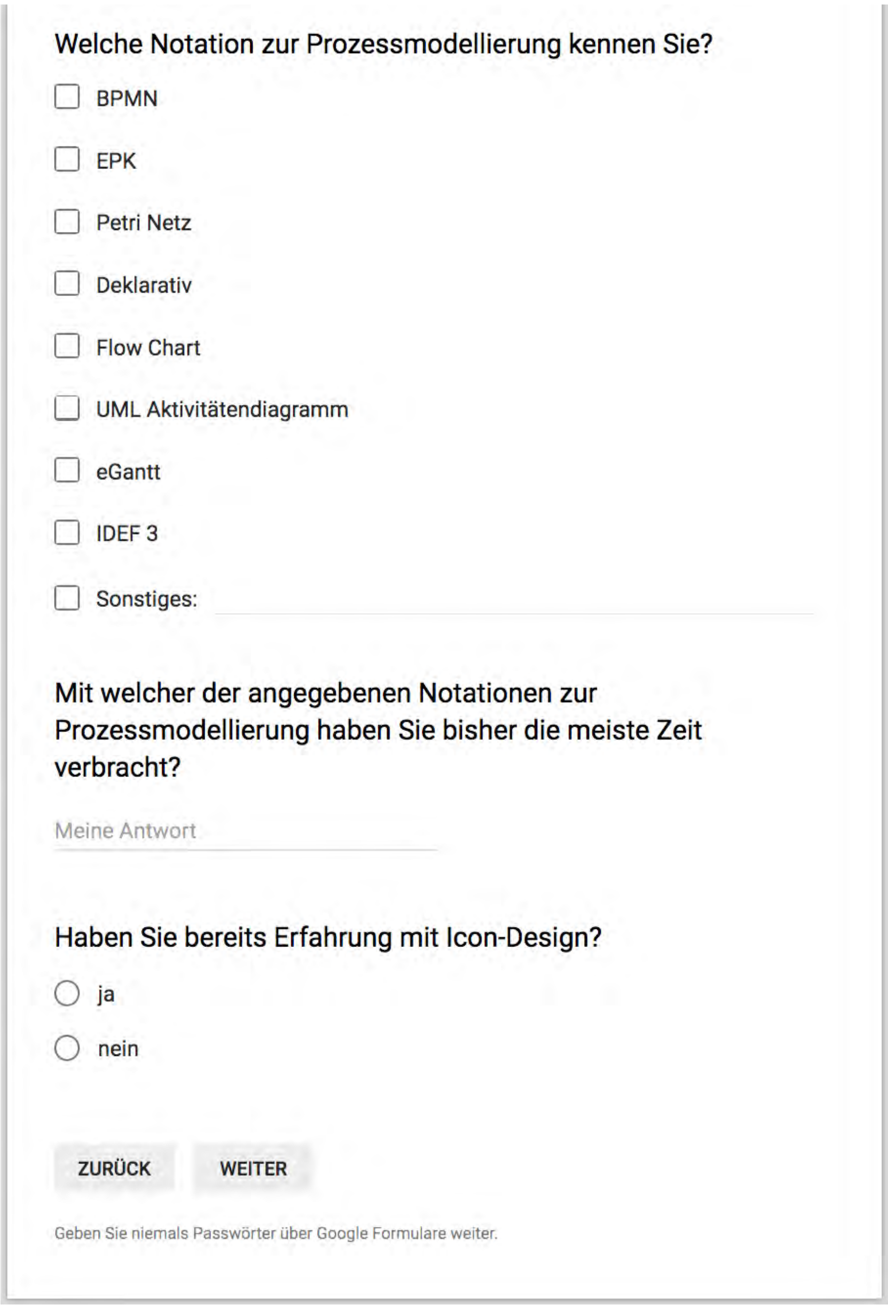
- ○ keine
- ○ 1-10
- ○ 11-20
- ○ 21-30
- ○ 31-40
- ○ 41-50
- ○ mehr als 50

Wie viele Tage haben Sie in den letzten 12 Monaten mit dem Selbststudium zum Thema „Prozessmodellierung" verbracht?

Eine Vorlesung mit 2 Stunden / Woche ergibt ca. 8 Stunden Ausbildung pro Monat. Das entspricht einem Arbeitstag pro Monat. Eine Vorlesung inkl. Übungen ergibt folglich 2 Arbeitstage pro Monat.

- ○ keine
- ○ 1-10
- ○ 11-20
- ○ 21-30
- ○ 31-40
- ○ 41-50
- ○ mehr als 50

Figure A.5: Section 2-4 of Demographic Questionnaire



Welche Notation zur Prozessmodellierung kennen Sie?

- [ ] BPMN
- [ ] EPK
- [ ] Petri Netz
- [ ] Deklarativ
- [ ] Flow Chart
- [ ] UML Aktivitätendiagramm
- [ ] eGantt
- [ ] IDEF 3
- [ ] Sonstiges:

Mit welcher der angegebenen Notationen zur Prozessmodellierung haben Sie bisher die meiste Zeit verbracht?

Meine Antwort

Haben Sie bereits Erfahrung mit Icon-Design?

- ja
- nein

ZURÜCK WEITER

Geben Sie niemals Passwörter über Google Formulare weiter.

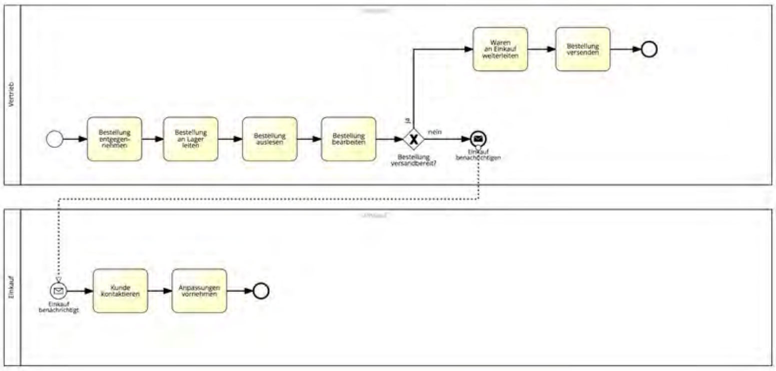
Figure A.6: Section 2-5 of Demographic Questionnaire

Section 3 - Process Models in the Modularization Approach

Umfrage: Geschäftsprozessmodelle (1)

Bewertung der Darstellung eines Prozessmodells

Betrachten Sie die Darstellung folgendes Prozessmodell und beantworten Sie untenstehende Fragen.



Prozessmodel größer: https://www.dropbox.com/s/amdxazcmxtuu4ed/1.png?dl=0

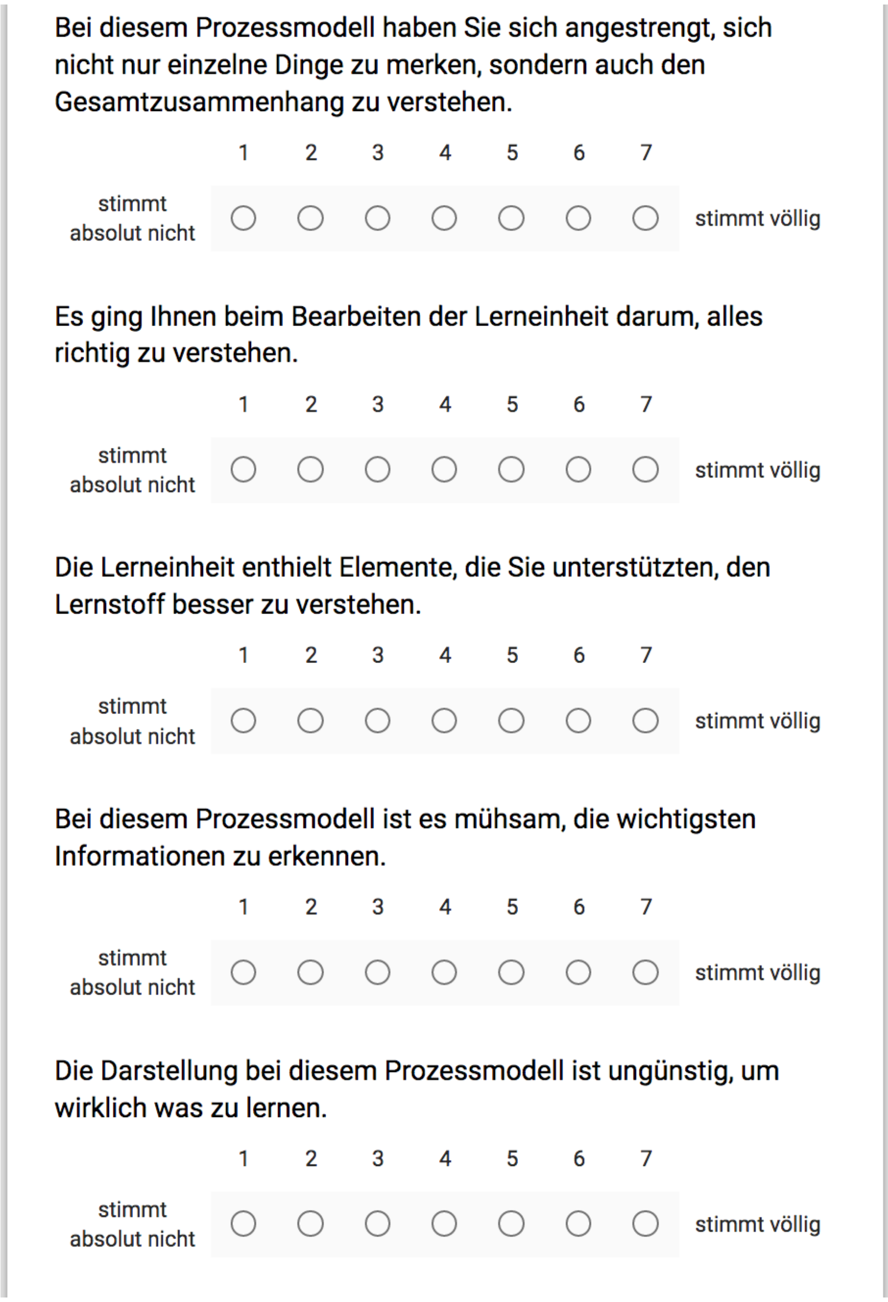
Bei diesem Prozessmodell muss man viele Dinge gleichzeitig im Kopf bearbeiten.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Das Prozessmodell ist sehr komplex.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Figure A.7: Section 3-1 Questions



Bei diesem Prozessmodell haben Sie sich angestrengt, sich nicht nur einzelne Dinge zu merken, sondern auch den Gesamtzusammenhang zu verstehen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Es ging Ihnen beim Bearbeiten der Lerneinheit darum, alles richtig zu verstehen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Die Lerneinheit enthielt Elemente, die Sie unterstützten, den Lernstoff besser zu verstehen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

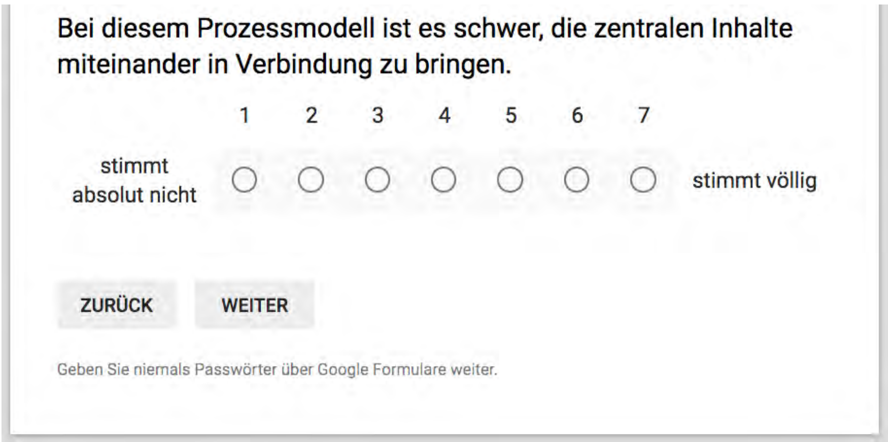
Bei diesem Prozessmodell ist es mühsam, die wichtigsten Informationen zu erkennen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Die Darstellung bei diesem Prozessmodell ist ungünstig, um wirklich was zu lernen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Figure A.8: Section 3-2 Questions


Bei diesem Prozessmodell ist es schwer, die zentralen Inhalte miteinander in Verbindung zu bringen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

ZURÜCK WEITER

Geben Sie niemals Passwörter über Google Formulare weiter.

Figure A.9: Section 3-3 Questions

Images in Horizontal Modularization (Iteration One up to Four)

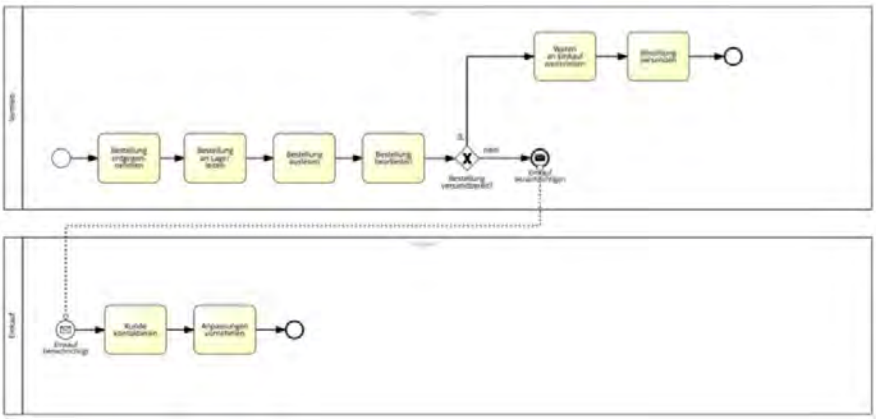


Figure A.10: Image of First Iteration in Horizontal Modularization

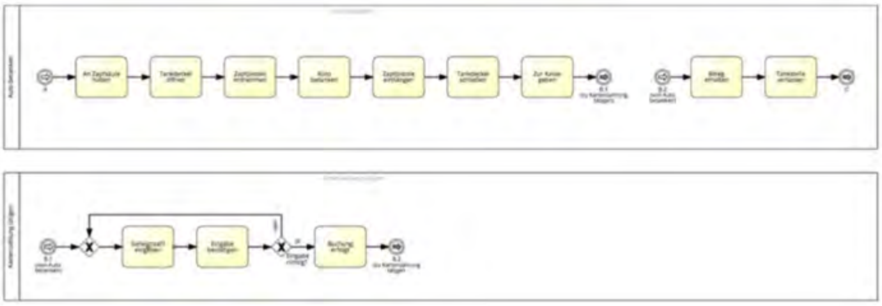


Figure A.11: Image of Second Iteration in Horizontal Modularization

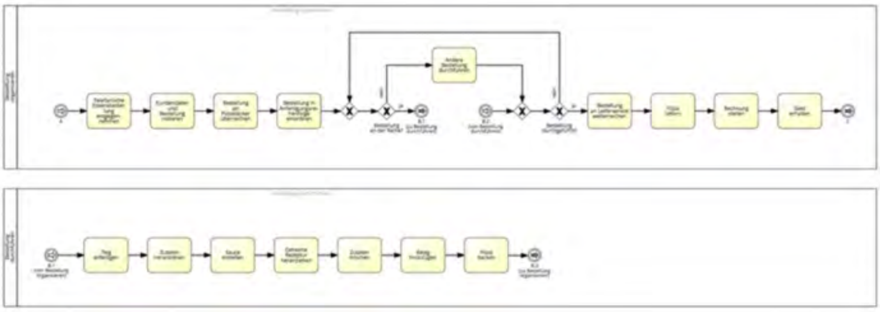


Figure A.12: Image of Third Iteration in Horizontal Modularization

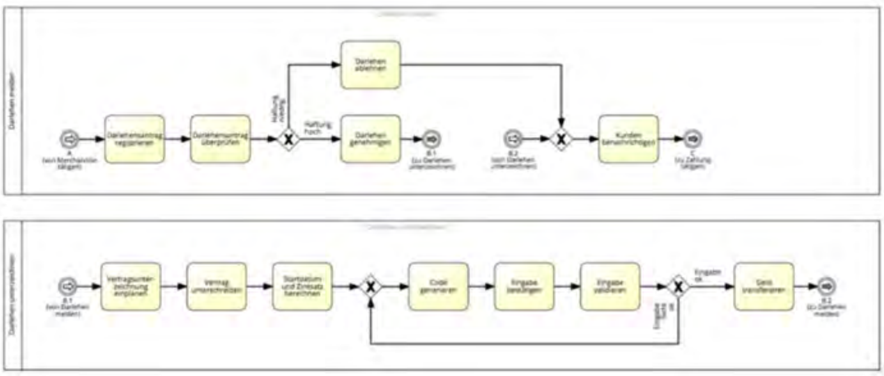


Figure A.13: Image of Fourth Iteration in Horizontal Modularization

Images in Vertical Modularization (Iteration One up to Four)

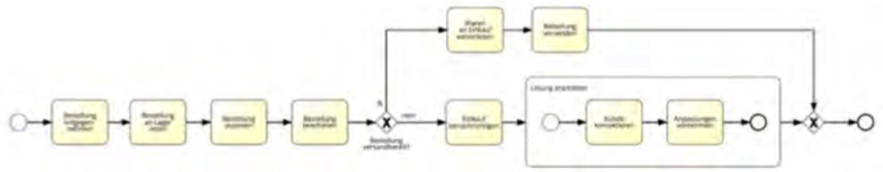


Figure A.14: Image of First Iteration in Vertical Modularization

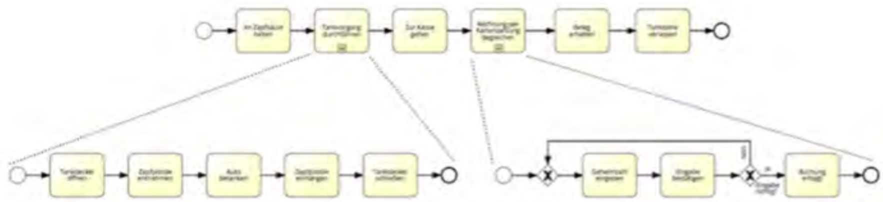


Figure A.15: Image of Second Iteration in Vertical Modularization

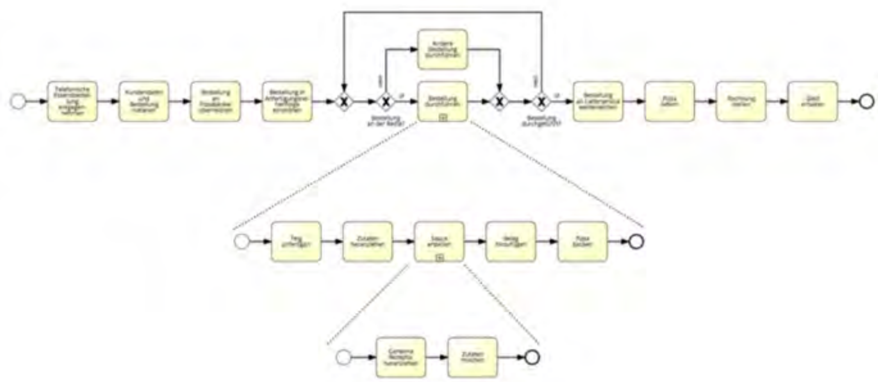


Figure A.16: Image of Third Iteration in Vertical Modularization

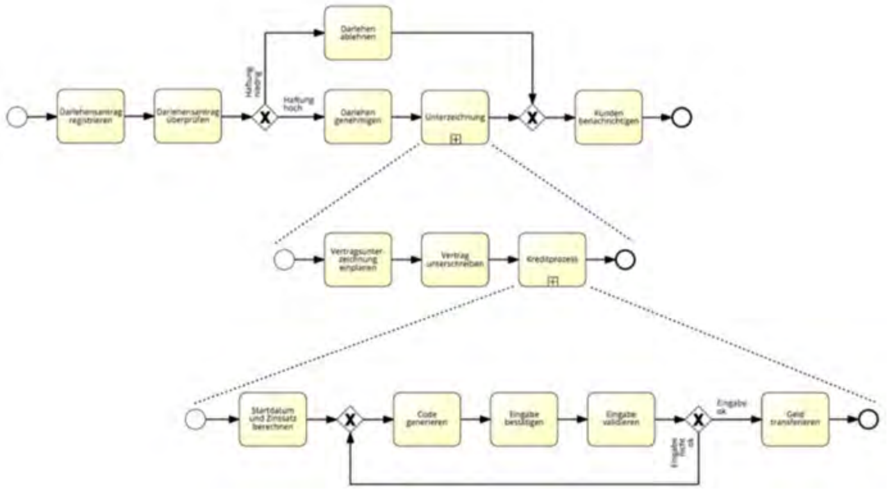


Figure A.17: Image of Fourth Iteration in Vertical Modularization

Images in Orthogonal Modularization (Iteration One up to Four)

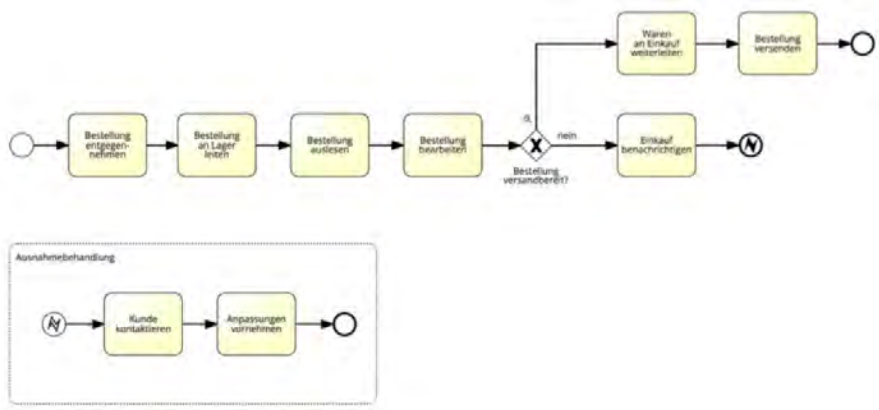


Figure A.18: Image of First Iteration in Orthogonal Modularization

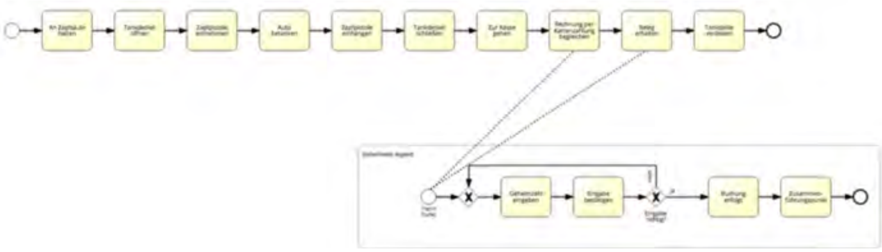


Figure A.19: Image of Second Iteration in Orthogonal Modularization

Figure A.20: Image of Third Iteration in Orthogonal Modularization

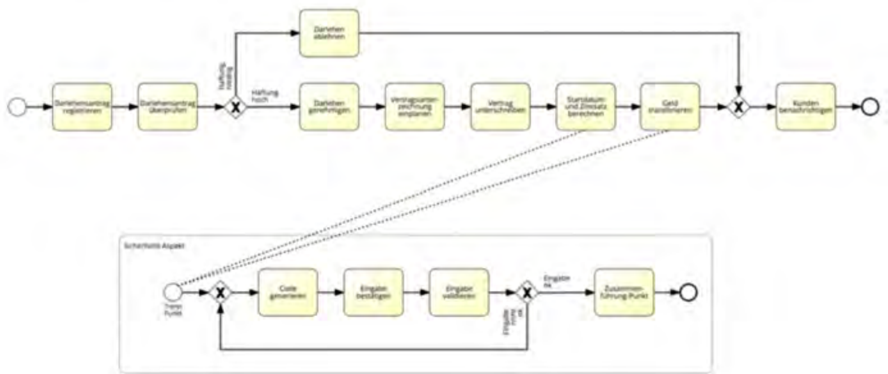


Figure A.21: Image of Fourth Iteration in Orthogonal Modularization

Section 4 - Modularization Approach

Umfrage: Geschäftsprozessmodelle (1)

* Erforderlich

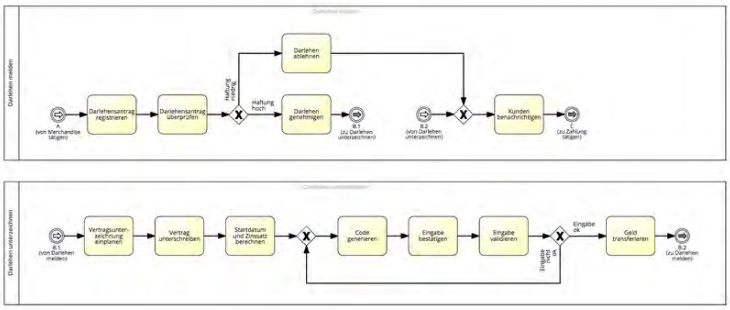
Horizontale Modularisierung

Beschreibung:
Gleichwertige Module durch Partitionierung eines Modells. Dies geschieht bei BPMN 2.0 durch die Verwendung von Pools. Ein Zielknoten eines Pools wird von einem Quellknoten eines anderen Pools aufgerufen. Dies kann durch unterschiedliche Ereignisse wie z. B. Nachrichten-Ereignisse, Link-Ereignisse, etc. realisiert werden.

Zweck:
Verantwortlichkeiten lassen sich besser zuweisen. Zusätzlich dient es der Übersichtlichkeit und der Verwaltung einzelner Module, da diese nun weniger komplex sind als ein ganzes Modell. Des Weiteren können einzelne Module wiederverwendet werden.

Darbietungsbeispiel:
Die einzelnen Module sollten möglichst gleich groß generiert werden. In diesem Beispiel werden aus einem großen Modell zwei logisch aufgespaltene Prozesse, wobei der Prozess „Darlehen unterzeichnen" aus dem Prozess „Darlehen melden" entnommen wurde. Die Entnahme des Prozesses „Darlehen unterzeichnen" wurde getätigt, da hierbei eine ganze Thematik zu einem Oberbegriff sinnvoll entnommen werden konnte. Die Verlinkung auf horizontaler Ebene wird symbolisch verdeutlicht, indem die ein- und ausgehenden Schnittstellen sowohl mit Wörtern wie auch visuell verdeutlicht werden.

(Die Beschreibung, der Zweck und das Beispiel basieren auf La Rosa et al. [3])



Prozessmodel größer: https://www.dropbox.com/s/8tjzfleeklmwq9x/4.png?dl=0

Figure A.22: Questions in Section 4-1

Es ging Ihnen beim Bearbeiten der Lerneinheit darum, alles richtig zu verstehen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Die Lerneinheit enthielt Elemente, die Sie unterstützten, den Lernstoff besser zu verstehen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Bei der horizontalen Modularisierung ist es mühsam, die wichtigsten Informationen zu erkennen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Die Darstellung bei horizontaler Modularisierung ist ungünstig, um wirklich was zu lernen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Bei horizontaler Modularisierung ist es schwer, die zentralen Inhalte miteinander in Verbindung zu bringen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Figure A.23: Questions in Section 4-2

Die horizontale Modularisierung ist für den Praxiseinsatz sehr geeignet.

	1	2	3	4	5	6	7	
stimmt absolut nicht								stimmt völlig

Die horizontale Modularisierung ist sehr nützlich.

	1	2	3	4	5	6	7	
stimmt absolut nicht								stimmt völlig

Die horizontale Modularisierung lässt sich sehr gut für die Modellierung von Prozessmodellen heranziehen.

	1	2	3	4	5	6	7	
stimmt absolut nicht								stimmt völlig

Bei der horizontalen Modularisierung muss man viele Dinge gleichzeitig im Kopf bearbeiten.

	1	2	3	4	5	6	7	
stimmt absolut nicht								stimmt völlig

Horizontale Modularisierung ist sehr komplex.

	1	2	3	4	5	6	7	
stimmt absolut nicht								stimmt völlig

Bei der horizontalen Modularisierung haben Sie sich angestrengt, sich nicht nur einzelne Dinge zu merken, sondern auch den Gesamtzusammenhang zu verstehen.

	1	2	3	4	5	6	7	
stimmt absolut nicht								stimmt völlig

Figure A.24: Questions in Section 4-3

Auf diese Weise repräsentierte Geschäftsprozessmodelle wären für die Benutzer schwer zu verstehen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Sie denken, dass dieser Präsentationsansatz eine effektive Lösung für das Problem der Darstellung von Geschäftsprozessmodellen bietet.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Die Verwendung von Prozessmodellen dieser Art würde die Kommunikation von Geschäftsprozessen an den Endbenutzer erschweren.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

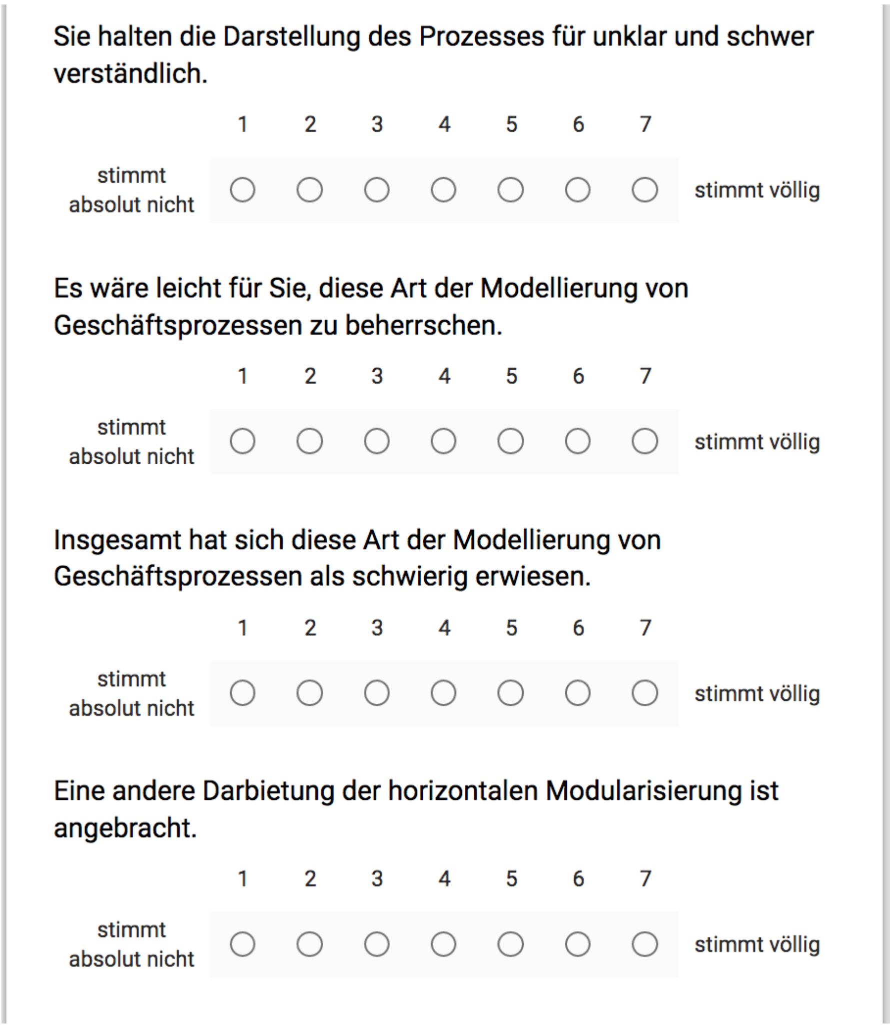
Insgesamt haben Sie das Geschäftsprozessmodell in diesem Experiment als nützlich erachtet.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Diese Art der Modellierung von Geschäftsprozessen zu erlernen, wäre für Sie einfach.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Figure A.25: Questions in Section 4-4



Sie halten die Darstellung des Prozesses für unklar und schwer verständlich.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Es wäre leicht für Sie, diese Art der Modellierung von Geschäftsprozessen zu beherrschen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

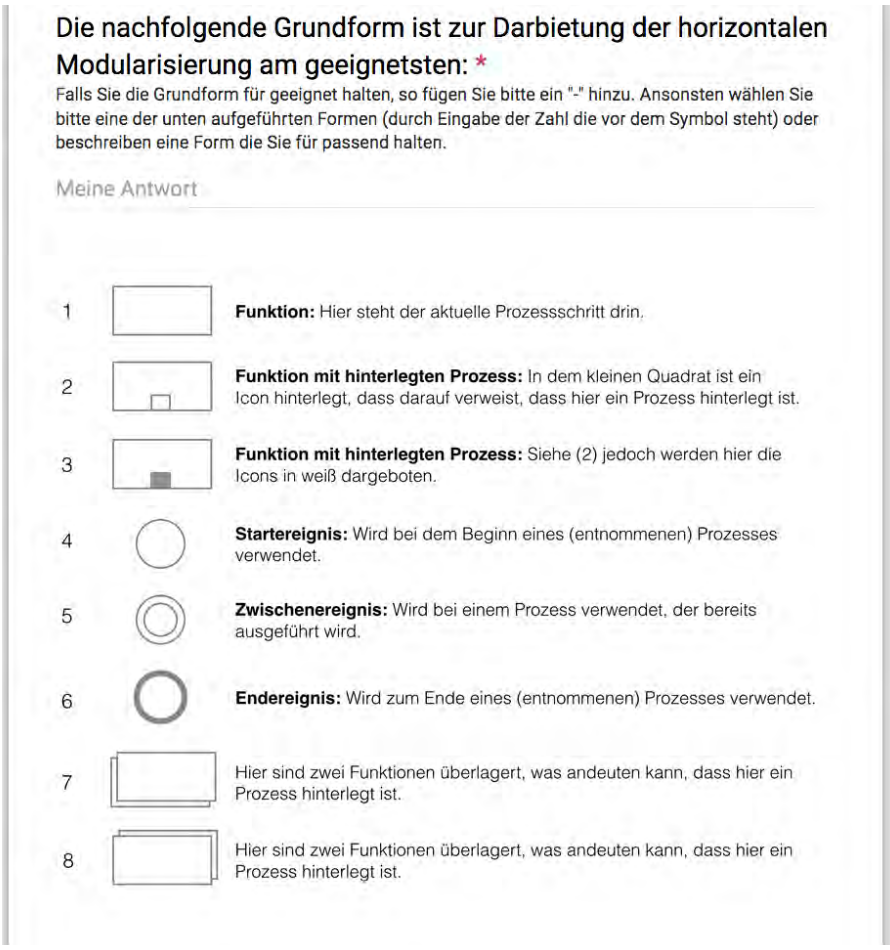
Insgesamt hat sich diese Art der Modellierung von Geschäftsprozessen als schwierig erwiesen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Eine andere Darbietung der horizontalen Modularisierung ist angebracht.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Figure A.26: Questions in Section 4-5



Die nachfolgende Grundform ist zur Darbietung der horizontalen Modularisierung am geeignetsten: *

Falls Sie die Grundform für geeignet halten, so fügen Sie bitte ein "-" hinzu. Ansonsten wählen Sie bitte eine der unten aufgeführten Formen (durch Eingabe der Zahl die vor dem Symbol steht) oder beschreiben eine Form die Sie für passend halten.

Meine Antwort

1 **Funktion:** Hier steht der aktuelle Prozessschritt drin.

2 **Funktion mit hinterlegten Prozess:** In dem kleinen Quadrat ist ein Icon hinterlegt, dass darauf verweist, dass hier ein Prozess hinterlegt ist.

3 **Funktion mit hinterlegten Prozess:** Siehe (2) jedoch werden hier die Icons in weiß dargeboten.

4 **Startereignis:** Wird bei dem Beginn eines (entnommenen) Prozesses verwendet.

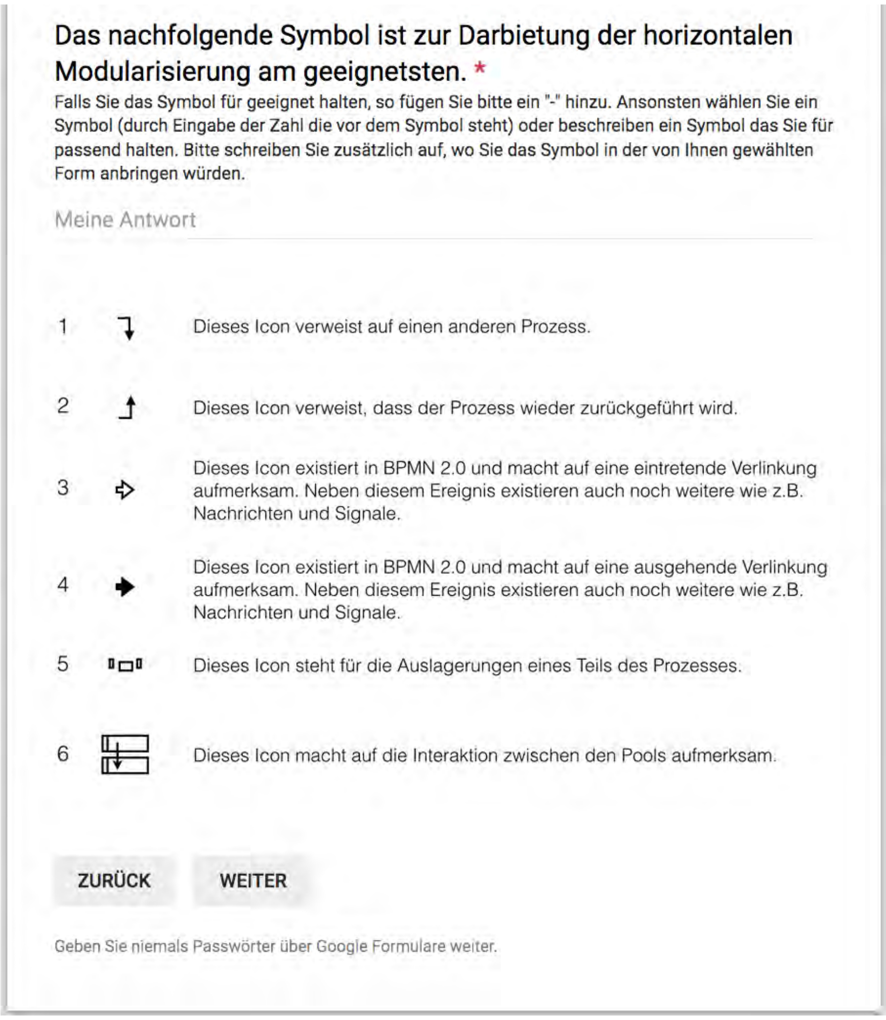
5 **Zwischenereignis:** Wird bei einem Prozess verwendet, der bereits ausgeführt wird.

6 **Endereignis:** Wird zum Ende eines (entnommenen) Prozesses verwendet.

7 Hier sind zwei Funktionen überlagert, was andeuten kann, dass hier ein Prozess hinterlegt ist.

8 Hier sind zwei Funktionen überlagert, was andeuten kann, dass hier ein Prozess hinterlegt ist.

Figure A.27: Questions in Section 4-6



Das nachfolgende Symbol ist zur Darbietung der horizontalen Modularisierung am geeignetsten. *

Falls Sie das Symbol für geeignet halten, so fügen Sie bitte ein "-" hinzu. Ansonsten wählen Sie ein Symbol (durch Eingabe der Zahl die vor dem Symbol steht) oder beschreiben ein Symbol das Sie für passend halten. Bitte schreiben Sie zusätzlich auf, wo Sie das Symbol in der von Ihnen gewählten Form anbringen würden.

Meine Antwort

1	Dieses Icon verweist auf einen anderen Prozess.
2	Dieses Icon verweist, dass der Prozess wieder zurückgeführt wird.
3	Dieses Icon existiert in BPMN 2.0 und macht auf eine eintretende Verlinkung aufmerksam. Neben diesem Ereignis existieren auch noch weitere wie z.B. Nachrichten und Signale.
4	Dieses Icon existiert in BPMN 2.0 und macht auf eine ausgehende Verlinkung aufmerksam. Neben diesem Ereignis existieren auch noch weitere wie z.B. Nachrichten und Signale.
5	Dieses Icon steht für die Auslagerungen eines Teils des Prozesses.
6	Dieses Icon macht auf die Interaktion zwischen den Pools aufmerksam.

ZURÜCK WEITER

Geben Sie niemals Passwörter über Google Formulare weiter.

Figure A.28: Questions in Section 4-7

Image and Description in Horizontal Modularization

Beschreibung:
Gleichwertige Module durch Partitionierung eines Modells. Dies geschieht bei BPMN 2.0 durch die Verwendung von Pools. Ein Zielknoten eines Pools wird von einem Quellknoten eines anderen Pools aufgerufen. Dies kann durch unterschiedliche Ereignisse wie z. B. Nachrichten-Ereignisse, Link-Ereignisse, etc. realisiert werden.

Zweck:
Verantwortlichkeiten lassen sich besser zuweisen. Zusätzlich dient es der Übersichtlichkeit und der Verwaltung einzelner Module, da diese nun weniger komplex sind als ein ganzes Modell. Des Weiteren können einzelne Module wiederverwendet werden.

Darbietungsbeispiel:
Die einzelnen Module sollten möglichst gleich groß generiert werden. In diesem Beispiel werden aus einem großen Modell zwei logisch aufgespaltene Prozesse, wobei der Prozess „Darlehen unterzeichnen" aus dem Prozess „Darlehen melden" entnommen wurde. Die Entnahme des Prozesses „Darlehen unterzeichnen" wurde getätigt, da hierbei eine ganze Thematik zu einem Oberbegriff sinnvoll entnommen werden konnte. Die Verlinkung auf horizontaler Ebene wird symbolisch verdeutlicht, indem die ein- und ausgehenden Schnittstellen sowohl mit Wörtern wie auch visuell verdeutlicht werden.

(Die Beschreibung, der Zweck und das Beispiel basieren auf La Rosa et al. [3])

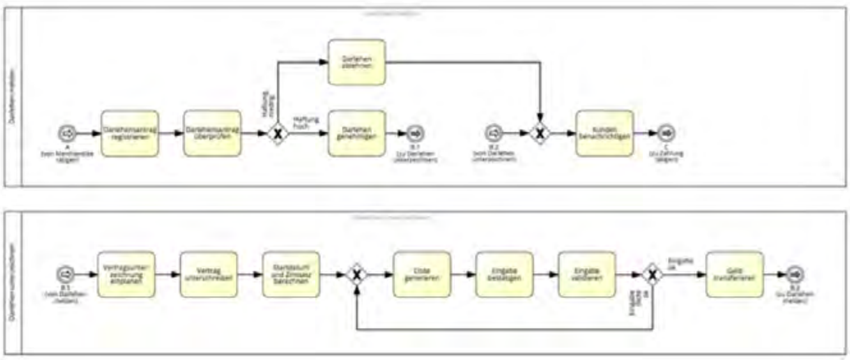
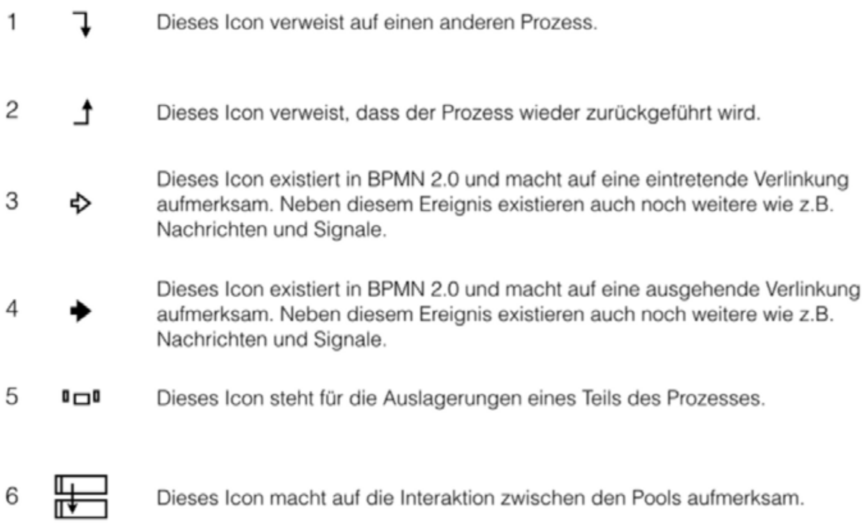


Figure A.29: Image and Description in Horizontal Modularization



1	Dieses Icon verweist auf einen anderen Prozess.
2	Dieses Icon verweist, dass der Prozess wieder zurückgeführt wird.
3	Dieses Icon existiert in BPMN 2.0 und macht auf eine eintretende Verlinkung aufmerksam. Neben diesem Ereignis existieren auch noch weitere wie z.B. Nachrichten und Signale.
4	Dieses Icon existiert in BPMN 2.0 und macht auf eine ausgehende Verlinkung aufmerksam. Neben diesem Ereignis existieren auch noch weitere wie z.B. Nachrichten und Signale.
5	Dieses Icon steht für die Auslagerungen eines Teils des Prozesses.
6	Dieses Icon macht auf die Interaktion zwischen den Pools aufmerksam.

Figure A.30: Suggested Icons in Horizontal Modularization

Image and Description in Vertical Modularization

Beschreibung:
Gemäß der hierarchischen Struktur wird ein Modell in vertikale Module unterteilt.

Zweck:
Dient der Verständlichkeit, der Vermeidung von Redundanzen, sowie der Wiederverwendung von Teilprozessen, indem Prozessdetails Ebene für Ebene dargeboten werden. Zusätzlich werden Änderungen am Prozessmodell vereinfacht, da diese lediglich an einer Stelle vorzunehmen sind.

Darbietungsbeispiel:
Wie bereits in der Beschreibung dargelegt ist eine hierarchische Struktur im Beispiel gegeben. Sie erfolgt auf drei Ebenen, dabei wurde eine Modularisierung stets bei Schlagwörtern wie „Unterzeichnung" und „Kreditprozess" getätigt, da diese sich zur Wiederverwendung eignen. Eine Verlinkung zur tieferen Ebene wird jeweils symbolisch verdeutlicht. Dabei sind die Linien nicht gegeben, da die Prozesse jeweils unter dem Subprozess liegen.

(Die Beschreibung, der Zweck und das Beispiel basieren auf La Rosa et al. [3])

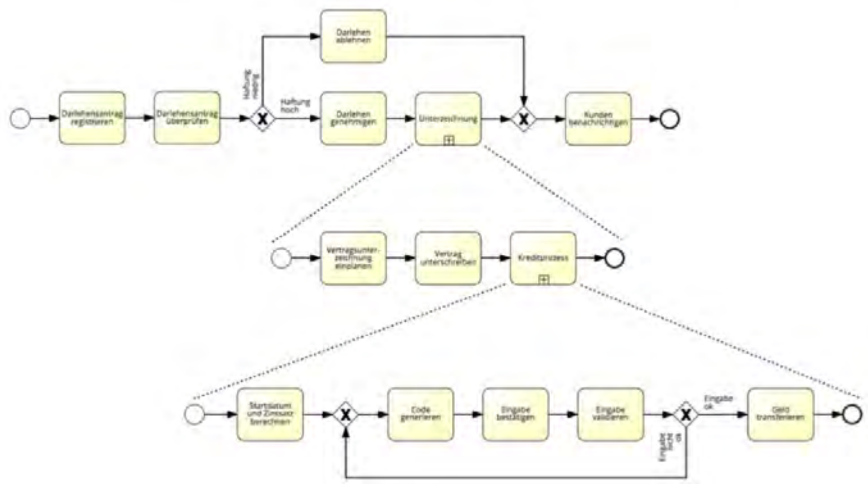


Figure A.31: Image and Description in Vertical Modularization

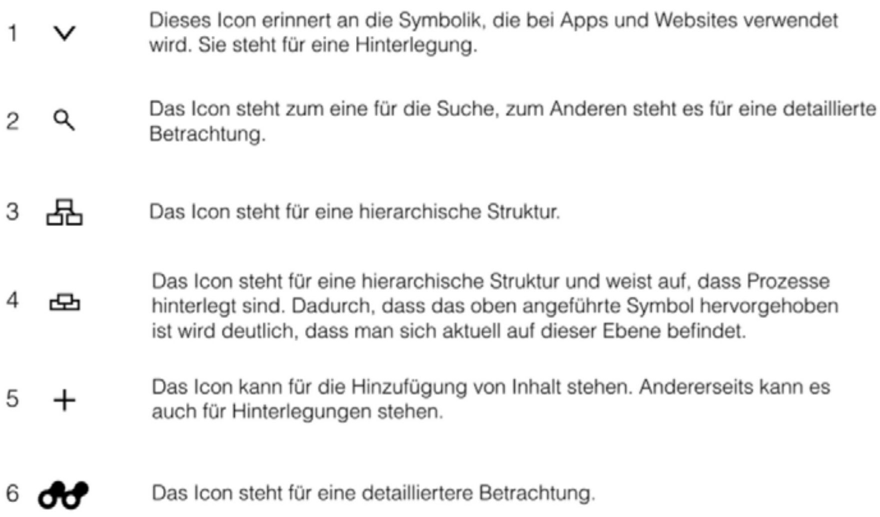


Figure A.32: Suggested Icons in Vertical Modularization

Image and Description in Orthogonal Modularization

Beschreibung:
Gemäß querschnittsicher Belange (Sicherheit, Ausnahmebehandlungen, etc.) wird das Modell unterteilt.

Zweck:
Dient der Differenzierung von Verantwortlichkeiten und Anliegen. Zusätzlich lässt sich auf dieser Basis eine Vereinfachung der individuellen, sowie unternehmensspezifische Wartung von Prozessmodellen erzielen.

Darbietungsbeispiel:
Wie bereits in der Beschreibung dargelegt werden hierbei Belange aus dem Prozessmodell entkoppelt. In diesem Beispiel wird ein sicherheitskritischer Aspekt aus dem Prozess genommen. Die Entkopplung eines sicherheitskritischen Aspekts wird dabei weder mit Wörtern noch symbolisch verdeutlicht.

(Die Beschreibung, der Zweck und das Beispiel basieren auf La Rosa et al. [3])

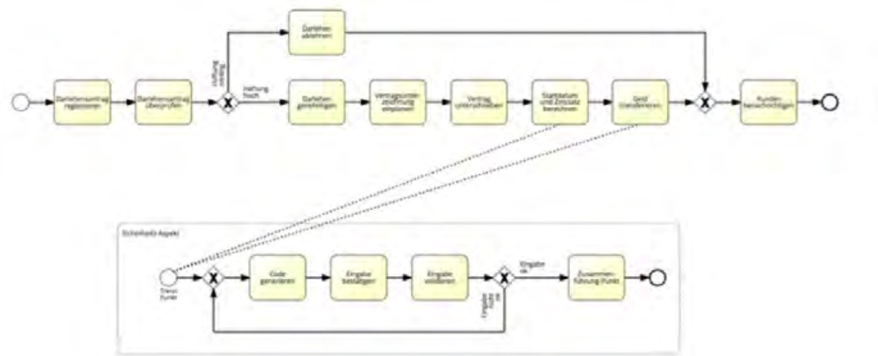


Figure A.33: Image and Description in Orthogonal Modularization

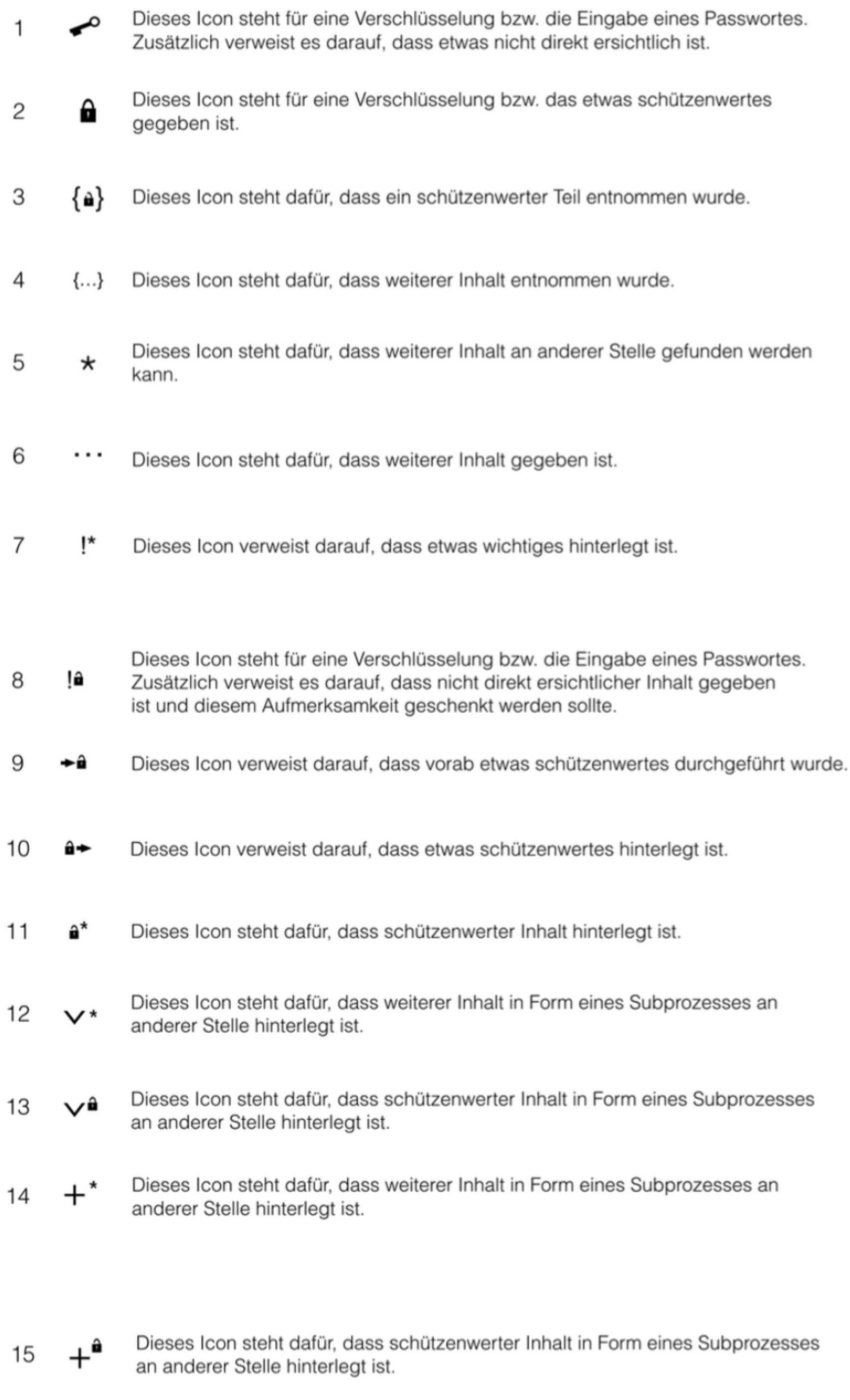
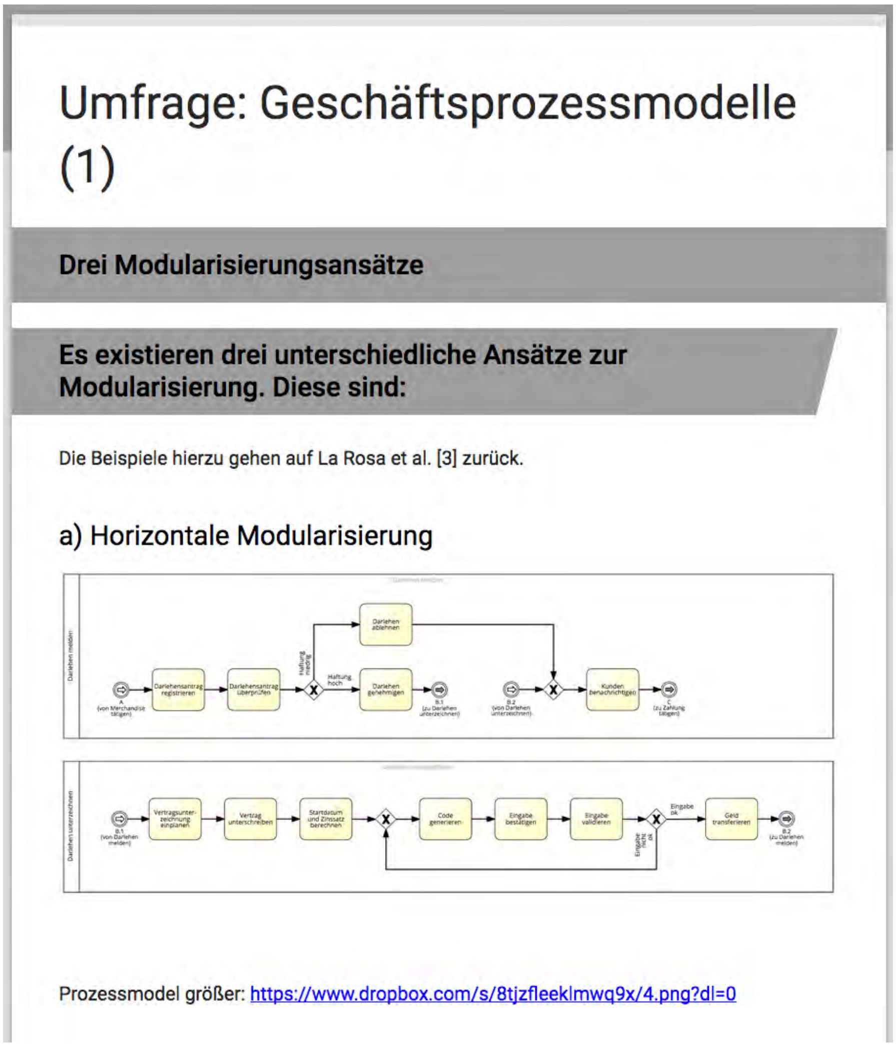


Figure A.34: Suggested Icons in Orthogonal Modularization

Section 5 - Modularization Approaches



Umfrage: Geschäftsprozessmodelle (1)

Drei Modularisierungsansätze

Es existieren drei unterschiedliche Ansätze zur Modularisierung. Diese sind:

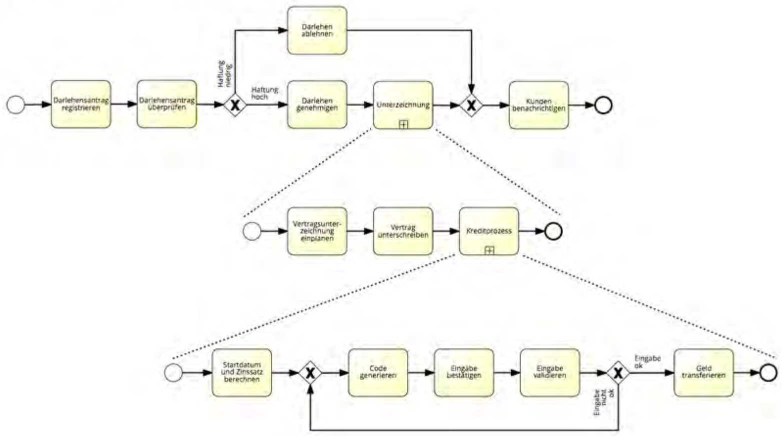
Die Beispiele hierzu gehen auf La Rosa et al. [3] zurück.

a) Horizontale Modularisierung

Prozessmodel größer: https://www.dropbox.com/s/8tjzfleeklmwq9x/4.png?dl=0

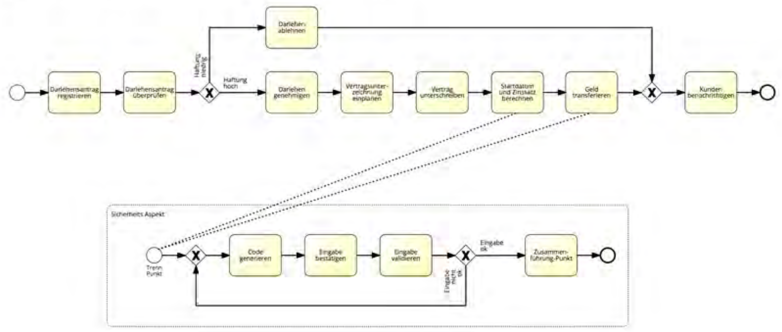
Figure A.35: Section 5-1

b) Vertikale Modularisierung



Prozessmodel größer: https://www.dropbox.com/s/dafcw0pbie1l00j/4.png?dl=0

c) Orthogonale Modularisierung



Prozessmodel größer: https://www.dropbox.com/s/4hpcgujbxs2u774/4.png?dl=0

Figure A.36: Section 5-2

Welche der genannten Ansätze kennen Sie bereits?

Kenntnisse, die Sie sich aktuell angeeignet haben sind für die Beurteilung ausgeschlossen.

- ☐ a
- ☐ b
- ☐ c

Welchen der genannten Ansätze finden Sie am ansprechendsten?

- ○ a
- ○ b
- ○ c

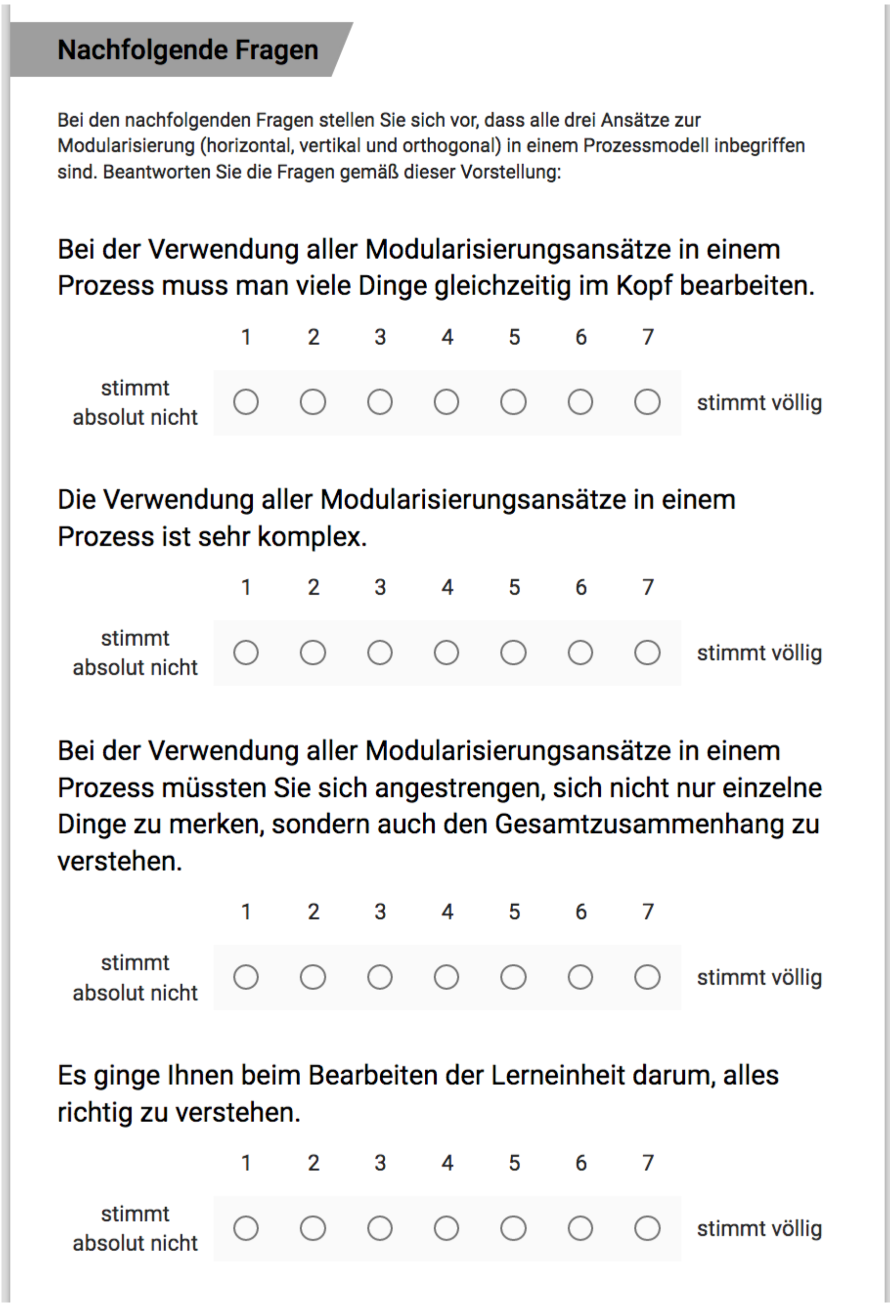
Welchen der genannten Ansätze finden Sie am verständlichsten?

- ○ a
- ○ b
- ○ c

Welche Kombination der Ansätze würden Sie bevorzugen?

- ○ a + b
- ○ a + c
- ○ b + c
- ○ a + b + c

Figure A.37: Section 5-3



Nachfolgende Fragen

Bei den nachfolgenden Fragen stellen Sie sich vor, dass alle drei Ansätze zur Modularisierung (horizontal, vertikal und orthogonal) in einem Prozessmodell inbegriffen sind. Beantworten Sie die Fragen gemäß dieser Vorstellung:

Bei der Verwendung aller Modularisierungsansätze in einem Prozess muss man viele Dinge gleichzeitig im Kopf bearbeiten.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Die Verwendung aller Modularisierungsansätze in einem Prozess ist sehr komplex.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

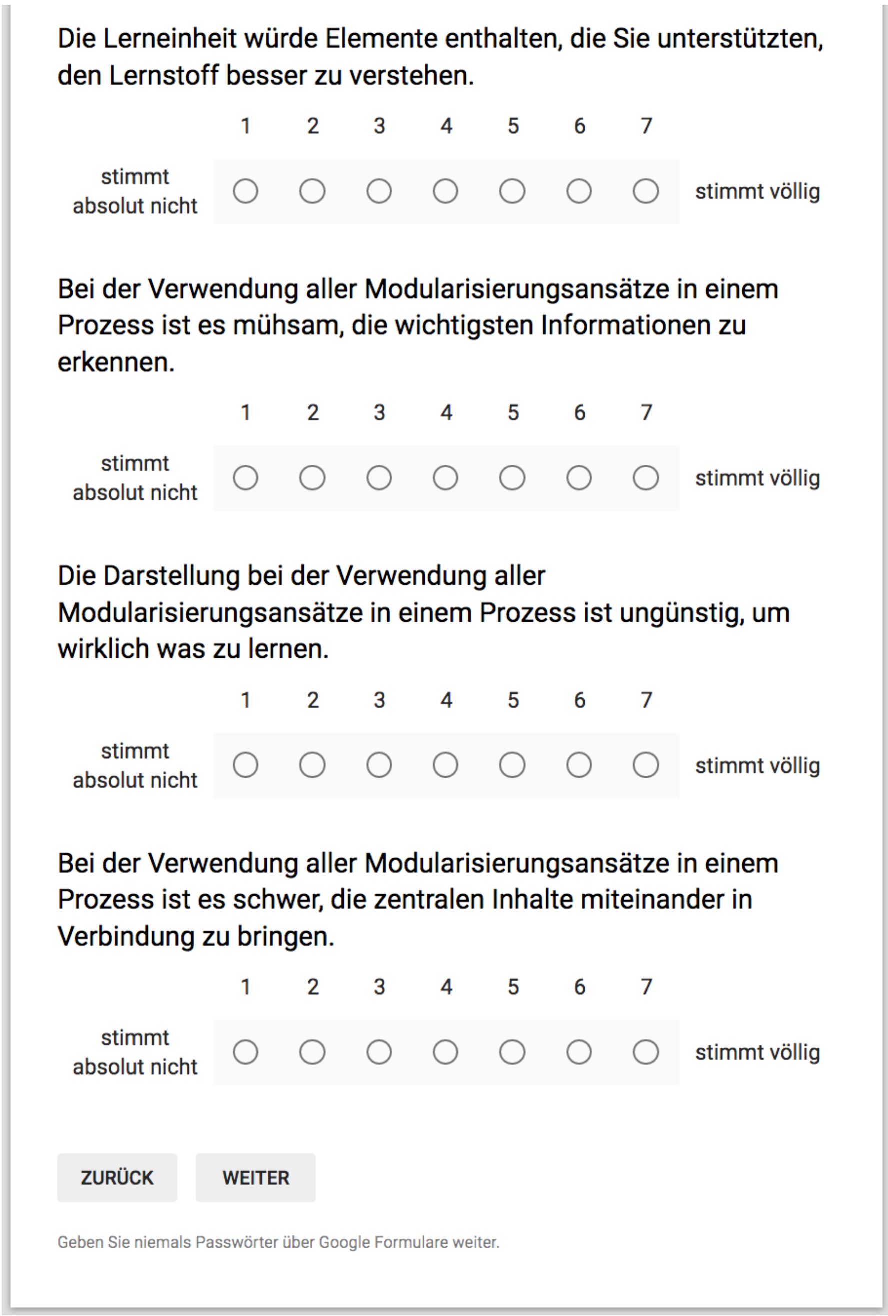
Bei der Verwendung aller Modularisierungsansätze in einem Prozess müssten Sie sich angestrengen, sich nicht nur einzelne Dinge zu merken, sondern auch den Gesamtzusammenhang zu verstehen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Es ginge Ihnen beim Bearbeiten der Lerneinheit darum, alles richtig zu verstehen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Figure A.38: Section 5-4



Die Lerneinheit würde Elemente enthalten, die Sie unterstützten, den Lernstoff besser zu verstehen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Bei der Verwendung aller Modularisierungsansätze in einem Prozess ist es mühsam, die wichtigsten Informationen zu erkennen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Die Darstellung bei der Verwendung aller Modularisierungsansätze in einem Prozess ist ungünstig, um wirklich was zu lernen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

Bei der Verwendung aller Modularisierungsansätze in einem Prozess ist es schwer, die zentralen Inhalte miteinander in Verbindung zu bringen.

	1	2	3	4	5	6	7	
stimmt absolut nicht	○	○	○	○	○	○	○	stimmt völlig

ZURÜCK WEITER

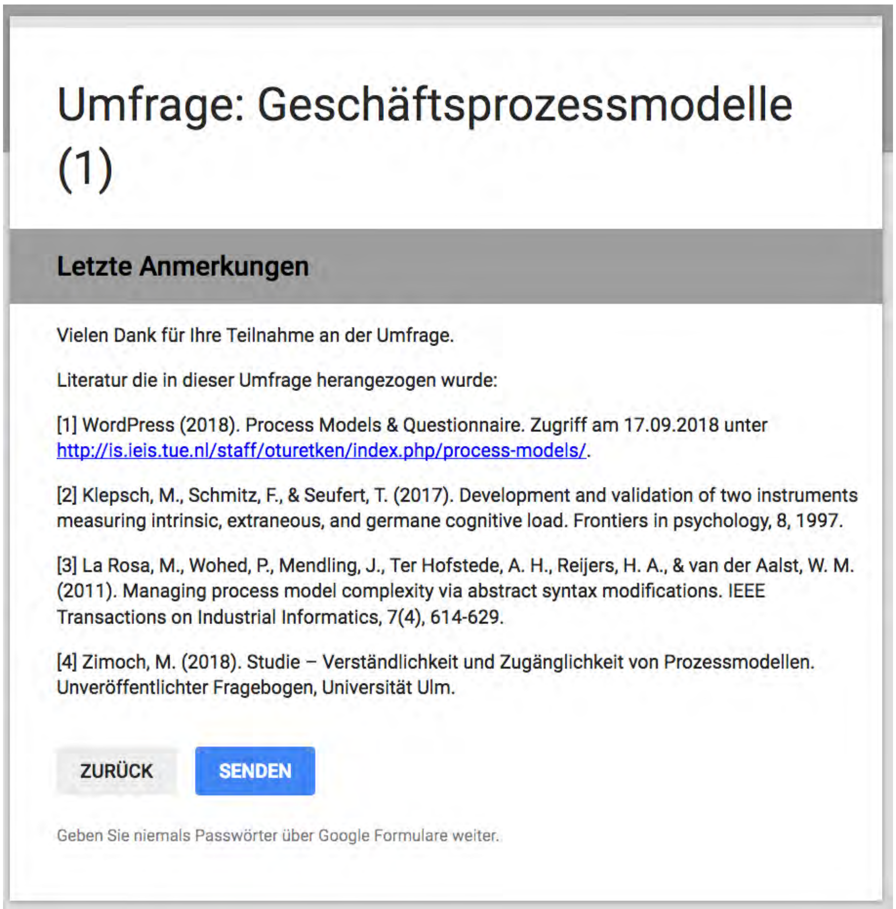
Geben Sie niemals Passwörter über Google Formulare weiter.

Figure A.39: Section 5-5

Section 6 - Final Input

Figure A.40: Feedback and Codeword

Section 7- Literature



Umfrage: Geschäftsprozessmodelle (1)

Letzte Anmerkungen

Vielen Dank für Ihre Teilnahme an der Umfrage.

Literatur die in dieser Umfrage herangezogen wurde:

[1] WordPress (2018). Process Models & Questionnaire. Zugriff am 17.09.2018 unter http://is.ieis.tue.nl/staff/oturetken/index.php/process-models/.

[2] Klepsch, M., Schmitz, F., & Seufert, T. (2017). Development and validation of two instruments measuring intrinsic, extraneous, and germane cognitive load. Frontiers in psychology, 8, 1997.

[3] La Rosa, M., Wohed, P., Mendling, J., Ter Hofstede, A. H., Reijers, H. A., & van der Aalst, W. M. (2011). Managing process model complexity via abstract syntax modifications. IEEE Transactions on Industrial Informatics, 7(4), 614-629.

[4] Zimoch, M. (2018). Studie – Verständlichkeit und Zugänglichkeit von Prozessmodellen. Unveröffentlichter Fragebogen, Universität Ulm.

ZURÜCK SENDEN

Geben Sie niemals Passwörter über Google Formulare weiter.

Figure A.41: Literature Presented

B Study

The study is composed of different contents. As presented in Subsection 5.2, division Study, an introduction is shown at the beginning of the study. The elements are given in B.1. Further, images (P1-P9) with a specific order were represented in a gradual visualization. Each image consists of a graphic and a statement as they are part of the study. The elements of the images are presented in B.2 to B.10. Then, the questionnaires are presented in B.11. Finally, the declaration of consent is shown in B.12.

B.1 Introduction

The introduction is divided into two sections. The subject-matter of the first section is the content of the document submitted. The second subject-matter focuses on the content of the oral report.

Content of the document submitted:
Studie – Verständlichkeit von Prozessmodellen

Bitte lesen Sie dieses Formular sorgfältig durch. Fragen Sie nach, wenn Sie etwas nicht verstehen oder mehr Informationen benötigen.

Ziel der Studie:
In dieser Studie sollen Sie die Aussagen zu neun Prozessmodelle mittels Falsch/Wahr beurteilen.

Die Studie wird unter der Leitung von Julia Baß (Masterstudentin, Universität Ulm) durchgeführt und verfolgt rein wissenschaftliche Ziele.

Ablauf:
Die Studie findet für jeden Studienteilnehmer an genau einem Termin statt. Für die Durchführung der Studie sind ca. 20 - 30 Minuten Zeit einzuplanen. Zu Beginn der Studie erhalten Sie insgesamt zwei Papierbogen. Der erste Papierbogen enthält die Studienbeschreibung, als auch einen demographischen Fragebogen. Der zweite Papierbogen enthält Fragen zum mentalen Aufwand während der Durchführung, sowie zur Verständlichkeit der Prozessmodelle.
Beantworten und füllen Sie zuallererst den ersten Papierbogen aus. Im Anschluss beginnt die Datenerhebung am Eye-Tracker. Zu Beginn erfolgt eine Kalibirerung. Anschließend beurteilen Sie die neun Prozessmodelle der Reihe nach am Eye-Tracker. Nach jeweils drei Prozessmodellen (12 Fragen) erfolgt erneut eine Kalibrierung. Nehmen Sie sich zur Beantwortung der Aussagen Zeit. Sollten Sie auf eine Aussage keine Antwort wissen, so klicken Sie die den Buchstaben der für Sie wahrscheinlicher ist. Nach der Beurteilung der neun Prozessmodelle, füllen Sie bitte den Fragebogen zum mentalen Aufwand und Verständlichkeit aus. Anschließend erhalten Sie Schokolade

Freiwilligkeit:
Sie nehmen an diesem Forschungsprojekt freiwillig teil. Ihr Einverständnis können Sie jederzeit und ohne Angabe von Gründen widerrufen. Alle bis dahin studienbedingt erhobenen Daten werden dann gelöscht. Dieser eventuelle Widerruf hat keine Auswirkungen auf Ihre Person.

Risiken:
Es sind keine Risiken mit Ihrer Teilnahme an der Studie verbunden.

Erreichbarkeit des Studienleiters:
Sollten während des Verlaufes der Studie Fragen auftauchen, so können Sie jederzeit Herrn Michael Zimoch unter der Telefonnummer erreichen: 0731 / 50 24 126.

Versicherung:
Während der Teilnahme an der Studie genießen Sie Versicherungsschutz. Die Universität Ulm und dessen an der Studie mitwirkende Mitarbeiter sind haftpflichtversichert für den Fall, dass Sie durch deren Verschulden einen Schaden erleiden. Gleichzeitig weisen wir darauf hin, dass Sie für die direkten Wege zum und vom Versuchsort nicht unfallver-

sichert sind. Einen Schaden, der Ihrer Meinung nach auf diese Studie zurückzuführen ist, melden Sie bitte unverzüglich dem Studienleiter.

Schweigepflicht und Datenschutz:
Alle Personen, welche Sie im Rahmen dieses Projektes betreuen, unterliegen der Schweigepflicht und sind auf das Datengeheimnis verpflichtet. Die studienbezogenen Untersuchungsergebnisse sollen in anonymisierter Form in wissenschaftlichen Veröffentlichungen verwendet werden. Soweit es zur Kontrolle der korrekten Datenerhebung erforderlich ist, dürfen autorisierte Personen (z.B.: des Auftraggebers, der Universität) Einsicht in die studienrelevanten Teile der erhobenen Daten nehmen.

Content of the oral report:
This subdivision includes the notes realized for the introduction:

Modularisierung:

- Unterteilung eines großen Prozessmodells in kleinere Module
- Module haben ein Start und ein Ende
- Module sind unabhängig managebar
- Ein Modul interagiert an Schnittstellen mit anderen Modulen

Aufbau der Studie:

- Fragebogen, Einverständniserklärung
- Probelauf mit einem Image
- Danach zur Studie: -> neun Prozessmodelle, zu jedem vier Aussagen -> Wahr/-Falsch
- Nach 12 Aussagen (3 Prozessmodelle) kommt immer eine Kalibrierung
- Ende: Fragebogen zu Kognitive Belastung und Verständlichkeit

B.2 Image 1 (P1)

Image 1 consists of a sequence regarding handling a computer console, including the steps for making changes requiring the entry of a process.

Aspect-Oriented

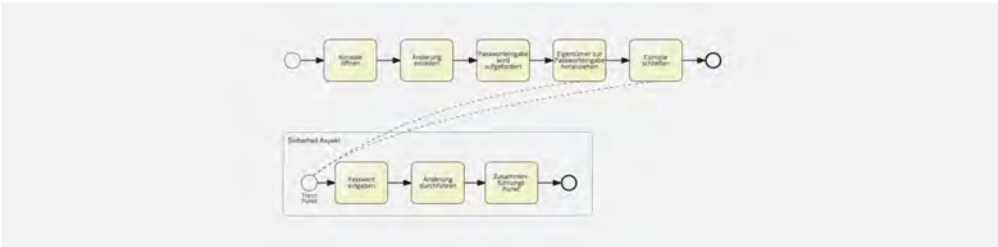


Figure B.1: Aspect-Ortiented in Orthogonal Modularization of P1

Exception Events

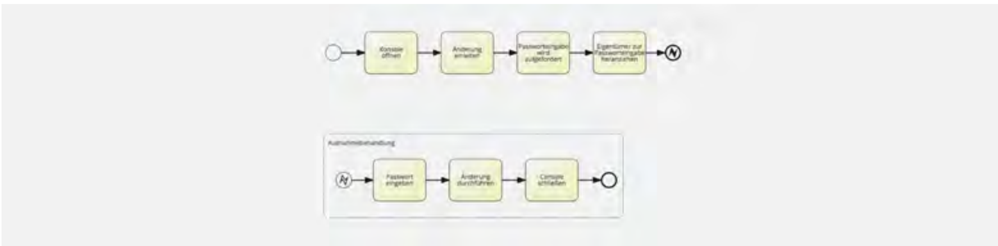


Figure B.2: Exception Events in Orthogonal Modularization of P1

Self Designed (Orthogonal)

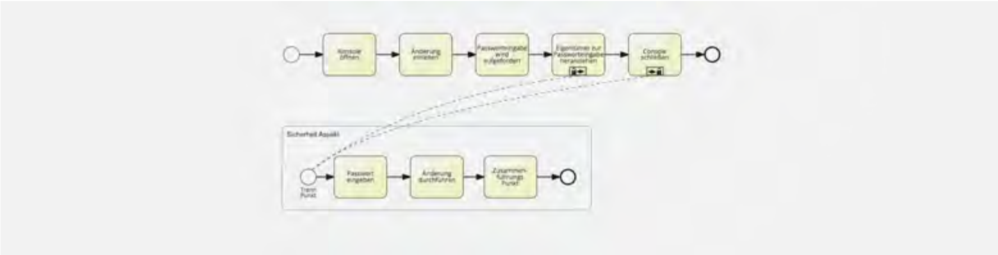


Figure B.3: Self Designed in Orthogonal Modularization of P1

Collapsed Subprocesses

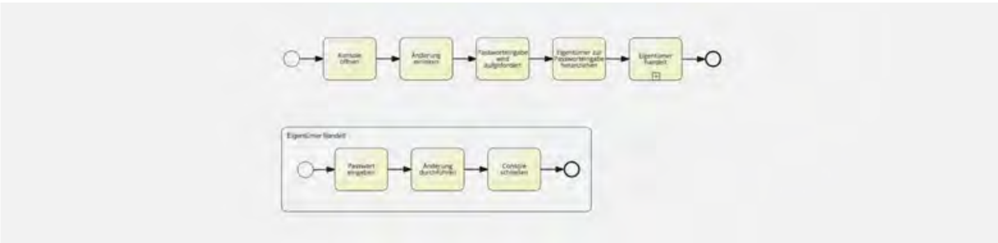


Figure B.4: Collapsed Subprocesses in Vertical Modularization of P1

Expanded Subprocesses

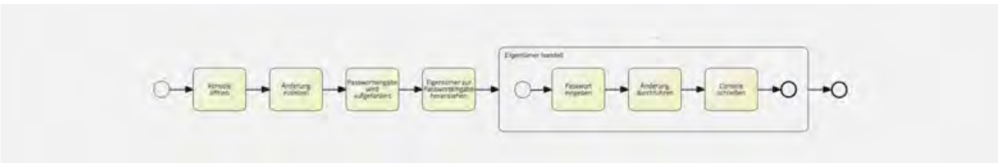


Figure B.5: Expanded Subprocesses in Vertical Modularization of P1

Self Designed (Vertical)

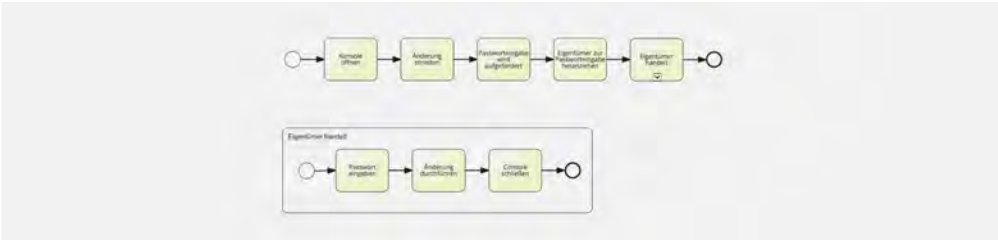


Figure B.6: Self Designed in Vertical Modularization of P1

Link Events

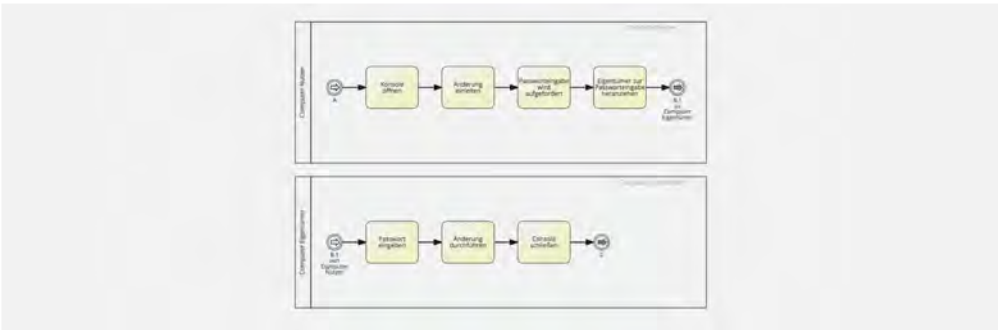


Figure B.7: Link Event in Horizontal Modularization of P1

Message Events

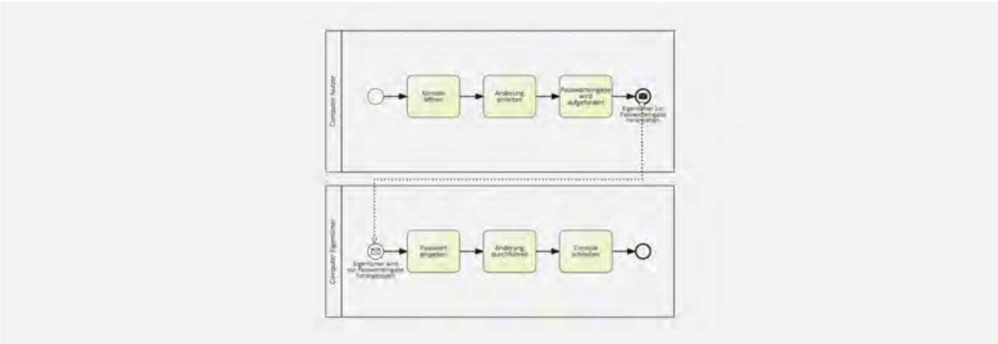


Figure B.8: Message Event in Horizontal Modularization of P1

Self Designed (Horizontal)

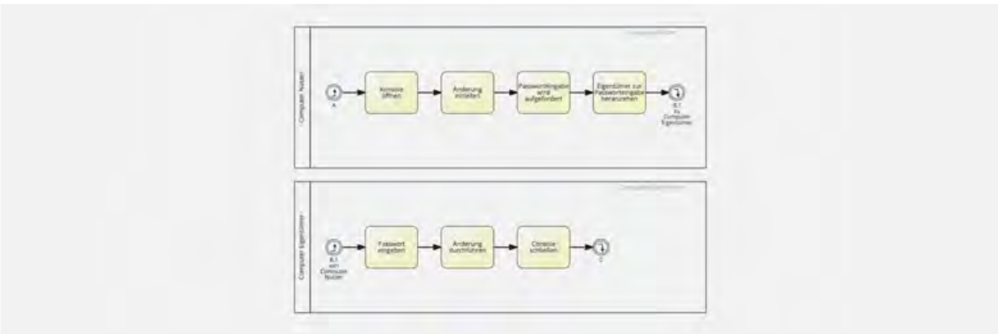


Figure B.9: Self Designed in Horizontal Modularization of P1

Set of Statements

Statement	Horizontal Modularization			Vertical Modularization			Orthogonal Modularization		
	ME	**LE**	**SDH**	**ES**	**CS**	**SDV**	**EE**	**AO**	**SDO**
Änderungen müssen durchgeführt werden	true	true	true	true	true	true	true	true	true
Es sind keine Module in der Abbildung gegeben	false	false	false	false	false	false	false	false	false
Module sind in der Abbildung gegeben	true	true	true	true	true	true	true	true	true
Änderungen müssen nicht durchgeführt werden	false	false	false	false	false	false	false	false	false

Table B.1: Statements of P1

B.3 Image 2 (P2)

Image 2 addresses an online purchase. It starts with filling a shopping cart and ends with receiving a confirmation.

Aspect-Oriented

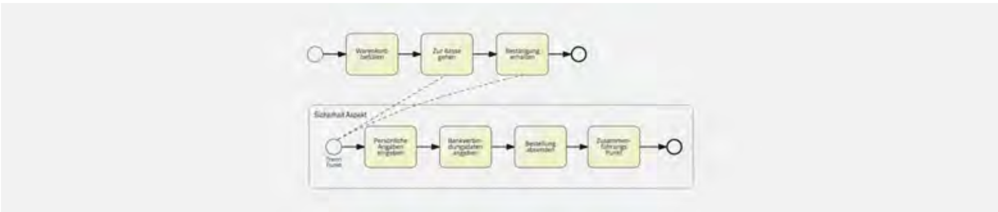


Figure B.10: Aspect-Ortiented in Orthogonal Modularization of P2

Exception Events

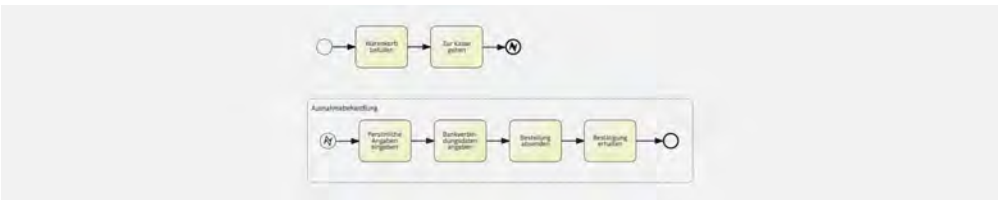


Figure B.11: Exception Events in Orthogonal Modularization of P2

Self Designed (Orthogonal)

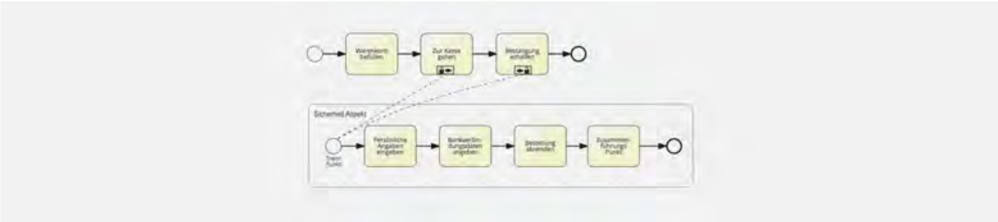


Figure B.12: Self Designed in Orthogonal Modularization of P2

Collapsed Subprocesses

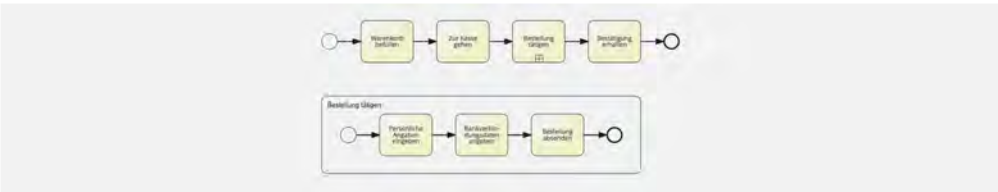


Figure B.13: Collapsed Subprocesses in Vertical Modularization of P2

Expanded Subprocesses

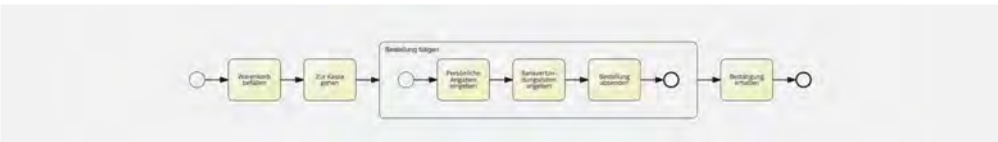


Figure B.14: Expanded Subprocesses in Vertical Modularization of P2

Self Designed (Vertical)

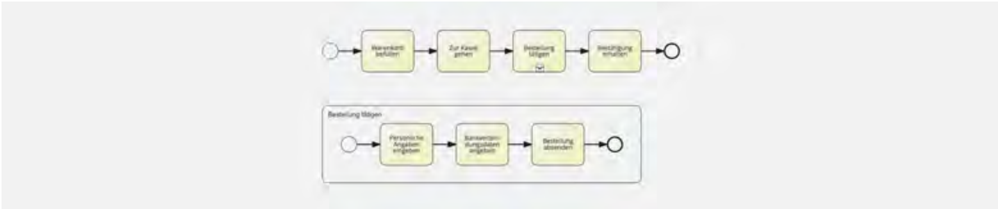


Figure B.15: Self Designed in Vertical Modularization of P2

Link Events

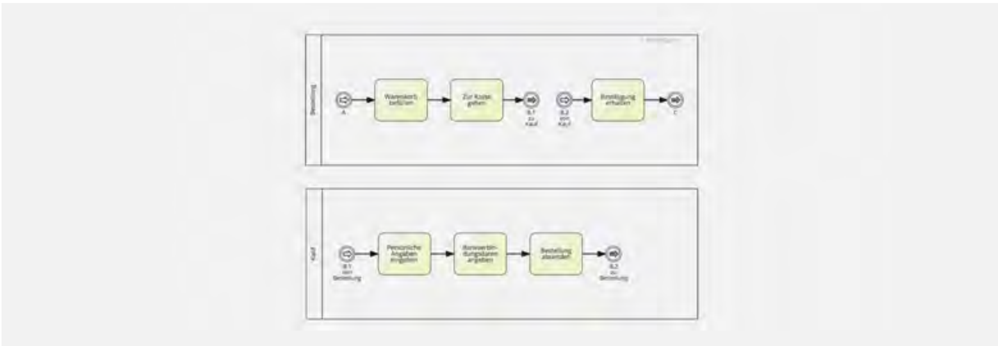


Figure B.16: Link Event in Horizontal Modularization of P2

Message Events

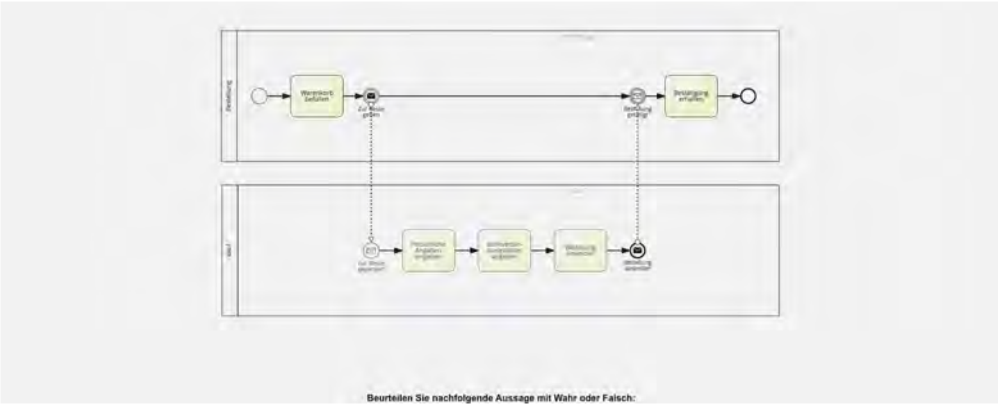


Figure B.17: Message Event in Horizontal Modularization of P2

Self Designed (Horizontal)

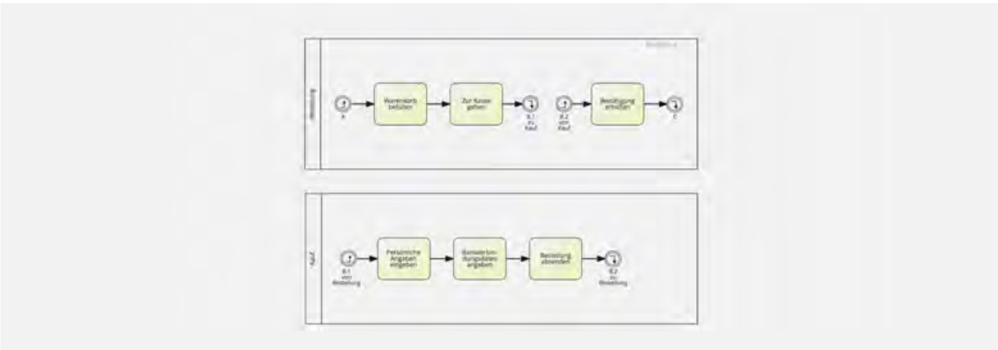


Figure B.18: Self Designed in Horizontal Modularization of P2

Set of Statements

Statement	Horizontal Modularization			Vertical Modularization			Orthogonal Modularization		
	ME	**LE**	**SDH**	**ES**	**CS**	**SDV**	**EE**	**AO**	**SDO**
Die Bestätigung muss erhalten werden	true	true	true	true	true	true	true	true	true
Die Aktivität "Warenkorb befüllen" befindet sich in dem Modul, welches das zweite aufgezeigte Modul aufruft	true	true	true	true	true	true	true	true	true
Bankverbindungsdaten müssen nicht angegeben werden	false	false	false	false	false	false	false	false	false
Der Warenkorb kann, muss aber nicht befüllt werden	false	false	false	false	false	false	false	false	false

Table B.2: Statements of P2

B.4 Image 3 (P3)

Image 3 comprises the topic baking pizza with a secret sauce.

Aspect-Oriented

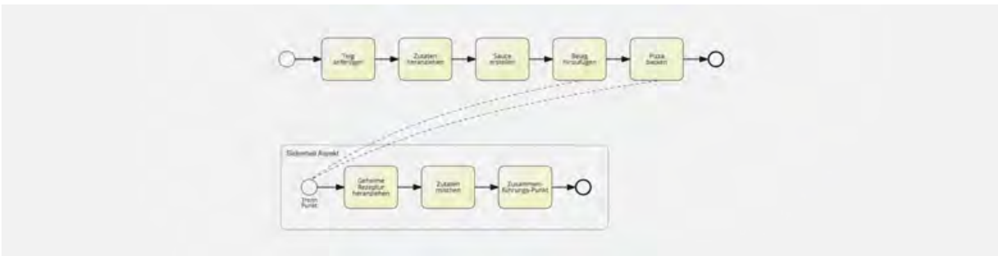


Figure B.19: Aspect-Ortiented in Orthogonal Modularization of P3

Exception Events

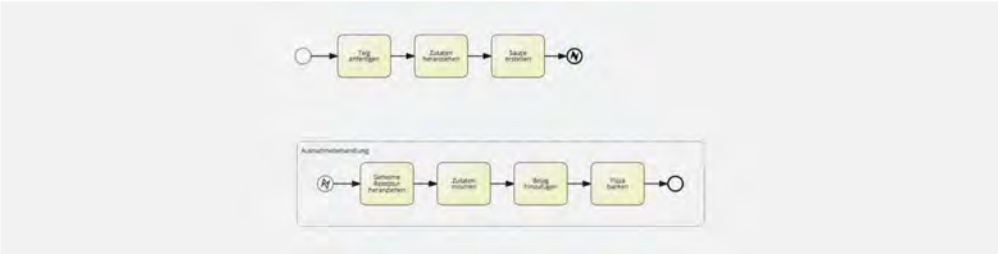


Figure B.20: Exception Events in Orthogonal Modularization of P3

Self Designed (Orthogonal)

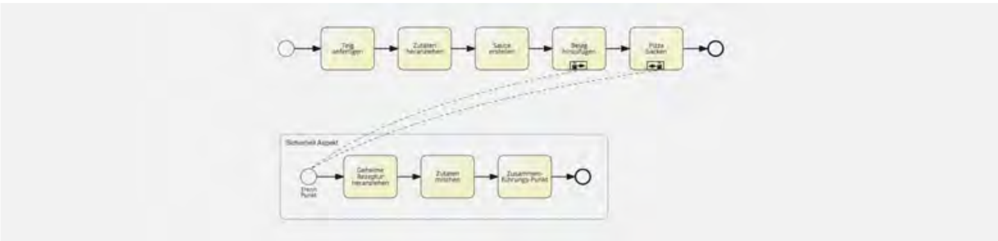


Figure B.21: Self Designed in Orthogonal Modularization of P3

Collapsed Subprocesses

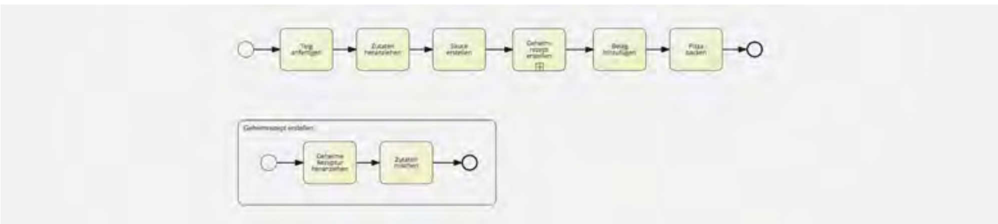


Figure B.22: Collapsed Subprocesses in Vertical Modularization of P3

Expanded Subprocesses

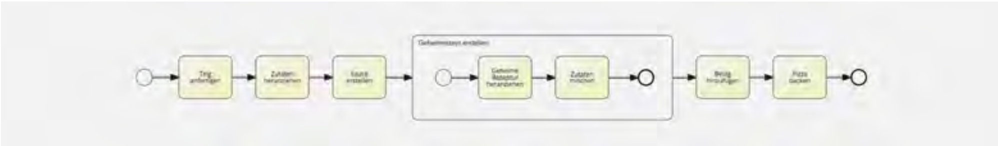


Figure B.23: Expanded Subprocesses in Vertical Modularization of P3

Self Designed (Vertical)

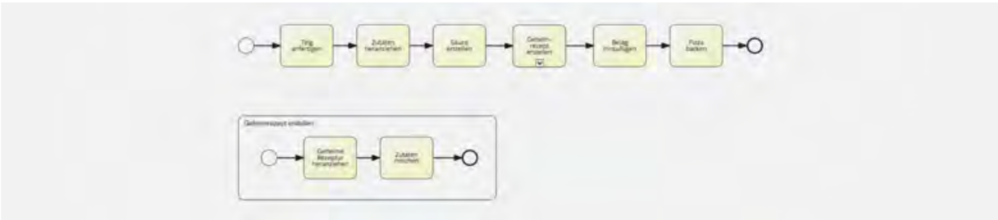


Figure B.24: Self Designed in Vertical Modularization of P3

Link Events

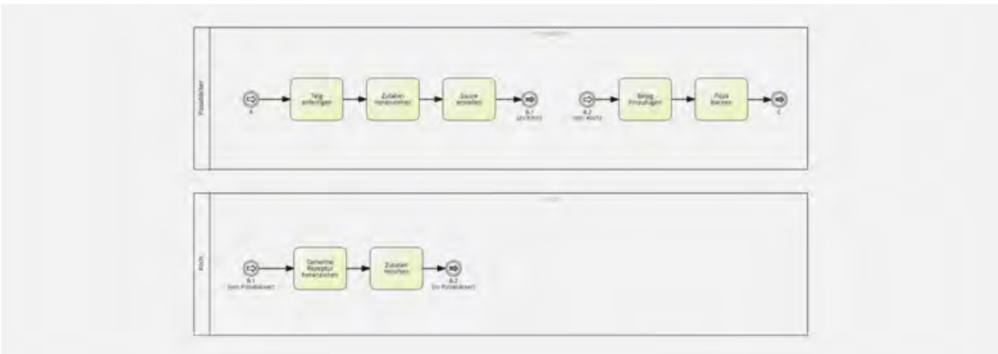


Figure B.25: Link Event in Horizontal Modularization of P3

Message Events

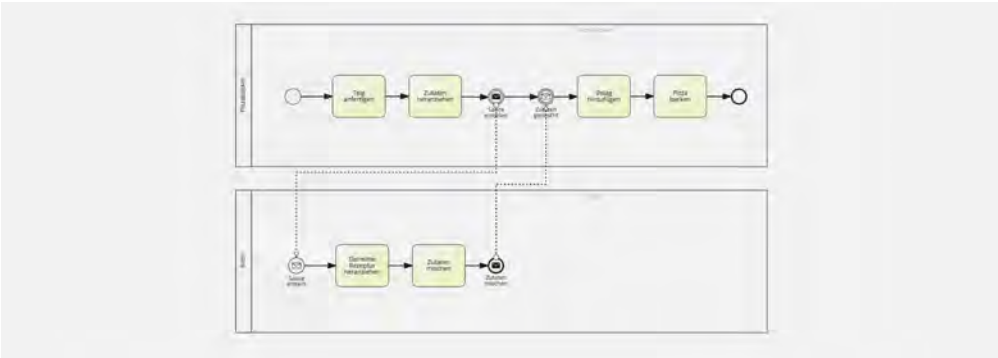


Figure B.26: Message Event in Horizontal Modularization of P3

Self Designed (Horizontal)

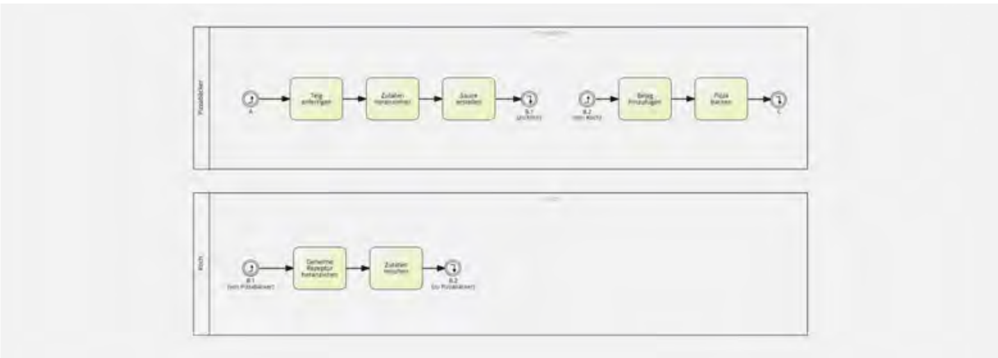


Figure B.27: Self Designed in Horizontal Modularization of P3

Set of Statements

Statement	Horizontal Modularization			Vertical Modularization			Orthogonal Modularization		
	ME	**LE**	**SDH**	**ES**	**CS**	**SDV**	**EE**	**AO**	**SDO**
Der Belag muss immer hinzugefügt werden	true	true	true	true	true	true	true	true	true
Die Zutaten müssen immer herangezogen werden	true	true	true	true	true	true	true	true	true
Der Belag muss nicht hinzugefügt werden	false	false	false	false	false	false	false	false	false
Module sind in der Abbildung gegeben	true	true	true	true	true	true	true	true	true

Table B.3: Statements of P3

B.5 Image 4 (P4)

Image 4 focuses on refueling and the settlement of the chargeable amount.

Aspect-Oriented

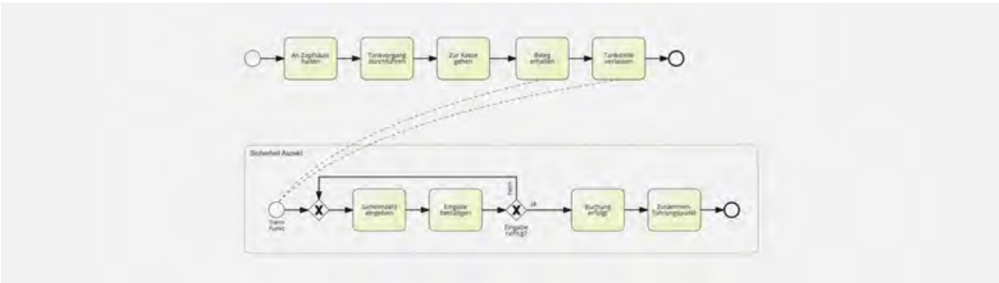


Figure B.28: Aspect-Ortiented in Orthogonal Modularization of P4

Exception Events

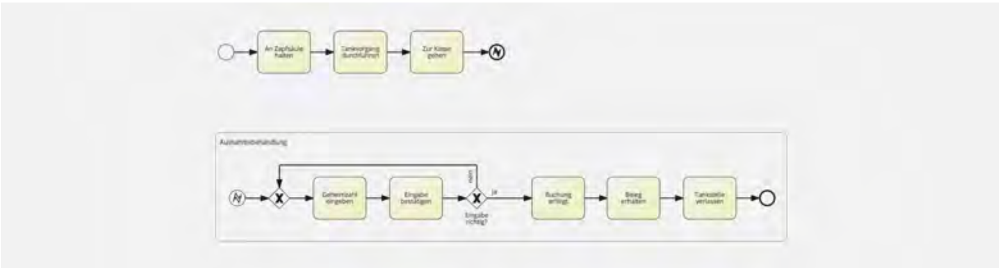


Figure B.29: Exception Events in Orthogonal Modularization of P4

Self Designed (Orthogonal)

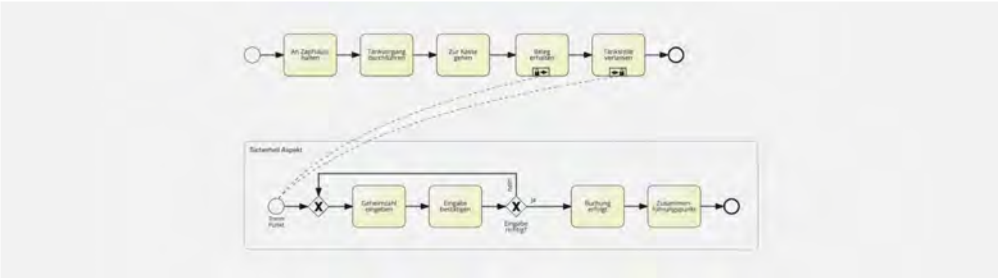


Figure B.30: Self Designed in Orthogonal Modularization of P4

Collapsed Subprocesses

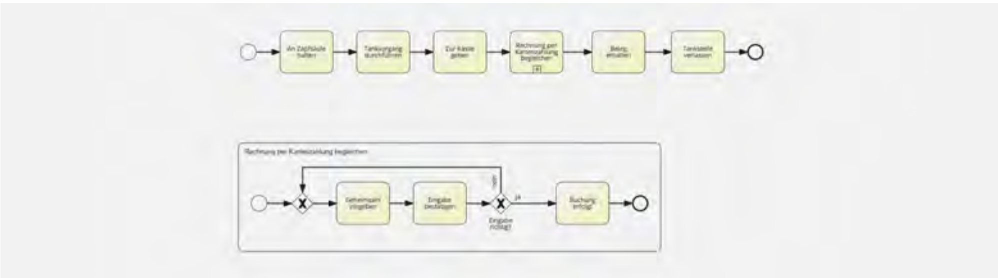


Figure B.31: Collapsed Subprocesses in Vertical Modularization of P4

Expanded Subprocesses

Figure B.32: Expanded Subprocesses in Vertical Modularization of P4

Self Designed (Vertical)

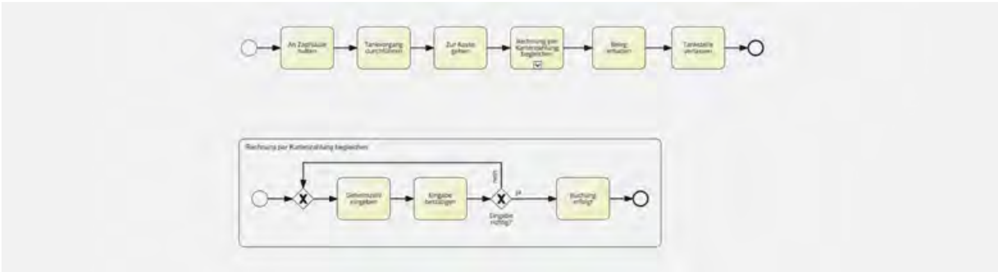


Figure B.33: Self Designed in Vertical Modularization of P4

Link Events

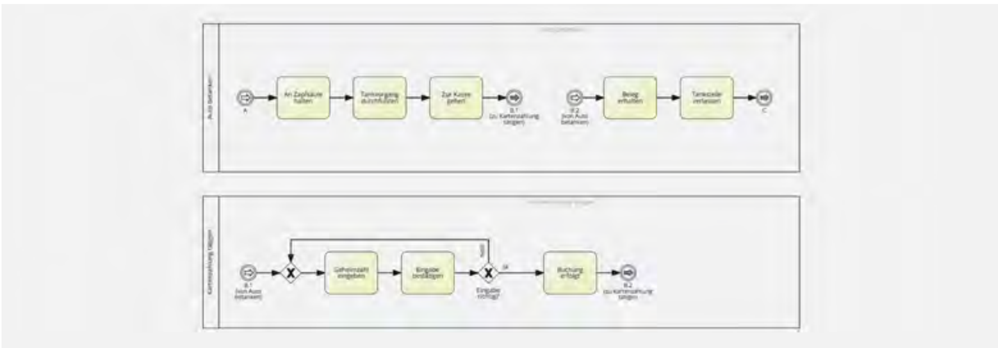


Figure B.34: Link Event in Horizontal Modularization of P4

Message Events

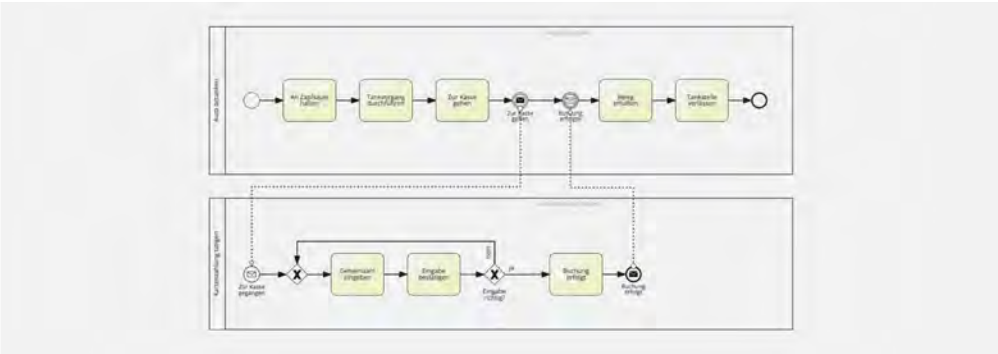


Figure B.35: Message Event in Horizontal Modularization of P4

Self Designed (Horizontal)

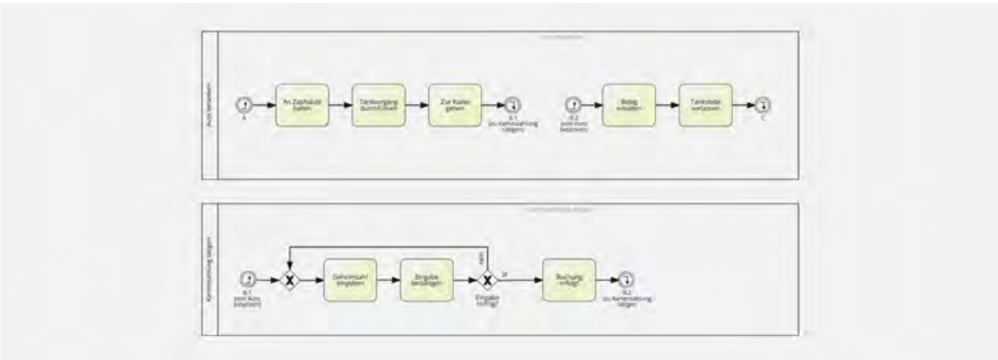


Figure B.36: Self Designed in Horizontal Modularization of P4

Set of Statements

Statement	Horizontal Modularization			Vertical Modularization			Orthogonal Modularization		
	ME	**LE**	**SDH**	**ES**	**CS**	**SDV**	**EE**	**AO**	**SDO**
Die Geheimzahl muss nicht eingegeben werden, jedoch muss die Buchung erfolgen	false	false	false	false	false	false	false	false	false
Direkt nachdem der Tankvorgang durchgeführt wurde, beginnt ein neues Modul	false	false	false	false	false	false	false	false	false
Direkt nachdem der Tankvorgang durchgeführt wurde, beginnt ein neues Modul	true	true	true	true	true	true	true	true	true
Die Aktivität "Tankstelle verlassen" muss ausgeführt werden	true	true	true	true	true	true	true	true	true

Table B.4: Statements of P4

B.6 Image 5 (P5)

Image 5 takes up the topic of a supplier of goods. It begins with the acceptance of the order. After an evaluation in terms of the availability of the goods, two options are possible. If the goods are available they are sent and the process ends. Otherwise, the process ends after running through the prepared solution.

Aspect-Oriented

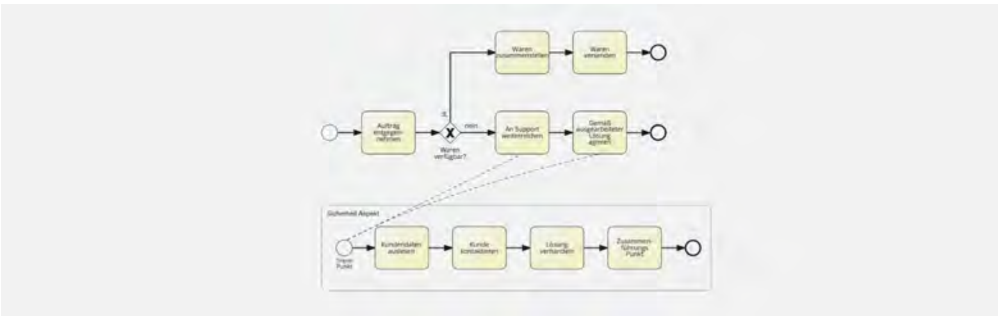


Figure B.37: Aspect-Ortiented in Orthogonal Modularization of P5

Exception Events

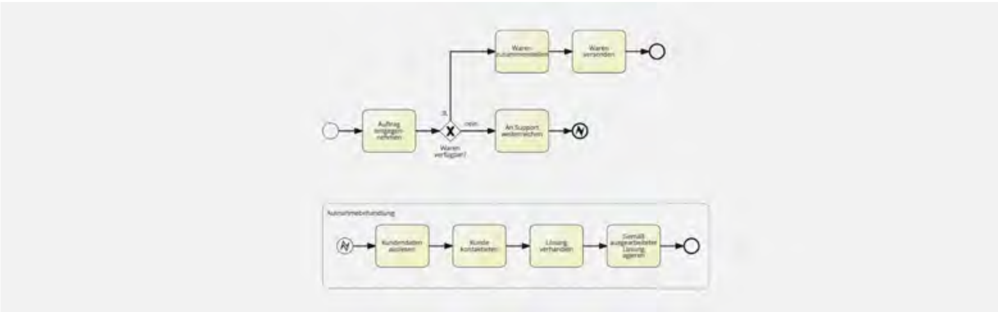


Figure B.38: Exception Events in Orthogonal Modularization of P5

Self Designed (Orthogonal)

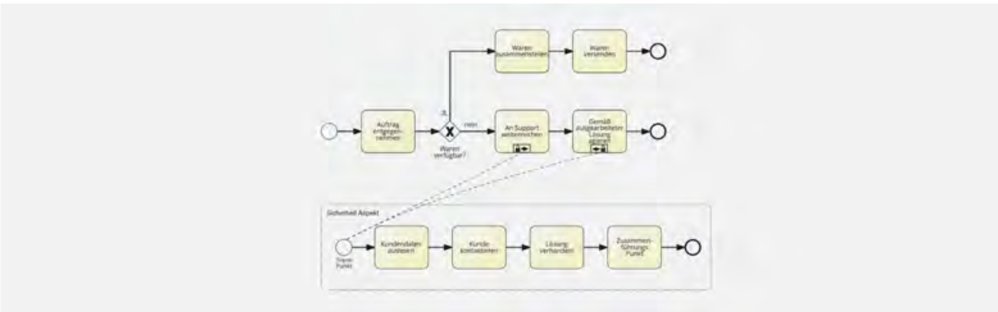


Figure B.39: Self Designed in Orthogonal Modularization of P5

Collapsed Subprocesses

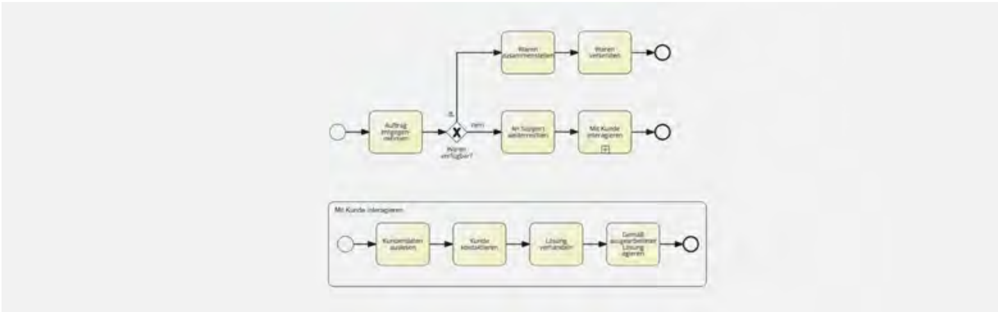


Figure B.40: Collapsed Subprocesses in Vertical Modularization of P5

Expanded Subprocesses

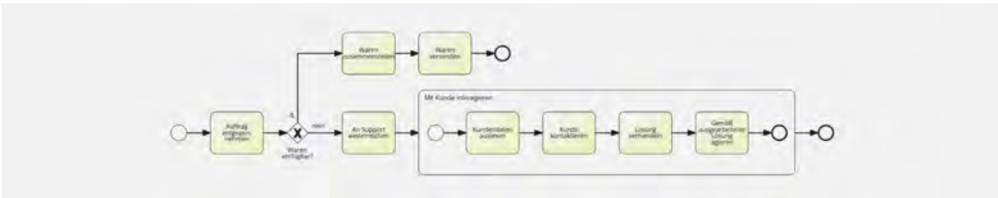


Figure B.41: Expanded Subprocesses in Vertical Modularization of P5

Self Designed (Vertical)

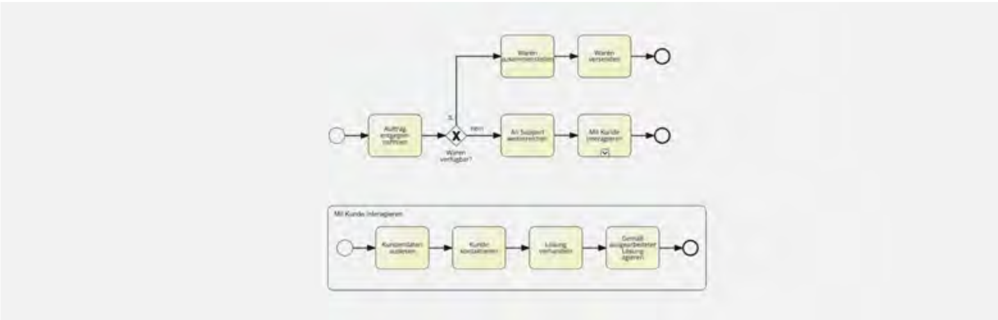


Figure B.42: Self Designed in Vertical Modularization of P5

Link Events

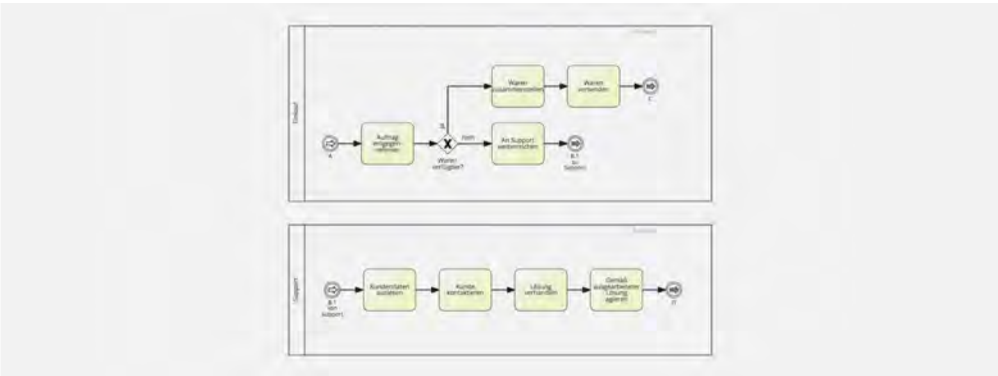


Figure B.43: Link Event in Horizontal Modularization of P5

Message Events

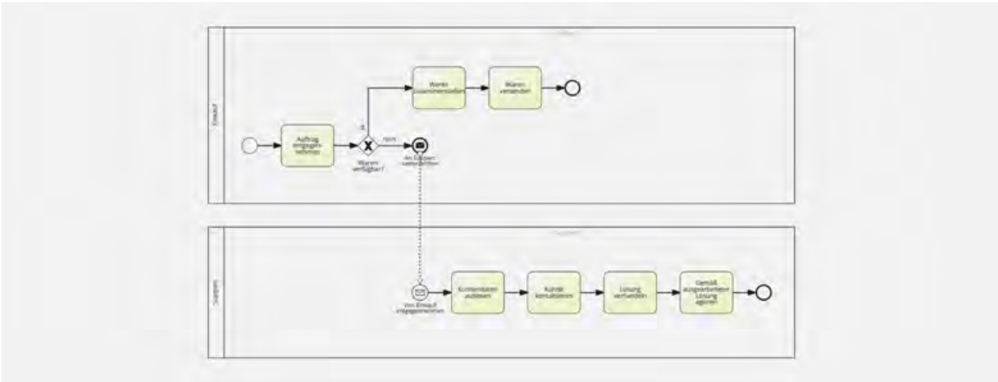


Figure B.44: Message Event in Horizontal Modularization of P5

Self Designed (Horizontal)

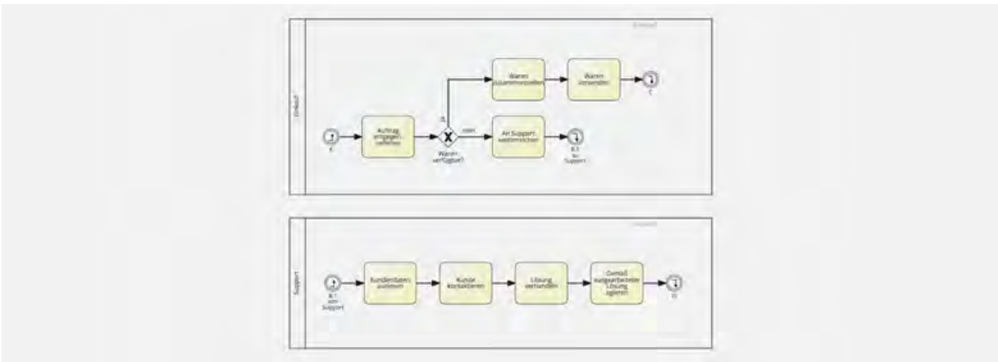


Figure B.45: Self Designed in Horizontal Modularization of P5

Set of Statements

Statement	Horizontal Modularization			Vertical Modularization			Orthogonal Modularization		
	ME	**LE**	**SDH**	**ES**	**CS**	**SDV**	**EE**	**AO**	**SDO**
Kein Modul ist in der Abbildung gegeben	false	false	false	false	false	false	false	false	false
Der Auftrag kann, muss aber nicht entgegengenommen werden	false	false	false	false	false	false	false	false	false
Die letzte Aktivität bei der Ausführung, des aufgerufenen Moduls ist "Gemäß ausgearbeiteter Lösung agieren"	true	true	true	true	true	true	true	false	false
Im aufgerufenen Modul ist die Aktivität "Lösung verhandeln" gegeben	true	true	true	true	true	true	true	true	true

Table B.5: Statements of P5

B.7 Image 6 (P6)

Image 6 comprises the process of managing an order. There are two possibilities regarding the outcome of the process. First, the order can be sent. Second, customization is carried out.

Aspect-Oriented

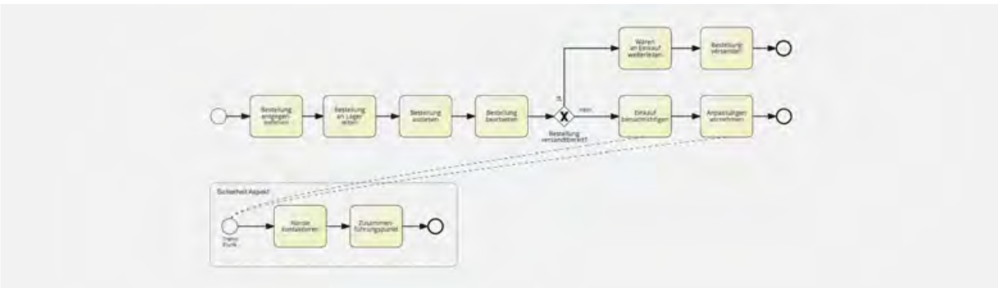


Figure B.46: Aspect-Ortiented in Orthogonal Modularization of P6

Exception Events

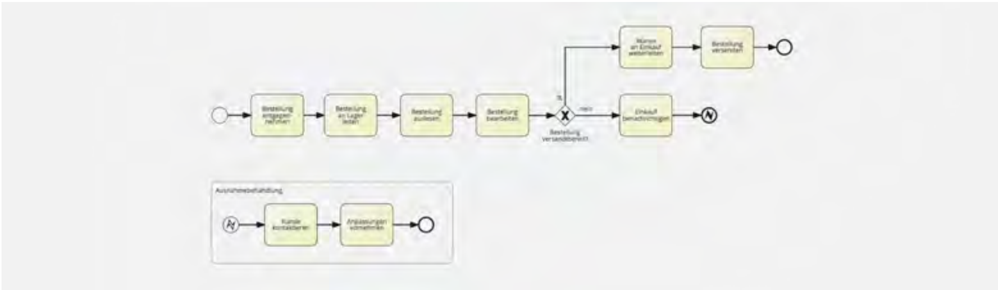


Figure B.47: Exception Events in Orthogonal Modularization of P6

Self Designed (Orthogonal)

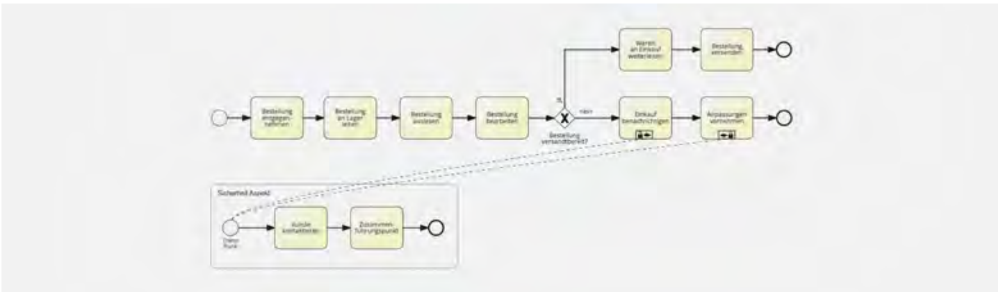


Figure B.48: Self Designed in Orthogonal Modularization of P6

Collapsed Subprocesses

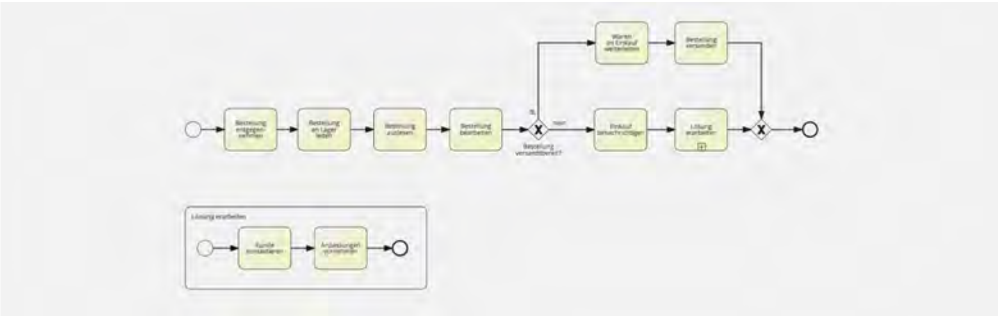


Figure B.49: Collapsed Subprocesses in Vertical Modularization of P6

Expanded Subprocesses

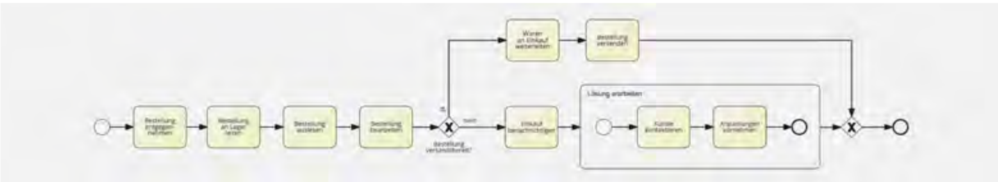


Figure B.50: Expanded Subprocesses in Vertical Modularization of P6

Self Designed (Vertical)

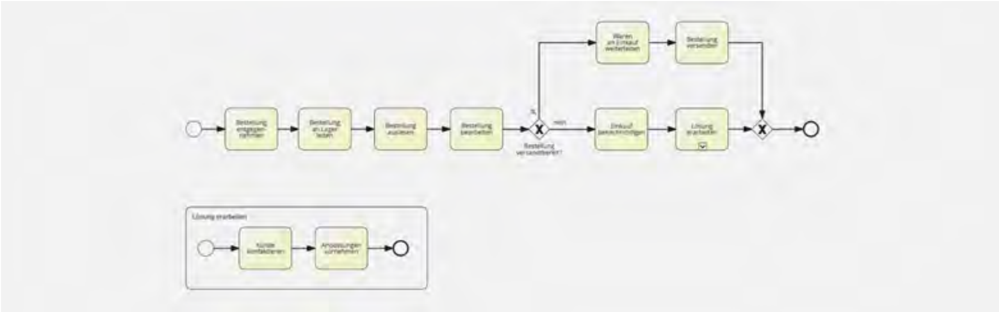


Figure B.51: Self Designed in Vertical Modularization of P6

Link Events

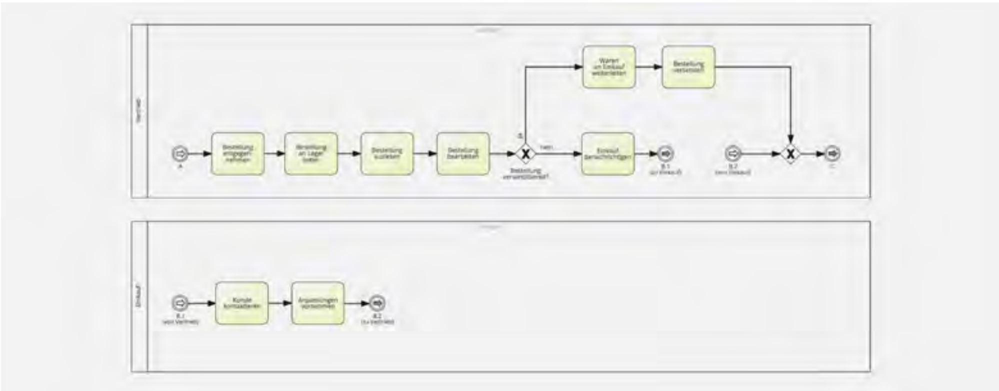


Figure B.52: Link Event in Horizontal Modularization of P6

Message Events

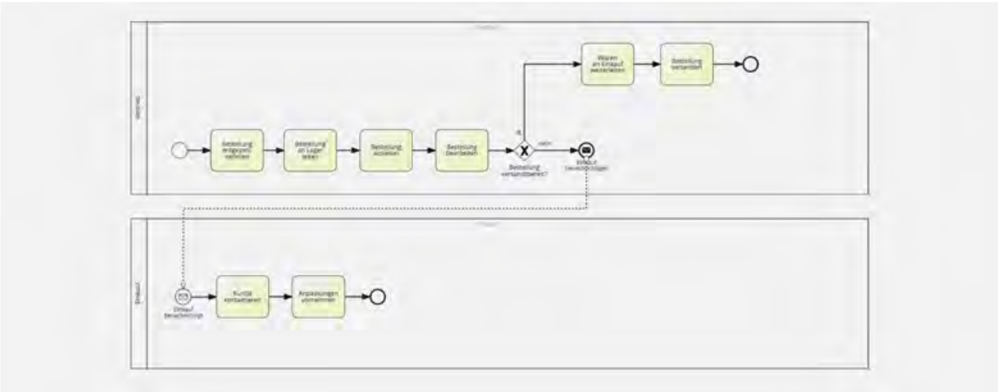


Figure B.53: Message Event in Horizontal Modularization of P6

Self Designed (Horizontal)

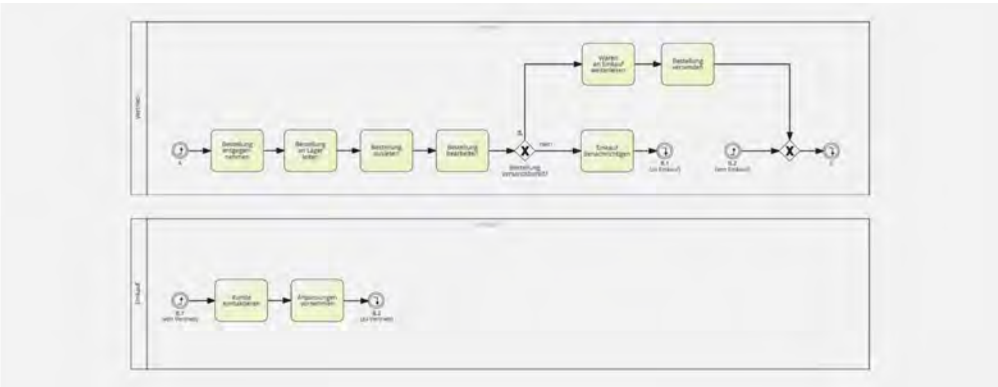


Figure B.54: Self Designed in Horizontal Modularization of P6

Set of Statements

Statement	Horizontal Modularization			Vertical Modularization			Orthogonal Modularization		
	ME	**LE**	**SDH**	**ES**	**CS**	**SDV**	**EE**	**AO**	**SDO**
Die Bestellung darf nicht versandbereit sein, um den Kunden zu kontaktieren	true	true	true	true	true	true	true	true	true
In der Darstellung wird ein Modul aufgezeigt, das ausgeführt wird wenn die Bestellung nicht versandbereit ist	true	true	true	true	true	true	true	true	true
Eine versandbereite Bestellung führt zur Modularisierung	false	false	false	false	false	false	false	false	false
In der Darstellung wird ein Modul aufgezeigt, das nicht ausgeführt wird wenn die Bestellung nicht versandbereit ist	false	false	false	false	false	false	false	false	false

Table B.6: Statements of P6

B.8 Image 7 (P7)

Image 7 comprises the topic PIN to a smartphone. If an incorrect pin is entered, the pin has to be entered correctly to enable smartphone usage. Otherwise, if the pin is entered correctly the smartphone is used.

Aspect-Oriented

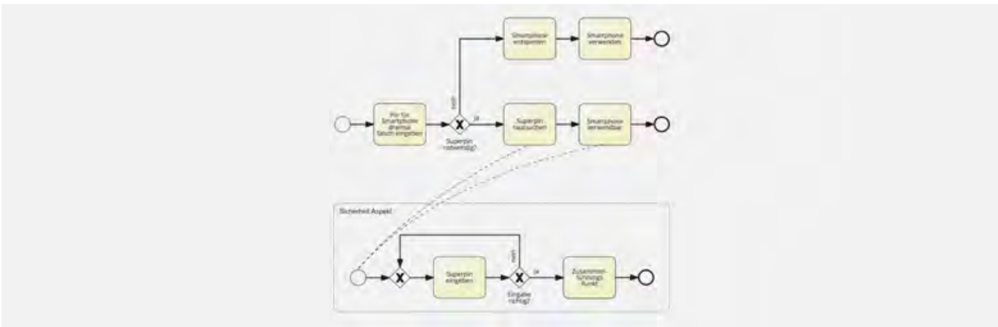


Figure B.55: Aspect-Ortiented in Orthogonal Modularization of P7

Exception Events

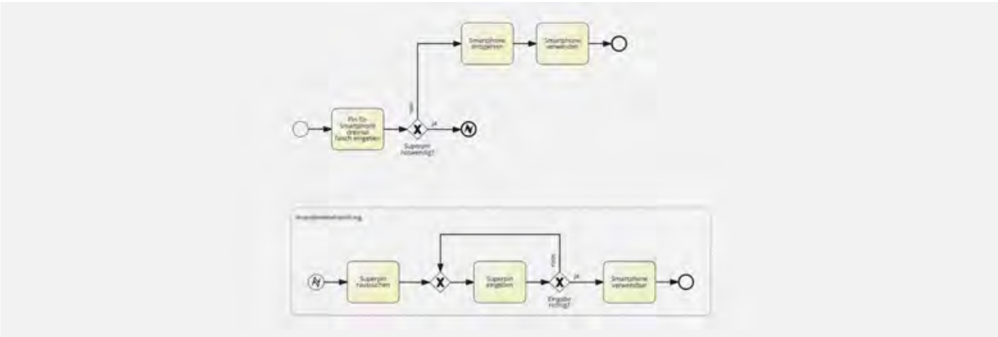


Figure B.56: Exception Events in Orthogonal Modularization of P7

Self Designed (Orthogonal)

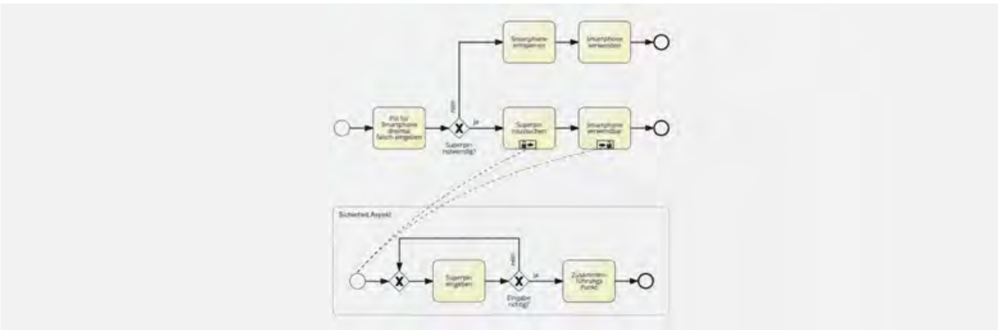


Figure B.57: Self Designed in Orthogonal Modularization of P7

Collapsed Subprocesses

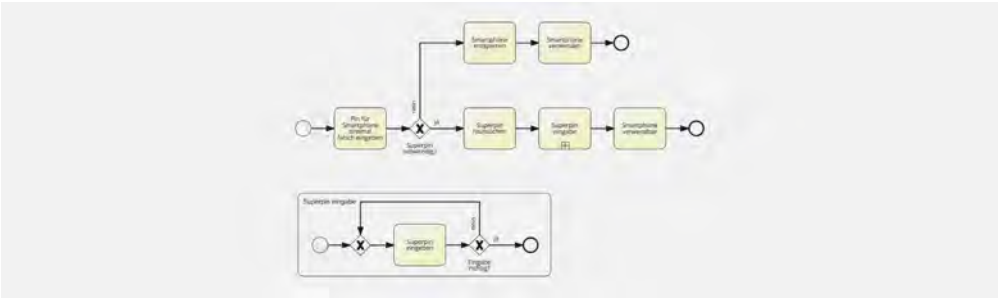


Figure B.58: Collapsed Subprocesses in Vertical Modularization of P7

Expanded Subprocesses

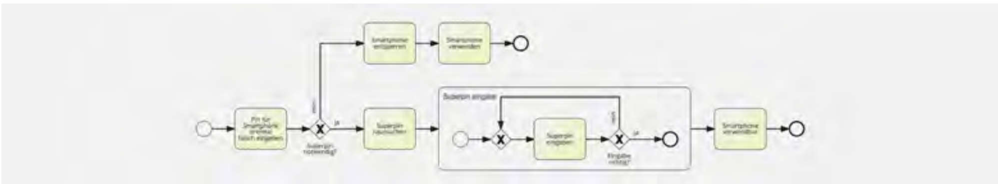


Figure B.59: Expanded Subprocesses in Vertical Modularization of P7

Self Designed (Vertical)

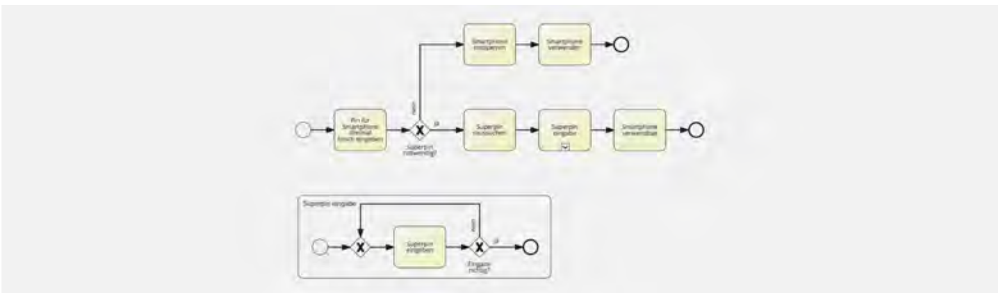


Figure B.60: Self Designed in Vertical Modularization of P7

Link Events

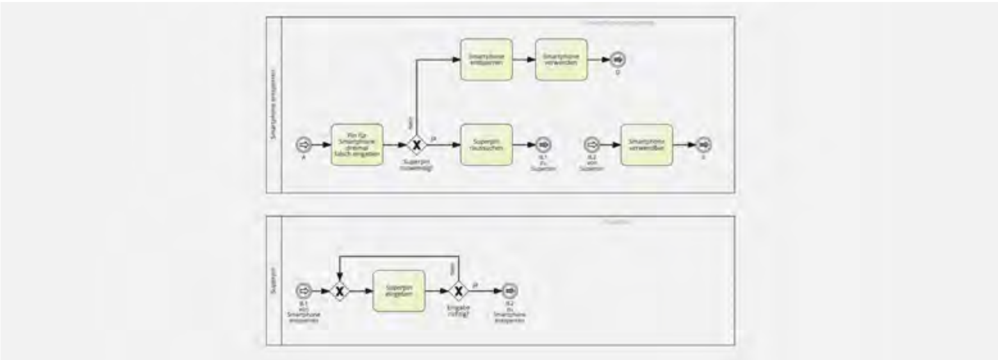


Figure B.61: Link Event in Horizontal Modularization of P7

Message Events

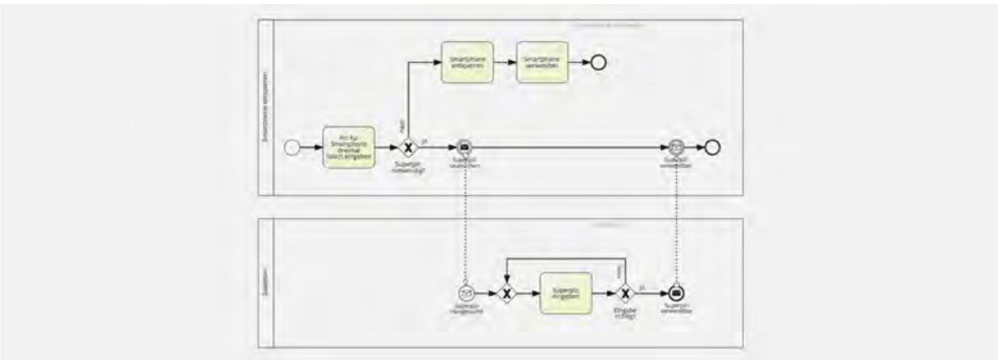


Figure B.62: Message Event in Horizontal Modularization of P7

Self Designed (Horizontal)

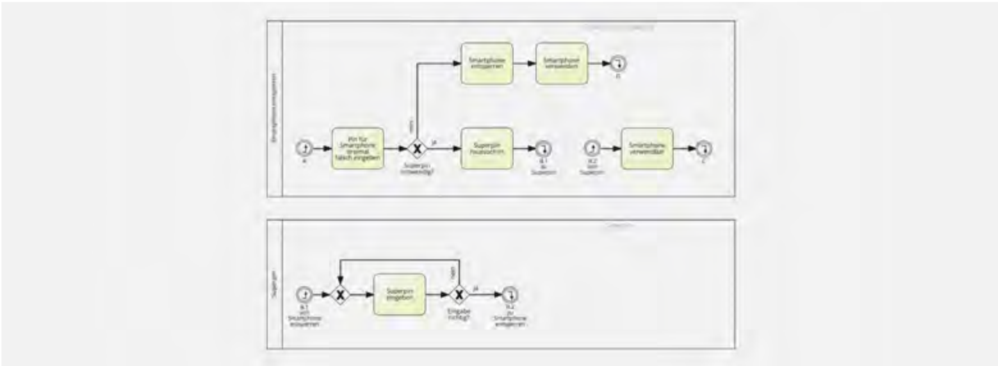


Figure B.63: Self Designed in Horizontal Modularization of P7

Set of Statements

Statement	Horizontal Modularization			Vertical Modularization			Orthogonal Modularization		
	ME	**LE**	**SDH**	**ES**	**CS**	**SDV**	**EE**	**AO**	**SDO**
Der modularisierte Bereich muss nach dessen Aufruf nicht ausgeführt werden	false	false	false	false	false	false	false	false	false
Der modularisierte Bereich muss nach dessen Aufruf ausgeführt werden	true	true	true	true	true	true	true	true	true
Das Smartphone muss verwendet werden	true	true	true	true	true	true	true	true	true
Wenn der Superpin notwendig ist, dann muss dieser richtig eingegeben werden, damit das Smartphone verwendbar ist	false	false	false	false	false	false	false	false	false

Table B.7: Statements of P7

B.9 Image 8 (P8)

Image 8 is inspired by [1] and includes the theme loan.

Aspect-Oriented

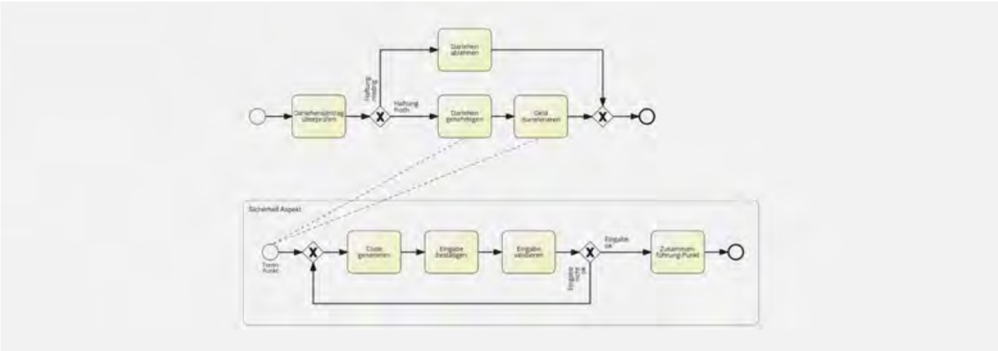


Figure B.64: Aspect-Ortiented in Orthogonal Modularization of P8

Exception Events

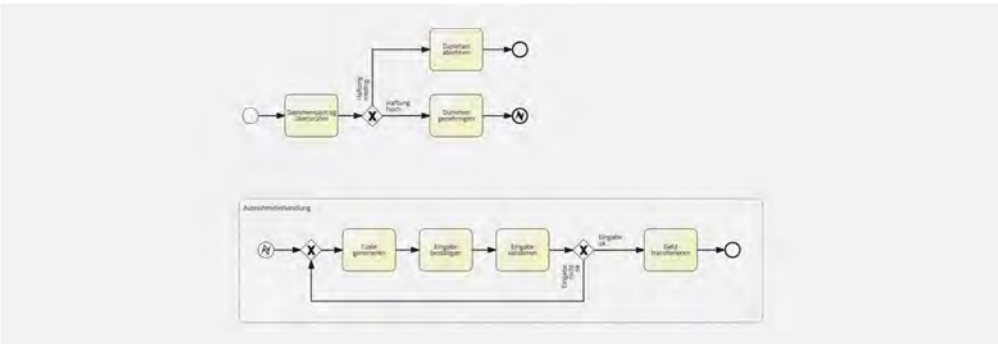


Figure B.65: Exception Events in Orthogonal Modularization of P8

Self Designed (Orthogonal)

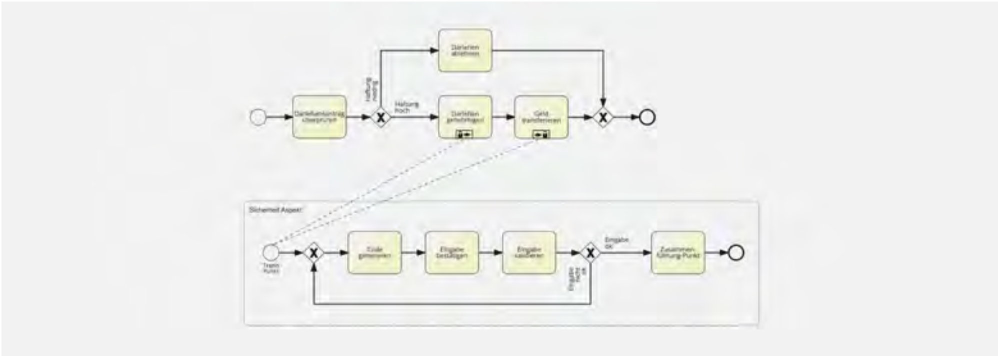


Figure B.66: Self Designed in Orthogonal Modularization of P8

Collapsed Subprocesses

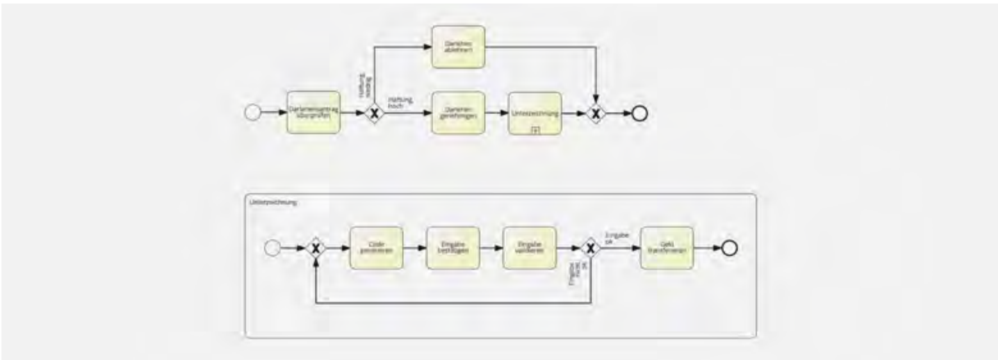


Figure B.67: Collapsed Subprocesses in Vertical Modularization of P8

Expanded Subprocesses

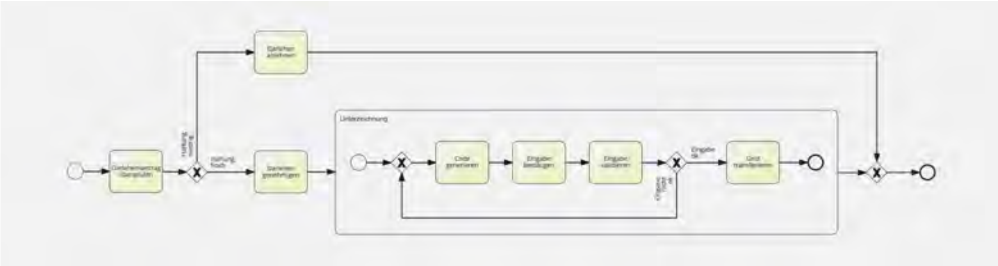


Figure B.68: Expanded Subprocesses in Vertical Modularization of P8

Self Designed (Vertical)

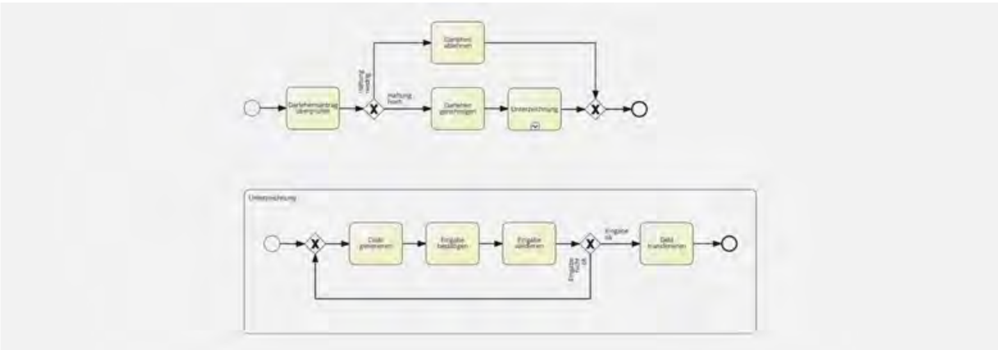


Figure B.69: Self Designed in Vertical Modularization of P8

Link Events

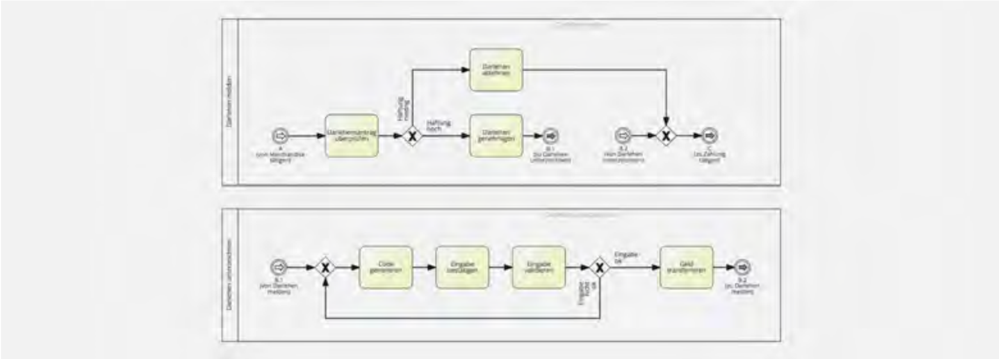


Figure B.70: Link Event in Horizontal Modularization of P8

Message Events

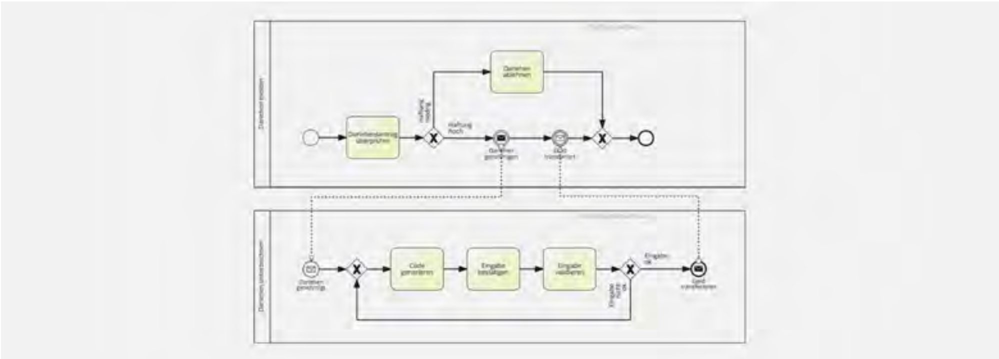


Figure B.71: Message Event in Horizontal Modularization of P8

Self Designed (Horizontal)

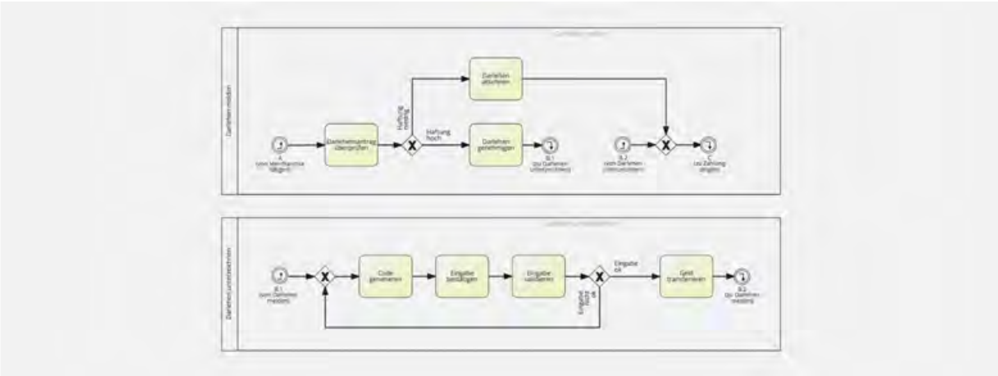


Figure B.72: Self Designed in Horizontal Modularization of P8

Set of Statements

Statement	Horizontal Modularization			Vertical Modularization			Orthogonal Modularization		
	ME	**LE**	**SDH**	**ES**	**CS**	**SDV**	**EE**	**AO**	**SDO**
"Haftung hoch" ist der Pfad der eine Modularisierung beinhaltet	true	true	true	true	true	true	true	true	true
Nach Genehmigung eines Darlehens, kann die Eingabe nicht bestätigt werden	false	false	false	false	false	false	false	false	false
Der Kunde wird am Ende immer benachrichtigt	false	false	false	false	false	false	false	false	false
Der Kunde wird am Ende nicht benachrichtigt	true	true	true	true	true	true	true	true	true

Table B.8: Statements of P8

B.10 Image 9 (P9)

Image 9 comprises the theme card payment. The method of validation is chosen. Either the entry of a pin is necessary, or a signature is required. The pin will be entered incorrectly and the precess finishes with blocking the card.

Aspect-Oriented

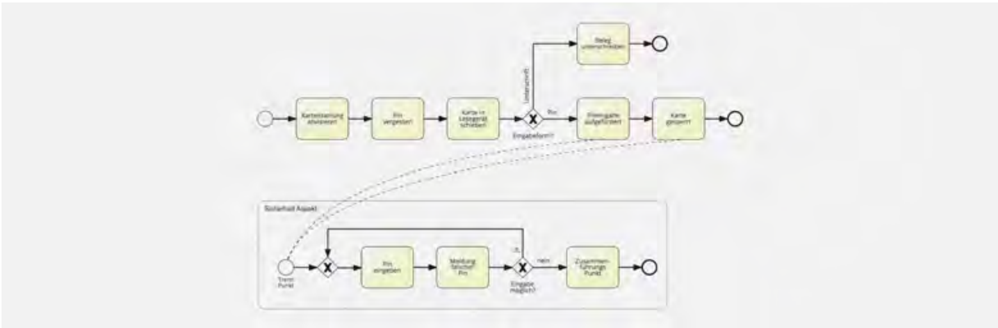


Figure B.73: Aspect-Ortiented in Orthogonal Modularization of P9

Exception Events

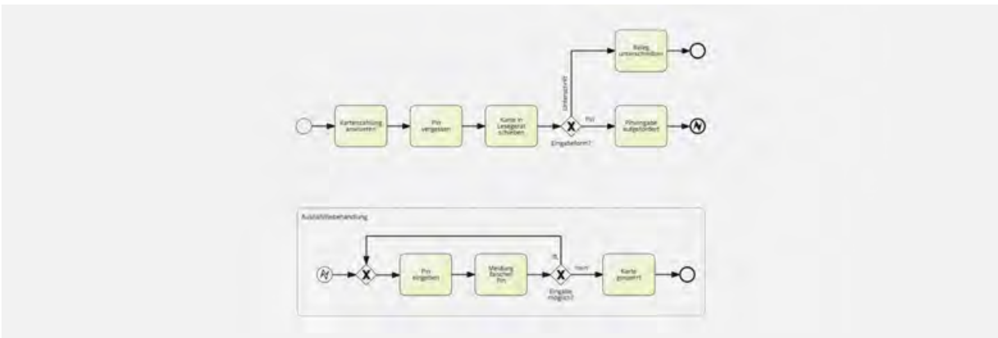


Figure B.74: Exception Events in Orthogonal Modularization of P9

Self Designed (Orthogonal)

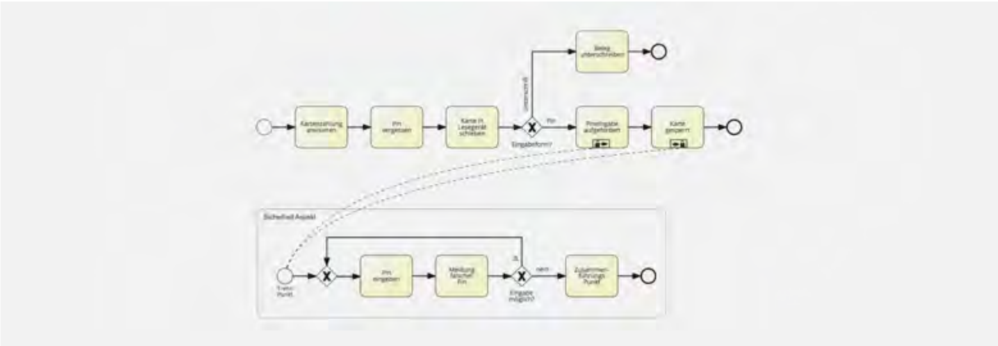


Figure B.75: Self Designed in Orthogonal Modularization of P9

Collapsed Subprocesses

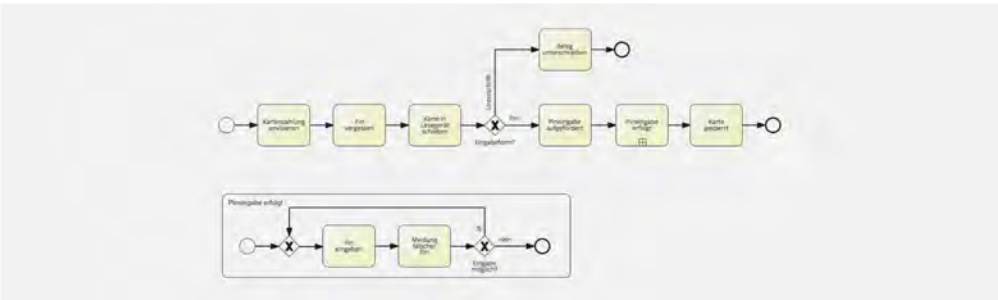


Figure B.76: Collapsed Subprocesses in Vertical Modularization of P9

Expanded Subprocesses

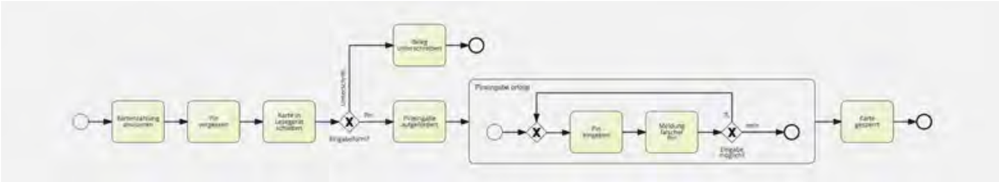


Figure B.77: Expanded Subprocesses in Vertical Modularization of P9

Self Designed (Vertical)

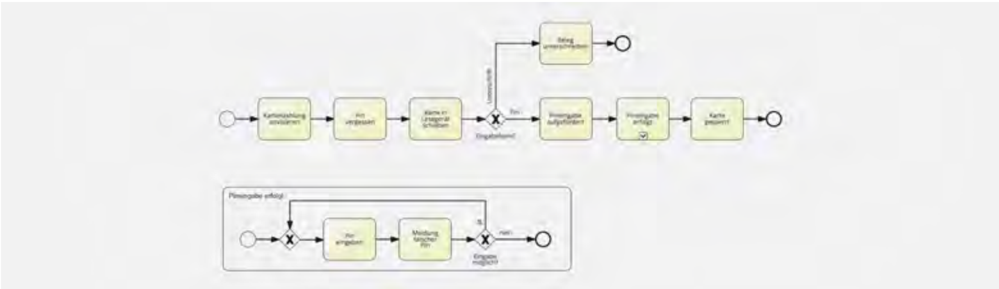


Figure B.78: Self Designed in Vertical Modularization of P9

Link Events

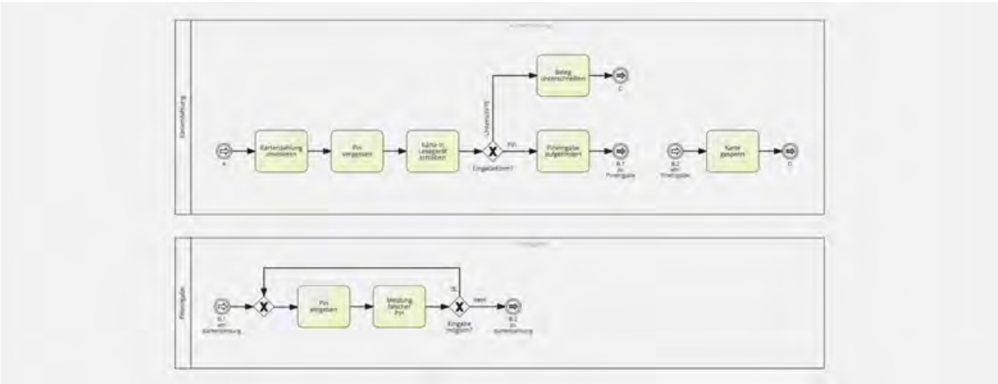


Figure B.79: Link Event in Horizontal Modularization of P9

Message Events

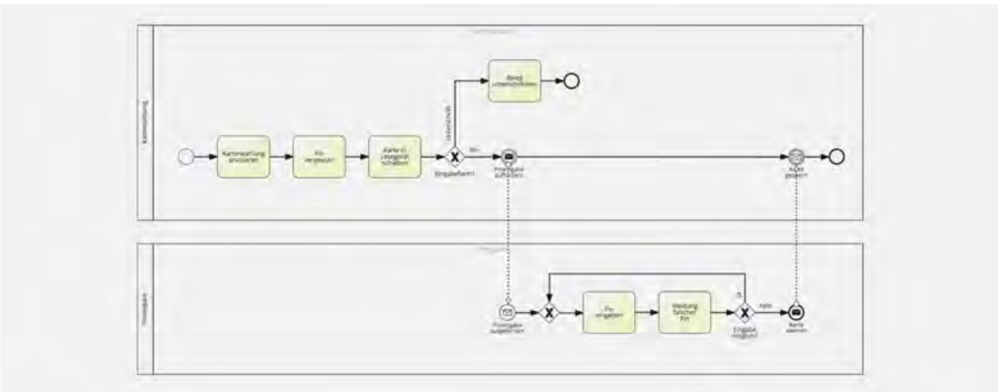


Figure B.80: Message Event in Horizontal Modularization of P9

Self Designed (Horizontal)

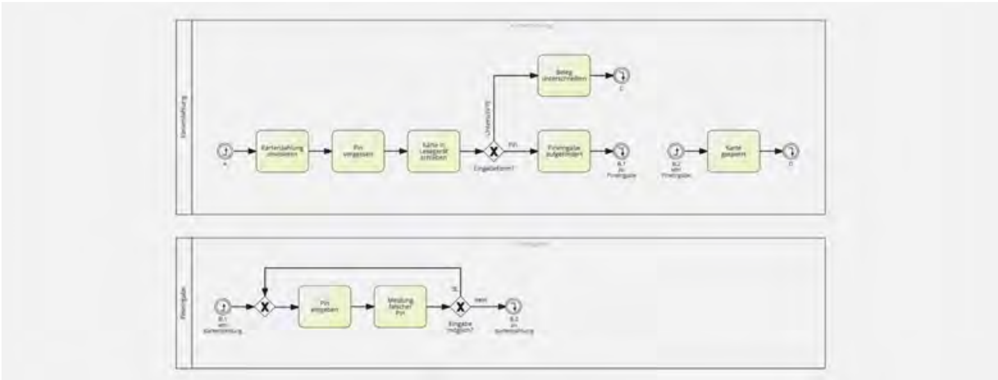


Figure B.81: Self Designed in Horizontal Modularization of P9

Set of Statements

Statement	Horizontal Modularization			Vertical Modularization			Orthogonal Modularization		
	ME	**LE**	**SDH**	**ES**	**CS**	**SDV**	**EE**	**AO**	**SDO**
Die Eingabeform "Pin" führt zu einem weiteren Modul	true	true	true	true	true	true	true	true	true
Der Beleg muss immer unterschrieben werden	false	false	false	false	false	false	false	false	false
Die Aktivität "Pin eingeben" muss immer durchgeführt werden	false	false	false	false	false	false	false	false	false
Modularisierung ist in der Abbildung gegeben	true	true	true	true	true	true	true	true	true

Table B.9: Statements of P9

B.11 Questionnaires

Three questionnaires are utilized in the study. First, the demographic questionnaire is given. The questionnaire concerning cognitive load and understandability are given at the end of the study.

Demographic Questionnaire

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Persönlicher Code

Um die erhobenen Daten zu anonymisieren, verwenden wir für den weiteren Verlauf der Studie einen Code. Erstellen Sie diesen Code nach dem folgenden Muster:

1. Zweite Ziffer des Tags Ihres Geburtsdatums
2. Erster Buchstabe Ihres Vornamens
3. Zweite Ziffer Ihres Alters
4. Letzter Buchstabe Ihres Familiennamens
5. Letzte Ziffer Ihres Geburtsjahres
6. Letzter Buchstabe des Vornamens
7. Erste Ziffer des Monats Ihres Geburtsdatums
8. Erster Buchstabe des Familiennamens
9. Berechnen Sie die Prüfsumme aller Ziffern

Beispiel:
Name: John Public
Alter: 29
Geburtstag: 19.05.1988

1.	Zweite Ziffer des Tags Ihres Geburtsdatums:	19	→ 9
2.	Erster Buchstabe Ihres Vornamens:	John	→ J
3.	Zweite Ziffer Ihres Alters:	29	→ 9
4.	Letzter Buchstabe Ihres Familiennamens:	Public	→ c
5.	Letzte Ziffer Ihres Geburtsjahrs:	1988	→ 8
6.	Letzter Buchstabe des Vornamens:	John	→ n
7.	Erste Ziffer des Monats Ihres Geburtsdatums:	05	→ 0
8.	Erster Buchstabe des Familiennamens:	Public	→ P
9.	Berechnen Sie die Prüfsumme aller Ziffern:	9+9+8+0	→ 26

Der in diesem Beispiel generierte Code lautet **9J9c8n0P26**.

Ihr persönlicher Code: ____________________________________

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Figure B.82: Declaration of Consent

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Demographischer Fragebogen

1. Geben Sie Ihr Geschlecht an:

   ○ weiblich ○ männlich ○ keine Angabe

2. Geben Sie Ihr Alter an:

   ○ jünger als 25 ○ 25 – 35 ○ 36 – 45 ○ 46 – 55 ○ älter als 55

3. Geben Sie Ihren höchsten Bildungsabschluss an:

   ○ Ohne Abschluss
   ○ Hauptschulabschluss oder Volkshochschulabschluss
   ○ Realschulabschluss (Mittlere Reife)
   ○ Fachhochschulreife
   ○ Hochschulreife (Abitur)
   ○ Fachhochschulabschluss
   ○ Bachelor Hochschulabschluss
   ○ Master Hochschulabschluss
   ○ Sonstiger Abschluss, und zwar ______________________________

4. Wie hoch ist Ihre aktuelle Anzahl an Ausbildungsjahren (inkl. Grundschule)?

   ____

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Figure B.83: Declaration of Consent

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5. Welche berufliche Ausbildung trifft am ehesten auf Sie zu?

   ○ Auszubildende(r) / Student(in)
   ○ Abgeschlossene Berufsausbildung
   ○ Abgeschlossene Ausbildung an einer Meister- oder Technikerschule
   ○ Akademiker(in)
   ○ Sonstiges, und zwar ______________________________________

6. Falls Sie studieren (oder studiert haben), geben Sie bitte Ihren Studiengang an:

   ____

7. Haben Sie bereits Erfahrung mit Prozessmodellen bzw. Prozessmodellierung?

   ○ ja ○ nein

8. Vor wie vielen Jahren haben Sie mit der Modellierung von Prozessmodellen begonnen?

   ____

9. Wie viele Prozessmodelle haben Sie innerhalb der letzten 12 Monate gelesen oder analysiert?

   ____

10. Wie viele Prozessmodelle haben Sie innerhalb der letzten 12 Monate erstellt oder bearbeitet?

   ____

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Figure B.84: Declaration of Consent

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11. Wie viele Aktivitäten hatten diese Modelle im Durchschnitt?

____

12. Wie viele Tage formale Ausbildung zum Thema „Prozessmodellierung“ haben Sie in den letzten 12 Monaten erhalten?

    Beispiel: Eine Vorlesung mit 2 Stunden / Woche ergibt ca. 8 Stunden Ausbildung pro Monat. Das entspricht einem Arbeitstag pro Monat. Eine Vorlesung inkl. Übungen ergibt folglich 2 Arbeitstage pro Monat.

____

13. Wie viele Tage haben Sie in den letzten 12 Monaten mit dem Selbststudium zum Thema „Prozessmodellierung“ verbracht? Beachten Sie die gleiche Beispielsrechnung wie vorher.

____

14. Bitte kreuzen Sie an, welche Notation zur Prozessmodellierung haben Sie während Ihrer Ausbildung/Studium als erstes gelernt?

○ BPMN	○ Deklarativ	○ eGantt
○ EPK	○ Flow Chart	○ IDEF 3
○ Petri Netz	○ UML Aktivitätsd.	○ Andere

15. Mit welcher der in Frage 14 angegebenen Notationen zur Prozessmodellierung haben Sie bisher die meiste Zeit verbracht?

____

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Figure B.85: Declaration of Consent

Cognitive Load and Understandability

Fragebogen

Ihr Code: ____________________

Bitte beurteilen Sie die soeben ausgeführte Aufgabe:

	sehr gering						sehr hoch
Bei der Aufgabe war Ihre mentale Anstrengung...	○	○	○	○	○	○	○

	sehr leicht						sehr schwer
Wie leicht oder schwer war die Aufgabe zu lösen?	○	○	○	○	○	○	○

	sehr wenig						sehr viel
Wieviel Spaß hatten Sie bei der Bearbeitung der Aufgabe?	○	○	○	○	○	○	○

	stimmt absolut nicht						stimmt völlig
Bei der Aufgabe musste man viele Dinge gleichzeitig im Kopf bearbeiten.	○	○	○	○	○	○	○
Diese Aufgabe war sehr komplex.	○	○	○	○	○	○	○
Sie haben sich angestrengt, sich nicht nur einzelne Dinge zu merken, sondern auch den Gesamtzusammenhang zu verstehen.	○	○	○	○	○	○	○
Es ging Ihnen beim Bearbeiten der Lerneinheiten darum, alles richtig zu verstehen.	○	○	○	○	○	○	○
Die Lerneinheit enthielt Elemente, die Sie unterstützten, den Lernstoff besser zu verstehen.	○	○	○	○	○	○	○
Bei dieser Aufgabe ist es mühsam, die wichtigsten Informationen zu erkennen.	○	○	○	○	○	○	○
Die Darstellung bei dieser Aufgabe ist ungünstig, um wirklich etwas zu lernen.	○	○	○	○	○	○	○
Bei dieser Aufgabe ist es schwer, die zentralen Inhalte miteinander in Verbindung zu bringen.	○	○	○	○	○	○	○
Sie haben sich bei der Aufgabe angestrengt.	○	○	○	○	○	○	○
Die Aufgabe war anstrengend.	○	○	○	○	○	○	○

Figure B.86: Questionnaire Section of Cognitive Load

	stimmt absolut nicht						stimmt völlig
Auf diese Weise repräsentierte Geschäftsprozessmodelle wären für die Nutzer schwer zu verstehen.	○	○	○	○	○	○	○
Sie denken, dass diese Präsentationsansätze eine effektive Lösung für das Problem der Darstellung von Geschäftsprozessmodellen bietet.	○	○	○	○	○	○	○
Die Verwendung von Prozessmodellen dieser Art würde die Kommunikation von Geschäftsprozessen an den Endnutzer erschweren.	○	○	○	○	○	○	○
Insgesamt erachten Sie die Geschäftsprozessmodelle in diesem Experiment als nützlich.	○	○	○	○	○	○	○
Diese Art der Modellierung von Geschäftsprozessen zu erlernen, wäre für Sie einfach.	○	○	○	○	○	○	○
Sie halten die Darstellung der Prozesse für unklar und schwer verständlich.	○	○	○	○	○	○	○
Es wäre leicht für Sie, diese Art von Modellierung von Geschäftsprozessen zu beherrschen.	○	○	○	○	○	○	○
Insgesamt hat sich die Modellierung dieser Art von Geschäftsprozessen als schwierig erwiesen.	○	○	○	○	○	○	○

Figure B.87: Questionnaire Section of Understandability

B.12 Declaration of Consent

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Fakultät für Ingenieurwissenschaften, Informatik und Psychologie
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Tel: +49 731 50-24230
michael.zimoch@uni-ulm.de
http://www.informatik.uni-ulm.de/dbis

Einwilligungserklärung:

Studie – Verständlichkeit von Prozessmodellen

Inhalt, Vorgehensweise, Risiken und Ziel des obengenannten Forschungsprojektes sowie die Befugnis zur Einsichtnahme in die erhobenen Daten wurden ausreichend erklärt.
Ich hatte zusätzliche Fragen:

____

____

Ich hatte Gelegenheit Fragen zu stellen und habe hierauf Antwort erhalten. Ich hatte ausreichend Zeit, mich für oder gegen die Teilnahme am Projekt zu entscheiden.

INFORMATION UND EINWILLIGUNGSERKLÄRUNG ZUM DATENSCHUTZ

Bei wissenschaftlichen Studien werden persönliche Daten über Sie erhoben. Die Speicherung, Auswertung und Weitergabe dieser studienbezogenen Daten erfolgt nach gesetzlichen Bestimmungen und setzt vor Teilnahme an der Studie folgende freiwillige Einwilligung voraus:

1. Ich erkläre mich damit einverstanden, dass im Rahmen dieser Studie erhobene Daten auf Fragebögen u. elektr. Datenträgern aufgezeichnet und ohne Namensnennung verarbeitet werden.
2. Außerdem erkläre ich mich damit einverstanden, dass eine autorisierte und zur Verschwiegenheit verpflichtete Person in meine erhobenen personenbezogenen Daten Einsicht nimmt, soweit dies für die Überprüfung des Projektes notwendig ist.

Ich willige in die Teilnahme am Forschungsprojekt und die beschriebene Verwendung meiner Daten ein.

Ort, Datum	Name (Druckbuchstaben)	Unterschrift (Teilnehmer)

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Figure B.88: Declaration of Consent

List of Figures

List of Tables

Name: Julia Baß Matriculation number: 759965

Honesty disclaimer

I hereby affirm that I wrote this thesis independently and that I did not use any other sources or tools than the ones specified.

Ulm, ...

Julia Baß