MASTER

The Influence of Model Sparsity on the Understandability of Business Process Models

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The Influence of Model Sparsity on the Understandability of Business Process Models

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1. Introduction

Every organization has to manage processes, and the way these processes are designed affects the quality and efficiency with which services are delivered (Dumas et al., 2018). That all kinds of different companies work with processes also means that people from different backgrounds are working with the process models. For example, process models that are used to inform various stakeholders on the possibilities of information systems are also consulted, validated and updated by stakeholders with different levels of expertise. This makes understandability of process models a key concern for business and research (Dumas et al., 2012). Previous literature reviews have already identified that there are at least six common indicators for process model understandability, indicating the complexity of measuring understandability (Dikici et al., 2018). And even when the understandability can be measured, there are twelve process model factors and eight personal factors that can influence the understandability (Dikici et al., 2018). One of the process model factors is visual layout, which is a broad definition. In empirical research it comes forward that the length of edges, the general direction of the model and the size of the model (how much space it takes up) are important for understandability (Bernstein & Soffer, 2015). These aspects of process models can all be related to the sparsity of a process model and the flow direction, where the length of edges is directly dependent on the amount of space between two elements and the model size in this sense becomes larger when the spacing between elements is bigger. However, these aspects are often not mentioned, or mentioned only as a side note, in most research studies on process model understandability. Therefore, we aim to identify what process model sparsity and flow direction is optimal for process model understandability, and find out if this is a general effect or an effect for certain groups of people. With this information, process modelling tools can use a standard flow direction and sparsity, and process modelling can be further standardized to make process models in general more understandable.

Accordingly, the main objective of this study is to research the influence of model sparsity on process model understandability. Model sparsity in this study is defined by the distance between two consecutive elements, or in other words the spacing between elements. This spacing is represented as a percentage of the width or height (depending on whether the distance is horizontal or vertical) of the elements in the model. For instance, a 50% spacing process model will have a distance of 50% of the element width or height between each pair of elements. In this study, we experimented with three levels of sparsity: 25%, 50%, and 100%.

As a secondary objective, the influence of the direction of process flow on process model understandability is investigated by comparing horizontal models to vertical models. The flow direction is defined as the direction in which most of the flow proceeds in a process model (Figl & Strembeck, 2014). We consider two options for flow direction; horizontal (left-to-right) and vertical (top-to-bottom) as these are in line with western handwriting and reading from left-to-right and then from top-to-bottom.

Additionally, the participants' BP Modelling Competency, cognitive style, learning style and field dependency are measured to investigate if they have an influence on understandability, or if there is an interaction effect between the factors discussed above and understandability.

The objectives described above are achieved by conducting an experiment with the participation of 148 graduate students in Eindhoven University of Technology following a business process management course. Each participant was given two different models with different sparsity levels and asked to answer questions regarding the content of the model, as well as questions regarding their perceived understandability of each model they saw. Accordingly, the process model understandability was operationalized using the following dependent variables aligned with previous research (Dikici et al., 2018):

- *Understandability task effectiveness, which* is defined as the number of correct answers to understandability questions about the process models. These questions are designed to find out if the process model reader understands the process model by, for example, asking whether two activities can be executed in one run of the process model.
- *Understandability task efficiency, which* is defined as the time it takes to correctly answer the understandability questions divided by the number of correct answers
- *Perceived usefulness for understandability, which* is a measure to define the utility a process model would give the user in the terms of understandability.
- *Perceived ease of use, which* is related to the level of effort it costs for a user to use a given process model in its given form.

The remainder of this paper is structured as follows. In section 2 related work is discussed with a focus on understandability of process models. Literature related to the cognitive profiles and learning styles will also be discussed shortly. In section 3 the research model that shows how all the factors relate to each other and the resulting hypotheses will be discussed. In section 4 the complete experiment setup will be discussed. Every aspect of the experiment will be discussed separately, explaining where every aspect comes from and how it is operationalized. In section 5 the results will be presented in a clear way, while the discussion follows in section 6. The discussion is meant to interpret these results and relate them to the research objective. Implications of why these results are found and what limitations there are will also be mentioned. Section 7 will be the conclusion, where there will be a brief overview of the complete study, and concrete answers to whether all the hypotheses were supported or not. Limitations of the study and future work will also be addressed here.

2. Related work

2.1. Process model understandability

Understandability is an important factor when researching process models (Dikici et al., 2018; Reijers & Mendling, 2011). When the goal is to investigate factors that influence the understandability of a process model, it is important to have a clear definition of what understandability means in this context (Houy et al., 2012). Lindland et al. (1994) described process models in three different qualities; syntactic, semantic and pragmatic quality, where the goal of pragmatic quality is comprehension of the model. This broad definition of understandability is a very logical one but does not give concrete indication of when someone understands a model. Mendling et al. (2007) asked themselves the question “What makes process models understandable?” and came to the conclusion that model characteristics (model size, average connector degree and density) influence the understandability. In this paper we focus on two model characteristics related to the visual layout. More specifically, the *process model sparsity* and the *flow direction* of a process model.

2.2. Process model sparsity

Purchase (1997) conducted research on layout aesthetics in graphs to find the aesthetics that have the biggest influence on human understanding of graphs. The research covered five aesthetics, and found support that for a better understandability it is good to minimize the number of crossings, minimize the number of bends in edges and maximize symmetry. No support was found for maximizing the orthogonal structure and maximizing the minimum angles between edges leaving a node. These aesthetics seem to be the core for other research on layout aesthetics as well, as they are also considered for example, in Effinger et al. (2010), Albrecht et al. (2010) and Gschwind et al. (2014). Similar to the previous research on layout aesthetics Bernstein & Soffer (2015) conducted an experiment where they asked participants to name the visual layout differences between models and indicate their preference, and came up with a list of key visual layout features and how to quantify them. A logical next step after identification of layout features is to develop an automatic layout algorithm for process models.

Gschwind et al. (2014) propose such an algorithm taking into account six constraints, namely edges drawn in the direction of the process flow, incoming and outgoing edges separated, edge crossings minimized, bend points of edges minimized, using an orthogonal layout of edges and minimizing the space used. However, one aspect that they do not explicitly investigate in their research is how far the different elements in a model are placed from each other; that is, the spacing between elements or process model sparsity. This is, however, one of the most basic and essential aspects that comes across in any business process modeling activity. Albrecht et al. (2010) propose a similar algorithm used for layout aesthetics of BPEL process models. However the authors do not provide specification of the spacing between elements. They use a variable to define the minimum distance between elements to avoid overlap, but do not give a specification of how this distance is determined. In effect, process model sparsity is a concern in the design of any conceptual model. The conceptual modelling layout algorithms proposed in the relevant literature such as the ones by Batini et al. (1984), Eiglsperger et al. (2003) and Effinger et al. (2009) come to the same conclusion in using the same set of layout aesthetics, without explicitly specifying the spacing between elements.

The study by Leopold et al. (2016) is one of the very few works that explicitly consider the spacing between process elements as an important concern. The authors analyze 565 BPMN process models to find out the type of quality issues that arise in BPMN models designed in practice. One of the five most found layout issues is *inappropriate spacing* between elements. The authors define appropriate spacing as the distance that is over 50% of element size (measured using width or height of the element, depending on the position of the elements relative to each other, and assuming elements of equal or comparable size). However, this conflicts -to a certain extent- with the best practices defined by Signavio process modeling tool on their website (https://www.modeling-guidelines.org/guidelines/usage-of-sufficiant-distances-between-elements/). In the Signavio tool the minimum distance between connected elements is suggested to be 75% of the element width (although, in their own example a smaller percentage of distance is kept between elements). The abovementioned studies leave a gap in the literature about the ideal spacing convention that should be maintained between process elements for better understandability of process models, and about how this property can be accurately measured.

Scholz & Lübke (2019) aimed to fill this gap by conducting an experiment to find out what the subjective preference for layouts of diagrams is. Among other variables, they also varied the horizontal and vertical spacing between elements in models. They chose to have three variations of these aspects and used 25, 50 or 70% of element width as the horizontal spacing between elements, and 12.5, 25 and 50% of element height as the vertical spacing between elements. They do not give any clarification on how they came to these exact percentages (these values are given the first time when stating the research questions). The experiment consisted of giving participants a pair of models that differed on one single aspect and asking them to indicate their preference. Participants had to answer this same question for all pairs of models in the experiment. This resulted in a preference for horizontal spacing of 70% over 25%, and a preference for vertical spacing of 25% over 12.5%. The other pairs of models did not yield any significant differences.

In brief, there is considerable research on the layout of process models, reflected also as several automatic layout algorithms covering a specific set of layout aesthetics. However, our extensive review of the literature resulted in only a single paper that reports on an experiment that tests with different distances used for spacing between elements. This leaves room for further research to investigate the optimal spacing of process elements for better model understandability.

2.3. Process flow direction

Process flow direction – i.e., whether the general direction of the process flow should be horizontal or vertical- is another factor whose influence on understandability is unclear. A common mention for general direction is that process flow should be horizontal from left-to-right, because this matches the progression of western writing (Kitzmann et al., 2009). That the modeling direction should consistently be left-to-right is also mentioned in a study about quality issues of BPMN models (Leopold et al., 2016). Another example is an algorithm that improves the layout of process models and is solely designed for BPMN models that have a left-to-right process flow (Gschwind et al., 2014). The study by Scholz & Lübke (2019) mentions in their limitations that they only used diagrams modelled from left to right, while especially the vertical spacing might be influenced by having a horizontal layout. So combining the differentiation between several horizontal and vertical spacings with a horizontal or vertical process flow makes sense. That is why in this research, the general direction of process flow is also considered. The standard models used in this experiment are both vertical, so a horizontal version was made of the 50% spacing versions.

2.4. Business Process Modelling Competency

One of the interaction variables that we investigate in our study is the BP Modelling Competency of the model reader. In previous work on process model understandability the BP Modelling Competency has been taken into account and found to be of influence on the results (Mendling et al., 2012; Reijers & Mendling, 2011; Turetken et al., 2017). For one of the works, the competency was measured using self-assessment, in the other two papers there was a small questionnaire that determined the competency. In this paper, we followed the questionnaire approach and adapted the questions reported in Turetken et al (2019).

2.5. Cognitive style

Cognitive style can be defined as the way a person organizes and processes information (Allinson & Hayes, 1996). In this sense, the cognitive style of a person can have an influence in how they perceive and deal with differences in representation of process models. This is why previous research has already linked cognitive style to process model understandability, and found that there is indeed supporting evidence that cognitive style has an influence (Turetken et al., 2017). The link between these two factors has not been extensively researched yet, and that is why we aim to confirm the previous findings in this research, and extend the research by looking for interaction effects.

2.6. Learning styles

Another factor that could influence process model understandability is the *learning style*. Process model understanding can be conceptualized as a learning process, and as such the learning style of a person is very relevant (Recker et al., 2014). Learning styles in combination with process model understandability has also been a topic in previous research, where it was concluded that a sensing learning style is more suitable for process model understanding compared to an intuitive learning style (Musser, 2005). In this research, we will therefor analyze the influence of learning style on the understandability, and we will use four different dimensions of learning style as will be explained later.

2.7. Field dependency

Field dependency is related to whether a person can easily extract the information he or she is looking for from surrounding information (Musser, 2005). As with the cognitive style measure, this is another way of describing someone's cognitive profile. In previous research this has been indicated as a possible factor to investigate in relation to process model understandability (Turetken et al., 2017), which is why we choose to use it in this research.

3. Research model and hypotheses

In accordance with our research objective, two independent variables have been identified; Sparsity (*spacing between elements)* and *general flow direction*. These factors are hypothesized to influence the two sets of dependent variables that we use to indicate process model understandability: *Objectively measured understandability* and *Perceived understandability*. Next to these, this experiment also takes four interaction variables into account, namely *Business Process Modelling Competency, Cognitive style, Learning style and Field dependency*. These interaction variables are expected to have an influence on the dependent variables, but are not controlled in the experiment. The exact way in which these are measured and taken into account are discussed later in this section and in the next section. The relation between all variables is made visible in the research model in Figure 1.

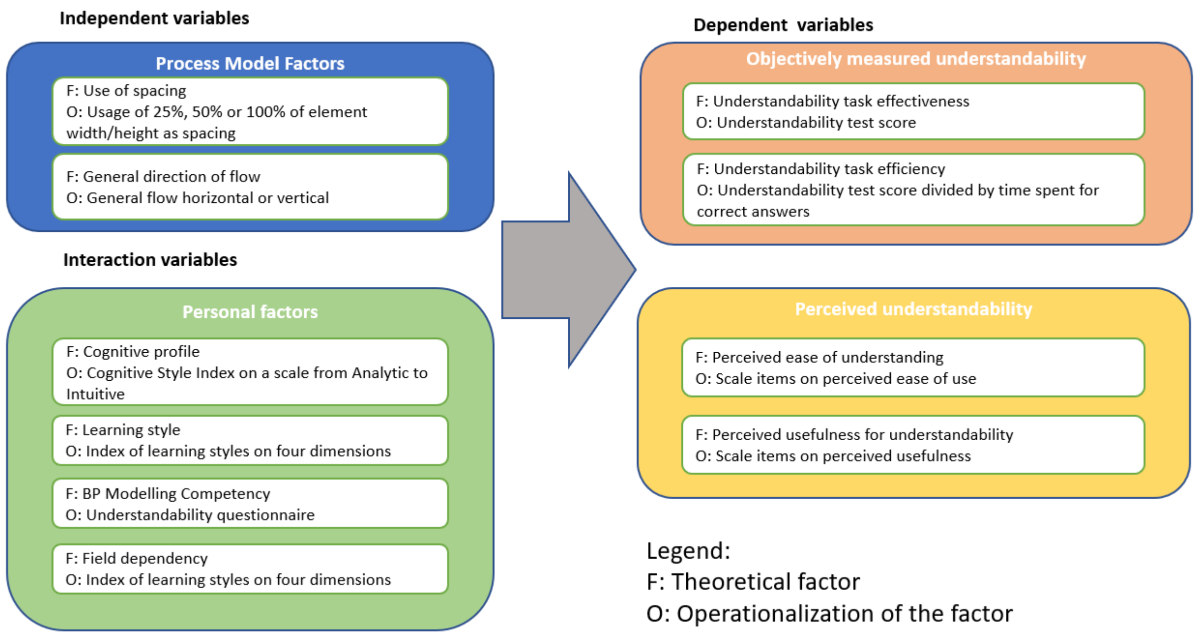

Figure 1: Research model

Previous research does not give a concrete answer on the spacing that is ideal for more understandable process models. Indications are given that spacing should be at least 50% or 75% of element width or height, but without an empirical evidence regarding why this is the optimal distance. Considering these previous findings, we can expect that 25% spacing (with respect to the element size) would lead to low sparsity (i.e., high density), and 100% would indicate high sparsity as far as the process model understandability is of concern. Accordingly the ideal spacing can be expected to be around 50%, leading to the following hypothesis.

H1. Process model sparsity will have a significant impact on both objectively measured process model understandability and perceived understandability, where a spacing of 50% element width/height is expected to result in a higher understandability compared to 25% and 100%.

The previous research as discussed in the related work advises the use of horizontal direction of general process flow (left to right) for improved understandability (Kitzmann et al., 2009; Leopold et al., 2016). One argument that is given for this is that the western handwriting is from left-to-right, which particularly becomes important when there is intensive text use in the labeling of process model elements. However, there is no empirical evidence for these claims, which we aim to provide in this research. We use models that have elements without textual labels to help isolate the influence of horizontal and vertical process flow on the understandability. As horizontal models are more prevalent, it is expected that model readers would find it easier to understand horizontal models. Thus, the second hypothesis is as follows:

H2. The general direction of process flow will have a significant impact on process model understandability, where a horizontal process flow is expected to result in a higher understandability than vertical process flow.

The interaction variable of BP Modelling Competency is also expected to have a significant effect on process model understandability. This variable is considered to be directly related to the process model understandability as participants need to have a basic understanding of how process models work to answer questions about them (Turetken et al., 2016; Turetken et al., 2019). In addition to that, it is expected that people with a higher level of BP Modelling Competency also have more experience in process modelling and consequently score higher and answer faster on understandability questions. This leads to the following hypothesis:

H3. Business Process Modeling Competency will have a positive significant influence on process model understandability.

That intuitive thinkers score significantly lower on process model understanding compared to people with other cognitive styles and that analytic thinkers score significantly higher than adaptive thinkers are two of the conclusions that support the hypothesis that there is an influence of cognitive style on process model understanding (Scholz & Lübke, 2019). While they found no significant differences between the other styles, this seems to indicate a trend that thinkers with a more analytical style score better on process model understanding than thinkers with a more intuitive style. Other work also shows that a more analytical style leads to a higher understanding of process models (Turetken et al., 2017). This leads to the following hypothesis:

H4. Participants with a more analytical cognitive style will score better on objectively measured understandability than participants with a more intuitive cognitive style.

An interesting aspect to research about process model understanding is how people tend to learn. Being a visual or verbal learner could make a difference where visual learners find it easier to understand process models than verbal learners. This aspect and three different dimensions can be measured by the Index of Learning Styles (Recker et al., 2014). Part of this index was already used in a previous experiment on process model understanding, where they concluded that a sensing learning style is more suitable for process model understanding than an intuitive learning style (Musser, 2005). In a systematic literature review about process model understandability it was also found that learning style can be an important factor for the understandability (Dikici et al., 2018). In our research study, all four dimensions (visual to verbal, sequential to global, sensing to intuitive and active to reflective) of the index are used with an exploratory perspective.

H5. Different learning styles have a significant effect on process model understandability

The last aspect that is investigated in this research is the field-dependency, which is another concept regarding a person's cognitive style. A person's cognitive style is of influence on the understandability of a process model as previous research found supporting evidence for (Turetken et al., 2017). Field dependence is related to whether a person can easily extract the information they are looking for from surrounding information (Musser, 2005). This could be influenced by the amount of spacing used, as information can either clog together if the spacing is small or be very widespread when the spacing is large. Therefore, it is expected that the field dependency has an influence on process model understandability.

H6. Field dependency has a significant effect on process model understandability.

4. Experiment design and execution

To test the hypotheses an experiment was conducted. A convenience sample involving 148 graduate students following a BPM course at Eindhoven University of Technology participated. The experiment consisted of three parts. The first part is to determine the cognitive profile, learning style and field dependency of participants. This was done using questionnaires to calculate the variables from the answers. The second part was a questionnaire to test participants' BP Modelling Competency and the third part tested both the perceived and objectively measured understandability of process models. Each participant had to do the third part for two models (model A and model B), where it was randomized which model every participant got to see first. The variant of the model that a participant tested was also randomized, with the restriction that the same person could not get the same variant twice. Hence, if the first model was vertical and with 50% spacing, the second model could not be vertical and 50% spacing. This method is a within-subjects design with respect to the process models, as all participants test both process model A and process model B. With regards to the different variants of the models it is mainly a between-subjects design, as every participant only tested two out of the four variants of the models. The complete experiment was set up using Sawtooth Software SSI Web 8.4.8, which is a software tool to generate online surveys. The information a participant got to see before any of the three parts of the experiment can be found in Appendix F: Information before starting any part of the experiment. In the rest of this section, the experiment design will be described in detail.

4.1. Process models used

The process models used for the experiment had to be of such a size that it would still be reasonably visible and readable on a normal laptop screen, even with the largest spacing/sparsity option. Next to that, it is preferable to use models originating from practice (instead of using fabricated ones) to make the results better applicable in practice. These specifications made the models from a previous study on process model understandability suitable (Mendling et al., 2007). Originally, the set of gathered models in the paper was created for documentation purposes in practice, after which they were altered slightly to use in research. The task labels were replaced by the letters A to W to prevent influence of domain knowledge, and variants of each model were designed changing one or two routing elements (Mendling et al., 2007). For the current study two of the models were chosen for the experiment and were remodeled in BPMN 2.0 using Signavio 13.10.0. The models were altered to make them 'sound' and have the desired degree of sparsity. The horizontal version of each process model was created by mirroring over the diagonal axis, such that in the horizontal model the letters A to Z are from left-to-right instead of top-down. The process models A and B have the same amount of activities, but differ in terms of their structure. For an indication of how the models look they are shown in Figure 2, bigger versions of the models and all variants can be found in Appendix A: Process models used in the experiment. The basic metrics to compare the two different models are presented in Table 1.

Table 1: Process model properties

Process model A		Process model B	
# Activities	23	# Activities	23
# Gateways	14	# Gateways	19
# Flow	49	# Flow	57
# AND-splits	2	# AND-splits	3
# AND-joins	4	# AND-joins	3
# XOR-splits	4	# XOR-splits	4
# XOR-joins	4	# XOR-joins	7
# OR-splits	0	# OR-splits	1
# OR-joins	0	# OR-joins	1

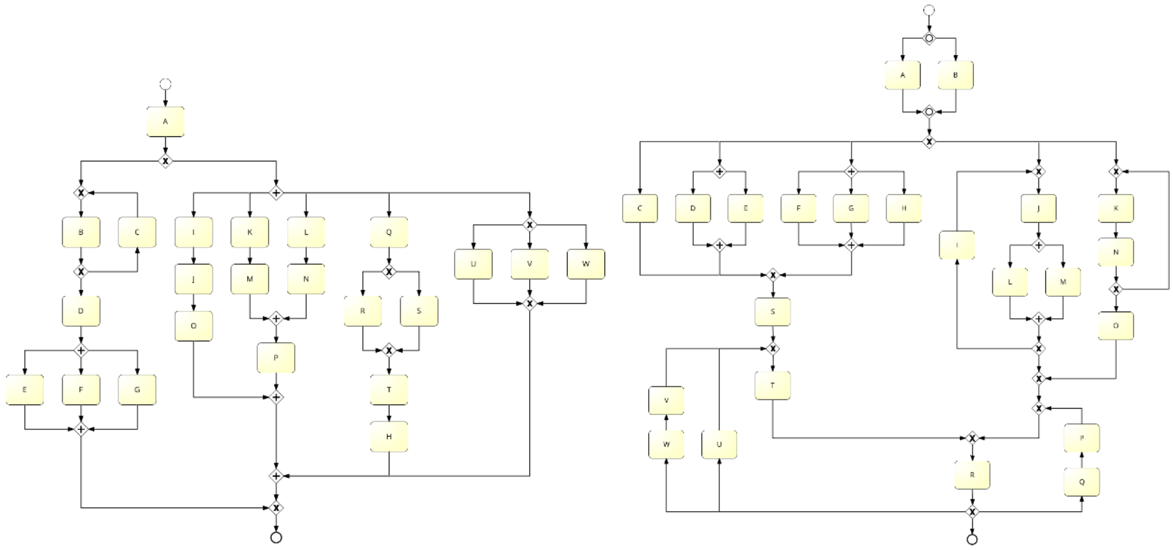

Figure 2: Model A 50% vertical (Left) and model B 50% vertical (Right)

4.2. Independent variable: Sparsity - Spacing of Elements

As noted above in section 4.1, different variations of the same models were used for the experiment. One of the aspects that differed between the variations is the spacing between model elements (model sparsity), which refers to the distance between process elements in the model. Previous research considered spacings between 12,5% and 70% of element's width (Leopold et al., 2016; Scholz & Lübke, 2019), while Signavio has a best practice of having 75% of the element width as spacing. However, Signavio's own examples already seem to have a spacing lower than that (*Usage of sufficient distances between elements | BPMN modeling guidelines*, n.d.). Hence, a consensus on what the best spacing is has not been reached. In this study, the choice was made for three variants of 25%, 50% and 100% of an activities width and height aligned with the alternatives investigated in the literature and with relevant findings.

Horizontal spacing and vertical spacing were always matched percent wise, so when the horizontal spacing is 50% the vertical spacing will also be 50%. To make sure that the distance was accurate an on-screen ruler was used to measure the distance between elements. The distance was calculated from the edge of one element to the edge of another element when there was a straight flow between them or if the elements were directly above or below each other. If there was no straight flow between two elements, so only a flow that was bend, the distance between the elements edge and the bend in the flow was taken. Lastly there were some elements that could be placed on multiple places in the model without influencing the spacing, in this case the elements were placed in such a way to make the process model as symmetric as possible.

4.3. Independent variable: General flow direction

In practice, only two flow directions are common, left to right (horizontal) and top to bottom (vertical). The choice was made to only use a single variant with regards to spacing for the horizontal models, to make sure there are enough participants for every scenario in the experiment. Therefore, only the 50% sparsity variant was used as a basis for representing two flow directions, as this is expected to be the best sparsity in terms of understandability.

4.4. Interaction variable: Business Process Modelling Competency

BP Modelling Competency was tested by using a questionnaire consisting of sixteen questions related to common process modelling practices and basic BPMN 2.0 constructs. This questionnaire was created by Turetken et al. (2019) for their study on process model understandability. It consisted of 12 questions, but they later added an additional four questions leading to the current questionnaire. All questions have the answer options “True”, “False” and “I don’t know”, hence the total score for BP Modelling is the number of correct answers. Some of these questions are about constructs that will not be used in this experiment, but they are useful to get a general understanding of their knowledge of business process modelling. While it is not measured or asked, it can be assumed that people that have a high BP Modelling Competency also spend more time working with BPMN models. The complete set of questions can be found in Appendix E: Business Process Modelling Competency Test.

4.5. Interaction variable: Cognitive profile

For measuring the cognitive style of the participants, the Cognitive Style Index (CSI) by Allinson and Hayes was used (Allinson & Hayes, 1996). This questionnaire consists of 38 items, which measures the cognitive style on a scale from intuitive to analytic. It does so by relating the answers to questions with a score, which can be 2, 1 or 0 depending on whether the answer indicates a more analytic style, a more intuitive style or the answer is ‘uncertain’. Counting up the scores the participant is classified in one of the five cognitive styles, intuitive, quasi-intuitive, adaptive, quasi-analytic or analytic. The cognitive profile questionnaire can be found in Appendix C: Cognitive profile questionnaire.

4.6. Interaction variable: Learning styles

To measure learning style the index of learning styles (ILS) by (Felder & Silverman, 1988) was used. The original version from 1988 was adapted to the current version in 2002 by the author into the version that is used in this research. This index assesses participants on their preferences on sensing versus intuitive, visual versus verbal, active versus reflective and sequential versus global dimensions. For every dimension there are 11 questions where the participant has to finish a sentence by choosing between two options, so 44 questions in total for four dimensions. Both options relate to one of the sides of the dimension, and give a score of plus one or minus one depending on which side of the dimension it points to. A score is then calculated by adding everything together, and participants are ranked as shown in Figure 3. The learning styles questionnaire can be found in Appendix D: Learning styles questionnaire.

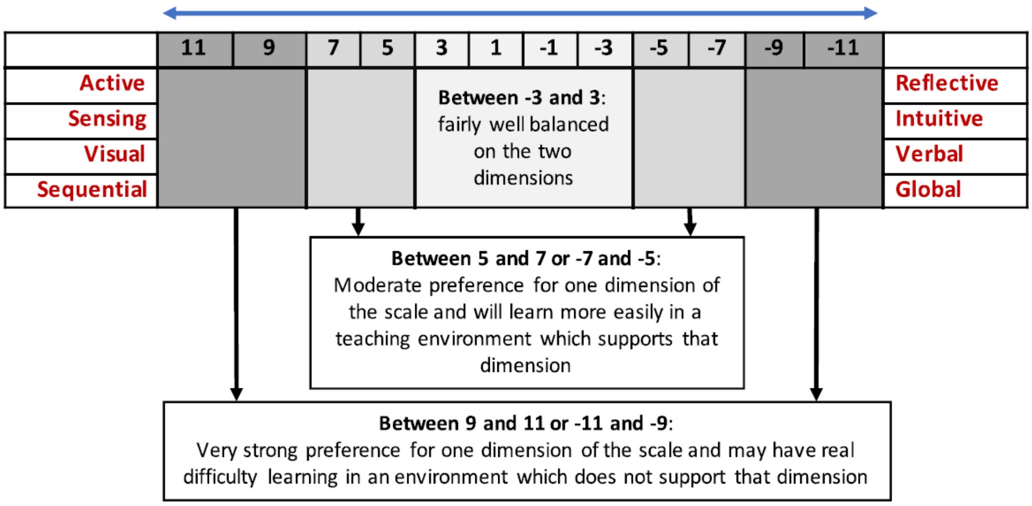

Figure 3: Learning styles and description scores (Musser, 2005)

4.7. Interaction variable: Field dependency

Field dependency is another concept of cognitive style about how easy it is for people to find the information they need and separate it from the surrounding information (Musser, 2005). This variable is of interest because it might be more difficult to find the information if information is more clogged together as in the densest model. To test whether a person is field dependent or field independent the hidden figures test was used (Ekstrom et al., 1963). In this test the participants have to identify a simple pattern that is hidden in a more complex pattern. Participants can choose between five options, and have to try to answer 16 questions within 12 minutes, this is done twice with different figures so in total there are 32 questions. The final score is the percentage of correctly answered questions, where all questions that were not answered because the time ran out are marked as incorrect. When a person answers a lot of questions correct he or she is field independent because of the ability to find the correct information between other information.

4.8. Dependent variable: Objectively measured understandability

There are two related measures for objective understandability, the number of correct answers on the understandability questions and the time it took to answer these questions correctly. As a basis for the understandability questions the original questions from the paper of (Reijers & Mendling, 2011) were used. These questions were adapted to be relevant for the specific variants of the model used, and to only relate to the understandability of the specific model. For both models there were seven questions, which were shown separately from each other with the model on screen. An example of a question and what this looked like in the experiment can be seen in Figure 4. The time it took to answer each question was measured, and the time for the correct answers was divided by the number of correct answers to calculate the efficiency score.

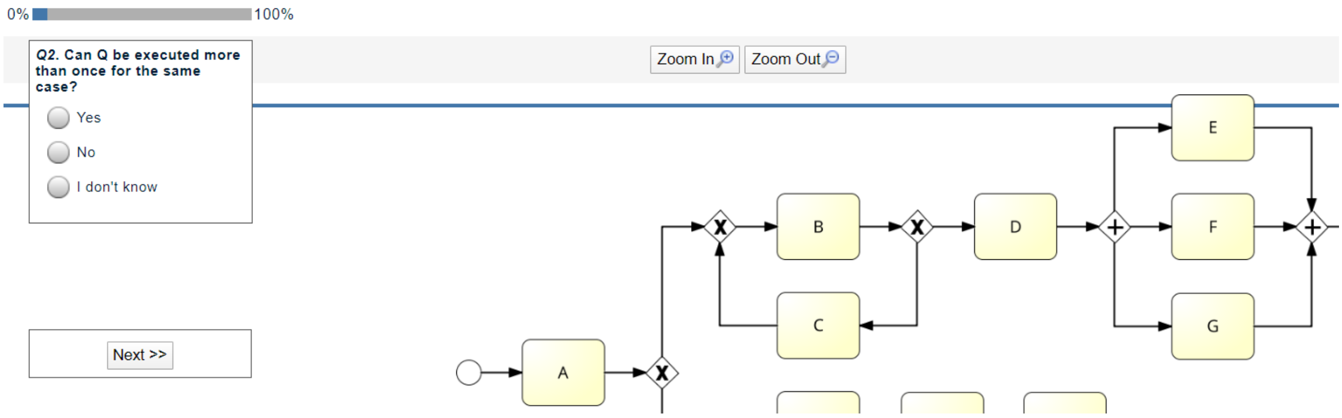

Figure 4: Example question and (part of the) experiment screen

4.9. Dependent variable: Perceived understandability

The perceived understandability was measured using two different constructs; perceived ease of use (PEU) and perceived usefulness for understandability (PUU). These constructs are based on the Technology Acceptance Model (Davis, 1989), adapted to fit the topic of this research. Both the PEU and the PUU were measured by four questions. The answer options were a 7-point Likert scale ranging from strongly disagree to strongly agree with a neutral option in the middle. The constructs were then calculated by attributing points to the answers, where seven points are given if the answer strongly agrees to, for example, being easy to use, and one point if the answer strongly disagrees with being easy to use. So a score between 4 and 28 was possible for both PUE and PUU.

4.10. Participants

The experiment took place between December 2019 and January 2020. The participants were a convenience sample of graduate students at Eindhoven University of Technology following a BPM graduate course. In return for participating in the experiment the students got some bonus points for their grade (3 points out of 100 of the overall course grade). In total 148 students participated in the experiment, 68% was male and 32% female. 63% of the students is doing the master's program of operations management and logistics, 20% is doing innovation management and the other 17% was distributed over several studies. The experiment took place online, where participants had to sign in using their student numbers, and all three parts had to be completed within a 3 weeks' timeframe. The students were informed that only serious participation in the experiment would give them the bonus points, and data would be checked afterwards to see if any abnormalities showed up. Because students did the experiment at their own time, this was the only control measure to make sure participants took it seriously.

5. Results

To check which statistical tests are appropriate to use first the normality of the distributions of the dependent variables over the independent variables is tested. For all dependent variables there are deviations from normality, so nonparametric tests have to be used. Because our dependent variables are all ordinal or interval scale, we used the nonparametric test of Kruskal-Wallis (Field & Hole, 2003). In the sections below the descriptive statistics, effects of design choices and the results of the hypothesis testing and interaction effects testing will be shown. The tests were performed using Stata version 14.2. The level of significance was set to α=0.05, as is the standard in experimental studies.

5.1. Descriptive statistics

From the 150 participants there were 148 participants who completed all three parts of the experiment. Every participant evaluated two different model variations leading to a total of 296 observations, which are uniformly distributed over the variants. In Table 2 the descriptive statistics of the independent variables tested in the experiment are shown. The number of datapoints between brackets is for the understandability task efficiency. For all tests on the understandability task efficiency four data-points are excluded as outliers. This was because these participants took more than 200 seconds for answering a number of understandability questions, which was considered unrealistic and not suitable to be considered for the calculation of task efficiency for these participants.

Table 2: Descriptive statistics for independent variables

Independent variable / Level	N	Understandability task effectiveness (score) (scale 0-7)		Understandability task efficiency (in score/hour)		Perceived usefulness for understandability (PUU) (scale: 4-28)		Perceived ease of understanding (PEU) (scale: 4-28)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Presentation variant	*296 (292)*	*6,43*	*0,78*	*175,17*	*51,18*	*19,96*	*5,61*	*22,36*	*4,32*
25% spacing vertical flow	74 (72)	6,46	0,80	171,18	52,84	18,65	6,44	21,32	5,17
50% spacing vertical flow	75 (73)	6,56	0,72	176,57	54,24	20,31	5,19	22,75	3,77
100% spacing vertical flow	80 (80)	6,33	0,78	173,21	50,86	21,00	5,34	23,04	3,69
50% spacing horizontal flow	67 (67)	3,39	0,83	180,27	46,81	19,78	5,18	22,24	4,46

In Table 3, the descriptive statistics for the interaction variables are shown. Because the results of the perceived understandability measures are tailored towards, and thus highly dependent on the specific model variant, it is not useful to show the descriptive statistics for them in relation to the interaction variables. Because the interaction variables are only measured once per participant, the objectively measured understandability variables are the scores from both models added together per participant.

The understandability task effectiveness ranges from 4 to 7 with a distribution of 3% on 4, 10% on 5, 28% on 6 and 59% on 7, so heavily skewed towards the higher scores. The understandability task efficiency results range from 43 to 351, with a normal distribution as shown in Figure 5. The perceived usefulness for understandability results range from 4 to 28 with a distribution skewed to the higher scores, as shown in Figure 6. The perceived ease of understanding results ranged from 6 to 28 with a distribution that is also skewed to the higher scores, as shown in Figure 7.

Table 3: Descriptive statistics for interaction variables

Interaction variables	N	Understandability task effectiveness (score) (scale 0-14)		Understandability task efficiency (in score/second)	
		Mean	SD	Mean	SD
General	*148*	*12,86*	*1,09*	*346,68*	*92,21*
Business process modelling competency					
Level 1	2	11,00	2,28	451,35	39,34
Level 2	18	12,44	1,11	347,10	112,65
Level 3	46	12,93	1,10	453,07	85,41
Level 4	53	12,94	1,03	342,92	95,35
Level 5	23	12,96	1,11	335,90	97,03
Level 6	6	13,17	0,75	335,97	68,96
Cognitive style					
Intuitive	10	12,90	1,45	316,54	76,74
Quasi-Intuitive	34	12,82	1,31	364,62	91,78
Adaptive	31	12,94	1,06	353,35	80,90
Quasi-Analytic	42	12,95	0,99	346,39	109,33
Analytic	31	12,71	0,86	330,42	87,56
Learning style					
Active or reflective					
Strongly active	14	12,79	1,19	385,13	68,51
Active	31	12,68	1,28	349,62	109,12
Balanced	83	12,98	1,01	341,06	91,93
Reflective	15	12,87	0,99	354,88	88,20
Strongly reflective	5	12,40	1,14	289,44	62,99
Sensing or intuitive					
Strongly sensing	28	12,64	1,13	315,30	84,22
Sensing	47	12,81	1,23	357,04	106,21
Balanced	62	13,08	0,93	351,61	90,64
Intuitive	8	12,63	1,06	351,54	65,28
Strongly intuitive	3	12,00	1,00	362,18	17,02
Visual or verbal					
Strongly visual	69	12,86	1,20	342,59	82,71
Visual	50	12,92	0,99	332,69	97,69
Balanced	27	12,93	0,83	380,10	106,87
Verbal	2	11,00	1,41	386,24	55,52
Strongly verbal	0	-	-	-	-
Sequential or global					
Strongly sequential	5	12,80	0,84	340,52	97,42
Sequential	18	13,00	1,14	371,94	99,05
Balanced	89	12,88	1,14	331,58	97,60
Global	29	12,79	0,98	367,78	74,07
Strongly global	7	12,71	1,11	390,56	60,71
Field dependency					
Field independent	62	12,77	1,19	371,08	105,73
Average	69	13,10	0,91	332,72	70,99
Field dependent	17	12,24	1,09	314,32	107,31

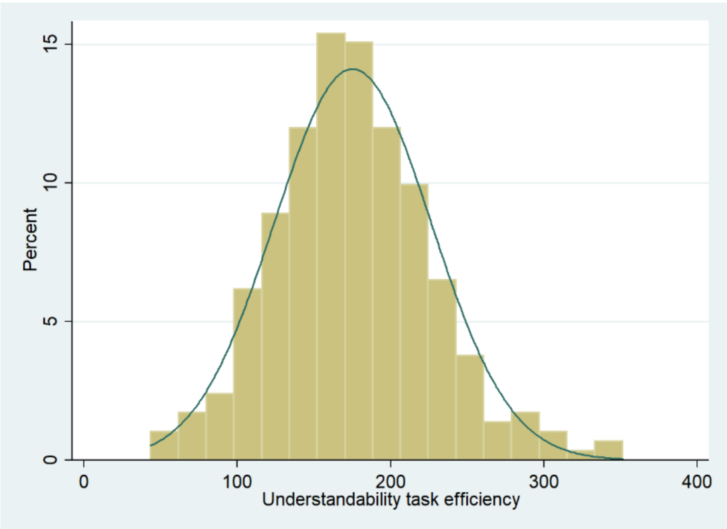

Figure 5: Histogram of understandability task efficiency

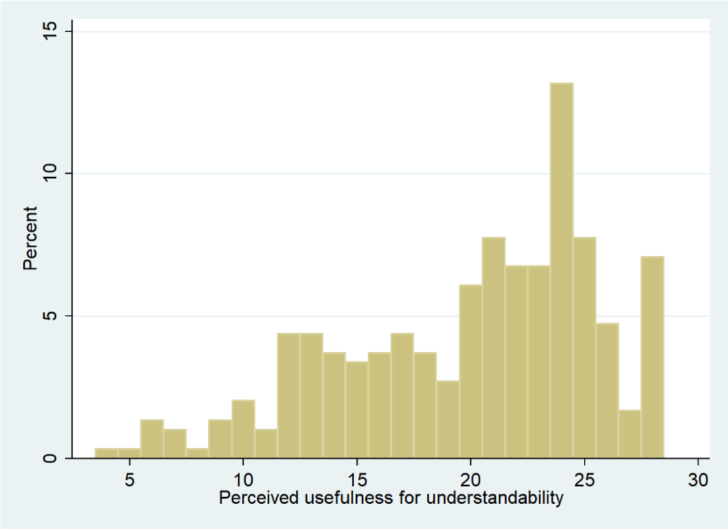

Figure 6: Histogram of perceived usefulness for understandability

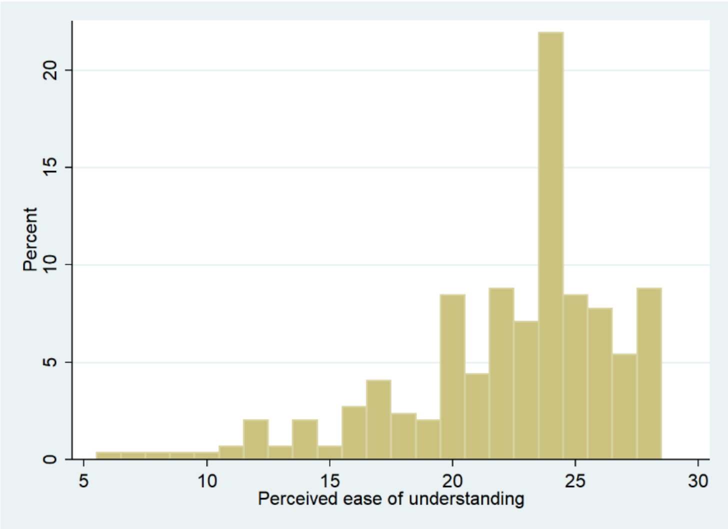

Figure 7: Histogram for perceived ease of understanding

5.2. Effects of experiment design choices

Design choices are always made when conducting an experiment, which makes it important to check if these design choices have any influence on the results. In this experiment, the participants always received two different models but it was randomized which of the two was given first. Thus we have to check if there is a learning effect for the second model, or if there is an effect because the complexity of the two models was different. The effect can be seen in Table 4 and Table 5, where it becomes clear that the results on all four understandability indicators differ significantly depending on whether it is the first or the second process model in the experiment, and the perceived understandability differs significantly between process model A and B as well. Further analysis shows that the first process model scores better on all measures compared to the second process model. It also shows that the perceived understandability is significantly better for process model A compared to process model B.

Table 4: Kruskal-Wallis test results for the first or second process model

	First or second model	
	H	Significance
Understandability task effectiveness	54,14	0,00
Understandability task efficiency	14,56	0,00
Perceived use for understandability	13,32	0,00
Perceived ease of understanding	9,89	0,00

Table 5: Kruskal-Wallis test results for process model A or B

	Process model A or B	
	H	Significance
Understandability task effectiveness	0,66	0,42
Understandability task efficiency	3,19	0,07
Perceived use for understandability	20,87	0,00
Perceived ease of understanding	26,34	0,00

5.3. Direct effects of interaction variables

To answer the hypotheses, we tested if there are any direct effects of the interaction variables. By testing for direct effects we can differentiate between the influence of the independent variables on the dependent variables, the influence of interaction variables on the dependent variables and the interaction effect of independent and interaction variables on the dependent variables. In Table 6, the influence of interaction variables on the independent variables are shown. The only significant effect is that of field dependency on understandability task effectiveness [H(2)]: 9.15, p = 0.01]. Further analysis shows that there is a difference between field dependent and balanced participants [H(1): 9.179, p = 0,002). Looking at the boxplot in Figure 8 it shows that field dependent participants score significantly lower than balanced participants.

Table 6: Kruskal-Wallis test results of the direct effects of interaction variables on objectively measured understandability

BP Competency	H	Significance
Understandability task effectiveness	5,55	0,35
Understandability task efficiency	4,04	0,54
Cognitive style		
Understandability task effectiveness	2,23	0,68
Understandability task efficiency	5,48	0,24
Active or reflective learning style		
Understandability task effectiveness	2,38	0,67
Understandability task efficiency	6,69	0,15
Sensing or intuitive learning style		
Understandability task effectiveness	6,23	0,18
Understandability task efficiency	4,56	0,34
Visual or verbal learning style		
Understandability task effectiveness	3,97	0,26
Understandability task efficiency	5,06	0,17
Sequential or global learning style		
Understandability task effectiveness	1,34	0,85
Understandability task efficiency	6,86	0,14
Field dependency		
Understandability task effectiveness	9,15	0,01
Understandability task efficiency	5,38	0,07

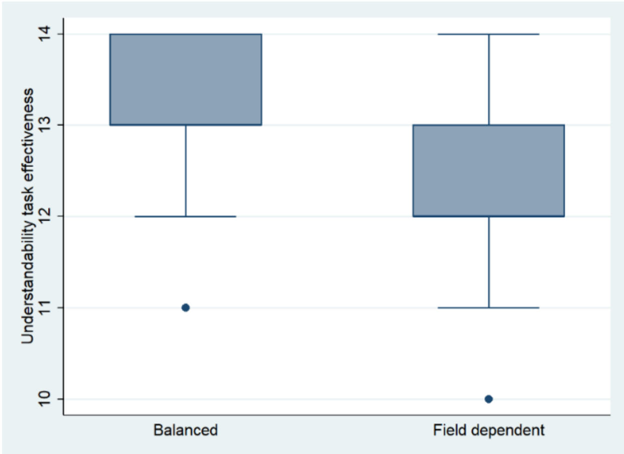

Figure 8: Boxplot diagram of field dependency and understandability task effectiveness

5.4. Influence of model sparsity on understandability

The first hypothesis argued that changing the sparsity of a process model by using different amounts of spacing would have a significant effect on process model understandability. The results of the Kruskal-Wallis tests are shown in Table 7. There are no significant direct effects of model sparsity on any of the dependent variables.

However, every participant received two different models and saw them in different orders. Because of this there could be an effect that only shows on one of the two process models, or an effect that only happens on the first or second process model. Therefore, we performed additional tests, testing individually for both process models or if the model was the first or second that a participant received. The results indicate that there is a significant difference in the perceived usefulness for understandability when we look only to the responses provided to the first process model that participants received [H(2): 9.05, p = 0.01]. When comparing two variants at a time it can be seen that the difference is between the 25% vertical variant and the 100% vertical variant [H(1)]: 4.885, p = 0.03]. This difference is shown in Figure 9 where it is clear that the perceived usefulness for understandability is higher when looking at the 100% vertical model compared to the 25% vertical model.

Table 7: Kruskal-Wallis test results for sparsity

Model sparsity	H	Significance
Understandability task effectiveness	5,18	0,08
Understandability task efficiency	0,68	0,71
Perceived use for understandability	5,34	0,07
Perceived ease of understanding	3,68	0,16

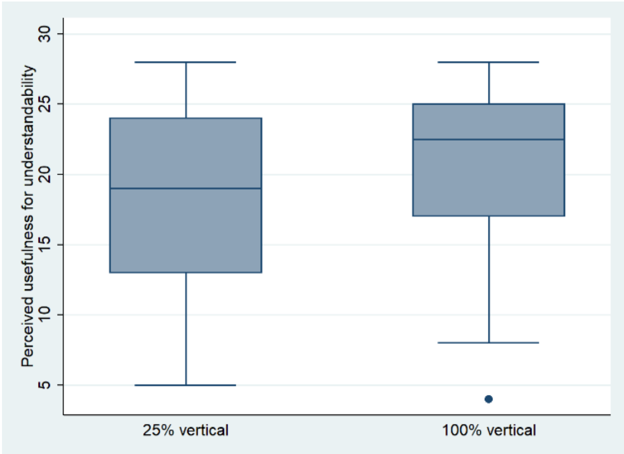

Figure 9: Boxplot diagram for perceived usefulness for understandability of 25% vertical and 100% vertical of the first process model a participant received

When looking at the results of process model B there is a significant difference in perceived ease of understanding [H(2): 6.05, p = 0.049]. However, when comparing the individual differences between all combinations of two variants of spacing there is no significant effect between any of the combinations. Hence, the overall effect that there is a difference between the groups cannot be explained by differences between two variants, possibly because the p value was just barely significant.

5.5. Influence of the flow direction on understandability

Our second hypothesis argued that there is an influence of the flow direction in a process model on the understandability. The Kruskal-Wallis test is used again, and the results can be seen in Table 8. As with the influence of sparsity, no significant differences are found when comparing the flow direction. The test for flow direction was done by comparing the 50% vertical variant against the 50% horizontal variant.

Table 8: Kruskal-Wallis test results for flow direction

Flow direction	H	Significance
Understandability task effectiveness	1,65	0,20
Understandability task efficiency	0,70	0,40
Perceived use for understandability	0,64	0,43
Perceived ease of understanding	0,30	0,58

Further testing to see if there is perhaps a difference between the first and second process model shown or the two different process model variants shows that there is a significant difference in understandability task effectiveness when comparing the flow direction only on the second model [H(1): 4.086, p = 0.04]. This effect is visually shown in Figure 10, where it can be seen that the horizontal direction scores significantly lower than the vertical version.

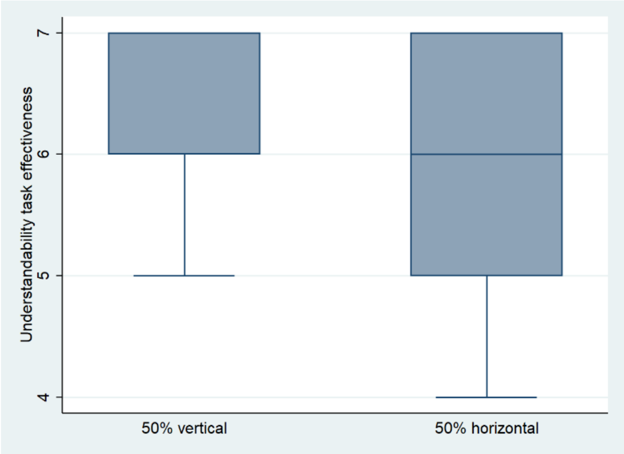

Figure 10: Boxplot diagram of effectiveness and flow direction, only for the second process model a participant received

Another effect on efficiency shows when only looking at participants with an analytical cognitive style [H(1): 3.861, n = 31, p = 0.049], where the horizontal variant scores significantly higher on the understandability task efficiency compared to the vertical variant. This is shown in the boxplot diagram in Figure 11.

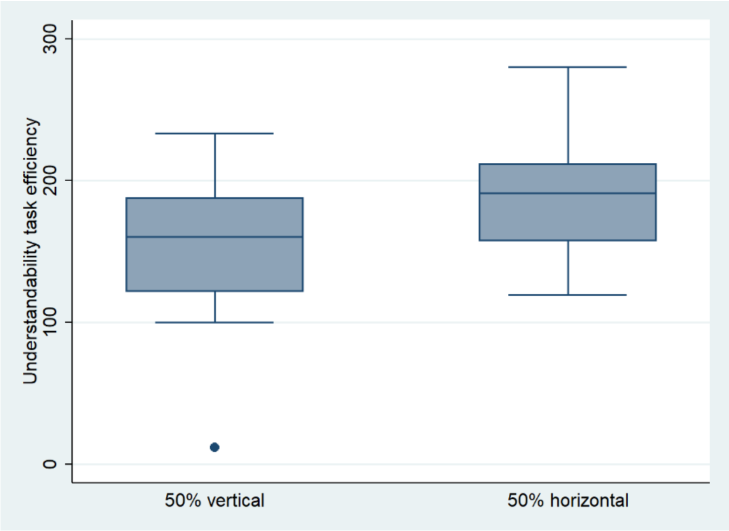

Figure 11: Boxplot diagram of efficiency and flow direction, for participants with an analytical cognitive style

5.6. Interaction effects of BP Modelling Competency on the relation between sparsity or flow direction and process model understandability

The third hypothesis argues that there is an interaction effect between the BP Modelling Competency of a participant and the sparsity of the model on the understandability. To check for this interaction effect we performed Kruskal-Wallis tests on the influence of sparsity on understandability like in hypothesis 1, but this time with the added constraint that the test is only for a specific group of BP Modelling Competency. This resulted in an effect for participants at a BP Modelling Competency of level 5 and higher [H(2): 7.586, n = 47, p = 0.02] for the understandability task effectiveness. Further analysis shows that there is a difference between the 25% spacing variant and the 50% spacing variant [H(1): 6.427, p = 0.01] and a difference between the 50% spacing variant and the 100% spacing variant [H(1): 6.834, p = 0.01]. The boxplot in Figure 12 shows that the understandability task effectiveness is significantly higher in the 50% variant compared to both the 25% and the 100% variant.

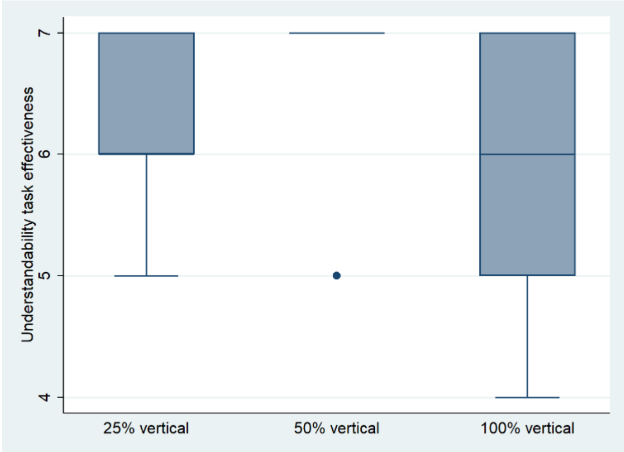

Figure 12: Boxplot diagram of the sparsity for BP Modelling Competency level 5 or higher compared to the understandability task effectiveness

5.7. Interaction effects of the cognitive profile on the relation between sparsity or flow direction and process model understandability

The fourth hypothesis argues that there is an interaction effect between the cognitive style of a participant and the sparsity of the business process model on the understandability. Again Kruskal-Wallis tests are performed for all different groups of cognitive styles to see if an effect shows for the different sparsity options. A significant effect is found if we exclude the intuitive participants, then there is a difference on the perceived usefulness for understandability [H(2): 7.895, n = 20, p = 0.02]. Further analysis shows that this effect is a difference between the 25% spacing process model and the 100% process model [H(1): 7.105, p = 0.01]. Figure 13 shows that the 100% spacing variant scores significantly higher on perceived usefulness for understandability compared to the 25% spacing variant.

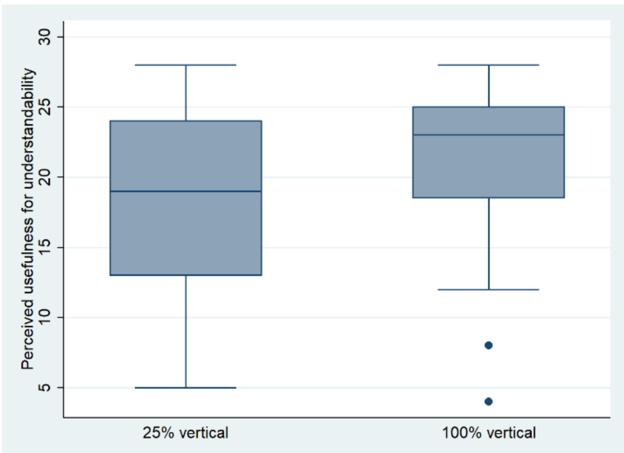

Figure 13: Boxplot diagram of the sparsity for participants that do not have an intuitive cognitive style compared to the perceived usefulness for understandability

5.8. Interaction effects of learning styles on the relation between sparsity or flow direction and process model understandability

The fifth hypothesis argues that there is an influence of the sparsity level on understandability when only looking at participants with specific learning styles. The first learning style tested is the active versus reflective learning style. The test results show that there is a significant effect when only testing the participants with a (strongly) reflective learning style on the perceived usefulness for understandability [H(2): 9.799, n = 33, p = 0.01]. Further analysis shows that the difference is between 25% spacing and both 50% spacing [H(1): 7.578, p = 0.01] and 100% spacing [H(1): 6.524, p = 0.01], where 25% spacing scores significantly lower on the perceived usefulness for understandability. This effect is visualized in the boxplot diagram of Figure 14.

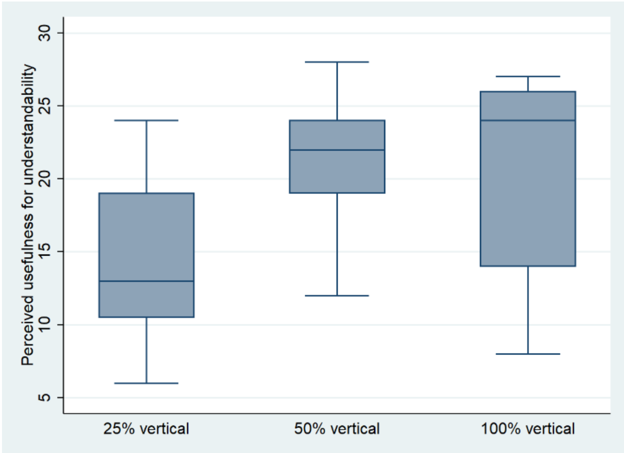

Figure 14: Boxplot diagram of the sparsity for participants with a reflective or strongly reflective learning style compared to the perceived usefulness for understandability

There also is an effect on the perceived ease of understanding when only looking at participants with a (strongly) active learning style [H(2): 6.742, n = 65, p = 0.03] or when only looking at participants with a (strongly) reflective learning style [H(2): 9.260, n = 33, p = 0.01]. In both cases the 25% variant scores significantly lower on the perceived ease of use compared to both the 50% variant [H(1): 5.976, p = 0.01], [H(1): 6.830, p = 0.01] and the 100% variant [H(1): 4.737, p = 0.03], [H(1): 6.450, p = 0.01]. In Figure 15 the difference for (strongly) active learners is shown and in Figure 16 the difference for (strongly) reflective learners is shown.

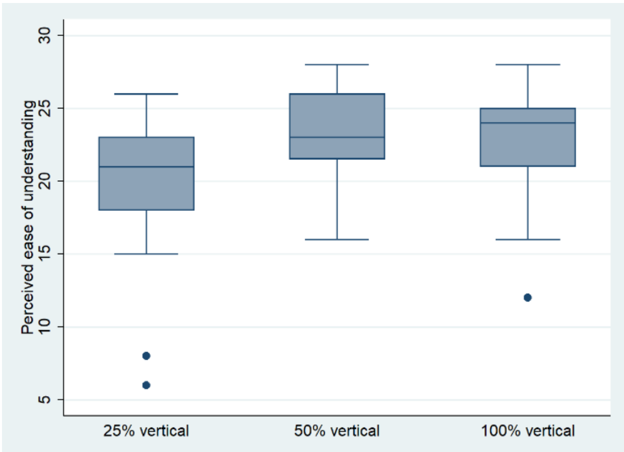

Figure 15: Boxplot diagram of (strongly) active learners and sparsity compared to perceived ease of understanding

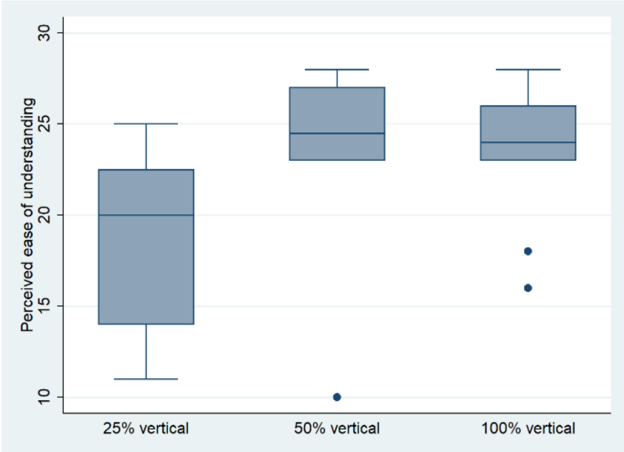

Figure 16: Boxplot diagram of (strongly) reflective learners and sparsity compared to perceived ease of understanding

Testing on the learning style spectrum of sensing to intuitive shows that there is an effect in relation to the perceived usefulness for understandability. The effect shows both when looking at participants with a strongly sensing learning style [H(2): 7.028, n = 48, p = 0.03] and when looking at participants that do not have a strongly intuitive learning style [H(2): 6.470, n = 224, p = 0.04]. In both cases further analysis shows that the difference is between the 25% spacing variant and the 100% spacing variant, [H(1): 6.031, p = 0.01] and [H(1): 5.861, p = 0.02] respectively. These effects can be seen in Figure 17 and Figure 18, where in both cases it shows that the 100% spacing variant scores significantly higher on perceived usefulness for understandability.

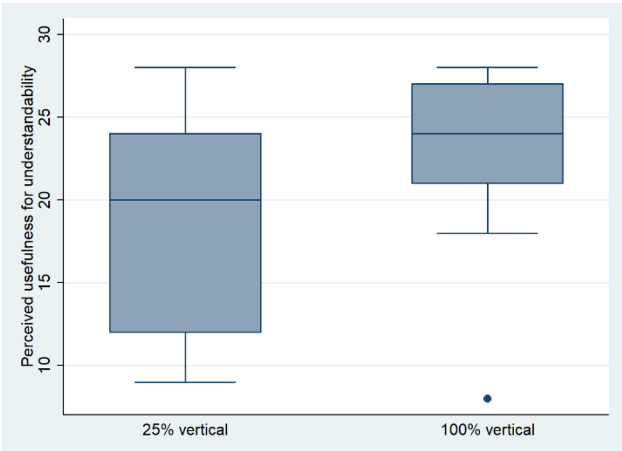

Figure 17: Boxplot diagram of strongly sensing learners and sparsity compared to perceived usefulness for understandability

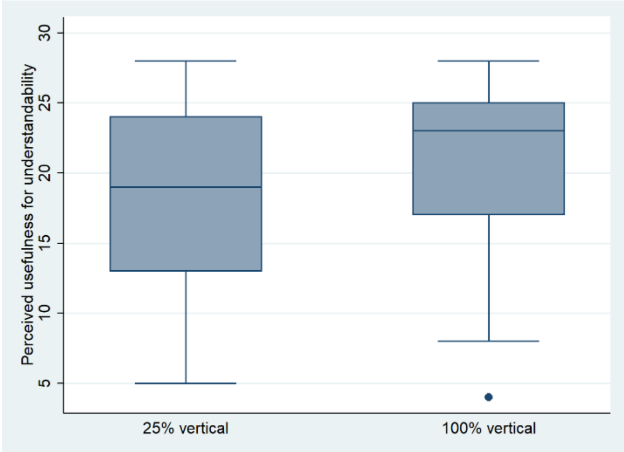

Figure 18: Boxplot diagram of not strongly intuitive learners and sparsity compared to perceived usefulness for understandability

When comparing the sensing to intuitive learning style spectrum on horizontal and vertical models there is an effect on the perceived usefulness for understandability. The effect shows when only looking at sensing learners [H(1): 4.248, n = 49, p = 0.04], and shows that the vertical model results in a higher score for the perceived usefulness for understandability. This is shown visually in Figure 19.

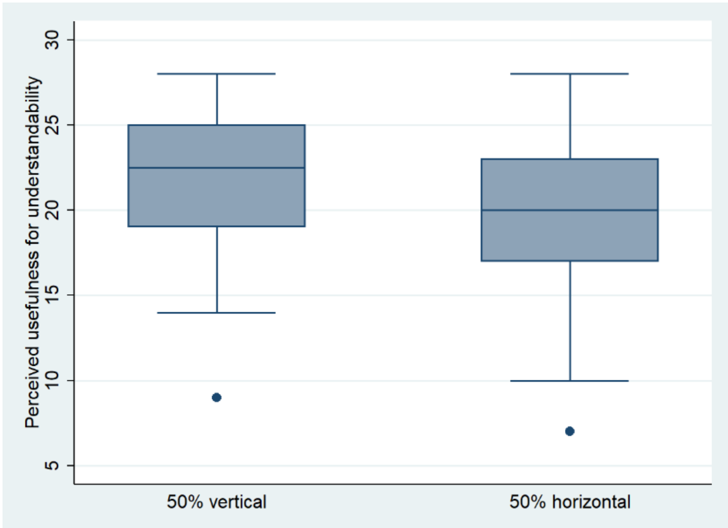

Figure 19: Boxplot diagram of flow direction and perceived usefulness for understandability, for sensing learners

The visual to verbal learning style spectrum show significant differences between the sparsity variants with regards to the understandability task effectiveness, perceived usefulness for understandability and perceived ease of use. For the understandability task effectiveness there is a significant effect when looking at participants that do not have a strongly visual learning style [H(2): 7.667, n =126, p = 0.02]. Further analysis shows that the understandability task effectiveness is significantly lower for the 100% spacing variant compared to both the 25% spacing variant [H(1): 5.563, p = 0.02] and the 50% spacing variant [H(1): 5.632, p = 0.02]. Because the understandability task effectiveness is measured on a scale from zero to seven and the effect size is quite small, a boxplot does not show the effect.

The effect on perceived usefulness for understandability is found when only looking at participants with a strongly visual learning style [H(2): 7.910, n =103, p = 0.02]. Looking further there is a difference between the 25% spacing variant and the 100% spacing variant [H(1): 7.724, p = 0.01], where the 100% variant scores significantly higher. This is shown in the boxplot in Figure 20.

The differences on perceived ease of understanding also show when only looking at the strongly visual participants [H(2): 8.448, n =103, p = 0.02]. Further analysis shows that the difference is between the 25% variant and both the 50% variant [H(1): 4.810, p = 0.03] and the 100% variant [H(1): 7.831, p = 0.01], where in both cases the 25% variant scores significantly lower on the perceived ease of use. This effect is shown in Figure 21.

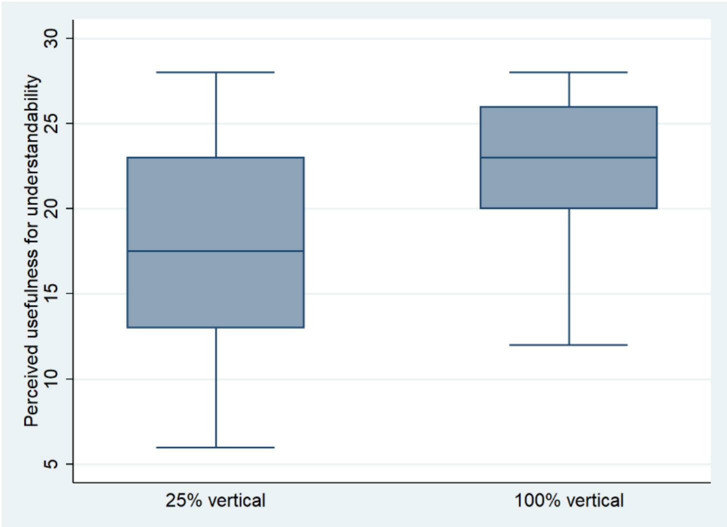

Figure 20: Boxplot diagram of strongly visual learners and sparsity compared to perceived usefulness for understandability

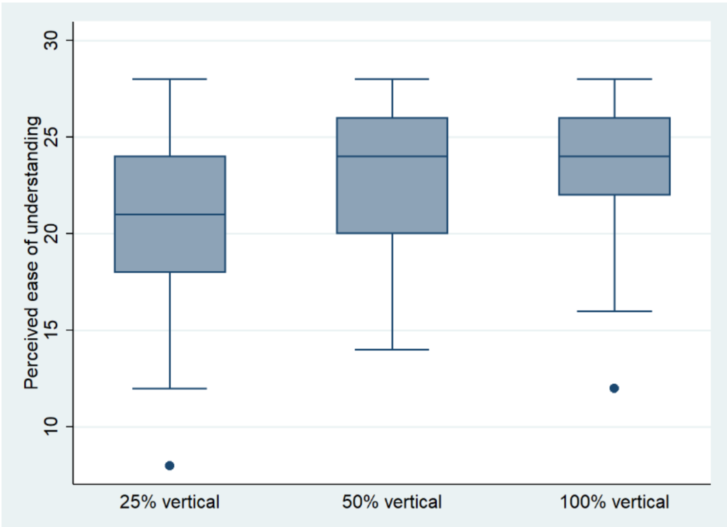

Figure 21: Boxplot diagram of strongly visual learners and sparsity compared to perceived ease of understanding

The last learning style spectrum tested is the sequential to global spectrum. Testing the understandability task effectiveness there is a significant effect when comparing the participants that are not strongly sequential [H(2): 6.347, n = 220, p = 0.04]. Further analysis shows that there is a difference between the 50% spacing variant and the 100% spacing variant [H(1): 6.029, p = 0.01], where the 50% spacing model scores significantly higher compared to the 100% spacing model. This effect cannot be visualized in a boxplot because the scale for understandability task effectiveness goes only from zero to seven.

The sequential or global learning style also has an effect on the perceived usefulness for understandability. When looking at participants with a (strongly) sequential or balanced learning style there is a difference [H(2): 6.437, n = 174, p = 0.04]. Further analysis shows that this effect is caused by a difference between the 25% spacing variant and the 100% spacing variant [H(1): 6.041, p = 0.01]. In Figure 22 it can be seen that the 100% spacing variant scores higher on the perceived usefulness for understandability score compared to the 25% spacing variant.

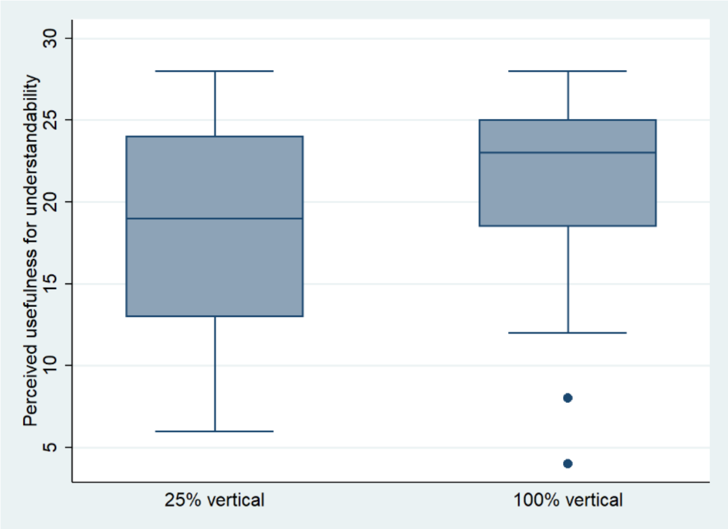

Figure 22: Boxplot diagram of (strongly) sequential and balanced learners comparing sparsity to perceived usefulness for understandability

The sequential or global learning style also has an interaction effect with the flow direction, where there is an effect when only looking at (strongly) global learners on the understandability task effectiveness [H(1): 5.639, n = 37, p = 0.02]. The understandability task effectiveness is higher for the vertical model than the horizontal model, as shown in Figure 23.

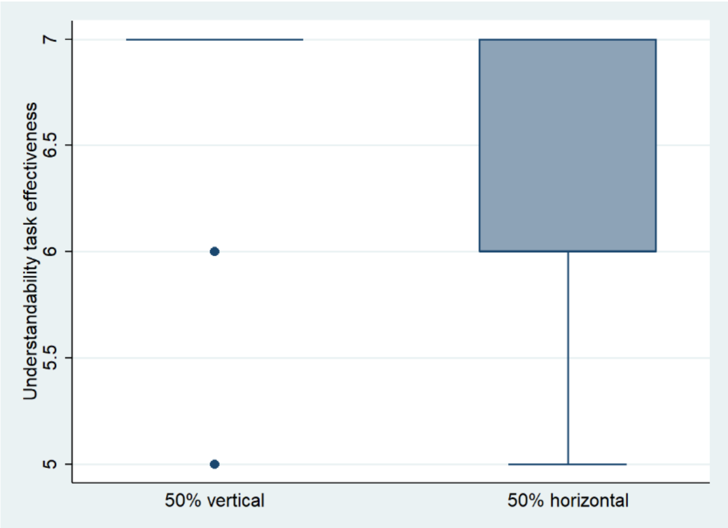

Figure 23: Boxplot diagram of flow direction and understandability task effectiveness, for (strongly) global learners

Looking at the (strongly) sequential or balanced learners there is an effect on efficiency [H(1): 5.606, n = 105, p = 0.02], where the horizontal model variant results in a higher efficiency than the vertical model. This is shown in Figure 24.

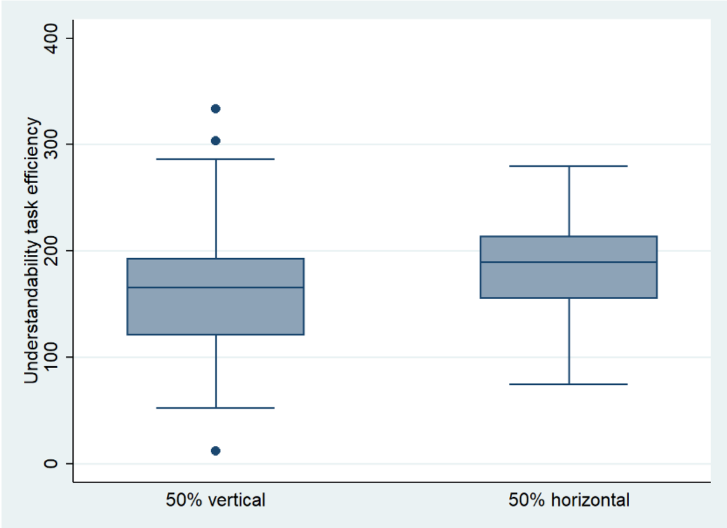

Figure 24: Boxplot diagram of flow direction and understandability task efficiency, for (strongly) sequential and balanced learners

5.9. Interaction effects of field dependency on the relation between sparsity or flow direction and process model understandability

Testing for interaction effects of field dependency and sparsity on the understandability only resulted in one effect, looking only at field dependent participants there is a difference in the understandability task effectiveness [H(2): 9.148, n = 28, p = 0.01]. Further analysis shows that this effect is caused comparing the 100% spacing variant to both the 25% spacing variant [H(1): 6.538, p = 0.01] and the 50% spacing variant [H(1): 6.498, p = 0.01]. The effect is visualized in the boxplot in Figure 25, showing that the 100% spacing variant scores lower on the understandability task effectiveness compared to both the 25% spacing and the 50% spacing.

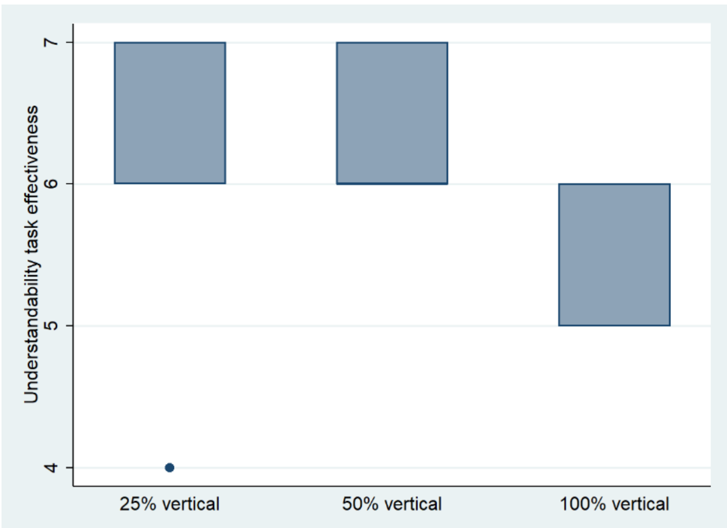

Figure 25: Boxplot diagram of field dependent participants comparing sparsity to understandability task effectiveness

6. Discussion

The objective of this study is to research the influence of the independent variables process model sparsity and flow direction on the dependent variable process model understandability. This is done for four different dimensions of understandability, namely understandability task effectiveness, understandability task efficiency, perceived usefulness for understandability and perceived ease of understanding. Understandability task effectiveness is measured by measuring how many of the seven understandability questions per model are answered correct. In the results of the experiment no direct effect is found for either flow direction or sparsity on the understandability. So in general without looking at any other aspects, there is no supporting evidence for the assumption that process model sparsity or flow direction has any influence on the understandability. However, we did take several other aspects into account, which showed that when looking at certain groups of participants there is supporting evidence that process model sparsity or flow direction has an influence on the understandability.

When looking at the descriptive statistics of the understandability task effectiveness it is clear that it will be difficult to find a result, as there is very little difference in the results. Over all the datapoints 87% had none or only one mistake on the understandability task effectiveness questions. However, there are some results that show an influence on understandability task effectiveness.

The understandability task efficiency results show a normal distribution in general, but had some high outliers that had to be removed. However, even with these outliers removed there was still a great variation of the time it took participants to answer the questions correctly. This is partly due to the fact that participants could do the experiment at home in their own time, and apart from telling them in the experiment explanation that they should focus on the experiment and do it without distraction there is no control over what they do. So quite possibly participants have been distracted during the experiment resulting in more time needed to answer the questions than actually needed.

6.1. Influence of model sparsity on understandability

Contrary to what was hypothesized there is no general direct result of the model sparsity on the understandability. There only is a direct effect when only looking at the first process model a participant sees, where the perceived usefulness for understandability is higher for the 100% spacing variant compared to the 25% spacing variant. This is however not an effect that was hypothesized or can logically be explained by literature.

6.2. Influence of flow direction on understandability

Also for flow direction there is no general direct effect on the understandability. While it was hypothesized that there would be an effect, there is only one direct effect that shows when looking at the flow direction. This is an effect when looking at the second process model a participant sees, where the understandability task effectiveness is higher for vertical models compared to horizontal models. While this result is not in line with our hypothesis, it can be explained by the experiment setup. In the experiment there are three model variants that use a vertical flow direction, and only one variant that uses a horizontal flow direction. This means that the chance that the first model a participants sees is a vertical one is 75%, which then could influence the results of the second model because participants are adapted to a vertical flow now and find it easier for the second model to understand a vertical model. So while this effect is significant it might be an effect caused by the experiment setup instead of a result caused by the flow direction.

6.3. Interaction effects of Business Process Modelling Competency on the relation between sparsity or flow direction and process model understandability

The understandability task effectiveness is also influenced by an interaction effect between the variant and the BP Modelling Competency when looking at the participants with the highest BP Modelling Competency scores. For participants with the highest BP Modelling Competency scores (top 20%) the understandability task effectiveness scores were significantly higher for the 50% spacing models compared to both the 25% and the 100% models. This result indicates that the sparsity of a model might not influence the understandability too much if a person is not that experienced with BPMN, but when a person is very experienced with BPMN models the sparsity does have an influence where 50% spacing is preferred.

6.4. Interaction effects of an intuitive or analytic cognitive style on the relation between sparsity or flow direction and process model understandability

When excluding intuitive participants there is an effect on the perceived usefulness for understandability. The 100% spacing variant scores higher on the perceived usefulness for understandability than the 25% spacing variant, which is an effect that shows for different learning styles as well. It seems like a sparser model is preferred when talking about perceived usefulness for understandability, which can be explained by that for understandability purposes it is preferred to have a sparse but clear model.

People with an analytical cognitive style score significantly higher on the understandability task efficiency for horizontal models compared to vertical models. There is no clear indicator why this is the case, but cognitive style seems to have an influence in the preference for horizontal or vertical models.

6.5. Interaction effects of different learning styles on the relation between sparsity or flow direction and process model understandability

There is an effect that shows for participants that do not have a strongly visual learning style. This effect shows that the 100% spacing variant of the model results in significantly worse understandability task effectiveness scores compared to both the 25% spacing variant and the 50% spacing variant. The effect is interesting because it is expected that especially the strongly visual learners would be influenced by changes in the model sparsity. No explanation has been found in literature about why this effect could show here.

For (strongly) reflective learners, strongly sensing learners, learners that are not strongly intuitive, strongly visual learners and learners that are not (strongly) global an effect shows where the perceived usefulness for understandability is higher for the 100% spacing variant compared to the 25% spacing variant. So for five different group compositions this effect shows, indicating that in general the 100% spacing variant might be better for the perceived usefulness for understandability compared to the 25% spacing variant. This effect is possibly because how fast someone can see things might be less relevant, and it is more about making sure that everything is clear when talking about usefulness for understandability. This is the case in the 100% spacing variant, because all elements are separated quite far from each other, making the general overview at once more difficult but making it really clear which elements follow each other. So for usefulness for understandability a very sparse model is a good model. For (strongly) reflective learners the 50% spacing variant is also better than the 25% spacing variant, which reinforces the idea that a sparser model is better for perceived usefulness for understandability.

When looking at the perceived ease of understanding there is also a general effect for different learning styles. For (strongly) reflective learners, (strongly) active learners and strongly visual learner the 25% spacing model variant scores significantly lower on the perceived ease of understanding compared to both the 50% spacing model variant and the 100% spacing model variant. So it seems like when only using 25% element width or height as the spacing between elements this makes a model more difficult to understand in general. This is in line with what was expected, as with 25% spacing the elements tend to clog together too much making it more difficult to understand the model.

Sensing learners also score the vertical model higher on perceived usefulness for understandability than the horizontal model. There is however no indication why a vertical model would be better here.

The (strongly) global learners score higher on understandability task effectiveness for vertical models, while (strongly) sequential and balanced learners have a higher efficiency for horizontal models. While these effects are not really big, it might indicate that the preference for a horizontal model or vertical model has something to do with whether someone is a global or a sequential learner. Where global learners have a preference for vertical models while sequential learners have a preference for horizontal models.

6.6. Interaction effects of field dependency on the relation between sparsity or flow direction and process model understandability

Field dependent learners score lower on task effectiveness than balanced learners, although there is no difference between field dependent and field independent learners. This result is in line with what was expected as field dependent learners find it difficult to distract the information they are looking for from all the information. It also is a direct effect, so regardless of the model variant field dependent learners get a lower score.

There also is an effect that shows for field dependent learners. This effect shows that the 100% spacing variant of the model results in significantly worse understandability task effectiveness scores compared to both the 25% spacing variant and the 50% spacing variant. This effect is in line with the direct effect of field dependency, so this might not be an interaction effect but just the direct effect.

7. Conclusion

Business process models are important in communication between different stakeholders with varying levels of expertise in business process modelling and, therefore, need to be clear and understandable. This paper investigated - through an experiment- the influence of the sparsity (i.e., the spacing between process model elements) and the flow direction of process models on process model understandability. In the experiment, participants were asked to go through a questionnaire to find out their BP Modelling Competency, cognitive style, learning style and field dependency. Next, they received two process models that also differ in their sparsity, and were asked to answer a set of seven understandability questions per-model to measure if they understood the model correctly. The number of correct answers represented the *understandability task effectiveness*. The average time it took for them to respond to each correctly answered question represented the *understandability task efficiency*. Participants also received additional questions per model to gather their perceived ease of use and perceived usefulness for understandability of the models. The participants were a convenience sample of 148 graduate students following a business process management course in Eindhoven University of Technology.

To examine the influence of sparsity and flow direction on business process model understandability, we analyzed both the direct effects and the interaction effects where we only looked at specific sub-groups of participants based on their BP Modelling Competency, cognitive style, learning style or field dependency. An overview of the hypotheses and their short answers is given in Table 9.

Table 9: Overview of the hypotheses and their results

Hypothesis	Result	Interpretation
Hypothesis 1		
Process model sparsity has a significant impact on objectively measured understandability	Partially supported	Sparsity does not have a direct influence, but when looking at participants with a high business process modelling competency, different learning styles and field dependent learners the sparsity has a significant influence.
Process model sparsity has a significant impact on perceived understandability	Partially supported	There is a direct effect for the first model, and effects also show when looking at specific cognitive styles, learning styles or field dependency levels.
Hypothesis 2		
Flow direction has a significant impact on objectively measured understandability	Partially supported	There is a direct effect for the second process model, this could however also be caused by the experiment setup. Also when looking at specific cognitive styles or learning styles effects show.
Flow direction has a significant impact on perceived understandability	Partially supported	There is no direct effect, but for certain cognitives styles or learning styles there is a preference for a certain flow direction.
Hypothesis 3		
Business process modelling competency has a significant impact on objectively measured understandability	Partially supported	People with a high score on business process modelling competency score highest on understandability task effectiveness when looking at the 50% spacing sparsity model.
Business process modelling competency has a significant impact on perceived understandability	Not supported	No indications have been found that business process modelling competency influences the perceived understandability.
Hypothesis 4		
The cognitive profile of a person has a significant impact on objectively measured understandability	Partially supported	People with an analytical cognitive style score higher on understandability task efficiency for horizontal models compared to vertical models.
The cognitive profile of a person has a significant impact on perceived understandability	Partially supported	There is an effect when excluding people with an intuitive cognitive style on the perceived usefulness for understandability
Hypothesis 5		
The learning style of a person has a significant impact on objectively measured understandability	Partially supported	There are some learning styles that affect which sparsity and/or flow direction is preferred
The learning style of a person has a significant impact on perceived understandability	Partially supported	There are some learning styles that affect which sparsity and/or flow direction is preferred
Hypothesis 6		
The field dependency of a person has a significant impact on objectively measured understandability	Supported	Field dependent learners score lower on understandability task effectiveness compared to balanced learners.
The field dependency of a person has a significant impact on perceived understandability	Not supported	No indications have been found that field dependency influences the perceived understandability.

From the overview table and the discussion section there are a couple of results that stand out. First, the participants with the highest BP Modelling Competency scores had the highest understandability task effectiveness for the 50% spacing model. This indicates that the model sparsity perhaps only matters if you have a higher understanding of business process modelling in general. It is also interesting that for several different sub-groups of participants the perceived usefulness for understandability was higher for the 100% spacing models compared to the 25% spacing models. This indicates that the 25% spacing model is too dense for people to get a clear overview. If the model is used for explaining people seem to prefer a model that is a bit sparser too make the overview clear.

Another interesting aspect is that there is one effect that is supported over all the data combined, which is the effect that field dependent learners score lower on understandability task effectiveness compared to balanced learners. We did expect more general effects as the experiment was designed to randomize which model and which variant a participant received first to eliminate learning effects. However, the tests in Table 4 show that there are significant differences for both objectively measured and perceived understandability when comparing the first model to the second model in the experiment. Further analysis showed that the second model scored worse on all factors compared to the first model, indicating that participants perhaps were less focused for the second model and therefor had a lower objectively measured understandability. For the perceived understandability, it could be that participants were primed by the first model they received, and therefor always perceive the second model as worse compared to the first model. This could indicate that the specific sparsity or flow direction does not matter that much for understandability, but that understandability is mostly influenced by the kind of modelling a person is used to work with.

Table 5 also shows that there is a difference between process model A and process model B when looking at the perceived understandability. This could be because model B is slightly more complex compared to model A. As can be seen in Table 1 and Figure 2 there are OR-Splits in model B but not in model A, there are more splits in general in model B and there are quite a few loops back in model B. These are all factors that can make the model more difficult to understand, and thus lead to the lower perceived understandability. Complexity of process models is a factor that should be taken into account when looking at process model understandability, as small changes can already have an influence.

This research contributes to existing work on process model understandability as one of the few empirical researches on what makes process models understandable as far as the model sparsity and flow direction are concerned. It explores the influence of two factors of process model sparsity and flow direction on understandability that have not been extensively researched in previous work. In general, it adds that process model understandability might not be a factor that can be described in general but heavily depends on the characteristics of the model reader, i.e., the audience for which the models are designed. It also gives an indication of what personal characteristics are important when looking at process model understandability and which characteristics do not have much influence. Future research could take this work as a reference point to decide for whom a process model should be understandable, instead of looking at general understandability. It could also further specify certain aspects that in this work have been researched exploratory, to proof that the results are generalizable.

Because we have tested many different aspects there is always the risk that results will be found that are not caused by the specific aspect tested. To limit this risk we have focused the results on the findings that were found in several cases or over a large portion of the data. This helps to make sure the found results are not random but actual results. The work is also limited by the dept of certain aspects, as for example the understandability task effectiveness was measured by only seven questions that are answered in the binary form (i.e., yes/no). These questions were also relatively easier to answer for people that have some experience with process modelling. As the participants already had experience with process modelling, the resulting task effectiveness was relatively high in the overall. This also means that the results that were found are relatively small differences, and might not appear if a broader scale for effectiveness is used. The future research should consider changing or extending the questions with more challenging questions to uncover the effects that did not come about in our experiment.

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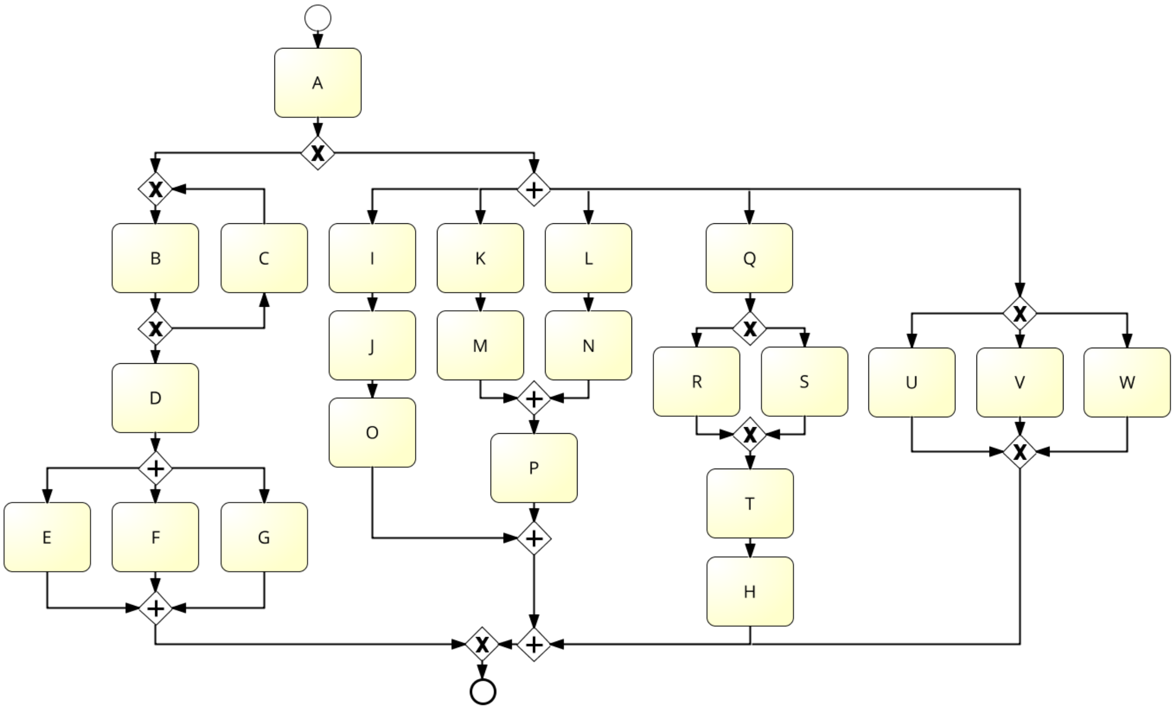
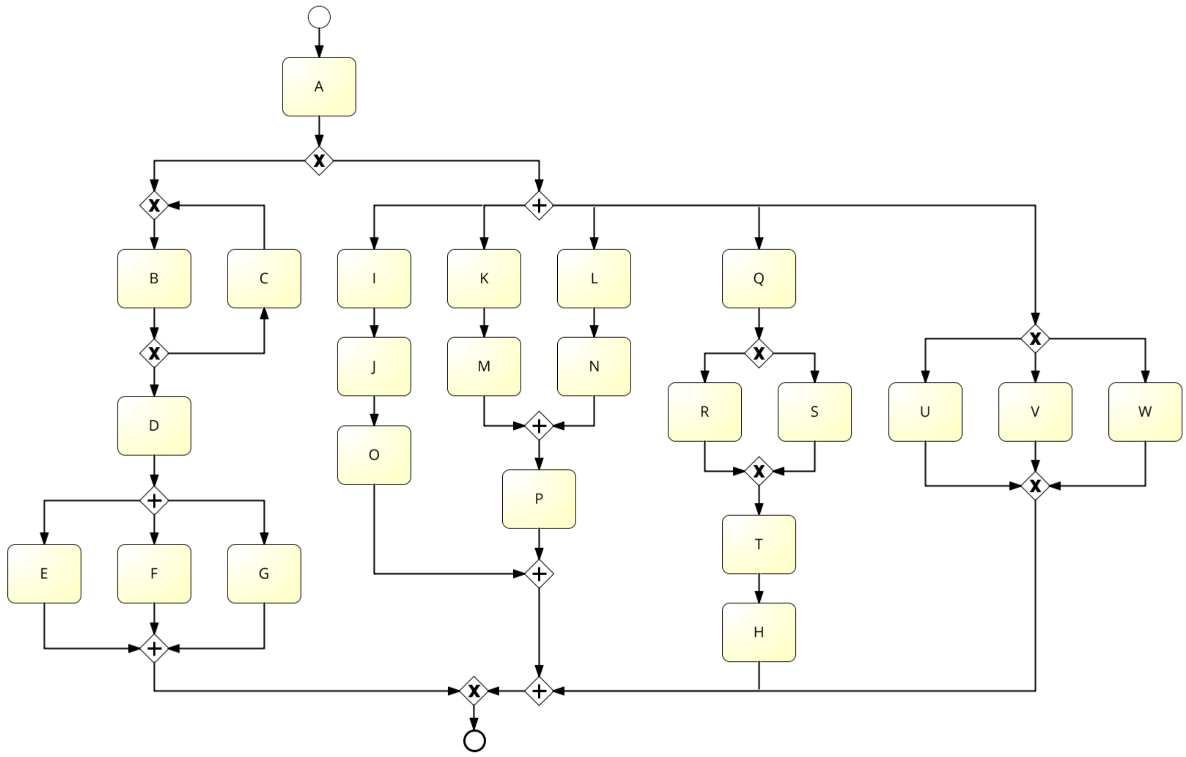
9. Appendix

9.1. Appendix A: Process models used in the experiment

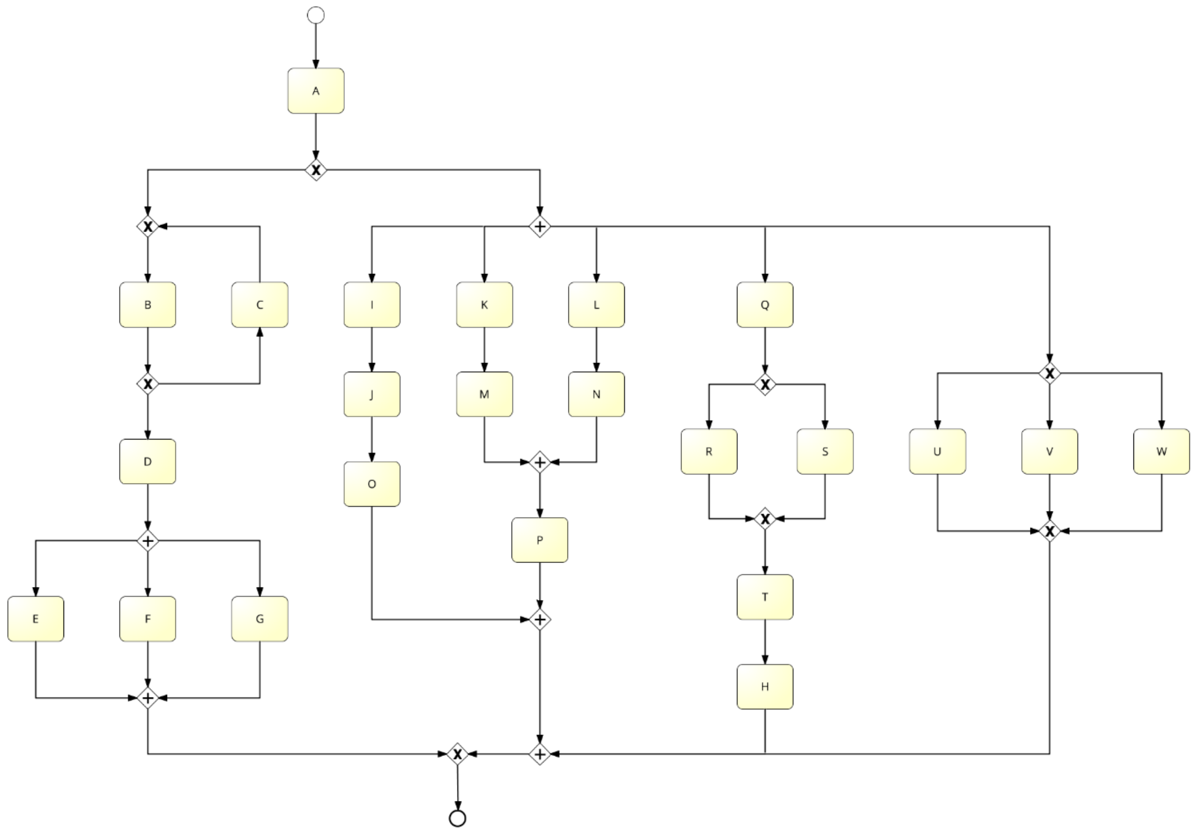
9.1.1. Process model A 25% vertical



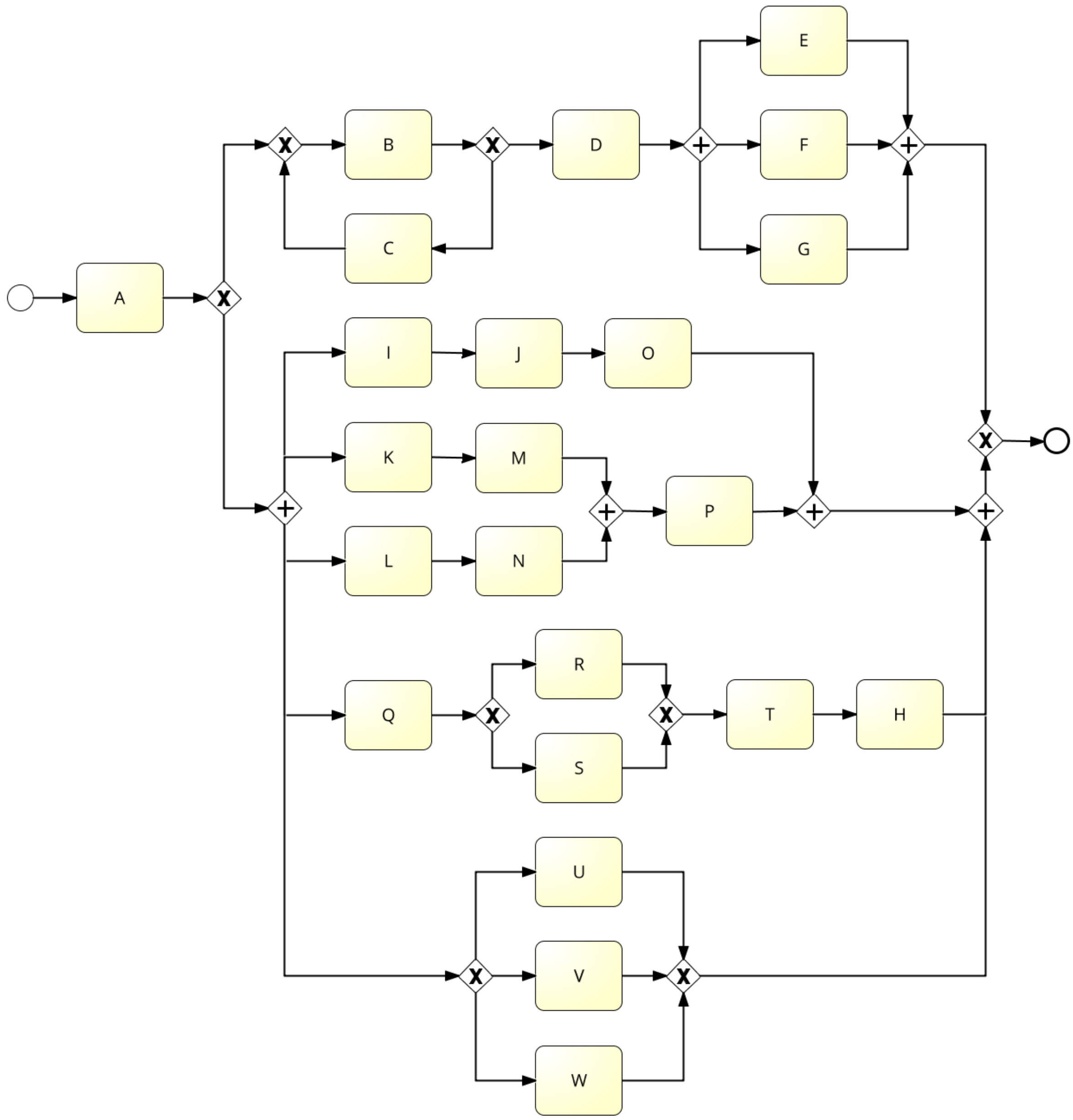
9.1.2. Process model A 50% vertical



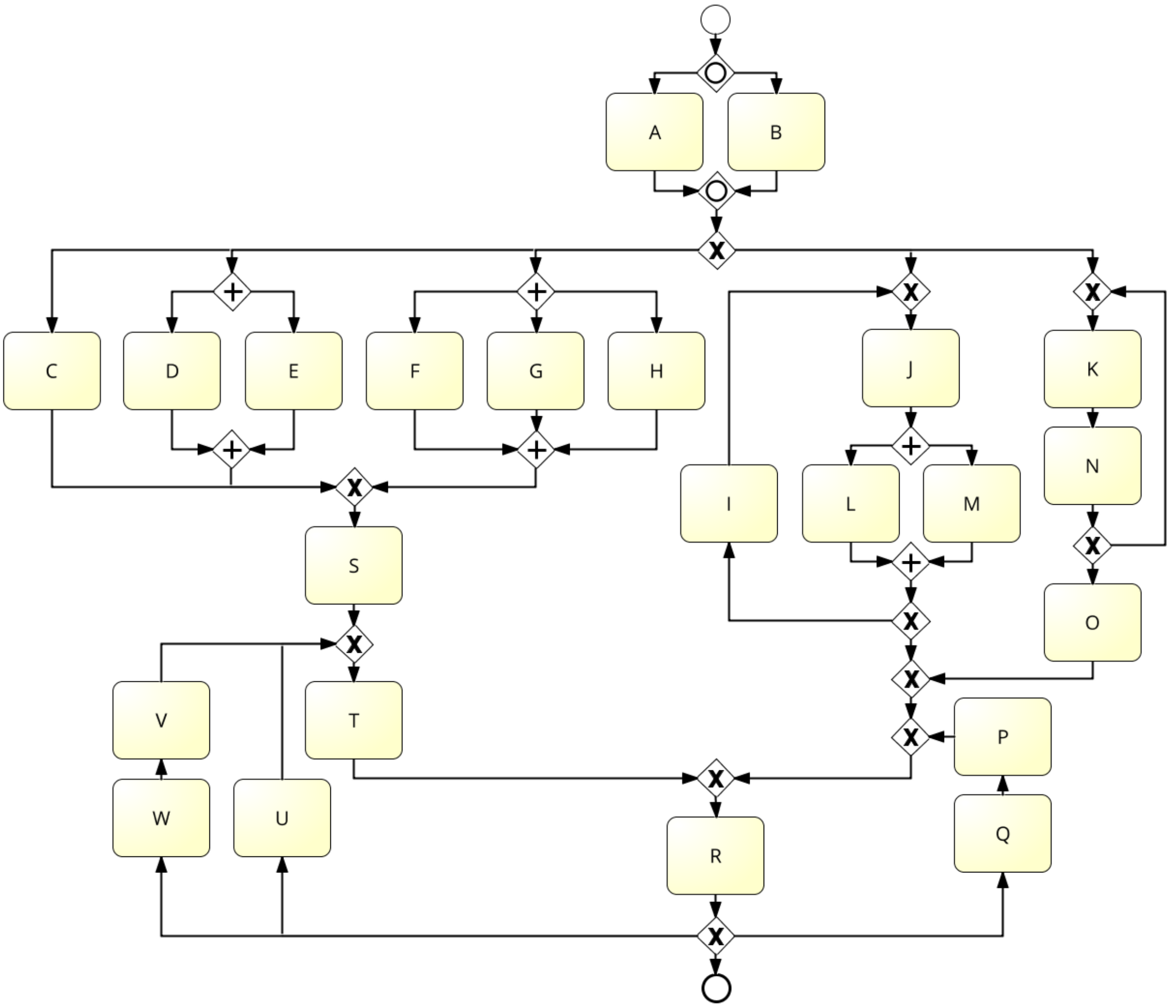
9.1.3. Process model A 100% vertical



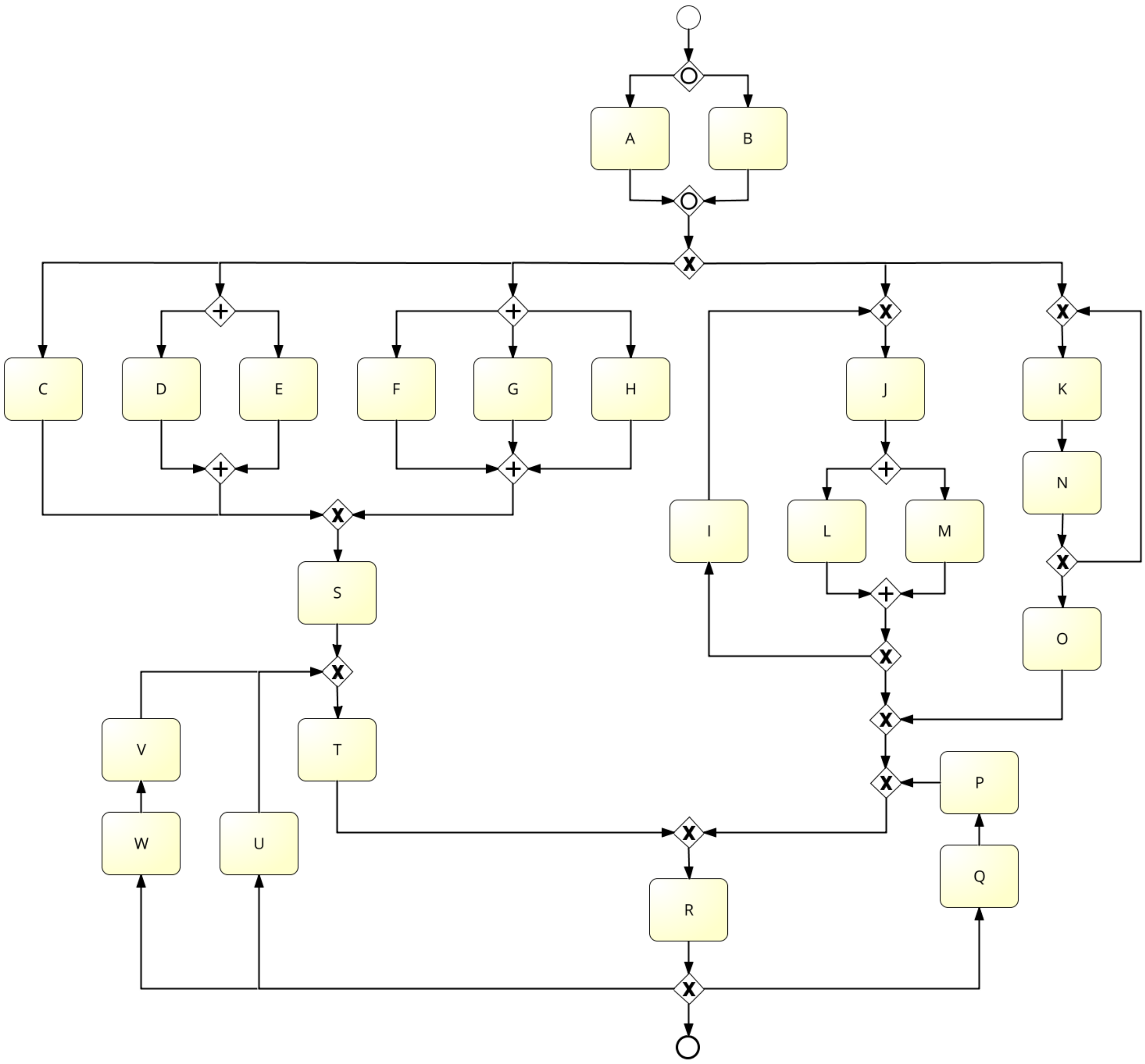
9.1.4. Process model A 50% horizontal



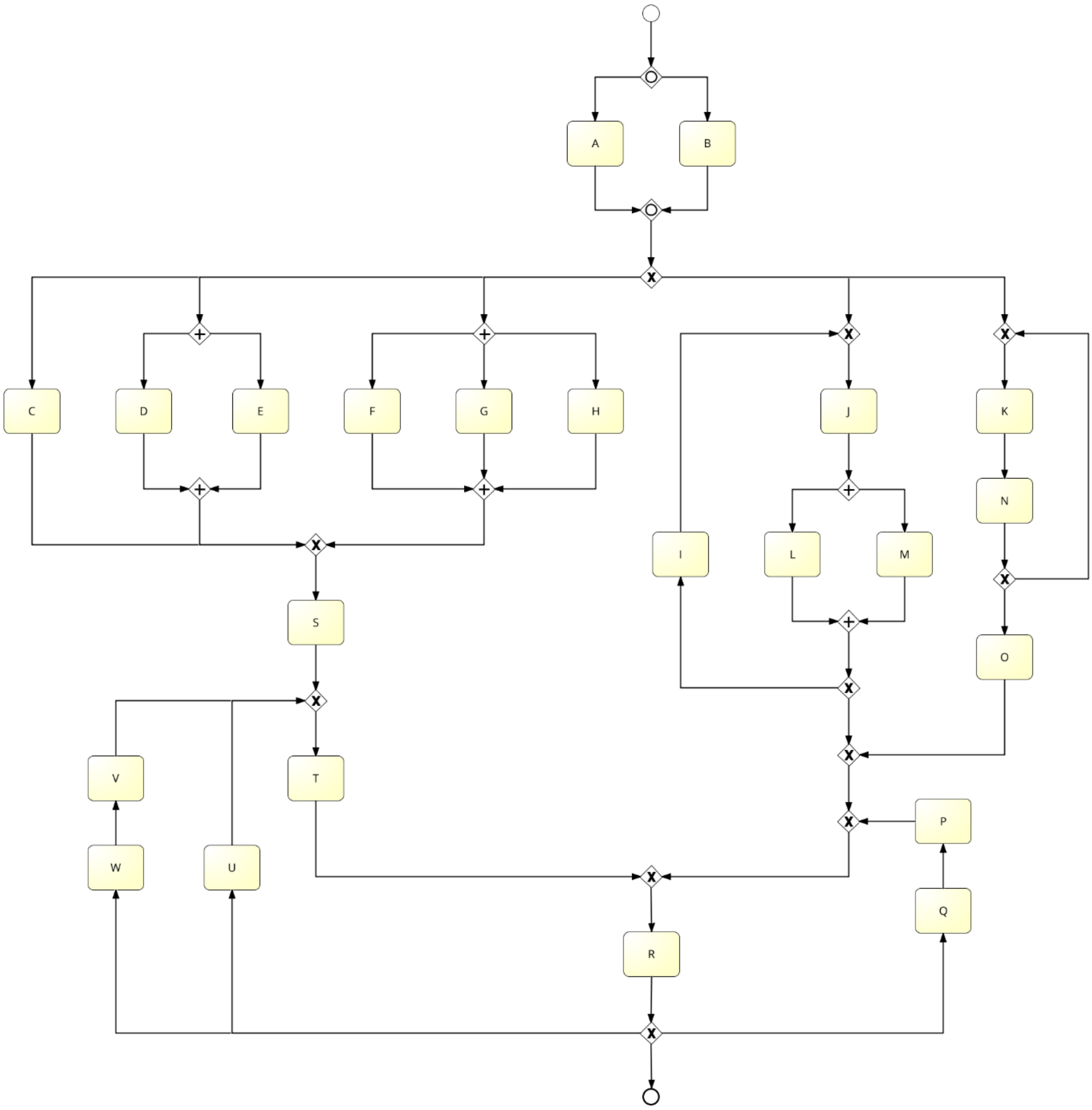
9.1.5. Process model B 25% vertical



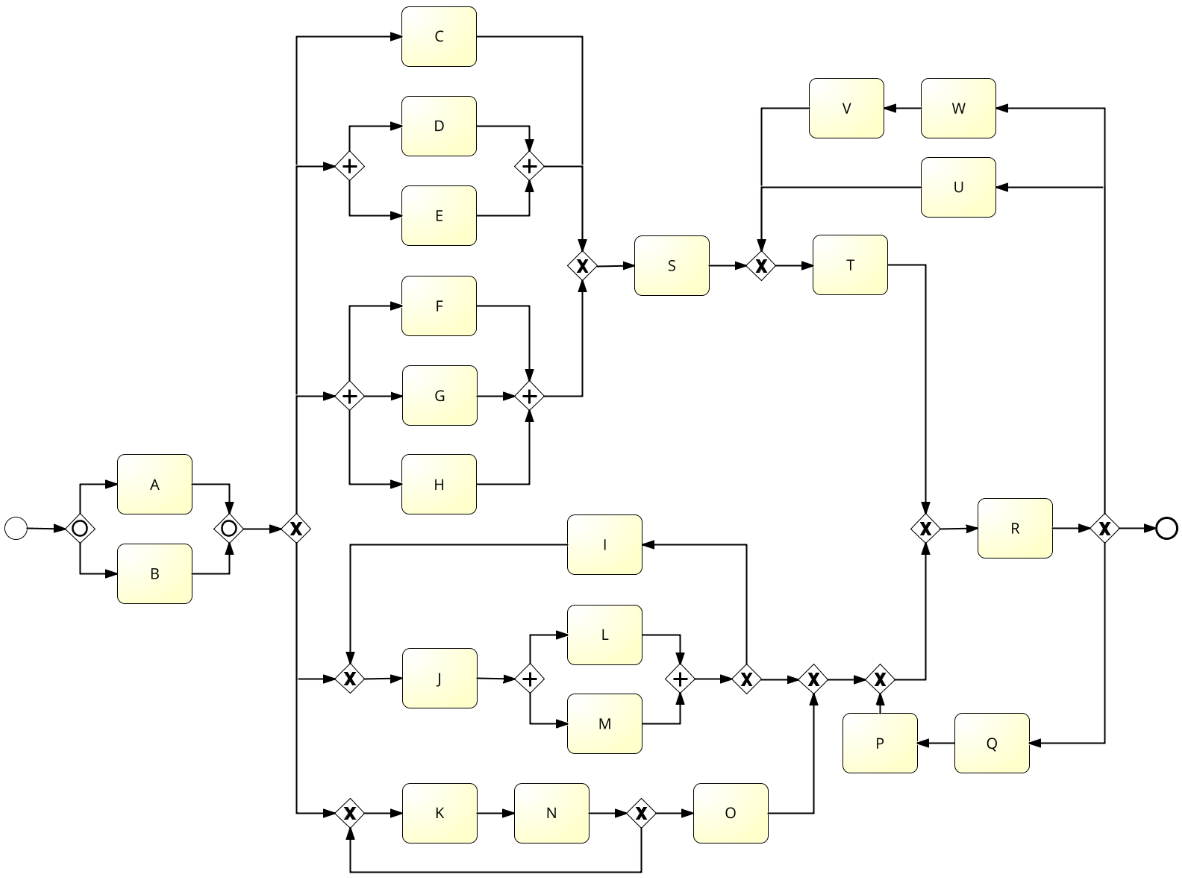
9.1.6. Process model B 50% vertical



9.1.7. Process model B 100% vertical



9.1.8. Process model B 50% horizontal



9.2. Appendix B: Understandability questionnaires

9.2.1. Process A

For the following questions answer with 'yes' or 'no' if you know the answer, if you don't know the answer please answer with 'I don't know' instead of guessing the answer.

1: If C is executed for a case, can I be executed for the same case? O yes O no O I don't know

2: Can Q be executed more than once for the same case? O yes O no O I don't know

3: If Q is executed for a case, can O be executed for the same case? O yes O no O I don't know

4: If J is executed for a case, can S be executed for the same case? O yes O no O I don't know

5: Can D be executed more than once for the same case? O yes O no O I don't know

6: If Q is executed for a case, is W then always executed for the same case? O yes O no O I don't know

7: Can G, O, and P all be executed for the same case? O yes O no O I don't know

For the following statements please indicate to what degree you agree or disagree with the statement.

8: Business models presented in this layout would be difficult for users to understand.

O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

9: I think this layout approach is effective for representing business process models.

O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

10: Using this layout for process models would make it more difficult to communicate business processes to end-users.

O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

11: Overall, I found the layout of the business process model in this part of the experiment to be useful.

O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

12: Learning to use this way of modelling business processes would be easy for me.

O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

13: I found the process model in this layout unclear and difficult to understand.

O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

14: It would be easy for me to become skillful at using this way of modelling business processes.
O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

15: Overall, I found this way of modelling business processes difficult to use.
O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

16: I would definitely **not** use this layout approach to model business processes.
O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

17: I would intend to use this layout approach in modelling business processes in preference to another layout approach, if I have to work with business process models in the future.
O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

9.2.2. Process A correct answers

1: No

2: No

3: Yes

4: Yes

5: No

6: No

7: No

8-17: Subjective questions

9.2.3. Process B

For the following questions answer with 'yes' or 'no' if you know the answer, if you don't know the answer please answer with 'I don't know' instead of guessing the answer.

1: If C is executed for a case, can H be executed for the same case? O yes O no O I don't know
2: Can F be executed more than once for the same case? O yes O no O I don't know
3: If F is executed for a case, can H be executed for the same case? O yes O no O I don't know
4: If N is executed for a case, can T be executed for the same case? O yes O no O I don't know
5: Can M be executed more than once for the same case? O yes O no O I don't know
6: If J is executed for a case, is I then always executed for the same case? O yes O no O I don't know
7: Can H, P, and V all be executed for the same case? O yes O no O I don't know

For the following statements please indicate to what degree you agree or disagree with the statement.

8: Business models presented with this layout would be difficult for users to understand.
O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

9: I think this layout approach is effective for representing business process models.
O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

10: Using this layout of process models would make it more difficult to communicate business processes to end-users.
O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

11: Overall, I found the layout of the business process model in this experiment to be useful.
O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

12: Learning to use this way of modelling business processes would be easy for me.
O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

13: I found the layout of the process model unclear and difficult to understand.
O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

14: It would be easy for me to become skillful at using this way of modelling business processes.
O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

15: Overall, I found this way of modelling business processes difficult to use.

O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

16: I would definitely **not** use this layout approach to model business processes.

O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

17: I would intend to use this layout approach in modelling business processes in preference to another layout approach, if I have to work with business process models in the future.

O strongly disagree O moderately disagree O somewhat disagree O neutral
O somewhat agree O moderately agree O strongly agree

9.2.4. Process B correct answers

1: No

2: No

3: Yes

4: Yes

5: Yes

6: No

7: Yes

8-17: Subjective questions

9.3. Appendix C: Cognitive profile questionnaire

The answer options for every question are True, False and Uncertain.

People differ in the way they think about problems. Below are 38 statements designed to identify your own approach.

If you believe that a statement is true about you, select **True.** If you believe that it is false about you, select **False.** If you are uncertain whether it is true or false, pick **Uncertain.**

This is not a test of your ability, and there are no right or wrong answers. Simply choose the one response which comes closest to your own opinion.

Please give your "first reaction" in each case!

Q1. In my experience, rational thought is the only realistic basis for making decisions.

Q2. To solve a problem, I have to study each part of it in detail.

Q3. I am most effective when my work involves a clear sequence of tasks to be performed.

Q4. I have difficulty working with people who 'dive in at the deep end' without considering the finer aspects of the problem

Q5. I am careful to follow rules and regulations at work.

Q6. I avoid taking a course of action if the odds are against its success.

Q7. I am inclined to scan through reports rather than read them in detail.

Q8. My understanding of a problem tends to come more from thorough analysis than flashes of insight.

Q9. I try to keep to a regular routine in my work.

Q10. The kind of work I like best is that which requires a logical, step-by-step approach.

Q11. I rarely make 'off the top of the head' decisions.

Q12. I prefer chaotic action to orderly inaction.

Q13. Given enough time, I would consider every situation from all angles.

Q14. To be successful in my work, I find that it is important to avoid hurting other people's feelings.

Q15. The best way for me to understand a problem is to break it down into its constituent parts.

Q16. I find that to adopt a careful, analytical approach to making decisions takes too long.

Q17. I make most progress when I take calculated risks.

Q18. I find that it is possible to be too organized when performing certain kinds of task.

Q19. I always pay attention to detail before I reach a conclusion.

Q20. I make many of my decisions on the basis of intuition.

Q21. My philosophy is that it is better to be safe than risk being sorry.

Q22. When making a decision, I take my time and thoroughly consider all relevant factors.

Q23. I get on best with quiet, thoughtful people.

Q24. I would rather that my life was unpredictable than that it followed a regular pattern.

Q25. Most people regard me as a logical thinker.

Q26. To fully understand the facts I need a good theory.

Q27. I work best with people who are spontaneous.

Q28. I find detailed, methodical work satisfying.

Q29. My approach to solving a problem is to focus on one part at a time.

Q30. I am constantly on the lookout for new experiences.

Q31. In meetings, I have more to say than most.

Q32. My 'gut feeling' is just as good a basis for decision making as careful analysis.

Q33. I am the kind of person who casts caution to the wind.

Q34. I make decisions and get on with things rather than analyze every last detail.

Q35. I am always prepared to take a gamble.

Q36. Formal plans are more of a hindrance than a help in my work.

Q37. I am more at home with ideas rather than facts and figures.

Q38. I find that 'too much analysis results in paralysis'.

9.4. Appendix D: Learning styles questionnaire

1. I understand something better after I
   - try it out.
   - think it through.

2. I would rather be considered
   - realistic.
   - innovative.

3. When I think about what I did yesterday, I am most likely to get
   - a picture.
   - words.

4. I tend to
   - understand details of a subject but may be fuzzy about its overall structure.
   - understand the overall structure but may be fuzzy about details.

5. When I am learning something new, it helps me to
   - talk about it.
   - think about it.

6. If I were a teacher, I would rather teach a course
   - that deals with facts and real life situations.
   - that deals with ideas and theories.

7. I prefer to get new information in
   - pictures, diagrams, graphs, or maps.
   - written directions or verbal information.

8. Once I understand
   - all the parts, I understand the whole thing.
   - the whole thing, I see how the parts fit.

9. In a study group working on difficult material, I am more likely to
   - jump in and contribute ideas.
   - sit back and listen.

10. I find it easier
    - to learn facts.
    - to learn concepts.

11. In a book with lots of pictures and charts, I am likely to
    - look over the pictures and charts carefully.
    - focus on the written text.

12. When I solve math problems
    - I usually work my way to the solutions one step at a time.
    - I often just see the solutions but then have to struggle to figure out the steps to get to them.
13. In classes I have taken
    - I have usually gotten to know many of the students.
    - I have rarely gotten to know many of the students.
14. In reading nonfiction, I prefer
    - something that teaches me new facts or tells me how to do something.
    - something that gives me new ideas to think about.
15. I like teachers
    - who put a lot of diagrams on the board.
    - who spend a lot of time explaining.
16. When I'm analyzing a story or a novel
    - I think of the incidents and try to put them together to figure out the themes.
    - I just know what the themes are when I finish reading and then I have to go back and find the incidents that demonstrate them.
17. When I start a homework problem, I am more likely to
    - start working on the solution immediately.
    - try to fully understand the problem first.
18. I prefer the idea of
    - certainty.
    - theory.
19. I remember best
    - what I see.
    - what I hear.
20. It is more important to me that an instructor
    - lay out the material in clear sequential steps.
    - give me an overall picture and relate the material to other subjects.
21. I prefer to study
    - in a study group.
    - alone.
22. I am more likely to be considered
    - careful about the details of my work.
    - creative about how to do my work.

23. When I get directions to a new place, I prefer
    - o a map.
    - o written directions.
24. I learn
    - o at a fairly regular pace. If I study hard, I'll "get it."
    - o in fits and starts. I'll be totally confused and then suddenly it all "clicks."
25. I would rather first
    - o try things out.
    - o think about how I'm going to do it.
26. When I am reading for enjoyment, I like writers to
    - o clearly say what they mean.
    - o say things in creative, interesting ways.
27. When I see a diagram or sketch in class, I am most likely to remember
    - o the picture.
    - o what the instructor said about it.
28. When considering a body of information, I am more likely to
    - o focus on details and miss the big picture.
    - o try to understand the big picture before getting into the details.
29. I more easily remember
    - o something I have done.
    - o something I have thought a lot about.
30. When I have to perform a task, I prefer to
    - o master one way of doing it.
    - o come up with new ways of doing it.
31. When someone is showing me data, I prefer
    - o charts or graphs.
    - o text summarizing the results.
32. When writing a paper, I am more likely to
    - o work on (think about or write) the beginning of the paper and progress forward.
    - o work on (think about or write) different parts of the paper and then order them.
33. When I have to work on a group project, I first want to
    - o have "group brainstorming" where everyone contributes ideas.
    - o brainstorm individually and then come together as a group to compare ideas.

34. I consider it higher praise to call someone
    - sensible.
    - imaginative.
35. When I meet people at a party, I am more likely to remember
    - what they looked like.
    - what they said about themselves.
36. When I am learning a new subject, I prefer to
    - stay focused on that subject, learning as much about it as I can.
    - try to make connections between that subject and related subjects.
37. I am more likely to be considered
    - outgoing.
    - reserved.
38. I prefer courses that emphasize
    - concrete material (facts, data).
    - abstract material (concepts, theories).
39. For entertainment, I would rather
    - watch television.
    - read a book.
40. Some teachers start their lectures with an outline of what they will cover. Such outlines are
    - somewhat helpful to me.
    - very helpful to me.
41. The idea of doing homework in groups, with one grade for the entire group,
    - appeals to me.
    - does not appeal to me.
42. When I am doing long calculations,
    - I tend to repeat all my steps and check my work carefully.
    - I find checking my work tiresome and have to force myself to do it.
43. I tend to picture places I have been
    - easily and fairly accurately.
    - with difficulty and without much detail.
44. When solving problems in a group, I would be more likely to
    - think of the steps in the solutions process.
    - think of possible consequences or applications of the solution in a wide range of areas.

9.5. Appendix E: Business Process Modelling Competency Test

All questions are Yes/No type of questions. Correct answers are shown after the questionnaire.

Q1. After an exclusive (XOR) gateway, exactly one alternative path is executed.

Q2. Consider the process fragment given in Fig.1. The parallel (AND) gateway that connects the activities B and C indicates that these two activities should be executed at the same time.

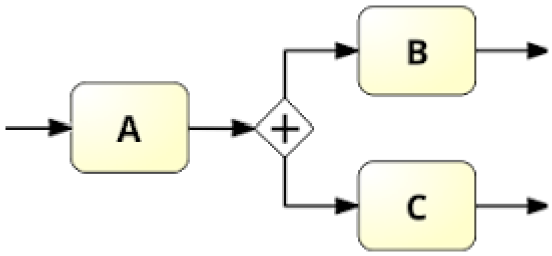


Fig.1

Q3. An exclusive (XOR) gateway can be used to model repetition.

Q4. An inclusive (OR) gateway can activate concurrent paths.

Q5. An event-based gateway (as given in Fig. 2) can activate either one or multiple paths but not all.

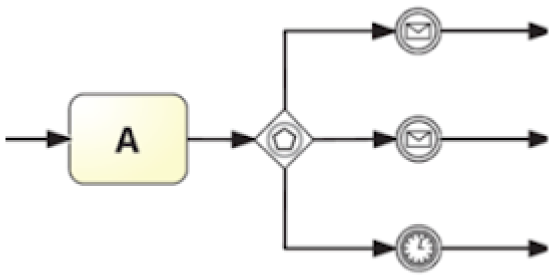


Fig.2

Q6. An event-based gateway cannot be directly followed by a message-sending event.

Q7. The process model given below (Fig.3) has syntactical errors (i.e. violates BPMN v2 modeling rules).

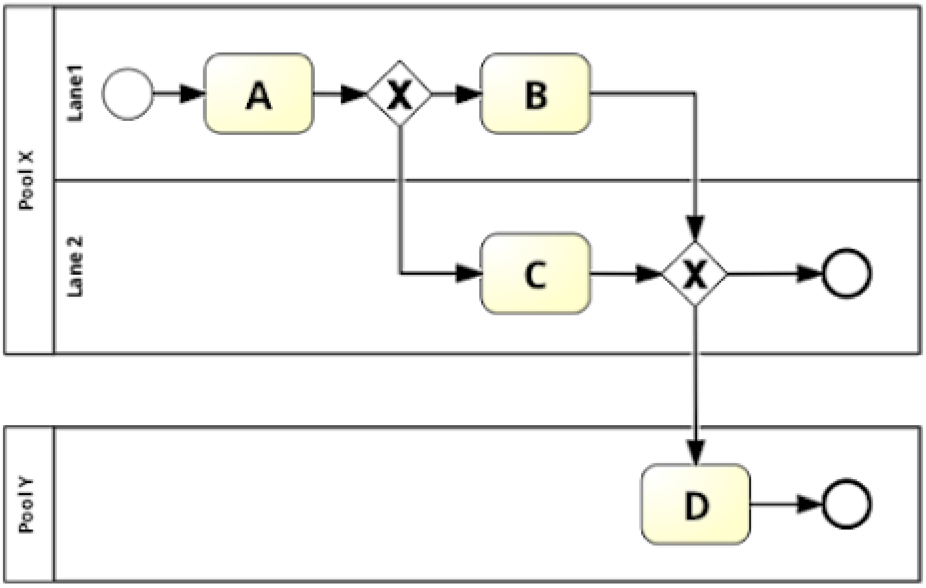


Fig.3

Q8. There is a deadlock in the process model given below (Fig.4).

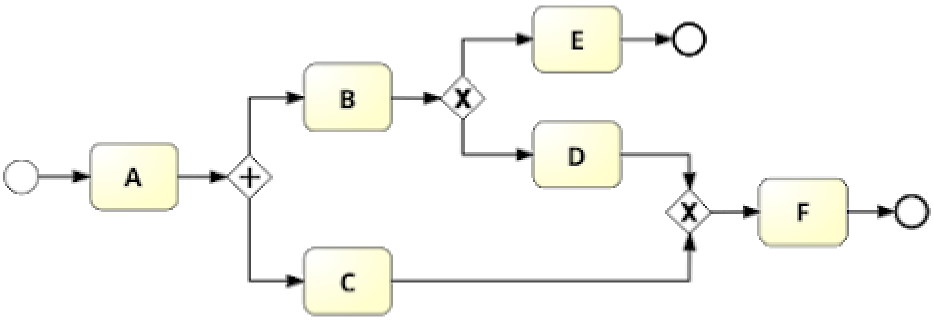


Fig.4

Q9. The problem in the process model given below (Fig.4) can be solved if the merging exclusive (XOR) gateway is replaced with merging parallel (AND) gateway.

Q10. There are two message-receiving events in the process model given below (Fig.5).

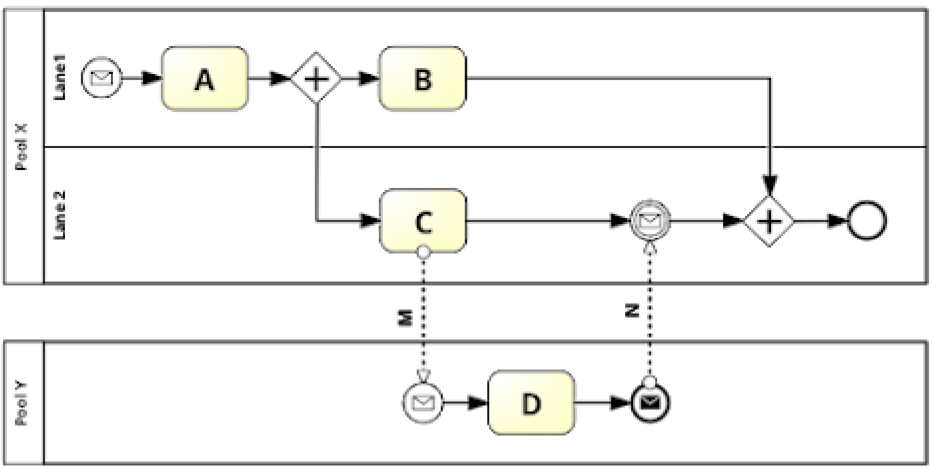


Fig.5

Q11. A message flow can be used to connect process elements in the same pool (e.g., Fig.6 gives an example where two collapsed sub-processes, A and C, are connected through a message flow).

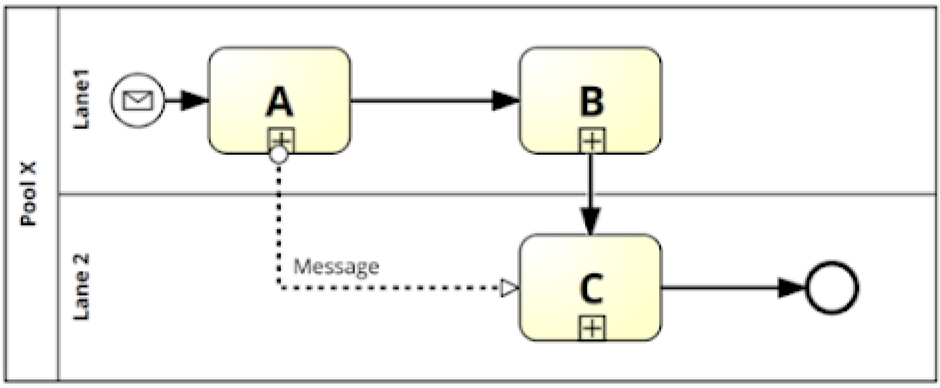


Fig.6

Q12. Fig. 7 shows a process model, where the labels for the activities show (besides the activity names) the minimum duration for each activity to complete (in days). Accordingly, the process in Fig.7 takes at minimum 8 days to complete.

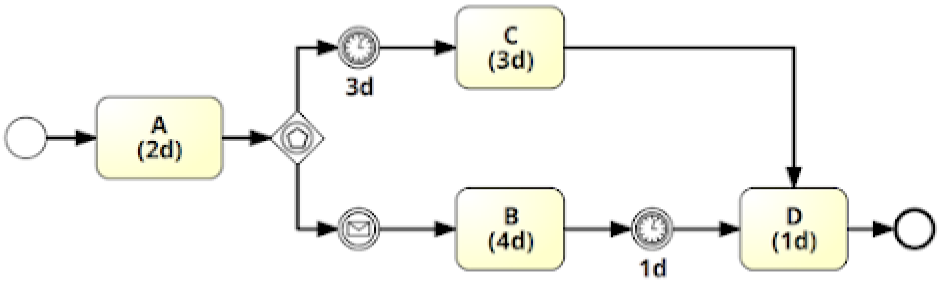


Fig.7

Q13. A sub-process cannot have another sub-process nested within.

Q14. If a task has two input arcs, it is the same as if the task was preceded by a joining exclusive (XOR-join) gateway.

Q15. In BPMN, both pools and lanes may represent a process participant, a business unit or a software system.

Q16. In BPMN, the tasks that are enclosed within a group (as exemplified in Fig.8) are related to each other for clarification or documentary purposes and may include tasks in multiple pools or lanes.

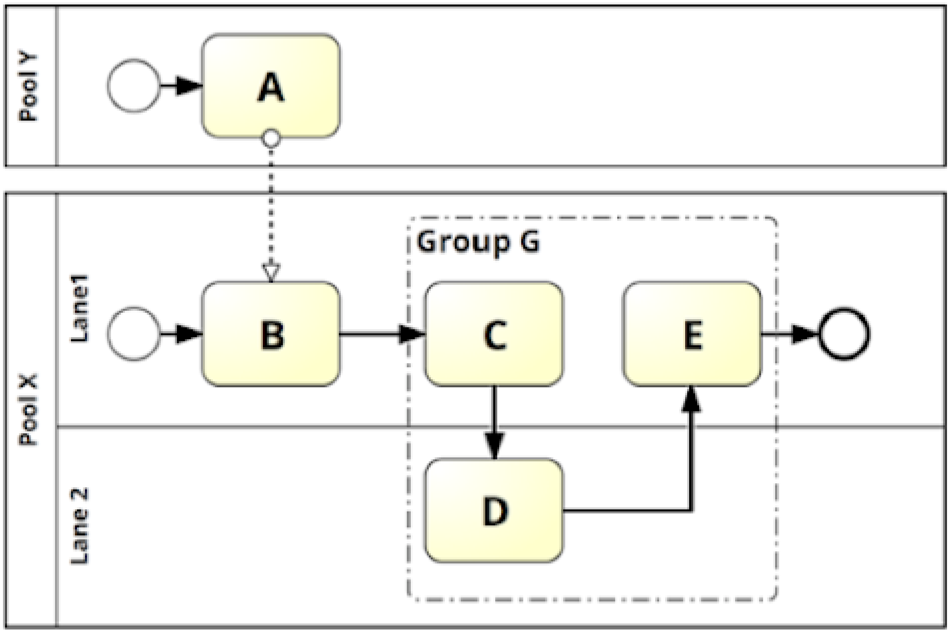


Fig.8

Correct answers: Q1. Yes Q2. No Q3. Yes Q4. Yes Q5. No Q6. Yes Q7. Yes Q8. No Q9. No Q10. No Q11. No Q12. Yes Q13. No Q14. Yes Q15. Yes Q16. Yes

9.6. Appendix F: Information before starting any part of the experiment

PLEASE READ CAREFULLY!

Dear Participant,

Thank you for participating in this study. Your contribution is valuable for our research on BPM.

This is part of an experiment on the understandability of business process models, designed by the researchers of the Eindhoven University of Technology, Information Systems Group.

Please note:

1. The experiment has THREE main parts, and the one you are viewing now is Part B on "process modeling knowledge". You are expected to do it in your convenient time until 12 January 2020 17:30. (Other parts are accessible via bpmresearch.net to be completed until the same deadline!)

2. Expect this part to take about 10-15 minutes to complete, but there is no time-limitation.

3. However, you are expected to complete the questionnaire in one go - without any break. So, please ensure now that you can start and complete in one-go.

4. This experiment is not appropriate to be performed through a mobile/smart phone. Please use a laptop (you may otherwise miss some questions).

5. The answers you will provide to the questions have no influence on your course grade. However, you are expected to take the experiment and questions seriously and attempt for an answer in order to be considered to have successfully participated. By participating in this experiment, you agree to this term.

6. The time you spent for answering each question is recorded (which gives a good indication of whether you took it seriously and deserve to be considered "done" with your assignment. Note that, we will have to evaluate the time spent by each participant for each question for validity/reliability in any case!).

7. It is not allowed to use any book, notes or other material.

8. The results of this experiment will not be released in any individually identifiable form. They will be treated strictly confidential and will only be used for scientific purposes. By participating in this experiment, you agree to the use of the data you provide for research purposes (please refer to the points below regarding confidentiality).

9. You will later receive the correct answers for this part of the experiment.

10. If you have any questions, please contact through email.

If you are ready, please enter your (student) ID number (7 characters possibly with a '0' in front*) and click NEXT to continue.

Student ID:

* PhD students may have an ID with 8 characters, in which case you need to enter with 8 characters.

Remarks about confidentiality:

Please note that the experiment requires your personal identification information (student-id) to be gathered. This is to confirm that you made a serious effort for the experiment (and became eligible for a the point that you can get from the assignment). (This analysis is also important for our research, as we need to identify outliers/unreliable cases in our dataset to derive valid conclusions from it).

Once we identify such cases, and prepare your performance report for you to review, the personal identification information will be permanently removed from the dataset. This is to make sure that the remaining data is completely anonymous - i.e. without any information that can allow anyone to connect/trace any response back to the person that created it. This data, which will be stored only in an anonymous form, is sufficient for our research purposes.

Thank you in advance for your participation.