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Ulm University | 89069 Ulm | Germany

Faculty of Engineering and Computer Science
Institute of Databases and Information Systems

Influence of Psychological Distance on Process Modeling: A Gamification Approach

Master Thesis at Ulm University

Submitted by:
Michael Zimoch
michael.zimoch@uni-ulm.de

Reviewer:
Prof. Dr. Manfred Reichert
Dr. Vera Künzle

Supervisor:
Jens Kolb

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Abstract

Nowadays, Business Process Management (BPM) has progressed significantly and established itself as an important management concept for enterprises. For creating efficient and effective business processes enterprises have given process models a high priority. A well-documented business process is intended not only to describe a procedure in detail, but serves as a foundation for further actions such as process automation, improving process performance, and the identification of potential consequences as well as the quickness to respond for changes. To this end, it is important to ensure that process models represent the corresponding real world business processes as accurately as possible. In turn, a not proper described business process may lead to ineffectiveness, costs, and even losses. Hence, a focus is set on the quality, granularity as well as structure of process models. By now, numerous guidelines exist for creating correct and sound process models in respect to their quality, granularity, and resulting structure. However, hardly research addresses cognitive aspects when creating process models. Thereby, cognitive aspects are of particular importance for creating and understanding process models.

This thesis contributes insights from a controlled experiment investigating the influence of psychological distance on the process of process modeling. More precisely, the effects of social distance of a process designer to the modeled domain has on the creation of process models are evaluated. In this context, the recent and emerging trend of gamification is applied. Therefore, gamification in a 3D virtual world is used to enhance the effects of social distance and for a better reflection of a real world problem.

The final results obtained from the experiment do not agree with the theory. In particular, significant differences between low and high social distance with respect to process model quality, granularity, and structure are observed but are contrary to the stated goal of the experiment. Hence, the findings underline the importance of understanding the effects of cognitive aspects on the process of process modeling. However, the results may provide valuable incitements for enterprises to compose adequate teams for creating or optimizing business process models.

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Contents

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Introduction

1.1 Motivation

In todays world, *process models* are crucial and have become indispensable for process-oriented enterprises. Current enterprise repositories comprise large process model collections [76]. Thereby, process models vary in respect to their *quality, granularity* as well as *process model structure* and, hence, their *usefulness*. A *high quality* of process models, however, is crucial for any enterprise in order to guarantee their proper use. Therefore, it is important to focus on well-designed process models for a better comprehension of the complex business processes within an enterprise. Further, well-designed process models serve to increase the transparency of business processes as well as the efficient placement of functions, roles, and interfaces. As a prerequisite for the later use, the respective process model should reflect its corresponding real world

business process at the right level of granularity and in sufficient detail [63].
In this context, considerable work exists that presents criteria for suitable process models and addresses also comprehensibility issues [57, 60]. Modeling guidelines (e.g., *Guidelines of Process Modeling (GoM)*, *Seven Process Modeling Guidelines (7PMG))* exist, which support process designers in creating process models of high quality [6, 59]. Thereby, hardly work exists evaluating the *process of process modeling* [68] from a cognitive point of view and their effects on the resulting process models [25, 26]. However, if we do not understand the cognitive aspects affecting process model quality, granularity, and structure, process modeling projects might not deliver the required results or even fail.
In this context, a fundamental factor presumably influencing the *process of process modeling* is the *social distance* [90]. *Social distance* is addressed by the *Construal Level Theory (CLT)* and constitutes an important part of *psychological distance* [88]. In particular, studies have shown that human thinking and acting are strongly influenced by psychological distance [89]. According to CLT, we can only experience the *here and now*, and, hence, we form an abstract mental construal of distant objects [89, 90]; e.g., when thinking about a music festival we plan to visit, it is important to know which bands will be playing, but details about the trip are not in our mind set yet. In turn, just before the festival takes place, it will be important for us to know with whom to visit the festival or how to get there, i.e., planning is done at a more fine-grained level.
Similarly, in the *process of process modeling*, various actors having different distance to the modeled business process and its environment may be involved. While certain process models are designed by people directly participating in the respective business processes, others are modeled by external consultants or people from organizational units (e.g., the quality assurance department) not involved in the process, i.e., people having a *high social distance* to the process. A relevant question in this context is how *social distance* influences the *process of process modeling*.

1.2 Contribution

Taking CLT as theoretical basis, previous experiment has shown that there exists a correlation between the psychological distance (i.e., social, spatial, temporal, and hypothetical distance) and their influence on the resulting process models [41, 99]. In particular, the results show a significant influence of psychological distance on the quality and granularity of the resulting process models. Among all distances, the social distance showed very significant results. For that reason and to get more adequate as well as profound insights, the focus is set only on the social distance in the experiment.

The goal of the experiment is to investigate the influence of social distance on the process of process modeling. Therefore, we adopt a new approach: *gamification*. The use of *gamification* is a recent and emerging trend in a non-game context [67, 81]. Gamification uses techniques from gaming to affect people improving their enthusiasm for "boring activities". In conjunction with process modeling new opportunities are created; e.g., facilitating the introduction of new processes within an enterprise using game-based thinking. The techniques of gamification are used to enthrall and engage process designers for business processes in a more enjoyable way than a formal instruction. This, in turn, has implications on the resulting process models with respect to their quality, granularity, and structure [83].

For the experiment, the concept of gamification is used in a 3D virtual world to convey the social distance to subjects (i.e., participants in an experiment) of the experiment. For this intention, a warehouse scenario in a 3D virtual world environment is developed. In this environment, one group of subjects are able to replay an *order processing in a warehouse*. A second group watches passively the same warehouse scenario in a video. Afterwards, both groups are asked to model the respective scenario based on their own experience. Through conveying the social distance by means of playing and watching the influence of the social distance on the process of process modeling can be evaluated.

1.3 Structure of the Thesis

The structure of this thesis is as follows:
Section 2 introduces the Construal Level Theory and the psychological distance in detail. Gamification, virtual world, and the development of the 3D warehouse scenario is described in Section 3. Section 4 presents the experiment planning and definition. Experiment operation, which includes preparation, execution, and data validation is introduced in Section 5. Analysis and interpretation of the results including descriptive statistics and visualization of data, hypothesis testing as well as summary and discussion of the results are presented in Section 6. Finally, Section 7 discusses related work and Section 8 summarizes the thesis.

The general process of the experiment is illustrated in Figure 1.1.

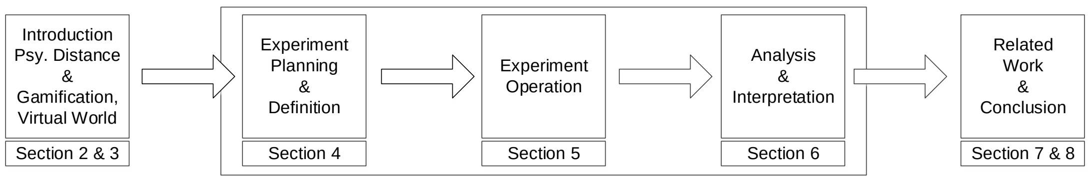

Figure 1.1: Experiment Process

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Fundamentals of Construal Level Theory

The main focus in this thesis is on the *social distance*. However, for a better understanding of the latter the basics of the *Construal Level Theory* and its properties are presented. Section 2.1 describes the *level of construal*. Section 2.2 introduces the *psychological distance* and their related distances, i.e., *social, spatial, temporal*, and *hypothetical distance*.

2.1 Level of Construal

Construal Level Theory (CLT) is a social-cognitive theory in *social psychology* introduced by [89] describing the effects of *psychological distance* on objects or events. The fundamental idea is, which is already proved empirically [88], increasing psychological distance affects the mental representation of objects or events. This influence on the perception has a strong impact on actions and thinkings of an individual. For example, moving house to a distant location in a distant future evokes general thoughts and actions; e.g. starting a new life, searching new friends. The same event happening in a near location and near future evokes more detailed thoughts and actions; e.g. moving box packs, register the residence [93].

Strangers, distant locations, past events - everything that is distant from us creates a more abstract reflection. The reason behind this effect is the *level of construal*. The *level of construal* describes how individuals interpret and perceive objects in surrounding [89]. Increasing psychological distance affects cognitive abilities of an individual and, thus, leads to a change in perception of objects or events.

Therefore, CLT describes two different levels of thinking: *high-level construal* and *low-level construal*. *High-level construals* are abstract, coherent, and superordinate representations, compared to *low-level construals*. The further away an object or event is the more we think in high-level construals and, on the other side, the smaller the distance the more we think in low-level construals. For example, from a distance we see the forest (i.e., high-level construal) and as we get closer, we see the trees (i.e., low-level construal) [89]. These two aspects are influenced by *psychological distance*, which is introduced in the following.

2.2 Psychological Distance

A basic aspect of CLT is the *psychological distance*. While, for example, *objective distance* describes the quantitative and in real world existing spatial distance of an object or event to someone, the psychological distance describes feelings, thinkings, and emotions in relation to an object or event. If an individual shall estimate the distance between two distant locations, then one location is perceived as further away.

For example, individuals shall estimate the distance between a city and four other cities. Two of them are in the same federal state and the other two cities are in different federal states. Distance of the four cities to the marked city is always the same. The results show that cities in foreign federal states are perceived more distant and are consequently estimated as further away [13].
An object or event is defined as *psychological distant*, when it is not experienced physically. Objects or events, which are not experienced in the *here and now*, must be constructed mentally. Therefore, psychological distance is separated into several subdistances, i.e., *social, spatial, temporal*, and *hypothetical distance* are being considered as most important and are explained in the following [47].

Social Distance: Experiences and decisions which are not self-experienced as well as the relation to other individuals are *social distant*. For example, choosing a more distant seat from another individual is taken to reflect social distance [65]. The way how an individual decides for himself or for others is also affected by social distance. An example are results of [72]: An individual expects more negative activities from others than from himself. The results are in accordance with CLT. With increasing social distance evaluation for distant individuals takes place at a more abstract information level [90].

Spatial Distance: *Spatial distance* refers to objects and events happening at another physical location. Events that take place at, for example, another country are described more abstract by individuals as if they occur in the same country. Studies show that individuals interactions between two or more individuals are described more detailed if it takes place at a nearby location. On the other hand, descriptions are more abstract if interactions are spatial distant [27].

Temporal Distance: *Temporal distance* deals with events on a temporal perspective. When an individual thinks about temporal distant objects or events they are perceived more abstract. Studies have shown, how individuals deal with temporal distance [17]. In this context, individuals have to categorize several items for an event happening in the near or distant future. If the event takes place in the near future, more categories are described in detail. A more distant event results in fewer, course-grained categories [46].

We retain the possibility of better planning to react against unexpected events in a distant future. For this reason, our actions are specified more abstract. On the other hand, our actions must be prepared more detailed for events happening in the near future.

Hypothetical Distance: *Hypothetical distance* accrues when an individual thinks about unreal or unlikely events but also worthwhile or elaborate situations. A study dealing with hypothetical distance is the following: as part of a contest, several prices are offered to individuals. These prices are either highly attractive but hard to win or less attractive but easy to win. It was shown that for highly attractive prices individuals are willing to take more effort to win. The other way around, for less attractive prices is the effort correspondingly low [88].

For a better understanding, Figure 2.1 summarizes the concept of CLT and the different distances (i.e., social, spatial, temporal, and hypothetical distance) up.

With increasing psychological distance perceived objects and events are more abstract in our mental representation. Although this leads to the fact that our actions and thoughts are more general but lacks on accuracy. On the contrary, lower psychological distance wages to a sophisticated but limited scope.

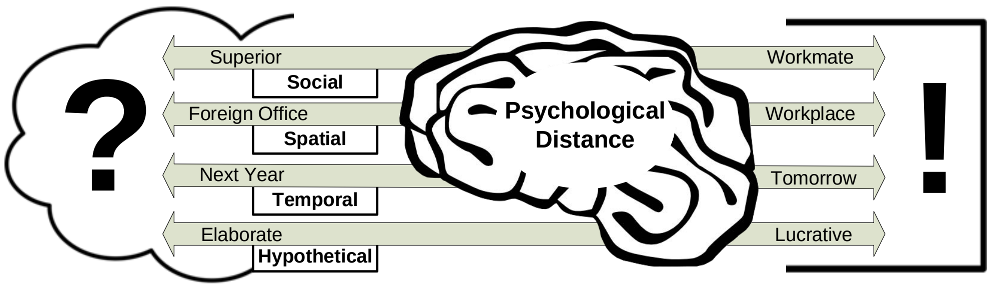


Figure 2.1: Psychological Distance

3

Introduction on Gamification, Virtual World, and 3D Warehouse Scenario

Section 3.1 introduces gamification with its essentials and principles. An introduction to virtual world is presented in Section 3.2. The implementation and application of gamification in the context of our experiment as well as the process and progressive development from concept to realization of the 3D warehouse scenario is presented in Section 3.3.

3.1 Gamification

Engaged and motivated employees are more productive and more valuable for enterprises [9, 97]; e.g., improved operational efficiency, increased quality in work. A variety of methods and possibilities exist to engage employees and boost their productivity as well as creativity [30, 31]. Currently, a promising trend for increasing motivation is *gamification* [52]. *Gamification* is a concept that uses techniques from gaming and integrates them in a non-game context to engage and motivate people (i.e., employees) in a rather enjoyable way. Studies have already shown and proven the effectiveness of gamification in a non-game context [1, 29]. Thereby, the formula for an effective use of gamification is straight forward: take an existing set of activities (e.g., banking or administrative work) and apply rather simple and inconspicuous game techniques or game elements like a set of game rewards in form of points; e.g., leveling or badges. As a consequence, the work will become automatically less boring and more enjoyable, thus resulting in higher efficiency [87, 98]. Among existing methods and approaches, the use of gamification promises new possibilities to engage and increase the motivation of employees [19]. Hence, more and more enterprises recognize the value and potential of gamification and move towards a gamified direction for more effectiveness and higher positive outcomes [32, 38]. Further, process-oriented enterprises make use of gamification and its benefits by identifying new modeling strategies for process modeling; e.g., translate the enthusiasm for play into workplaces [20]. Aside the use in enterprises, gamification is becoming widely used in education, politics, and healthcare [40, 44, 50].

3.2 Virtual World

A *virtual world*, also known as *virtual reality*, is a computer-based simulated environment, using the metaphor of the real world but without its physical limitations [4]. Thereby, a virtual world can reflect the reality or a fantasy world; e.g., a fable world. However, a virtual world is restricted to the laws and possibilities a developer of a virtual world determines. Individuals interact in this simulated world as textual, two, or three-dimensional *avatars* (i.e., created character in a virtual world) with each other or the environment, thus experience a *degree of telepresence*, i.e., experience of presence in a remote location [16, 79]. Among others, the best-known virtual worlds are the massive multiplayer online role-playing game *World of Warcraft* and the massive multiplayer universe *Second Life* [8, 48]. Nowadays, the use of virtual worlds has proven its worth and has become an important tool in education, entertainment, a laboratory for collaborative work, and an appropriate instrument to present the real world in a simplified form [21, 37]. Moreover, the use of virtual worlds has proved to be a effective means for process modeling. Hence, virtual worlds increase collaboration and consensual development of process models and provide easy to understand and rich visualizations for process model elicitation, thus improving the mutual understanding between stakeholders [12].

3.3 3D Warehouse Scenario

For the experiment, we want to make use from the benefits of gamification in a virtual world in the context of process modeling. Therefore, relative to a real world process, a simple scenario about an *order processing in a warehouse* is contrived. The entire process takes place in a full 3D virtual environment with aspects of gamification; e.g., exploring (i.e., learn more about the virtual construct) and puzzle elements (i.e., motivate subjects to solve a problem).

Firstly, by means of using gamification in a virtual world, we want an adequate reflection of the real world problem; secondly, an increase in the motivation of subjects; and thirdly, an enhancement of the effects of social distance, thus leading to an increase in the quality, granularity, and structure of resulting process models.

As described in Section 2.2, experiences and decisions which are not self-experienced are social distant. In other words, procedures or decisions where one is not actively participating are, according to CLT, psychological distant, and in this regard social distant. Hence, the idea evolved to create a manner in which a low as well as high social distance is experienced. Therefore, to create a low and a high social distance, one group is actively involved in the process while another group only has a passive position (cf. Section 4.4). As a consequence, since the passive group has no possibility to intervene in the process, they are confronted with a higher social distance than the active group because the procedures and decisions in the scenario are not self-experienced.

In the following, the *order processing in the warehouse scenario* is introduced.
The scenario starts in the office of the warehouse. First of all, an order must be taken from the table which provides information about what and which items need to be processed. According the order, the following six items must be processed by the subjects as shown in Table 3.1.

Item	**Quantity**
Headphone	3
Smartphone	8
Display	2
Playstation 4 Console	3
Drone	2
Supersized Teddy Bear	1

Table 3.1: Items

At the storage racks, the subjects have the choice to get the items either with the forklift or the automatic picking system. Since the forklift can carry only one pallet at a time the items must be collected in a sequential order. The automatic picking system comprises several grappler allowing to collect all items separately or at once. Afterwards, items are disclosed at the collection point and must be checked for completeness. The next step is to pack the items in appropriate boxes and, thereafter, the boxes are palletized. After placing each box on a respective pallet, the subjects have the choice how to transport the pallets to the shipping area either by using the forklift or the automatic loading system. As before, the forklift can transport the pallets only sequentially while the automatic loading system takes care of everything automatically. The distinguish feature of the automatic loading system is that the subjects can print the required delivery documents (i.e., bill of delivery and pallet receipts) in parallel. The latter is not possible when using the forklift. Thereafter, the pallets are labeled with the printed pallet receipts and are loaded on the trailer with the forklift. At the end, the bill of delivery is placed in the trailer and doors are closed.

Hereafter, the entire order processing in the warehouse scenario is presented and summarized as corresponding process model in Figure 3.1 and 3.2.

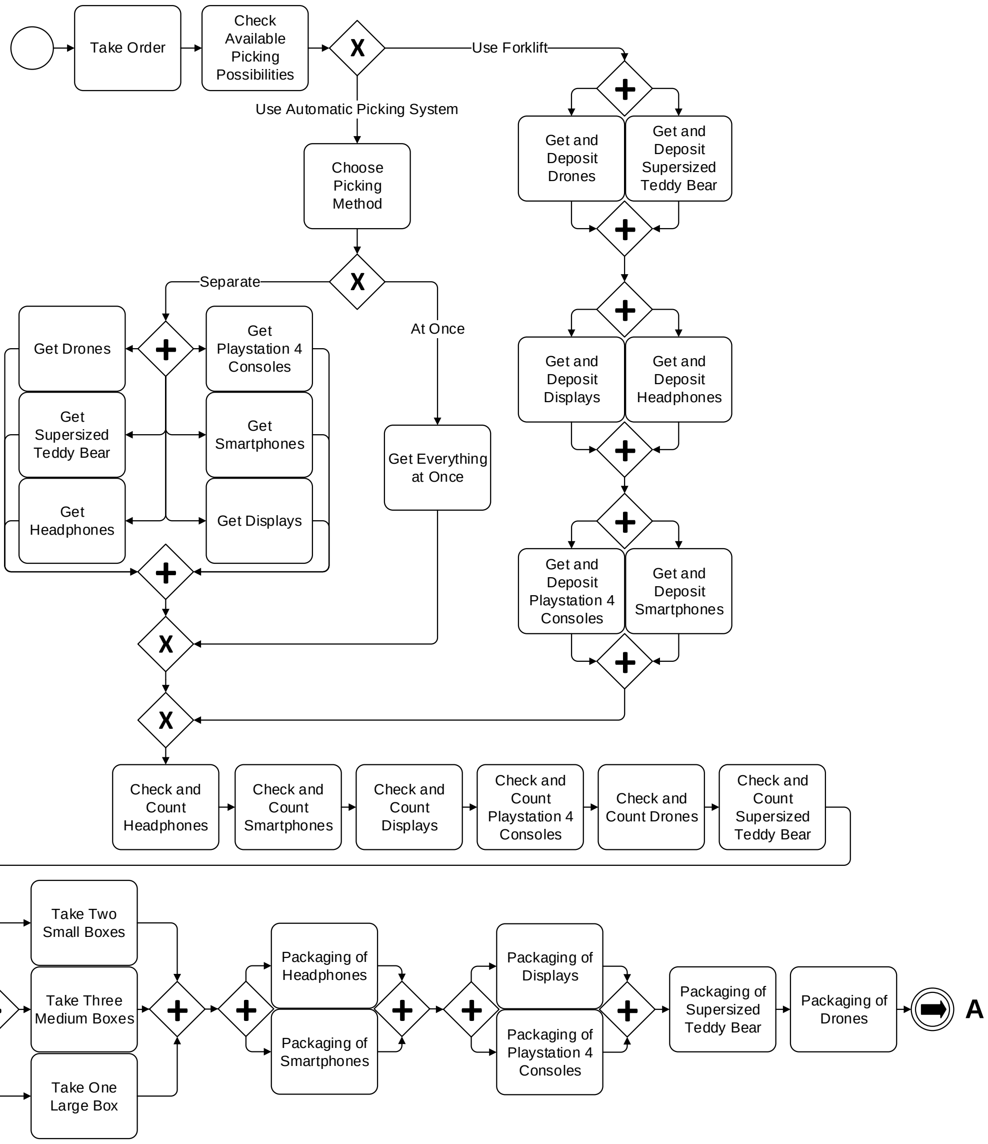


Figure 3.1: Process Model of the Warehouse Scenario - Part 1

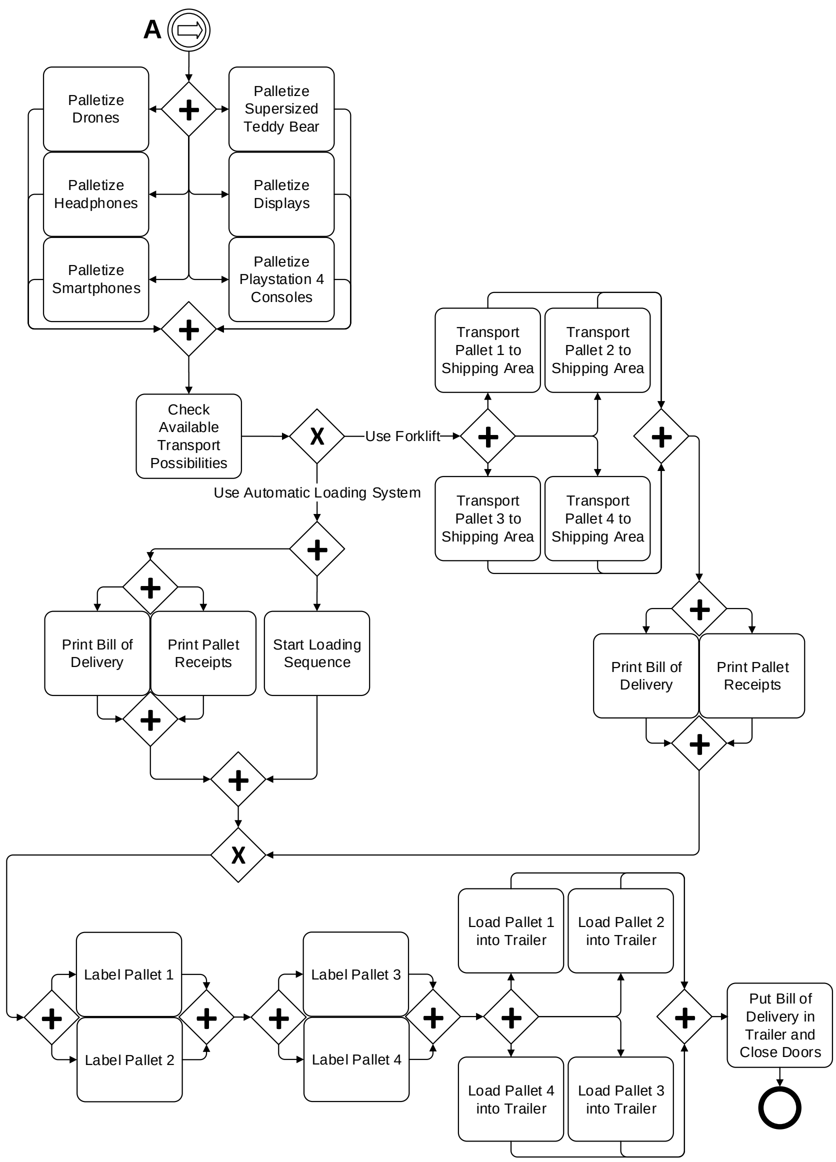


Figure 3.2: Process Model of the Warehouse Scenario - Part 2

As introduced in Section 3.1, a fundamental component of the experiment is to simulate a social distance which the subjects can perceive. Therefore, for perceiving a low social distance, a warehouse scenario in a 3D virtual world environment is developed. For implementing the respective 3D scenario several game engines are considered; e.g., *CryEngine*, *Unreal Engine* [15, 22]. Finally, we have decided that *Unity* meets all necessary requirements; e.g., integration with native code, deployment, and documentation. *Unity* is a game development platform including a game engine and integrated development environment to create interactive 3D and 2D content [91]. Besides a wide dissemination and a great community, it also offers a wide range of useful extensions.

After some considerations about the type and genre of the warehouse scenario, we have come to the conclusion that a simple *point and click scenario* is suitable for the experiment. We contend that a point and click scenario is appropriate for subjects because it can be learned quickly and easily within minutes and without any foreknowledge.

Afterwards, initial concept drawings and documents are made which described the gameplay, features, and appearances. Based on the initial concepts, the first scenario objects (e.g., pallets, crates) and a rough draft of the warehouse surroundings are created. Figure 3.3 shows a part of the warehouse surrounding, i.e., storage racks.

Figure 3.3: Storage Racks

Most scenario objects and graphics are designed and created within Unity but the possibilities are very limited. Therefore, the external tool *Blender* is used for the design and creation of objects and graphics [7]. *Blender* is a free and open-source 3D computer graphics software for creating animated videos, visual effects, models, and interactive applications.

For further assistance during the implementation, the extensions *Adventure Creator* and *Playmaker* are applied [35, 36]. *Adventure creator* is a feature-packed 2D and 3D adventure scenario creation kit which provides useful features and functionalities for creating a point and click scenario. *Playmaker* adds a powerful visual state machine editor to Unity for the making of A.I. behaviors, animation graphs, and interactive objects. The first playable prototype containing only a single scene (i.e., empty warehouse) acted as a *proof-of-concept* for testing and adding of features.

For better control, test, and overview a modular programming approach is chosen. Therefore, the whole implementation is separated into several independent modules and each module represents an area of the scenario. In total, there are seven modules in the respective scenario and for each module the necessary aspects (i.e., functions, items, scenario objects) are implemented separately. Upon completion and successful testing of each single module, all modules are combined. Table 3.2 and Figure 3.4 are showing all seven modules and the final layout of the warehouse as well as the chronological progress through the areas of the 3D scenario.

Module	**No.**
Office 1	1
Storage Racks	2
Collection Point	3
Packaging Area	4
Palletizing Area	5
Office 2	6
Shipping Area	7

Table 3.2: Modules

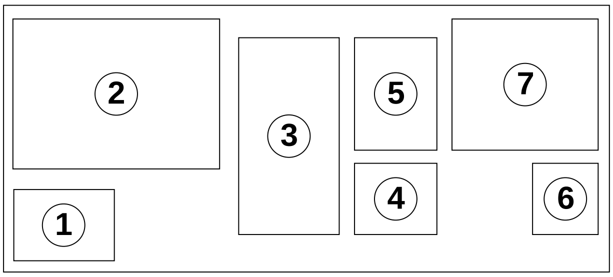


Figure 3.4: Layout

Afterwards, all dialogues and dialogue options are written. Dialogues serve as instructions for subjects and are pointing out what needs to be done next. For further assistance and to make navigation easier, static cameras are already pointing in the direction the subjects need to move for the next step, i.e., field of view is defined and cannot be changed. For interactions (e.g., take order, use forklift) so-called interactions points are

implemented and highlighted while hovering with the mouse-cursor and are initiated by pressing the left mouse button. Additionally, to counteract the language barrier and other linguistic problems, all texts in the scenario are available in English and German language. Before the scenario is going gold (i.e., final scenario build), an extensive test phase is carried out to fix bugs and to remove uncertain instructions.
Figure 3.5 shows the graphical user interface of the final 3D warehouse scenario. The graphical user interface is kept deliberately simple to avoid potential misunderstandings and problems. All items collected during gameplay (e.g., order, items, pallets) are stored and displayed in the inventory bar on the top of the screen (1). Additional accessories and interior are placed in the warehouse to create and improve an immersive virtual environment, i.e., created perception in a non-real world (2). The avatar provides subjects with informations and instructions about what needs to be done next and is controlled with the mouse (3). As explained above, interactions are performed by clicking on interaction points (4).

Figure 3.5: Graphical User Interface

4

Experiment Planning and Definition

An experiment is conducted to investigate the effects of *psychological distance* (i.e., *social distance*) on the *process of process modeling* and resulting *artifacts*.

The implementation of an experiment is not trivial and requires a proper arrangement in order to guarantee that data obtained is valid and risks are minimized. Therefore, the experiment planning and definition strongly considers recommendations given in [95] to guarantee the validity of the results.

First, the definition of *why* the experiment is carried out is given and thereupon follows the instruction of *how* the experiment is performed.

Section 4.1 explains the context of the experiment and define its goal. Section 4.2 introduces the context selection. The hypotheses considered for testing are introduced in Section 4.3. Experimental setup is described in Section 4.4. The experiment design is explained in Section 4.5. Section 4.6 discusses factors threatening the validity of results.

Figure 4.1 gives an overview on the structure of this section.

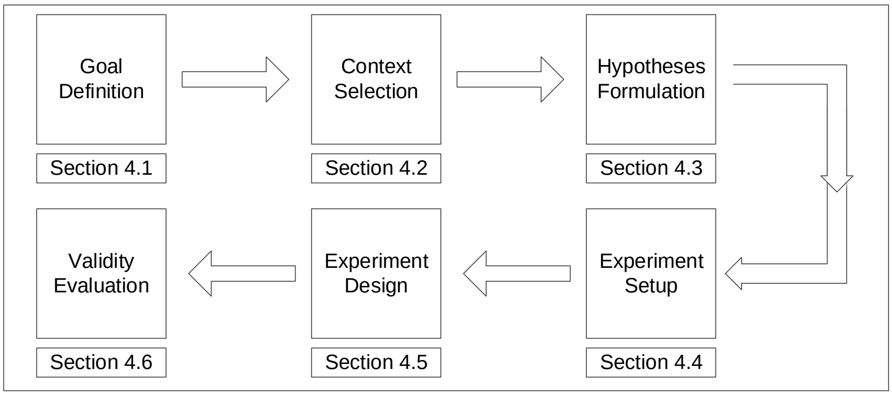


Figure 4.1: Experiment Planning and Definition

4.1 Goal Definition

In enterprises, process models are either created by in-house teams or external consultants. Respective process designers are responsible for interviewing process participants and capturing gathered knowledge in process models. However, these process designers are often not directly involved in the business process to be documented; e.g., they may be a staff member of the quality assurance department. In other cases, due to limited resources, enterprises assign such modeling tasks to external consultants [73, 86]. For want of information, the risk involved here is that resulting process models may differ a lot and the documentation of the real world business process is flawed and inadequate. However, it is not well understood and still unclear how such an increased psychological distance, in our context the social distance, affects the quality, granularity, and structure of process models. To close this gap, this thesis investigates the following fundamental research question:

Is the process of process modeling, i.e., the quality, granularity, and structure of process models resulting from it, affected by the social distance process designers have on respective business processes?

Despite the large number of research on process model quality [42, 54, 59, 64, 84], granularity [33, 45], and structure [55, 70] hardly research considering the cognitive aspects in the context of process modeling exist [24, 25, 26, 62]. In particular, it is not well understood how and if cognitive aspects actually lead to minor process model quality (i.e., deficiencies regarding syntactic, semantic, pragmatic, and perceived quality), and how they impact granularity and structure of process models. Until now, it has been shown that there exists a correlation between the psychological distance (i.e., social, spatial, temporal, and hypothetical distance) and their influence on the resulting process models [41, 99]. Continuing the previous experiment, the emphasis is one aspect of the psychological distance: the *social distance*. According to CLT, however, existing *social distance* to objects influences the way we act and, therefore, presumably also impacts the way how process models are created. Based on a controlled software experiment, this thesis investigates the influence social distance has on the *process of process modeling* and its *outcomes*. The experiment varies social distance with the use of gamification in a 3D virtual world to learn whether social distance has any influence on the quality and granularity as well as structure of the resulting process models.

A proper experiment definition in information system research ensures a safe implementation of an experiment and minimizes or even eliminates potential risks threatening the experiment. As a starting point, for goal definition of the experiment, we use the *Goal Quality Metric (GQM)* proposed in [5] defined as follows:

Object of Study: The *objects of study* are resulting process models created by subjects of the experiment while confronting different *social distances*.

Purpose: The *purpose* of the experiment is to evaluate the resulting process models with respect to the influence of social distance on the *process of process modeling*.

Quality Focus: The main effect studied in the experiment is the *level of construal*. To measure the level of construal the focus is set on the *quality, granularity*, and *structure* of each resulting process model.

Perspective: The *perspective* is set from the point of view of researchers. We want to find out if there are any differences in the process models confronting different social distances.

Context: The experiment is conducted at the Institute of Databases and Information Systems at Ulm University. Students and research assistants with basic and advanced knowledge in process modeling are invited. The study is conducted as a *single object study* and can be judged as being a *randomized, blocked, and balanced single factor experiment* [95] (cf. Section 4.5).

The focus is set to the measurement of the level of construal of each process model and is defined in Table 4.1 as goal definition template:

Analyze	*process models*
for the purpose of	*evaluating*
with respect to their	*level of construal*
from the point of view of	*researchers*
in the context of	*students and research assistants.*

Table 4.1: Goal Definition Template

4.2 Context Selection

Obviously, the most significant results of an experiment are achieved in a *practical environment* with trained and professional employees. However, it is not reasonable to perform an experiment in a practical environment. A practical environment involves unsuspected risks and, therefore, it is advisable to perform an experiment in a *controlled environment*, which is comparable to a practical environment, i.e., enclosure in which measures are taken to provide an environment that meets certain requirements. On the one hand, this option reduces the risks of an experiment and, on the other hand, it reduces the emerging costs performing an experiment [95].

Our experiment participate students and research assistants in a controlled environment and, hence, is run *off-line*, i.e., not in a practical environment. Therefore, not much effort is needed for creating and defining the environment in which the experiment is run. The experiment provides an insight to the research question (cf. Section 4.1) and, thus, may serve as a foundation for further experiments. In addition, the results can be transferred to a practical environment and the experimental context provides other researchers with excellent opportunities to replicate the experiment.

4.3 Hypotheses Formulation

The *hypothesis* describes in concrete terms what are the intentions of an experiment. Therefore, a hypothesis has to be clearly and unambiguously stated. In this context, two types of hypotheses have to be formulated: *null hypothesis* and *alternative hypothesis*.

Null Hypothesis $\mathbf{H}_0$ describes the assumption that no effects or differences between an old (μ_{old}, i.e., expected value of the old approach) and new approach (μ_{new}, i.e., expected value of the new approach) exist in the experimental setting. Initially, the null hypothesis is assumed to be true and the experiment tries to reject or disprove it. The only reason for differences in observations are coincidental, i.e., H_0: $\mu_{old} = \mu_{new}$

Alternative Hypothesis $\mathbf{H}_1$ is exactly the opposite of the null hypothesis and describes the existence of an association between research question and obtained experimental results. It is typically what the researcher wants to show, i.e., H_1: $\mu_{old} < \mu_{new}$

Based on the goal of our experiment (cf. Section 4.1), the following hypotheses are derived: The experiment investigates whether *social distance* (i.e., low (μ_1) and high (μ_2)) influences the *level of construal* during the *process of process modeling* and, thus, the quality, granularity, and structure of the corresponding process model. In total, we have derived seven hypotheses: four referring to the quality dimensions (i.e., *syntactic, semantic, perceived*, and *pragmatic quality*), one referring to the *level of granularity*, one referring to the *process model structure*, and one referring to *additional factors*:

Does social distance lead to an increase of the
syntactic quality *when modeling a process?*

$H_{0,1}$: There are no significant differences in the syntactic quality when modeling processes with low social distance. $H_{0,1}$: $\mu_2 = \mu_1$
$H_{1,1}$: There are significant differences in the syntactic quality when modeling processes with low social distance. $H_{1,1}$: $\mu_2 < \mu_1$

Does social distance lead to an increase of the
***semantic quality** when modeling a process?*

$H_{0,2}$: There are no significant differences in the semantic quality when modeling processes with low social distance. $H_{0,2}$: $\mu_2 = \mu_1$
$H_{1,2}$: There are significant differences in the semantic quality when modeling processes with low social distance. $H_{1,2}$: $\mu_2 < \mu_1$

Does social distance lead to an increase of the
***perceived quality** when modeling a process?*

$H_{0,3}$: There are no significant differences in the perceived quality when modeling processes with low social distance. $H_{0,3}$: $\mu_2 = \mu_1$
$H_{1,3}$: There are significant differences in the perceived quality when modeling processes with low social distance. $H_{1,3}$: $\mu_2 < \mu_1$

Does social distance lead to an increase of the
***pragmatic quality** when modeling a process?*

$H_{0,4}$: There are no significant differences in the pragmatic quality when modeling processes with low social distance. $H_{0,4}$: $\mu_2 = \mu_1$
$H_{1,4}$: There are significant differences in the pragmatic quality when modeling processes with low social distance. $H_{1,4}$: $\mu_2 < \mu_1$

Does social distance lead to an increase of the
***level of granularity** when modeling a process?*

$H_{0,5}$: There are no significant differences in the level of granularity when modeling processes with low social distance. $H_{0,5}$: $\mu_2 = \mu_1$
$H_{1,5}$: There are significant differences in the level of granularity when modeling processes with low social distance. $H_{1,5}$: $\mu_2 < \mu_1$

Does social distance lead to an increase of the
***process model structure** when modeling a process?*

$H_{0,6}$: There are no significant differences in the process model structure when modeling processes with low social distance. $H_{0,6}$: $\mu_2 = \mu_1$
$H_{1,6}$: There are significant differences in the process model structure when modeling processes with low social distance. $H_{1,6}$: $\mu_2 < \mu_1$

Does social distance lead to an increase of the
additional factors *when modeling a process?*

$H_{0,7}$: There are no significant differences in the additional factors when modeling processes with low social distance. $H_{0,7}$: $\mu_2 = \mu_1$
$H_{1,7}$: There are significant differences in the additional factors when modeling processes with low social distance. $H_{1,7}$: $\mu_2 < \mu_1$

Additionally to introduced hypotheses, the following factors need to be considered when planning an experiment, i.e., *type-I-error, type-II-error*, and *power*.

Type-I-Error: Rejecting the null hypothesis although it is in fact true is called a *type-I-error*. P(type-I-error) = P(reject H_0| H_0 is true)

Type-II-Error: The second type of error is not to reject the null hypothesis although the alternative hypothesis is true. This kind of error is called a *type-II-error*.
P(type-II-error) = P(not reject H_0| H_0 is false)

Power: The *power* of a statistical test is used to indicate the probability of rejecting the null hypothesis and the alternative hypothesis is true.
Power = P(reject H_0| H_0 is false) = 1 - P(type-II-error)

Therefore, it is generally advisable to choose a statistical test with a high power as possible to reduce the probability of a wrong assumption (cf. Section 6.3).

4.4 Experiment Setup

Based on the goal definition template (cf. Table 4.1), this section describes *subjects*, *objects*, *factor* and *factor levels*, and *response variables* of our experiment.

Selection of Subjects: Since it is not possible to evaluate the entire desired population it is required to select a representative sample group. This enables to reason for the whole population. A sample group is also known as a defined collection of *subjects* (i.e., participants in an experiment) with similar properties [23]. Ideally, process designers in enterprises are modeling experts. Typically they only obtain basic training and, hence,

have limited process modeling skills [96].
Therefore, the selected subjects are students and research assistants. Any student and research assistant with basic and advanced knowledge of process modeling in general and about *Business Process Model and Notation (BPMN)* is able to participate.

Selection of Objects: After selecting subjects, the *objects of the study* have to be selected. The objects are the entities that are studied in the experiment.
The object of study are the resulting process models of each subject using process modeling language *Business Process Model and Notation 2.0 (BPMN 2.0)* [66] (cf. Section 4.1). To ensure familiarity and competence of subjects and to ensure that differences in quality, granularity, and structure of process models are not caused due to a lack of familiarity, but rather due to differences in social distance, we choose an easy and understandable scenario, i.e., *order processing in a warehouse* (cf. Section 3.3).
We created task descriptions in two versions reflecting different social distances (cf. Appendix A). One group is directly involved in the process while the other group is only indirectly involved. More precise, subjects dealing with low social distance are playing the warehouse scenario and, on the other hand, subjects dealing with high social distance are watching the warehouse scenario in a video. The description of the task is rather abstract and short to give subjects the possibility to model it as detailed as they like.

Factor and Factor Levels: *Factor* and *factor levels* of an experiment are an important consideration since they manipulate and control effects in the experiment. Generally, a factor is divided into two or more factor levels and these factor levels have an influence on the response variables.
The factor considered in our experiment is the *social distance*. Factor levels are *low social distance* and *high social distance* and can be manipulated and controlled by varying the distance: i.e., modeling the order processing in a warehouse either based on the playable 3D scenario (i.e., low social distance) or video (i.e., high social distance).
As described in Section 3.3, in the context of our experiment, aspects of gamification in a 3D virtual world are used to emerge a low social distance. Therefore, in order to ensure the effects of social distance (cf. Section 2.2), subjects have full control and freedom of choice about the process and decisions. Subjects dealing with high social distance are watching the warehouse scenario in a video. Therefore, they have no

possibility of intervening and need to adopt a passive position. In our view, a passive participation without the option of intervening will emerge a high social distance as opposed to an active participation. Unlike the playable scenario, subjects only perceive one way through the scenario and therefore have no freedom of choice. Hence, in the warehouse scenario there are two main decisions, i.e., forklift or automatic picking system and forklift or automatic loading system (cf. Section 3.3). Thereby, in the video only the same decisions are used. For getting the ordered items from the storage racks the forklift is used and for transporting the palletized items to the shipping area the automatic loading system is used. The other decisions are mentioned but never used.

Response Variables: *Response variables* can only be measured or observed and must depend on the factor levels. A change in the factor levels lead to a change in the response variables. The choice of response variables determine the measurement scales and range of variables (i.e., categorical or continuous) and are used later for evaluation. The choice of the appropriate statistical test depends on the basis of the chosen measurement scales and range of variables.
As response variable, we consider the *level of construal* which cannot be directly measured. Considering the level of construal, everything being distant from us is created more abstract (cf. Section 2.1). Hence, we assume that the level of construal impacts quality, granularity, and structure of the resulting process models. Therefore, statistical methods as well as an established analysis framework to measure the quality of process models are applied [43]. Additionally, we identify the level of granularity and analyze the process model structure using process metrics proposed in [56].
We assume that high social distance may lead to course-grained, more abstract, and imprecise process models (i.e., reflecting a low process model quality, level of granularity, and process model structure), while low social distance may result in more fine-grained and precise process models (i.e., reflecting a high process model quality, level of granularity, and process model structure). An adapted *semiotic theory framework* is used to determine *process model quality* [49]. The latter is characterized by the following four dimensions: *syntactic, semantic, pragmatic*, and *perceived quality*.

The *syntactic quality* of a process model is measured by counting the number of syntactical errors (i.e., syntactical rule violations) of the applied modeling language, i.e., BPMN 2.0 [66].

The *semantic quality* is subdivided into the aspects *correctness, completeness, relevance*, and *authenticity* of a process model. *Correctness* expresses that all elements in the process model are correct and relevant to the business process. *Completeness* implies that no correct and relevant elements are missing in the final process model. Further, *relevance* connotes that all elements in the process model are relevant for the business process. In contrast to completeness, superfluous elements are also considered. Finally, *authenticity* expresses that the chosen representation gives a true account of the domain. In general, semantic quality is determined on a 7-point Likert scale ranging from strongly disagree (0) to strongly agree (6).

The *pragmatic quality* describes the process model comprehension and is measured by the *level of understanding*. Therefore, a 7-point Likert scale ranging from very hard to understand (0) to very easy to understand (6) is applied.

Finally, *perceived quality* depends on the degree to which a subject agrees with the resulting process model [78]. Therefore, the following questions are used as proposed in [77]:

1. Does the final process model agree with your view of business process?
2. Are there significant aspects that are missing in the final process model?
3. Does the final process model describe the business process accurately?
4. Are there any serious mistakes in the final process model?
5. Would you have done the final process model in a different way?

Derived from the questions above, perceived quality can be further subdivided into *agreement, missing aspects, accurate description, mistakes*, and *satisfaction*. *Agreement* expresses to which degree the process model matches with the real world business process. *Missing aspects* rates whether significant aspects are missing in the resulting process model. In turn, *accurate description* expresses how accurate the process model matches the real world business process. *Mistakes* corresponds to the subject rate indicating whether there are serious mistakes in the resulting process model. Finally, *satisfaction* expresses the degree of satisfaction a subject has with his process model. The questions are put after the modeling task to score each question on a 5-point Likert scale ranging from strongly disagree (0) to strongly agree (4).

Level of granularity is measured by the complexity of the resulting process models. Therefore, the *number of activities, gateways, nodes, edges*, and *elements* as well as the *number of possible execution paths* are counted.

Process model structure is analyzed with a set of process metrics presented in [56, 60, 75]. These process metrics consists of four determinants, i.e., *separability, sequentiality, cyclicity*, and *diameter*. Therefore, we consider a process model to be a kind of graph G = (N,E) with at least three node types $N = T \cup S \cup J$, i.e., *tasks T*, *splits S*, *joins J*, and *edges* $E \subseteq N \times N$.

Separability: Π is defined as the ratio of the number of cut-vertices (i.e., a node whose deletion separates the process model into multiple components) to the total number of nodes in the process model. An increase in $\Pi(G)$ should imply a decrease in error probability of the process model [56].

$$\Pi(G) = \frac{|n \in N| n\ is\ cut - vertex|}{|N| - 2}$$

Sequentiality: The degree to which the model is constructed of pure sequence tasks. Sequentiality Ξ relates edges of a sequence to the total number of edges in a process model. An increase in $\Xi(G)$ should imply a decrease in error probability of the process model [56].

$$\Xi(G) = \frac{|e \in E| e \in (T \times T)|}{|E|}$$

Cyclicity: $|N_C|$ gives the number of nodes on cycle and cyclicity CYC_G relates it to the total number of nodes in a process model. An increase in CYC_G should imply an increase in error probability of the process model [56].

$$CYC_G = \frac{|N_C|}{|N|}$$

Diameter: Describes the length of the longest path from a start node to an end node in the process model [75].

Moreover, *number of modeling steps* and *modeling duration* are taken into consideration. Further, we determine *mental effort* for creating a process model and *naming* of each process model activity. Mental effort is rated on a 7-point Likert scale ranging from extreme low mental effort (0) to extreme high mental effort (6). Activity naming is rated on a 3-point Likert scale ranging from normal detailed (0) to complex detailed (2). Therefore, we consider each label of an activity of the process models and evaluate the level of detail.

Summarizing all the above, each process model of the subjects is reviewed for their respective quality level, level of granularity, structure, and the additional factors. These criteria are used later to determine whether the two different social distances (i.e., low and high) have an influence on the process of process modeling. Figure 4.2 provides a brief overview of the factor, factor levels, and variables in a research model.

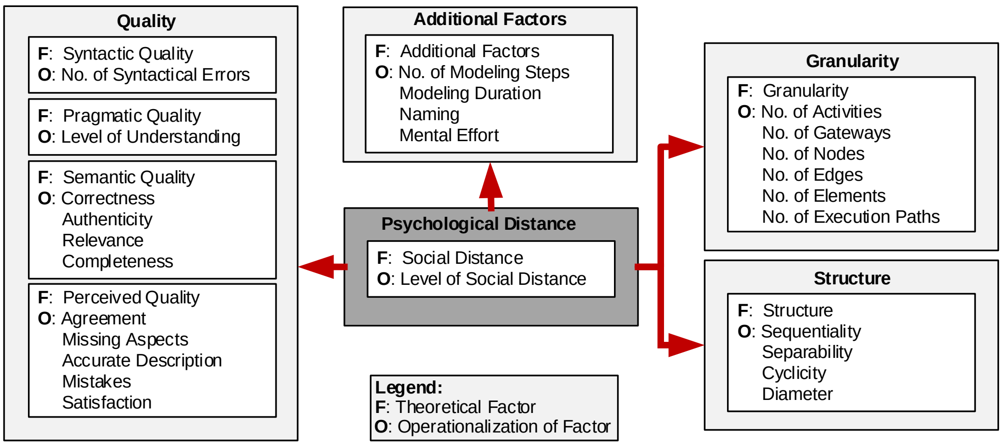


Figure 4.2: Research Model

4.5 Experiment Design

After formulation of hypotheses and definition of the experimental setup an appropriate experiment design has to be determined. An experiment design describes the structure and progress of an experiment. The selection of an unsuitable experiment design could cause erroneous data or lead to a failure of the experiment. There are three general principles that must be guaranteed for a correct experiment design.

Randomization: *Randomization* is a principle based on chance by which subjects are assigned. By randomization an uniform distribution between subject groups can be achieved. In our experiment, we assign each subject into one of two groups, i.e., low or high social distance. Assigning subjects to groups, randomization is used.

Blocking: In each experiment, undesired effects may occur that probably have an effect on subjects. Hence, if there are no interests in these effects, a principle called *blocking* can be used. Therefore, the subjects are grouped into two blocks, i.e., one dealing with low social distance and one dealing with high social distance.

Balancing: When investigating differences between two subject groups, it is desired to use a balanced design, i.e., each group has an equal number of subjects. Thus, we avoid imbalance between groups for each social distance in our experiment.

Summarizing, we use a *randomized, blocked*, and *balanced single factor experiment*. Further, the study is characterized as a *single object study* in terms of the number of subjects and objects. In particular, among all subjects, a single object study is conducted on a single subject and a single object [95]. Figure 4.3 illustrates the chosen experiment design.

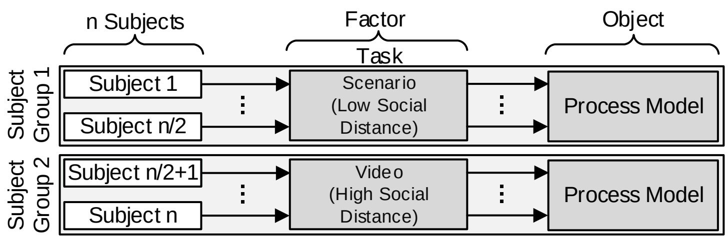


Figure 4.3: Experiment Design

Instrumentation: For measuring of response variables it is essential to apply an adequate *instrumentation* to guarantee that collected and analyzed data is valid. Obviously, instrumentations shall not influence the outcome of the experiment, but rather provide means for performing and to monitor it, without affecting the control of the experiment.
For the 3D warehouse scenario (i.e. low social distance), the respective application built in Unity is used (cf. Section 3.3). Hence, the entire scenario is realized in this application. After the respective scenario, the latter shuts itself down and the subjects continue to use the provided experimental platform.
For the other part of the experiment (i.e., high social distance), a video of the warehouse scenario is captured. For video capturing the tool *ActivePresenter* is used [3]. *ActivePresenter* is a desktop-camcorder for capturing videos or creating presentations and screencasts. To capture the respective scenario in a video, the scenario is played while the tool is recording in the background. Likewise in the playable variant, to counteract the language barrier and other linguistic problems, the video is recorded in English and German language. Further, to ensure that subjects catch every action and text, the play of the scenario is slowed down and sufficient pauses are integrated. For video playback any media player is suitable. Therefore, we use the free and open-source *VLC Media Player* [92].
Afterwards, the *Cheetah Experimental Platform (CEP)* is used by both groups [68]. CEP is developed to foster experimental research on business process modeling. CEP allows creating process models as well as integrating questionnaires. In particular, CEP is able to record every modeling step, i.e., timestamps, type of modeling action, and duration.
Before modeling any task, a *questionnaire* (cf. Table 4.2) must be filled out by subjects to characterize them and the individual skill levels. Subsequently, a second *questionnaire* for the purpose of gathering information about the subjects gaming experience needs to be answered (cf. Table 4.3).
The subjects use the modeling environment of CEP to resolve the modeling task of the warehouse scenario. All modeling actions plus modeling duration and needed modeling steps are logged and stored separately in a database. After modeling the task, subjects which played the scenario need to answer which decisions they made while playing the respective scenario, i.e., choosing forklift or automation systems (i.e., automatic picking

system and automatic loading system) (cf. Table 4.4). For evaluation of experimental results we use the admin environment of CEP with assistance of a self-developed evaluation sheet (cf. Appendix A). The individual evaluation points are described in Section 4.4.

Question	Possible Answers
Which description matches best your current work status?	Student, Academic, Professional
What is your gender?	Male, Female, Other
Course of studies	User-Defined Text
Overall, I am very familiar with the BPMN.	7-point Likert scale[1]
I feel very confident in understanding process models created with the BPMN.	7-point Likert scale[1]
I feel very competent in using the BPMN for process modeling.	7-point Likert scale[1]
How many years ago did you start process modeling?	User-Defined Text
How many process models have you analyzed or read within the last 12 months	User-Defined Text
How many process models have you created or edited within the last 12 months?	User-Defined Text
How many activities did all these models have on average?	User-Defined Text
How many work days of formal training on process modeling have you received within the last 12 months?	User-Defined Text
How many work days of self education have you made within the last 12 months?	User-Defined Text
How many months ago did you start using BPMN?	User-Defined Text

Table 4.2: Demographic Questionnaire

Question	Possible Answers
Are you familiar with video games?	7-point Likert scale[1]
Which platform do you prefer for playing video games?	Platform[2]
What is your favorite video game genre?	Genre[3]
How many hours per week do you spend playing video games?	User-Defined Text

Table 4.3: Game Questionnaire

Question	Possible Answers
At the first choice, have you chosen the Picking System or the Forklift? (If you watched the video, please choose the Forklift)	Picking System, Forklift
At the second choice, have you chosen the Loading System or the Forklift? (If you watched the video, please choose the Loading System)	Loading System, Forklift

Table 4.4: After Game Questionnaire

[1]Strongly Agree, Agree, Somewhat Agree, Neutral, Somewhat Disagree, Disagree, Strongly Disagree
[2]Computer, Nintendo, Playstation, Xbox, Phone or Tablet, Other
[3]Action, Action-Adventure, Adventure, Role-Playing, Simulation, Strategy, Sports, Other

4.6 Risk Analysis and Mitigations

In an experiment, certain adverse factors have to be taken into account. These factors may affect the results of the experiment. Therefore, it is important to pose the question, how valid are the obtained results?
In the experiment, we have four levels of validity on social distance to consider: *conclusion validity* (Is there a relationship between the treatment and the outcome?), *internal validity* (Are the effects caused by the treatment?), *construct validity* (Does the operational definition reflect the theoretical meaning?), and *external validity* (Can the results be generalized?). The four levels of validity are presented in Figure 4.4 [14].

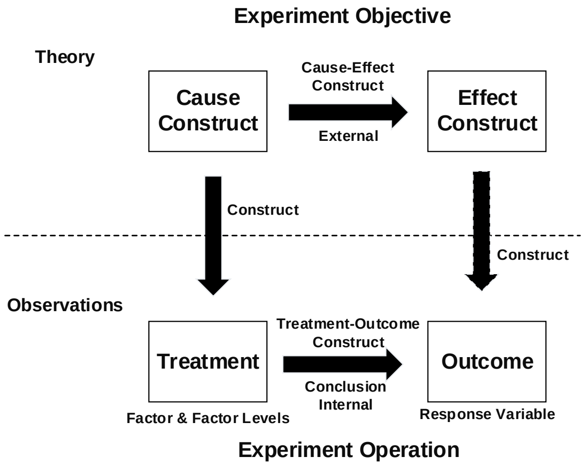


Figure 4.4: Levels of Validity

Threats to *conclusion validity* are:

The major threat regarding the conclusion validity is the use of a statistical test with low power. The power of statistical tests is the probability that correctly rejects the null hypothesis and reveals a true pattern in the data (cf. Section 4.3). Therefore, we use a low *significance level (i.e., p-value (p))* between $0.01 < p \leq 0.05$. This helps to ensure a strong presumption against the null hypothesis.
Another threat concerning the conclusion validity is the violated assumption of statistical tests. Specific statistical tests have certain requirements which must be met for successful testing; e.g., gaussian distribution, independent sample. In order to avoid the

violation and if assumptions seem uncertain we use the *Wilcoxon-Mann-Whitney-U-Test* (cf. Section 6.3).
Finally, a standardized application and procedure of the treatment is another important point that needs to be considered. Applying different procedures of the treatment between different appointments may affect the subjects positively or negatively. Hence, a standardized procedure is applied to subjects of all appointments (cf. Section 5.2).

Threats to *internal validity* are:

The selected modeling task is one of the most critical threats for internal validity. A completely unknown and hard to understand scenario may lead to a strong lack of familiarity. To ensure familiarity of subjects and to ensure differences in quality, granularity, and structure are not caused due to a lack of familiarity, but rather due to social distance, we choose an intuitive scenario, i.e., order processing in a warehouse (cf. Section 3.3). Badly designed instrumentation (e.g., forms, documents) may affect the experiment as well. Therefore, good practices and approved methods from literature and previous experiment are used to minimize respective effects (cf. Section 4.5).
Threats that might influence the modeling outcome include process modeling experience of the subjects involved and uneven distributions of subjects over two groups. With a sufficiently large group, however, the scope of experience varies. Furthermore, data validation ensures that in both groups the subjects are at least moderately familiar with process modeling (cf. Section 5.3). With randomization, an even distribution is guaranteed and, thus, it is assured that familiarity with process modeling is approximately the same in both groups (cf. Section 4.5). Particularly, this prevents faulty models due to lack of domain knowledge.
Another threat for internal validity is the process of maturation. To ensure that subjects are not negatively influenced by tiredness, boredom, or hunger, the experiment is conducted at a time of the day for which the mentioned frame of mind can be excluded. Furthermore, expected duration of the experiment is about 60 minutes. About 30 minutes are required to play or watch the warehouse scenario and another 30 minutes are required for process modeling and answering questionnaires. The composition of those two parts should prevent faulty models due to lack of motivation. All subjects are recruited on a voluntary basis combined with the prospect of a bonus (cf. Section 4.4).

Threats to *construct validity* are:

A major threat for construct validity is the inadequate preoperational explication of constructs. A not sufficiently defined preoperational definition of the experiment results in a poorly experiment execution and obtained results are invalid. For this purpose, planning and definition strongly considers recommendations given in [95] to guarantee the validity. Furthermore, from previous experiments a proper and approved preoperational design is used [41, 99].
Another threat regarding construct validity is the interaction of testing and treatment. The application of specific treatments (e.g., measuring the number of syntactical errors) may make subjects more sensitive and raises awareness on specific parts of the treatment. Therefore, instructions are rather abstract and simple to disclose no information about measured response variables.

Threats to *external validity* are:

A high threat to the external validity is involving students and research assistants instead of professionals, which might limit generalizability of results. However, subjects rather have profound knowledge in process modeling and experiments have shown that such kind of results are transferable to professionals [34]. Hence, we may consider them as proxies for professionals who have only obtained basic training.
Another threat is the resulting quality of process models. The quality of resulting process models always depends on quality of applied instrumentation. To mitigate this threat we use an up-to-date tool and modeling language, i.e., BPMN 2.0 and CEP (cf. Section 4.5).
Finally, a potential threat to external validity is the measuring of social distance with one modeling task. However, previous experiment has shown that psychological distance has an impact on the process of process modeling [41, 99]. Further, to mitigate and to improve generalizability, experiments in different environments or conditions one may conduct.

5

Experiment Operation

Section 5 summarizes the experiment operation (cf. Figure 5.1). Generally, the operational phase of an experiment consists of three steps: *preparation, execution*, and *data validation*. Therefore, Section 5.1 describes all necessary arrangements of experiment preparation. The progress of experiment execution is discussed in Section 5.2. Section 5.3 provides data validation and presents insights of collected data during the experiment.

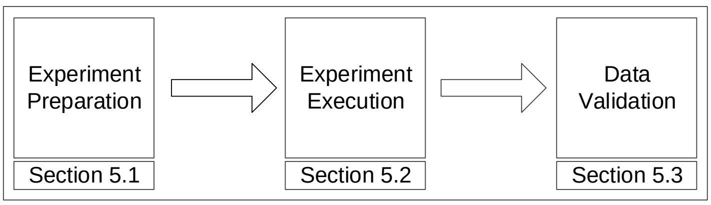


Figure 5.1: Experiment Operation

5.1 Experiment Preparation

As subjects for the experiment, students and research assistants with basic and advanced knowledge in process modeling are invited to join the experiment. A majority of the subjects are participants of the *Business Process Management (BPM)* course. The teaching objective of BPM is to introduce the principles and methods of business process management, i.e., initial insights into process modeling and analysis. For motivation and attraction to seriously take part in the experiment, subjects are offered bonus points for the BPM exercise lesson. Other subjects are participants on a voluntary basis or out of pure interest. However, none of the subjects are aware of the intention of the experiment. They only know that they take part in an experiment in the context of a thesis about process modeling. All subjects are guaranteed anonymity and discrete treatment of obtained data.

Before conducting the experiment pilot studies are performed. For each distance (i.e., low and high social distance) two pilot studies are performed whose results are used to eliminate ambiguities and misunderstandings as well as to improve task description and to optimize the 3D warehouse scenario and the video. Additionally, it is checked whether social distance between the modeling tasks is sufficiently large and perceived adequately.

Further, an evaluation sheet (cf. Appendix A) is created to assess the level of construal by analyzing the quality, granularity, and structure of resulting process models (cf. Section 4.4). In order to perform the experiment, CEP is configured and provided for all emerging data (cf. Section 4.5). The entire process of the experiment is planned within CEP (cf. Section 5.2). In CEP, relative to BPMN, it is defined when and in which sequence questionnaires and tasks (i.e., modeling tasks) appear. Changes can be made quickly and easily by editing the correlate activity. In addition, a database is established in which all emerging data is stored.

5.2 Experiment Execution

The experiment takes place in the computer lab of the Institute of Databases and Information Systems at Ulm University. Due to the spatial limitation of this computer lab only 10 subjects can participate the experiment at the same time. Therefore, several appointments within a period of two weeks are offered to the subjects. Each experiment session lasts about 60 minutes and is assigned to one distance, i.e., low or high social distance. Each appointment is based on the following procedure:

At the beginning, an introduction to the experiment is offered and explains the procedure of the experiment. Further, questions arising from the subjects are answered. Afterwards, worksheets with task description (cf. Appendix A) are handed out as well as a blank piece of paper for notes in the execution. Then, subjects start playing or watching the warehouse scenario. Afterwards, subjects are requested to fill out the questionnaire capturing their actual modeling experience (cf. Table 4.2). Subsequently, subjects need to answer another questionnaire on issues relating to their gaming experience (cf. Table 4.3). Finally, subjects are asked documenting the warehouse scenario based on their own experience and in a way they think it is performed. After finishing the modeling task, subjects assigned to low social distance (i.e., playing the scenario) need to indicate their choices which they have made during play, i.e., choosing forklift or automation systems (cf. Table 4.4). Then, all subjects fill out additional questions concerning perceived quality (cf. Section 4.4). At the end, subjects are able to provide feedback. All results (i.e., questionnaires, created process models) are collected with CEP and stored in a established database.

5.3 Data Validation

After performing the experiment, data is collected from 95 subjects in 19 sessions. Fortunately, only data from one subject is removed due to the following reason:

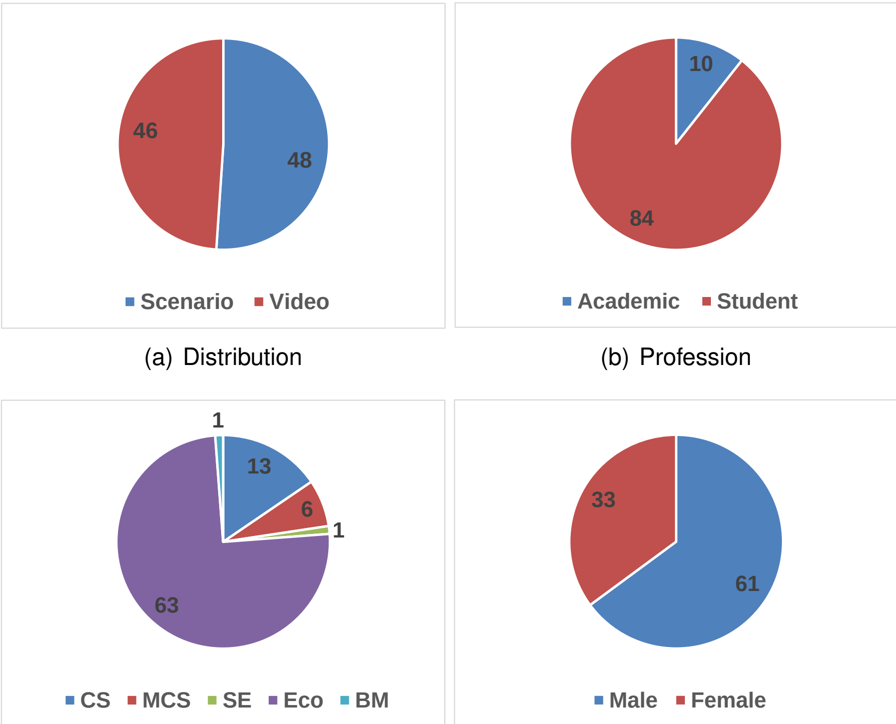
- The resulting process model is very flawed and questionable, i.e., the process model differ substantially from the task description. This may have negatively affected the data.

After removing, data of 94 subjects are considered in data analysis (cf. Section 6). The subjects consists of 84 students and 10 research assistants. The allocation of the students is presented in Table 5.1.

Background	**Number**
Computer Science (CS)	13
Media Computer Science (MCS)	6
Software Engineering (SE)	1
Economics (Eco)	63
Business Mathematic (BM)	1

Table 5.1: Allocation of Students

33 of them are female and 61 are male (cf. Figure 5.2). All subjects have stated that they are already experienced in BPMN. Therefore, we screened the subjects for familiarity with BPMN, since our research setup requires subjects to be familiar with BPMN. On a 7-point Likert scale the median value for familiarity with BPMN is 3, i.e., above average. For confidence in understanding BPMN process models, a median value of 3 is obtained. Perceived competence in creating BPMN models has a median value of 3. Prior to the experiment, subjects analyzed 19 process models and created 7 in average. Since all values range above average and subjects are familiar with process modeling, we may conclude that the participating subjects fit to the targeted profile. The full data set can be found in Appendix B.



(a) Distribution (b) Profession

(c) Course of Studies (d) Gender

Figure 5.2: Demographic Questionnaire

Concerning gaming experience, based on a 7-point Likert scale ranging from strongly disagree (0) to strongly agree (6) familiarity with video games from both groups is above the average (median value of 5 for low and 4 for high social distance). The favorite video game platform is a computer system and the preferred video game genres are action for low and sports for high social distance. Subjects with low social distance spend 4.06 hours per week playing video games while subjects with high social distance spend 2.28 hours per week playing video games. As a result of the video game questionnaire, we also conclude that participating subjects fit to the targeted profile. The full data set can be found in Appendix C.

6

Experiment Analysis and Interpretation

Section 6 describes the *statistical analysis* and *interpretation* of the experiment. Section 6.1 characterizes obtained data with assistance of visualization. Section 6.2 deals with data set reduction and Section 6.3 tests the hypotheses for validity. Finally, Section 6.4 provides a summary and discussion about the results (cf. Figure 6.1).

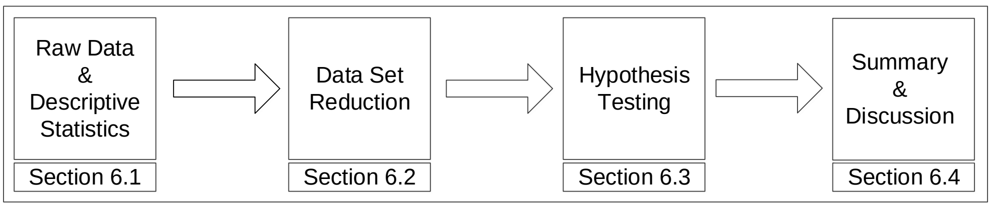


Figure 6.1: Experiment Analysis and Interpretation

6.1 Analysis of Raw Data and Descriptive Statistics

Descriptive statistics visualizes collected data as tables or graphics to provide a better comprehension and to gain first impressions of how data is distributed, concentrated, or spread out. Particularly worth mentioning is that descriptive statistics gives no decisions about the validity of the results and serves only as a provider of informations for a better understanding of the data.

The following tables show median values (i.e., middle value separating the lower half of the data from the higher half of the data) from collected data (cf. Appendix D). Therefore, each table consists of three classes (i.e. low, high, total) and each class represents median values for low and high social distance as well as the median value of both groups together. Furthermore, obtained results are visualized as box plots, i.e., low and high social distance. Box plots span a distance between the 25% percentile (i.e., values that are lower than the median) and the 75 % percentile (i.e., values that are greater than the median). Hence, the line in the box plot represents the median. Straight lines outside a box plot are so-called whiskers representing data not within the span of percentile. The end of the whisker represents the smallest and largest data set.

Table 6.1 and Figure 6.2 present the results of *syntactic* (i.e., number of syntactical error), *pragmatic* (i.e., level of understanding), and *semantic quality* (i.e., validity and completeness of process models).

	Syntactic	Pragmatic	Semantic			
Group	**No. Errors**	**Understanding**	**Correctness**	**Relevance**	**Completeness**	**Authenticity**
Low	2	4	4	4	3	3
High	3	3	5	5	4	4
Total	3	4	4	4	3	3.5

Table 6.1: Syntactic, Pragmatic, and Semantic Quality

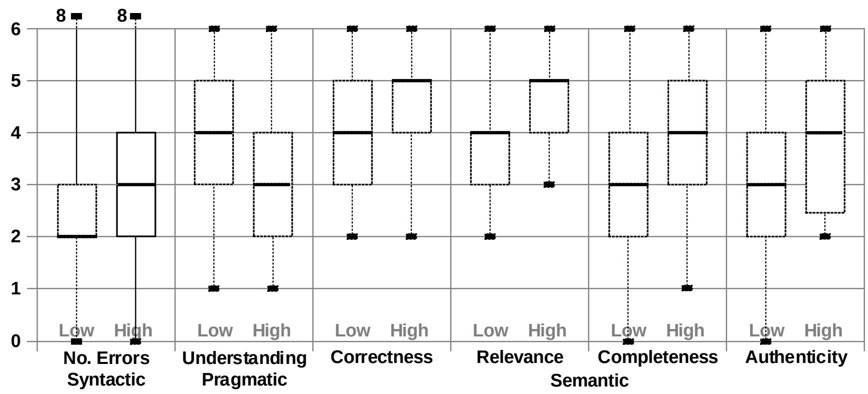


Figure 6.2: Syntactic, Pragmatic, and Semantic Quality

As shown in Table 6.1 and Figure 6.2, subjects with low social distance make less syntactical errors (median of 2) and the final process models reflect a better level of understanding (median of 4). Reversely, subjects with high social distance make more syntactical errors (median of 3) and the resulting process models reflect a smaller level of understanding (median of 3). This may be explained by the fact that the larger and more complex the process models are the greater the risk to lose the overview, thus resulting in more syntactical errors [53]. Semantic quality reflects notable differences and process models affected by high social distance seem to give a better account to the domain than process models affected by low social distance.

The obtained results for *perceived quality* (i.e., process model agreement) are shown in Table 6.2 and Figure 6.3.

Group	Agreement	Missing Aspects	Description	Mistakes	Satisfaction
Low	3	2	2	2	2
High	3	3	2	2	2
Total	3	3	2	2	2

Table 6.2: Perceived Quality

For perceived quality (cf. Table 6.2 + Figure 6.3), the only differences can be found in missing aspects (median of 2 for low and 3 for high social distance). However, there are no clear differences between the subject groups.

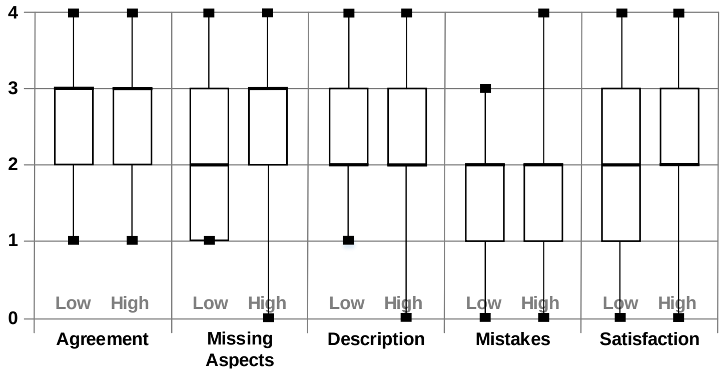


Figure 6.3: Perceived Quality

Table 6.3 and Figure 6.4 present the results regarding the *level of granularity* showing the *number of activities, gateways, nodes, edges, number of elements*, and the *number of possible execution paths* through a process model.

Group	No. Activities	No. Gateways	No. Nodes	No. Edges	No. Elements	No. Paths
Low	20	6	28	32	60	4
High	26	8	37.5	43.5	81	4
Total	22.5	7	32	36	68.5	4

Table 6.3: Level of Granularity

Regarding level of granularity (cf. Table 6.3 + Figure 6.4), process models affected by high social distance represent the warehouse scenario in more detail than process models affected by low social distance. This is especially evident in the overall number of elements. For low social distance the median for number of elements has a value of 60 while high social distance has a median of 81. In spite of the differences in the number of elements, the number of possible execution paths does not differ between the distances and has a median of 4.

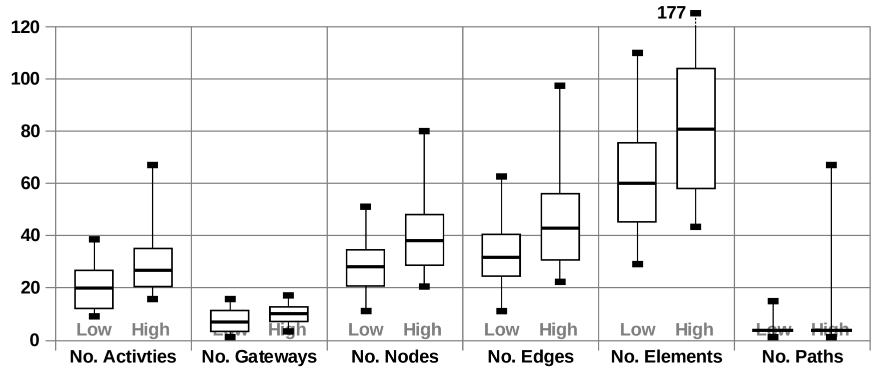


Figure 6.4: Level of Granularity

Following, Table 6.4 and Figure 6.5 present the results for *process model structure*, i.e., *sequentiality, separability, cyclicity*, and *diameter*.

Group	Sequentiality	Separability	Cyclicity	Diameter
Low	0.366	0.610	0	23
High	0.362	0.577	0.031	30.5
Total	0.364	0.596	0	27

Table 6.4: Process Model Structure

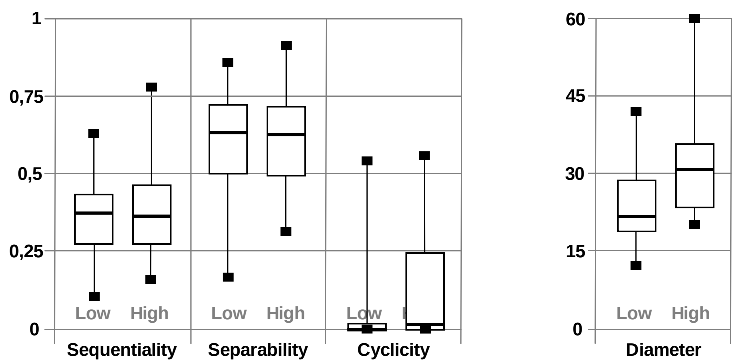


Figure 6.5: Process Model Structure

According Table 6.4 and Figure 6.5, there are only minimal differences in process model structure between the process models. However, diameter shows a clear distinction between the social distances. Again, process models affected by high social distance containing notable longer paths, i.e., median of 23 for low and 30.5 for high social distance.

Finally, the results of *additional factors* containing the *number of modeling steps, modeling duration (in seconds), naming of process model activities*, and *mental effort* for creating a process model are shown in Table 6.5 and Figure 6.6.

Group	No .Steps	Duration (sec)	Effort	Naming
Low	250.5	993	3	0
High	253.5	1489.5	3	1
Total	253.5	1210	3	0

Table 6.5: Additional Factors

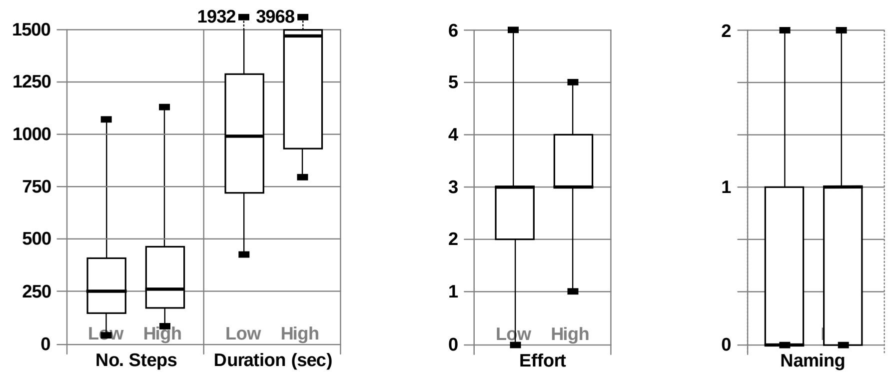


Figure 6.6: Additional Factors

Considering the additional factors (cf. Table 6.5 and Figure 6.6), the only noticeable aspect is the modeling duration. While the number of modeling steps slightly differ the modeling duration is very differentiating. Subjects with high social distance needed nearly 50% more time for modeling (median of 1489.5 sec) than subjects with low social distance (median of 993 sec). Despite the huge difference in modeling duration the mental effort for creating the process models is in both groups the same value (median of 3).

To gain an even better understanding of the data, results are visualized as various graphs (cf. Appendix E).

Our observations are merely based on descriptive statistics. For a more rigid investigation, hypotheses will be tested for statistical significance in Section 6.3.

Incidentally, one interesting side effect, however, not further explained in this thesis, regarding the granularity, quality, and structure, process models created by women tend to reflect a higher level of granularity, quality as well as process model structure.

6.2 Data Set Reduction

Generally, results of statistical analysis depends on the quality of input data. Faulty data may lead to an incorrect conclusion. Therefore, it is important to identify outliers and decide how to deal with them, i.e., a data set reduction might become necessary. Data set reduction is critical when analyzing data because removed data could modificate the results and that may lead to a loss of information.

In the experiment, we identified several outliers. For example:

- One subject modeled a process model with 64 branches.
- One subject needed for process modeling 3968 seconds.
- One subject made at process modeling 1146 steps.

We decided not to remove these subjects since they seem to be correct values and not a result of wrong process modeling or due to strange events that never will happen again. Removing them would falsify obtained results.

6.3 Hypothesis Testing

Even if descriptive statistics shows differences, hypotheses have to be tested to proof the assumptions. With support of test procedures null hypotheses need to be rejected. Initially, it is important to choose an adequate test procedure. [95] offers a selection of common methods. Thereby, each method has a critical threshold that must be observed in order to reject the null hypothesis. When testing hypotheses, it has to be observed whether results exceed the critical threshold or not. There are basically two outcomes:

- Result is significant: If the critical threshold is exceeded, results of the experiment are significant. The null hypothesis $\mathbf{H}_0$ is refuted and the alternative hypothesis $\mathbf{H}_1$ is accepted.
- Result is not significant: If the threshold is not exceeded, results of the experiment are not significant. The null hypothesis $\mathbf{H}_0$ cannot be refuted and needs to be accepted. This does not indicate a failure of the alternative hypothesis $\mathbf{H}_1$, but no difference could be found between the experimental results.

To test the hypotheses, we use the *One-Tailed Wilcoxon-Mann-Whitney-U-Test (U-Test)* [51, 85]. The U-Test is a non-parametric test with greater efficiency on non-gaussian distributions, such as a mixture of guassian-distributions. For testing the hypotheses, several values need to be calculated and the procedure reads as follows:

Every single data set is assigned with a numeric rank beginning with 1. Initially, the ranks of both groups are summed up separately, i.e., R_1 (i.e., low social distance) and R_2 (i.e., high social distance). Afterwards, a test value for U_1 (i.e., low social distance) and U_2 (i.e., high social distance) is calculated using the following equations:

$$U_1 = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1 \qquad U_2 = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2$$

Here, n_1 represents the number of subjects of group one (i.e., low social distance) and n_2 represents the number of subjects of group two (i.e., high social distance).
For a small sample size, it is sufficient to determine the smaller *u-value* and compare the u-value with the critical values for the U-Test [51].
However, since we have a larger sample size one can assume that U is approximately gaussian-distributed. Therefore, the *standardized value* (i.e., *z-value*) must be determined using the following equation:

$$z = \frac{U - m_u}{\sigma_u}$$

Whereas, U is the smallest calculated u-value from both groups and m_u and σ_u are the *mean* and *standard deviation* of U calculated as follows:

$$m_u = \frac{n_1 n_2}{2}$$

$$\sigma_u = \sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}}$$

The calculated z-value can be compared with the values in the standard normal table and, thus, it can be determined the probability of significance, i.e., *p-value*. A p-value below 0.05 indicates a significant result and the null hypothesis can be rejected. The calculated values of hypothesis testing can be found in Appendix E.

Table 6.6 and 6.7 are showing the results of hypothesis testing.

Syntactic Quality $\mathbf{H}_1$		
Response Variable	**p-value**	**Significant?**
Number of Syntactical Errors	0.046 (< 0.05)	Yes
Semantic Quality $\mathbf{H}_2$		
Response Variable	**p-value**	**Significant?**
Correctness	0.186 (> 0.05)	No
Relevance	<0.01 (< 0.05)	Yes
Completeness	<0.01 (< 0.05)	Yes
Authenticity	<0.01 (< 0.05)	Yes
Perceived Quality $\mathbf{H}_3$		
Response Variable	**p-value**	**Significant?**
Agreement	0.936 (> 0.05)	No
Missing Aspects	0.603 (> 0.05)	No
Accurate Description	0.529 (> 0.05)	No
Mistakes	0.424 (> 0.05)	No
Result Satisfaction	0.368 (> 0.05)	No
Pragmatic Quality $\mathbf{H}_4$		
Response Variable	**p-value**	**Significant?**
Level of Understanding	<0.01 (< 0.05)	Yes
Level of Granularity $\mathbf{H}_5$		
Response Variable	**p-value**	**Significant?**
Number of Activities	<0.01 (< 0.05)	Yes
Number of Gateways	0.039 (< 0.05)	Yes
Number of Nodes	<0.01 (< 0.05)	Yes
Number of Edges	<0.01 (< 0.05)	Yes
Number of Elements	<0.01 (< 0.05)	Yes
Number of Paths	0.435 (> 0.05)	No

Table 6.6: Results of Hypothesis Testing

Process Model Structure $\mathbf{H}_6$		
Response Variable	**p-value**	**Significant?**
Sequentiality	0.849 (> 0.05)	No
Cyclicity	0.091 (> 0.05)	No
Separability	0.617 (> 0.05)	No
Diameter	<0.01 (< 0.05)	Yes
Additional Factors $\mathbf{H}_7$		
Response Variable	**p-value**	**Significant?**
Number of Modeling Steps	0.395 (> 0.05)	No
Modeling Duration	<0.01 (< 0.05)	Yes
Mental Effort	0.285 (> 0.05)	No
Naming	0.384 (> 0.05)	No

Table 6.7: Results of Hypothesis Testing

As already indicated in raw data and descriptive statistics (cf. Section 6.1), several response variables are revealing significant differences. In particular, $\mathbf{H}_1$ and $\mathbf{H}_4$ show high significant results, whereas $\mathbf{H}_2$ and $\mathbf{H}_5$ likewise indicate high differences but not in a complete extent. However, $\mathbf{H}_3$ does not include any significant results and $\mathbf{H}_6$ as well as the tested additional factors $\mathbf{H}_7$ reveal a few significant results.
In spite of the fact that several of the tested results are showing significant differences, the alternative hypotheses are neither fully nor partial supported. Quite the contrary, the results are against all defined alternative hypotheses and are supporting only the null hypotheses (cf. Section 4.3). Therefore, the null hypotheses cannot be rejected and must be accepted while alternative hypotheses must be rejected with respect to the results of hypothesis testing.
A summary of the experiment analysis and interpretation as well as a in-depth discussion about possible factors which lead to that outcome can be found in the following section.

6.4 Summary and Discussion

Introduced in Section 4.1, the objective of the controlled experiment is to get new insights of the effects of social distance on the process of process modeling. Therefore, particularly focus is on the following fundamental research question:

Is the process of process modeling, i.e., the quality, granularity, and structure of process models resulting from it, affected by the social distance process designers have on respective business processes?

Hence, this experiment provides preliminary empirical results of the effects of social distance of a process designer to the modeled domain has on the creation of process models. Significant results are obtained for several tested aspects but in the end they are not in accordance with the defined alternative hypotheses. Surprisingly, obtained results do not agree with the theory and are contrary to the stated goal of the experiment. It is expected that a low social distance leads to fine-grained and precise process models while high social distance results in more course-grained and imprecise process models. However, the contrary effect occurred. Accordingly, process models influenced by high social distance reflect a higher process quality, level of granularity, and process model structure than process models influenced by low social distance.
What are the reasons for causing such an outcome contrary to the expectations and assumptions? Considering the fact that currently no work exist, in the context of process modeling, dealing with cognitive aspects, in particular with social distance, and gamification in a virtual world. Therefore, without replication or further results only vague assumptions about the reasons can be made.
First of all, despite the pilot studies and the necessary prearrangements, one reason may be the gamification approach. According to CLT and with properties obtained from the previous experiment, a similar experiment is conducted to investigate the effects of social distance on the process of process modeling. The difference in this experiment is that a gamification approach is used to enhance the effects of social distance, to increase the motivation of subjects, and for a better reflection of the real world problem. Hence, the gamification approach may has an opposite effect. Although, gamification should have a positive effect it is nevertheless possible that the effects of social distance and gamification cancel each other out.
It is also possible that gamification in a 3D virtual world has no effects on process modeling. Reason can be that the full virtual depiction of the domain is too abstract and, therefore, it is hard for subjects to create a corresponding concrete representation. It is conceivable, however, only to use inconspicuous game techniques instead of a full

virtual environment.
On the other side, the intended effects of social distance (i.e., experiences and decisions which are not self-experienced) do not exert a strong influence as expected. Maybe, in this context, this intention plays a relatively secondary role and the social distance refers stronger to the relation to other individuals.
Further, it must be considered that the distance between low and high social distance may be not large enough or that a social distance is not perceived.
Moreover, the handling of the 3D warehouse scenario (i.e. learn to play) may be another reason. Due to the fact that none of the subjects played the scenario before and there is no proper introduction to the scenario the subjects need to familiarize themselves first. The learning process disturbs or hinders the focus of the subjects and, thus, affects the process modeling later.
Further, it is conceivable that subjects playing the warehouse scenario are more easily distracted and busy than subjects watching the video. This follows from the fact that subjects watching the video just need to watch the scenario and are able to write down personal notes. In turn, subjects playing the scenario need to focus at the scenario and, thereby, making the notes fades into the background.
Another possibility is, regarding process capturing, that a passive observation is more effective than an imitation of the corresponding domain. With an observation of the process en bloc details attract more attention which are easily overlooked by an active participation.
In conclusion, there are many reasons that may have an impact on the results and, therefore, it is not possible to make a clear statement. On the contrary, especially after the obtained outcome, more results are needed by additional experiments either through replication, similar, or control experiments with different focal points. Only in this way it can be guaranteed to get a better understanding from the many influencing factors and, thereby, to define proper guidelines dealing with cognitive aspects as well as the use of gamification and virtual worlds on the process of process modeling.

7

Related Work

This thesis investigates the impact of social distance on the quality, granularity, and structure of process models. Accordingly, our work is related to these aspects.

By now, different frameworks and guidelines in respect to process model quality exist. Among others, the *SEQUAL framework* uses *semiotic theory* for identifying various aspects of process model quality [42], whereas *Guidelines of Process Modeling (GoM)* describe quality considerations for process models [6] and *Seven Process Modeling Guidelines (7PMG)* characterize desirable properties of a process model [59].

Moreover, significant research on factors affecting process model comprehensibility and maintainability exists. The influence of model complexity on process model comprehensibility is investigated in [57]. In turn, [74] analyzes the effect of modularity on process understanding. The influence of grammatical styles for labeling activities on model understanding is discussed in [58], and an experiment investigating the impact of secondary notations is presented in [82]. The impact of different quality metrics on error probability is discussed in [61]. [80] provides prediction models for true usability and maintainability of process models. Effects of how and at which level of granularity a process designer models a particular process is described in [33].

Notwithstanding, in the context of process modeling there exists little work looking at cognitive aspects. [62] presents the effects of reducing cognitive load on end user understanding of conceptual models. Understanding complex models quickly reach cognitive limits and the investigation on the cognitive difficulty of understanding different relations between model elements is described in [25].

Common to all these works is the focus on the resulting process model (i.e., the product of process modeling), while little attention has been paid on the process of the process modeling itself. The Nautilus project complements these approaches by taking a close-up view on the process of process modeling for tracing model quality back to different modeling strategies resulting in process models of different quality [69].

Considering the process model structure, [56] introduces a set of process metrics that investigates the influence of errors on domain factors of process models. [60] presents results from a questionnaire dealing with process model structure as a particular quality aspect and the connection with model, content, and personal related factors. Furthermore, influence of model and personal factors on the process model structure and understandability is studied in [75].

Aside of the impact of social distance on the quality, granularity, and structure of process models, gamification in a 3D virtual world is used to enhance the influence of social distance, for a better reflection of the real world problem, and to increase motivation of subjects. Meanwhile, there exist several research considering the use of gamification as well as virtual worlds and is related to our work.

[18] introduces gamification and the possibilities of use in a non-gaming context. Further, a shared understanding and findings from gamification concerning information systems in regard to collaboration and opportunities are presented in [18]. [2] discusses the effectiveness of gamification based on a quality service model analyzing the social and psychological motivations of participants. Thereby, a study investigating social factors towards gamification and the intention to use gamified services are discussed in [28].

Agile and efficient responds to changing requirements and consequential amendments to corresponding business processes are provided in [81] using a gamification and BPM approach incorporated into a social network. In turn, [67] concerns itself with adaptive case management and the improvement of process planning with the use of gamification. Furthermore, [10] provides preliminary evidence that blending business process management to gamification concepts can increase morale as well as the willingness for learning. Considerable work involving conceptual modeling of business processes in a 3D virtual world can be found in [11]. Thereby, a BPMN process editor is embedded in a 3D virtual world for extra support during process modeling. In addition, [94] provides an approach for collaborative business process modeling using a 3D environment technology. A similar use case in a 3D warehouse scenario to visualize storyboards for business process models is proposed in [39]. Finally, [71] takes a step further and combines collaborative process modeling with augmented reality, i.e., hybrid of perceived and computer-based reality.

All these works and researches cover many aspects in respect to process model quality, granularity, and structure as well as the use of gamification and virtual worlds. However, none of them has taken the social distance and gamification in a virtual world concurrently into account. However, more quantitative data is needed to support enterprises in the selection of appropriate process designers and to ensure ideal conditions for creating correct and sound process models. With this thesis we want to induce more experimental research in the BPM field to attain this endeavor.

8 Conclusion

This thesis investigates whether social distance affects the process of process modeling, i.e., the quality, granularity, and structure of process models resulting from it. In particular, based on a previous experiment and with the use of gamification in a virtual world, another controlled experiment with 95 participants is conducted to get further insights about the effects the social distance of a process designer to the modeled domain has on the creation of process models. Therefore, one group is perceiving a low social distance with the use of gamification in a 3D virtual world scenario (i.e., order processing in a warehouse) while another group is watching the same scenario in a video, thus perceiving a high social distance. Afterwards, both groups need to create a process model from the played or watched scenario based on their own experience.

The resulting process models are revealing in several aspects significant differences and results but are not in accordance with the defined alternative hypotheses. Surprisingly, and interesting at the same time, contrary to the expectations and assumptions and de-

spite the use of gamification in a virtual world, process models influenced by high social distance tend to reflect a higher syntactic, semantic, and pragmatic quality compared with the process models influenced by low social distance. Most notably, process designers with high social distance create more fine-grained and detailed process models.
Due to these observed differences and results the null hypotheses must be assumed and the defined alternative hypotheses need to be rejected. Nonetheless, the final results are very interesting and further research is highly recommended dealing with cognitive aspects affecting process modeling as well as the use of gamification and virtual worlds. Finally, generalization of the results needs to be confirmed by additional experiment, i.e., in order to obtain more accurate results allowing such a generalization, additional studies are needed either through replication, similar, or control experiments in other environments to investigate the influence of social distance as well as the use of gamification and virtual worlds on the process of process modeling. Furthermore, experiments related to other psychological distances (i.e., spatial, temporal, and hypothetical distance) will be subject of future work. Combining results for all psychological distances enables to extract guidelines on how modeling teams in enterprises should be put together for creating or optimizing business process models.

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A
Evaluation and Task Sheets

Evaluation Sheet

Number of Activities: __ Number of Edges: __

Number of Gateways: __ Number of Nodes: __

Overall: __ Number of Branches: __

Steps: __ Duration: __

Error Metrics

Sequentiality __ Cyclicity __

Diameter __ Separability __

Syntactic

Number of Rule Violations: __

Semantic (7-Point Scale: 0 to 6)

Indicator	Definition	Rating
Correctness	All statements in the representation are correct.	
Relevance	All statements in the representation are relevant to the problem	
Completeness	The representation contains all statements about the domain that are correct and relevant	
Authenticity	The representation gives a true account of the domain	

Pragmatic (7-Point Scale: 0 to 6)

Understandable: __

Perceived Model Quality (Mental Effort 7-Point Scale: 0 to 6; Others 5-Point Scale: 0 to 4)

Mental Effort __
Agreement __
Missing Aspects __
Accurate Description __
Mistakes __
Result Satisfaction __

Naming (3-Point Scale: 0 to 2)

Points: __

Figure A.1: Evaluation Sheet

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Code: 1111

Experiment

Play the 3D warehouse scenario. You may take notes during gameplay. Afterwards, model the played process using BPMN 2.0. Model the process based on your own experience and in the way you think it was performed. Furthermore, consider all eventualities in your process model. After finishing the modeling task, press “Finish Modeling”.

Thank you for participation!

Figure A.2: Task Sheet 1 - Low Social Distance

Code: 9999

Experiment

Watch the 3D warehouse scenario. You may take notes during playtime.
Afterwards, model the watched process using BPMN 2.0. Model the process based on your own experience and in the way you think it was performed. Furthermore, consider all eventualities in your process model. After finishing the modeling task, press “Finish Modeling”.

Thank you for participation!

Figure A.3: Task Sheet 2 - High Social Distance

B
Demographic Questionnaire

Based on demographic questionnaire (cf. Table 4.2), Figure B.1-B.4 present the obtained results. All questions refer to a period within the past 12 months. We only count work days within a year and, therefore, we assume that a year has about 250 work days. Familiar, competent, and confident are determined on a 7-point Likert scale ranging from strongly disagree (0) to strongly agree (6). The last question relates to the release date of BPMN. The first version of BPMN stems from May 2004.

Subject	Type	Distance	Profession	Gender	Course of Study
1	Game	Low	Academic	Male	Academic
2	Game	Low	Academic	Male	Academic
3	Game	Low	Academic	Female	Academic
4	Game	Low	Academic	Male	Academic
5	Game	Low	Academic	Male	Academic
6	Game	Low	Academic	Male	Academic
7	Game	Low	Academic	Male	Academic
8	Game	Low	Academic	Male	Academic
9	Game	Low	Academic	Male	Academic
10	Game	Low	Academic	Male	Academic
26	Game	Low	Student	Female	Economics
27	Game	Low	Student	Female	Economics
28	Game	Low	Student	Female	Economics
29	Game	Low	Student	Female	Economics
30	Game	Low	Student	Female	Economics
31	Game	Low	Student	Male	Economics
32	Game	Low	Student	Female	Economics
33	Game	Low	Student	Female	Economics
34	Game	Low	Student	Female	Economics
35	Game	Low	Student	Male	Computer Science
42	Game	Low	Student	Male	Computer Science
43	Game	Low	Student	Male	Computer Science
44	Game	Low	Student	Male	Economics
45	Game	Low	Student	Female	Media Computer Science

Figure B.1: Demographic Questionnaire - Low - Part 1

Subject	Type	Distance	Profession	Gender	Course of Study
46	Game	Low	Student	Male	Economics
47	Game	Low	Student	Female	Economics
48	Game	Low	Student	Female	Business Mathematics
62	Game	Low	Student	Male	Economics
63	Game	Low	Student	Male	Economics
64	Game	Low	Student	Female	Computer Science
65	Game	Low	Student	Male	Economics
66	Game	Low	Student	Male	Computer Science
67	Game	Low	Student	Male	Media Computer Science
68	Game	Low	Student	Male	Media Computer Science
69	Game	Low	Student	Female	Media Computer Science
70	Game	Low	Student	Female	Software Engineering
71	Game	Low	Student	Male	Computer Science
72	Game	Low	Student	Male	Computer Science
73	Game	Low	Student	Male	Media Computer Science
82	Game	Low	Student	Male	Economics
83	Game	Low	Student	Male	Economics
84	Game	Low	Student	Female	Economics
85	Game	Low	Student	Male	Media Computer Science
86	Game	Low	Student	Male	Computer Science
87	Game	Low	Student	Male	Economics
93	Game	Low	Student	Male	Economics
94	Game	Low	Student	Male	Economics
95	Game	Low	Student	Male	Computer Science

Figure B.2: Demographic Questionnaire - Low - Part 2

Subject	No. Process Analyzed/Read	No. Process Created/Edited	No. Estimated Activites	No. Training Days	No. Self Education (Days)	Familiar	Competent	Confident	Start BPMN (Months)
1	30	20	10	0	200	5	6	6	36
2	150	100	10	1	5	6	6	6	6
3	30	12	4	0	2	5	5	5	7
4	5	3	10	1	10	3	4	4	24
5	30	15	8	0	2	6	6	6	60
6	120	30	7	15	180	6	6	6	80
7	250	40	15	0	10	6	6	6	60
8	20	10	10	0	5	5	6	5	5
9	15	10	20	0	0	5	5	5	60
10	50	20	10	0	30	6	6	6	74
26	5	3	3	2	10	3	3	3	0
27	10	0	20	20	5	2	3	3	1
28	5	5	15	3	2	1	1	1	2
29	4	3	10	2	3	2	2	3	1
30	20	8	6	1	1	2	3	2	1
31	25	7	15	1	1	3	3	3	1
32	1	1	10	1	1	0	0	0	1
33	2	0	5	0	1	2	2	2	1
34	20	8	20	25	10	3	3	3	2
35	15	20	12	5	2	4	5	4	2
42	10	5	7	3	5	3	5	5	6
43	10	10	15	1	1	3	5	4	20
44	0	0	30	0	0	1	1	3	26
45	50	20	15	9	4	5	5	5	6

Figure B.3: Demographic Questionnaire - Low - Part 3

Subject	No. Process Analyzed/Read	No. Process Created/Edited	No. Estimated Activites	No. Training Days	No. Self Education (Days)	Familiar	Competent	Confident	Start BPMN (Months)
46	5	1	10	3	2	1	1	1	1
47	0	0	0	3	2	3	1	2	1
48	0	0	0	3	10	3	2	2	0
62	15	5	10	1	2	2	3	3	5
63	5	0	5	1	4	1	3	1	1
64	3	10	20	20	20	4	5	5	24
65	5	5	15	14	10	3	3	3	2
66	5	5	15	3	5	4	4	3	3
67	20	5	30	3	2	4	4	4	12
68	10	5	10	5	10	4	4	3	8
69	6	3	8	5	8	2	2	3	3
70	15	8	15	7	3	5	5	4	14
71	50	25	40	3	3	4	4	5	2
72	20	5	20	3	2	3	4	3	12
73	2	5	15	3	5	5	2	2	3
82	50	5	5	3	1	0	0	0	2
83	40	10	10	2	1	4	4	4	3
84	25	5	10	3	3	2	4	2	2
85	20	10	10	20	5	3	4	3	3
86	1	1	3	1	0	2	2	2	1
87	20	8	15	5	5	3	3	4	3
93	20	5	10	5	2	0	1	0	3
94	10	3	20	7	3	2	2	2	1
95	50	20	20	2	5	4	5	5	36

Figure B.4: Demographic Questionnaire - Low - Part 4

Subject	Type	Distance	Profession	Gender	Course of Study
11	Video	High	Student	Female	Economics
12	Video	High	Student	Male	Economics
13	Video	High	Student	Male	Economics
14	Video	High	Student	Male	Economics
15	Video	High	Student	Male	Economics
16	Video	High	Student	Male	Economics
17	Video	High	Student	Female	Economics
18	Video	High	Student	Male	Economics
19	Video	High	Student	Male	Computer Science
20	Video	High	Student	Male	Computer Science
22	Video	High	Student	Male	Economics
23	Video	High	Student	Female	Economics
24	Video	High	Student	Male	Computer Science
25	Video	High	Student	Male	Computer Science
36	Video	High	Student	Female	Economics
37	Video	High	Student	Male	Economics
38	Video	High	Student	Female	Economics
39	Video	High	Student	Female	Economics
40	Video	High	Student	Male	Economics
41	Video	High	Student	Male	Economics
49	Video	High	Student	Female	Economics
50	Video	High	Student	Female	Economics
51	Video	High	Student	Female	Economics

Figure B.5: Demographic Questionnaire - High - Part 1

Subject	Type	Distance	Profession	Gender	Course of Study
52	Video	High	Student	Female	Economics
53	Video	High	Student	Female	Economics
54	Video	High	Student	Male	Economics
55	Video	High	Student	Male	Economics
56	Video	High	Student	Female	Economics
57	Video	High	Student	Female	Economics
58	Video	High	Student	Male	Economics
59	Video	High	Student	Female	Economics
60	Video	High	Student	Male	Economics
61	Video	High	Student	Male	Economics
74	Video	High	Student	Male	Economics
75	Video	High	Student	Male	Economics
76	Video	High	Student	Male	Economics
77	Video	High	Student	Male	Economics
78	Video	High	Student	Male	Economics
79	Video	High	Student	Male	Economics
80	Video	High	Student	Male	Economics
81	Video	High	Student	Female	Economics
88	Video	High	Student	Male	Economics
89	Video	High	Student	Female	Economics
90	Video	High	Student	Female	Economics
91	Video	High	Student	Male	Economics
92	Video	High	Student	Male	Economics

Figure B.6: Demographic Questionnaire - High - Part 2

Subject	No. Process Analyzed/Read	No. Process Created/Edited	No. Estimated Activites	No. Training Days	No. Self Education (Days)	Familiar	Competent	Confident	Start BPMN (Months)
11	10	1	15	3	2	1	1	1	1
12	10	10	5	1	1	1	1	1	3
13	10	2	10	3	1	5	5	2	2
14	0	0	0	0	0	0	0	0	2
15	20	5	300	6	3	3	3	3	2
16	50	15	30	3	3	4	4	4	2
17	6	3	5	1	1	3	3	3	1
18	2	3	2	6	6	3	3	2	1
19	10	1	5	2	1	4	4	3	24
20	10	2	15	1	1	4	5	5	24
22	20	2	10	3	0	2	2	2	4
23	20	2	8	3	0	1	2	1	3
24	40	20	30	8	1	3	5	4	24
25	20	5	10	7	1	3	4	2	8
36	10	5	15	2	1	3	3	3	2
37	10	0	10	2	1	1	2	2	2
38	40	10	20	15	10	3	3	3	12
39	10	2	6	3	0	3	2	2	2
40	5	5	20	2	1	3	2	2	2
41	5	2	8	10	2	4	4	4	2
49	5	1	2	30	5	2	2	2	12
50	20	10	15	30	5	4	4	4	48
51	10	2	10	3	2	4	5	3	2

Figure B.7: Demographic Questionnaire - High - Part 3

Subject	No. Process Analyzed/Read	No. Process Created/Edited	No. Estimated Activites	No. Training Days	No. Self Education (Days)	Familiar	Competent	Confident	Start BPMN (Months)
52	25	10	50	5	3	3	3	3	2
53	7	1	10	2	2	3	3	3	2
54	10	7	10	2	1	4	5	4	2
55	5	2	10	15	2	3	3	3	2
56	5	1	10	5	5	1	4	1	2
57	1	1	10	2	1	3	3	3	1
58	7	5	15	5	5	2	3	2	6
59	10	6	20	2	0	1	1	1	2
60	3	3	10	1	1	3	3	3	2
61	5	2	8	1	1	4	4	3	2
74	5	0	5	1	0	1	2	2	1
75	10	3	7	2	1	4	3	3	2
76	2	1	20	6	6	0	1	2	1
77	1	1	3	1	1	2	2	2	2
78	5	2	8	1	1	1	4	1	2
79	15	10	15	2	2	3	4	3	2
80	15	7	15	2	1	2	3	3	2
81	20	3	15	1	0	4	2	2	2
88	10	1	5	1	0	2	4	2	1
89	10	0	15	3	0	4	5	4	24
90	5	3	15	3	2	0	0	0	1
91	10	5	20	10	0	4	4	4	1
92	1	2	8	2	1	2	2	2	2

Figure B.8: Demographic Questionnaire - High - Part 4

C
Game Questionnaire

Based on game and after game questionnaire (cf. Table 4.3 + 4.4), Figure C.1-C.4 present the obtained results. Familiar is determined on a 7-point Likert scale ranging from strongly disagree (0) to strongly agree (6).

Subject	Familiar with Video Games	Favorite Video Game Platform	Favorite Video Game Genre	Hours of Gameplay (Week)	First Choice	Second Choice
1	6	Computer	Role-Playing	60	Picking System	Loading System
2	6	Computer	Action	2	Forklift	Loading System
3	6	Computer	Simulation	10	Forklift	Loading System
4	5	Computer	Sports	0	Picking System	Loading System
5	6	Computer	Strategy	0	Forklift	Forklift
6	6	Xbox	Action	6	Picking System	Forklift
7	6	Computer	Action	1	Forklift	Loading System
8	6	Computer	Action	1	Forklift	Forklift
9	5	Computer	Other	0	Forklift	Forklift
10	5	Computer	Action	0	Forklift	Loading System
26	1	Computer	Action	0	Picking System	Loading System
27	1	Other	Other	0	Forklift	Loading System
28	5	Computer	Action-Adventure	10	Picking System	Loading System
29	1	Phone or Tablet	Other	0	Picking System	Loading System
30	1	Phone or Tablet	Role-Playing	0	Forklift	Loading System
31	2	Phone or Tablet	Simulation	1	Picking System	Loading System
32	0	Phone or Tablet	Strategy	1	Forklift	Loading System
33	0	Other	Sports	0	Picking System	Loading System
34	1	Phone or Tablet	Strategy	1	Forklift	Loading System
35	3	Playstation	Sports	1	Picking System	Loading System
42	5	Xbox	Sports	0	Picking System	Forklift
43	5	Computer	Strategy	1	Forklift	Loading System
44	5	Computer	Strategy	10	Forklift	Loading System
45	4	Computer	Strategy	2	Picking System	Forklift

Figure C.1: Game and After Game Questionnaire - Low - Part 1

Subject	Familiar with Video Games	Favorite Video Game Platform	Favorite Video Game Genre	Hours of Gameplay (Week)	First Choice	Second Choice
46	4	Playstation	Sports	2	Forklift	Loading System
47	1	Phone or Tablet	Other	1	Picking System	Forklift
48	0	Computer	Strategy	0	Picking System	Forklift
62	2	Playstation	Action	1	Picking System	Loading System
63	5	Computer	Action	0	Picking System	Loading System
64	0	Playstation	Strategy	0	Picking System	Loading System
65	6	Playstation	Sports	1	Picking System	Loading System
66	6	Computer	Strategy	12	Forklift	Loading System
67	6	Computer	Other	15	Forklift	Forklift
68	6	Playstation	Action-Adventure	4	Picking System	Loading System
69	0	Computer	Strategy	0	Forklift	Loading System
70	6	Computer	Action	4	Forklift	Forklift
71	3	Playstation	Sports	3	Forklift	Forklift
72	4	Computer	Action	1	Picking System	Forklift
73	5	Computer	Action-Adventure	6	Forklift	Forklift
82	0	Computer	Sports	0	Picking System	Loading System
83	6	Computer	Role-Playing	6	Picking System	Loading System
84	0	Phone or Tablet	Strategy	1	Picking System	Loading System
85	6	Computer	Action	20	Picking System	Loading System
86	3	Computer	Sports	1	Forklift	Loading System
87	4	Computer	Strategy	6	Picking System	Loading System
93	2	Computer	Action	0	Picking System	Loading System
94	5	Xbox	Sports	1	Forklift	Loading System
95	6	Computer	Action	3	Picking System	Loading System

Figure C.2: Game and After Game Questionnaire - Low - Part 2

Subject	Familiar with Video Games	Favorite Video Game Platform	Favorite Video Game Genre	Hours of Gameplay (Week)	First Choice	Second Choice
11	4	Phone or Tablet	Strategy	1	Forklift	Loading System
12	3	Playstation	Sports	1	Forklift	Loading System
13	5	Playstation	Sports	2	Forklift	Loading System
14	4	Playstation	Sports	1	Forklift	Loading System
15	4	Computer	Action	5	Forklift	Loading System
16	1	Computer	Strategy	0	Forklift	Loading System
17	2	Nintendo	Strategy	0	Forklift	Loading System
18	4	Playstation	Sports	2	Forklift	Loading System
19	5	Computer	Role-Playing	0	Forklift	Loading System
20	5	Playstation	Role-Playing	0	Forklift	Loading System
22	6	Computer	Strategy	7	Forklift	Loading System
23	2	Computer	Action-Adventure	3	Forklift	Loading System
24	2	Playstation	Action-Adventure	0	Forklift	Loading System
25	5	Computer	Role-Playing	10	Forklift	Loading System
36	3	Playstation	Sports	1	Forklift	Loading System
37	4	Playstation	Sports	1	Forklift	Loading System
38	4	Other	Sports	1	Forklift	Loading System
39	2	Phone or Tablet	Other	0	Forklift	Loading System
40	6	Computer	Role-Playing	5	Forklift	Loading System
41	4	Playstation	Sports	4	Forklift	Loading System
49	2	Phone or Tablet	Strategy	1	Forklift	Loading System
50	2	Computer	Strategy	1	Forklift	Loading System
51	0	Phone or Tablet	Other	0	Forklift	Loading System

Figure C.3: Game and After Game Questionnaire - High - Part 1

Subject	Familiar with Video Games	Favorite Video Game Platform	Favorite Video Game Genre	Hours of Gameplay (Week)	First Choice	Second Choice
52	0	Other	Other	0	Forklift	Loading System
53	1	Other	Other	0	Forklift	Loading System
54	6	Computer	Role-Playing	20	Forklift	Loading System
55	5	Computer	Role-Playing	5	Forklift	Loading System
56	0	Other	Other	0	Forklift	Loading System
57	1	Computer	Other	0	Forklift	Loading System
58	3	Computer	Sports	1	Forklift	Loading System
59	5	Xbox	Role-Playing	2	Forklift	Loading System
60	2	Playstation	Sports	0	Forklift	Loading System
61	5	Computer	Action	1	Forklift	Loading System
74	5	Computer	Strategy	1	Forklift	Loading System
75	4	Xbox	Sports	2	Forklift	Loading System
76	6	Computer	Other	2	Forklift	Loading System
77	2	Computer	Strategy	0	Forklift	Loading System
78	5	Computer	Simulation	0	Forklift	Loading System
79	5	Playstation	Sports	4	Forklift	Loading System
80	6	Computer	Action	15	Forklift	Loading System
81	1	Computer	Simulation	0	Forklift	Loading System
88	3	Playstation	Sports	1	Forklift	Loading System
89	3	Phone or Tablet	Simulation	1	Forklift	Loading System
90	1	Phone or Tablet	Strategy	1	Forklift	Loading System
91	4	Computer	Sports	1	Forklift	Loading System
92	5	Nintendo	Sports	2	Forklift	Loading System

Figure C.4: Game and After Game Questionnaire - High - Part 2

D
Raw Data

Figure D.1-D.16 present detailed evaluation results from each process model.

Subject	No. Activities	No. Gateways	No. Nodes	No. Edges	Overall	No. Branches	No. Steps	Duration (in Sec)
1	17	6	25	27	52	4	158	535
2	14	8	24	27	51	8	422	520
3	24	8	34	37	71	4	298	617
4	14	6	22	24	46	4	105	515
5	13	4	19	20	39	4	381	483
6	12	4	18	19	37	4	92	432
7	13	6	21	23	44	4	72	390
8	16	5	23	24	47	4	210	536
9	12	2	16	16	32	1	50	428
10	15	8	25	28	53	8	187	650
26	20	7	29	32	61	4	177	1307
27	25	10	37	44	81	4	189	1226
28	39	10	51	55	106	4	416	1378
29	36	8	46	54	100	4	447	1166
30	21	9	32	41	73	4	1093	995
31	20	10	32	36	68	4	272	1195
32	13	4	19	20	39	4	106	919
33	10	3	15	16	31	4	53	722
34	23	6	31	34	65	12	329	1014
35	18	6	26	28	54	4	602	1379
42	22	10	34	39	73	8	337	981
43	30	15	47	56	103	4	687	1099
44	16	4	22	26	48	4	244	853
45	11	2	15	16	31	2	153	734

Figure D.1: Raw Data - Low - Part 1

Subject	No. Activities	No. Gateways	No. Nodes	No. Edges	Overall	No. Branches	No. Steps	Duration (in Sec)
46	25	8	35	44	79	4	160	1211
47	23	5	30	36	66	4	127	1210
48	13	3	18	19	37	2	128	819
62	26	5	33	37	70	12	173	1932
63	25	10	37	41	78	16	228	1704
64	27	5	34	44	78	4	583	1828
65	34	9	45	50	95	8	188	1886
66	29	10	41	46	87	8	514	802
67	35	16	53	62	115	4	281	1173
68	13	4	19	19	38	4	257	856
69	17	7	26	28	54	4	468	1277
70	35	12	49	58	107	1	343	1372
71	11	2	15	15	30	2	101	478
72	24	6	32	34	66	4	158	836
73	17	6	25	27	52	4	312	445
82	11	3	16	17	33	2	76	895
83	17	8	27	32	59	4	286	1264
84	13	4	19	20	39	4	416	1311
85	23	8	33	36	69	4	609	979
86	23	6	31	33	64	4	547	991
87	36	12	50	58	108	4	358	1590
93	22	10	34	42	76	4	166	1296
94	20	4	26	26	52	4	113	1318
95	18	6	26	28	54	4	468	1074

Figure D.2: Raw Data - Low - Part 2

	Process Metrics				Syntactic
Subject	Diameter	Sequentiality	Separability	Cyclicity	No. Syntactical Errors
1	22	0.37	0.6	0	0
2	20	0.185	0.182	0	2
3	29	0.405	0.471	0.118	2
4	18	0.364	0.45	0	2
5	17	0.421	0.665	0	2
6	16	0.389	0.65	0	2
7	18	0.286	0.684	0	0
8	20	0.391	0.614	0.13	6
9	15	0.625	0.757	0	2
10	21	0.36	0.501	0.28	2
26	23	0.3125	0.481	0	3
27	26	0.223	0.514	0	3
28	37	0.491	0.469	0	2
29	37	0.371	0.66	0	2
30	22	0.098	0.4	0	3
31	27	0.222	0.533	0	2
32	17	0.4	0.765	0	2
33	13	0.25	0.692	0	3
34	27	0.412	0.759	0	3
35	23	0.357	0.708	0	2
42	28	0.205	0.438	0.441	5
43	41	0.283	0.387	0.489	7
44	18	0.346	0.6	0.5	1
45	14	0.563	0.769	0	4

Figure D.3: Raw Data - Low - Part 3

	Process Metrics				Syntactic
Subject	Diameter	Sequentiality	Separability	Cyclicity	No. Syntactical Errors
46	26	0.204	0.545	0.00	2
47	23	0.4	0.607	0.00	3
48	13	0.474	0.5	0.00	3
62	27	0.405	0.613	0.333	4
63	32	0.268	0.686	0	4
64	28	0.25	0.687	0.412	4
65	34	0.4	0.581	0	4
66	34	0.37	0.538	0.488	6
67	32	0.226	0.333	0	2
68	16	0.368	0.706	0	3
69	20	0.286	0.209	0	2
70	39	0.241	0.532	0	0
71	14	0.6	0.846	0	1
72	29	0.559	0.733	0	2
73	21	0.333	0.696	0	2
82	15	0.529	0.786	0.25	0
83	22	0.313	0.48	0.259	0
84	17	0.4	0.765	0	2
85	29	0.333	0.677	0	0
86	27	0.455	0.759	0	2
87	37	0.293	0.396	0	3
93	25	0.238	0.5	0.529	8
94	23	0.538	0.792	0	4
95	23	0.464	0.667	0	1

Figure D.4: Raw Data - Low - Part 4

	Semantic				Pragmatic	
Subject	Correctness	Relevance	Completeness	Authenticity	Understandable	Naming
1	5	4	2	3	6	1
2	4	4	2	3	5	2
3	5	5	5	5	4	1
4	5	4	4	4	3	2
5	4	4	2	3	6	2
6	5	4	2	3	6	2
7	5	3	2	3	6	1
8	4	3	3	3	5	1
9	5	4	2	2	5	0
10	5	4	4	4	3	2
26	3	4	3	3	4	1
27	3	3	3	3	1	2
28	6	6	6	6	5	1
29	6	5	5	5	5	3
30	2	3	3	2	5	2
31	3	2	3	3	5	0
32	4	4	1	2	6	0
33	2	3	1	1	6	0
34	4	3	2	2	5	0
35	4	4	2	2	6	0
42	3	4	3	3	3	0
43	6	6	6	6	4	0
44	5	4	2	2	4	0
45	3	3	0	1	4	0

Figure D.5: Raw Data - Low - Part 5

	Semantic				Pragmatic	
Subject	Correctness	Relevance	Completeness	Authenticity	Understandable	Naming
46	4	4	3	3	3	0
47	3	4	3	3	4	0
48	2	3	0	1	6	0
62	5	5	4	5	3	1
63	5	5	4	5	4	0
64	4	4	4	4	3	0
65	5	5	5	4	3	0
66	3	3	4	4	3	0
67	6	6	5	6	3	0
68	3	4	0	2	6	0
69	3	4	3	3	3	1
70	5	5	3	3	4	0
71	2	3	0	0	6	0
72	5	5	3	4	4	0
73	3	3	2	2	5	0
82	2	2	0	2	4	0
83	5	5	4	4	5	1
84	3	2	0	2	5	0
85	3	3	2	2	5	1
86	4	4	2	3	4	0
87	2	2	4	3	2	0
93	5	5	5	5	3	2
94	3	3	3	3	3	0
95	4	4	3	4	5	0

Figure D.6: Raw Data - Low - Part 6

	Perceived					
Subject	Agreement	Missing Aspects	Accurate Description	Mistakes	Result Satisfaction	Mental Effort
1	3	1	4	0	0	0
2	3	1	3	1	1	3
3	2	3	1	3	3	3
4	3	2	3	2	2	2
5	3	1	3	1	1	2
6	1	4	2	2	3	3
7	3	1	3	1	1	2
8	3	1	3	1	2	2
9	3	2	3	2	1	1
10	3	2	2	1	1	2
26	2	2	1	3	2	3
27	1	3	1	3	3	4
28	3	2	1	3	3	2
29	2	2	1	2	2	3
30	3	1	2	3	2	5
31	3	1	2	1	3	3
32	2	3	3	2	2	2
33	3	2	2	2	2	3
34	3	1	3	1	0	5
35	1	3	1	2	3	2
42	3	1	1	1	4	3
43	2	3	3	1	3	3
44	3	3	3	1	2	3
45	2	2	2	2	2	3

Figure D.7: Raw Data - Low - Part 7

	Perceived					
Subject	Agreement	Missing Aspects	Accurate Description	Mistakes	Result Satisfaction	Mental Effort
46	2	2	3	2	1	5
47	2	2	2	2	1	3
48	2	2	2	2	2	3
62	3	1	2	2	1	4
63	3	1	2	2	2	4
64	2	2	3	1	4	3
65	3	2	3	2	2	3
66	3	2	2	1	2	2
67	3	1	4	0	0	3
68	3	1	2	2	3	2
69	2	2	1	3	2	3
70	3	3	2	3	3	3
71	1	3	1	1	2	2
72	3	2	3	1	2	2
73	3	1	3	0	1	1
82	1	3	4	3	0	6
83	3	3	2	1	1	3
84	3	2	2	2	2	4
85	2	4	2	2	3	1
86	3	3	3	1	3	3
87	3	1	2	3	3	4
93	2	2	1	2	2	3
94	2	2	2	2	2	3
95	4	1	2	1	2	3

Figure D.8: Raw Data - Low - Part 8

Subject	No. Activities	No. Gateways	No. Nodes	No. Edges	Overall	No. Branches	No. Steps	Duration (in Sec)
11	26	6	34	38	72	4	132	1042
12	18	4	24	23	47	4	109	1166
13	29	8	39	44	83	12	171	1911
14	25	4	31	26	57	4	145	979
15	31	8	41	48	89	4	634	1713
16	39	10	51	60	111	4	260	1965
17	32	11	45	55	100	6	462	2294
18	21	6	29	31	60	4	215	1497
19	21	9	32	36	68	4	145	1159
20	21	7	30	34	64	4	198	1166
22	54	9	65	75	140	51	489	1825
23	33	8	43	55	98	4	231	1710
24	19	4	25	26	51	4	186	1162
25	15	4	21	22	43	4	156	1210
36	35	8	45	48	93	4	443	1957
37	22	8	32	37	69	4	175	1205
38	24	6	32	34	66	4	174	1615
39	45	6	53	69	122	8	276	1653
40	24	12	38	46	84	4	404	1840
41	18	6	26	28	54	2	124	1287
49	60	4	66	68	134	4	474	1579
50	46	7	55	65	120	64	254	1446
51	21	5	28	30	58	4	127	1988

Figure D.9: Raw Data - High - Part 1

Subject	No. Activities	No. Gateways	No. Nodes	No. Edges	Overall	No. Branches	No. Steps	Duration (in Sec)
52	27	8	37	43	80	8	620	1510
53	17	6	25	27	52	4	307	1454
54	15	6	23	25	48	1	152	843
55	16	5	23	25	48	4	160	1431
56	17	4	23	24	47	4	96	789
57	28	11	41	45	86	4	191	1010
58	55	14	71	90	161	4	809	2085
59	43	12	57	69	126	8	1049	1687
60	28	8	38	44	82	8	172	1089
61	18	6	26	28	54	4	1146	1110
74	29	4	35	39	74	4	507	1776
75	26	13	41	48	89	12	374	2112
76	26	11	39	44	83	4	244	1001
77	41	12	55	69	124	4	516	1815
78	19	14	35	42	77	16	963	1656
79	20	9	31	35	66	4	171	951
80	22	14	38	44	82	4	155	1384
81	36	10	48	58	106	1	359	1482
88	58	14	74	85	159	4	253	1882
89	27	8	37	43	80	4	272	1387
90	16	7	25	28	53	4	759	1115
91	66	11	79	98	177	4	503	3968
92	64	14	80	89	169	4	267	2956

Figure D.10: Raw Data - High - Part 2

	Process Metrics				Syntactic
Subject	Diameter	Sequentiality	Separability	Cyclicity	No. Syntactical Errors
11	30	0.5	0.715	0.353	4
12	20	0.478	0.608	0	4
13	31	0.386	0.591	0.154	6
14	23	0.5	0.513	0	4
15	32	0.313	0.561	0	4
16	41	0.333	0.494	0	2
17	38	0.327	0.558	0.533	5
18	25	0.419	0.63	0	2
19	27	0.419	0.533	0.241	5
20	27	0.382	0.679	0.267	4
22	51	0.48	0.76	0.154	1
23	28	0.275	0.341	0	2
24	23	0.5	0.667	0	2
25	19	0.455	0.737	0	2
36	41	0.542	0.721	0	3
37	27	0.27	0.633	0	3
38	29	0.471	0.667	0	3
39	35	0.232	0.49	0	8
40	29	0.239	0.472	0.553	1
41	21	0.393	0.708	0	2
49	60	0.765	0.891	0.06	2
50	47	0.492	0.66	0.2	8
51	25	0.5	0.808	0.179	3

Figure D.11: Raw Data - High - Part 3

	Process Metrics				Syntactic
Subject	Diameter	Sequentiality	Separability	Cyclicity	No. Syntactical Errors
11	30	0.5	0.715	0.353	4
12	20	0.478	0.608	0	4
13	31	0.386	0.591	0.154	6
14	23	0.5	0.513	0	4
15	32	0.313	0.561	0	4
16	41	0.333	0.494	0	2
17	38	0.327	0.558	0.5333	5
18	25	0.419	0.63	0	2
19	27	0.419	0.533	0.241	5
20	27	0.382	0.679	0.267	4
22	51	0.48	0.76	0.154	1
23	28	0.275	0.341	0	2
24	23	0.5	0.667	0	2
25	19	0.455	0.737	0	2
36	41	0.542	0.721	0	3
37	27	0.27	0.633	0	3
38	29	0.471	0.667	0	3
39	35	0.232	0.49	0	8
40	29	0.239	0.472	0.553	1
41	21	0.393	0.708	0	2
49	60	0.765	0.891	0.06	2
50	47	0.492	0.66	0.2	8
51	25	0.5	0.808	0.179	3

Figure D.12: Raw Data - High - Part 4

	Semantic				Pragmatic	
Subject	Correctness	Relevance	Completeness	Authenticity	Understandable	Naming
11	4	5	4	4	2	1
12	5	5	1	2	6	0
13	5	5	5	5	1	1
14	5	5	2	2	5	0
15	4	4	2	2	4	1
16	4	5	5	4	2	1
17	3	3	3	3	2	0
18	5	4	3	3	3	2
19	5	5	5	5	2	2
20	4	5	3	4	3	1
22	4	5	5	5	4	1
23	5	5	5	5	3	1
24	4	4	2	3	5	1
25	5	4	2	2	6	0
36	5	5	5	6	3	1
37	5	5	4	5	4	1
38	4	5	3	4	4	0
39	5	5	6	5	3	0
40	6	5	5	5	2	0
41	5	5	4	5	4	0
49	5	6	5	6	3	1
50	4	6	6	5	1	0
51	5	5	4	3	2	0

Figure D.13: Raw Data - High - Part 5

	Semantic				Pragmatic	
Subject	Correctness	Relevance	Completeness	Authenticity	Understandable	Naming
52	5	5	4	4	3	1
53	5	5	3	3	4	0
54	5	5	2	3	6	0
55	5	5	3	4	5	0
56	3	4	2	2	6	0
57	3	5	4	4	2	0
58	5	5	6	5	4	1
59	3	4	6	5	4	1
60	3	4	4	4	4	1
61	3	4	2	2	5	0
74	3	4	4	3	4	1
75	4	5	4	4	3	2
76	3	4	4	4	2	1
77	5	4	4	5	4	0
78	5	5	5	5	4	0
79	4	4	4	4	3	1
80	5	5	5	5	2	0
81	2	4	3	3	3	0
88	4	5	6	6	3	2
89	4	5	4	4	3	1
90	5	5	3	3	4	1
91	5	5	6	6	1	2
92	2	5	6	5	2	1

Figure D.14: Raw Data - High - Part 6

	Perceived					
Subject	Agreement	Missing Aspects	Accurate Description	Mistakes	Result Satisfaction	Mental Effort
11	2	3	1	3	2	1
12	3	1	3	4	2	2
13	1	3	1	3	3	5
14	2	3	1	3	3	3
15	2	2	1	2	3	3
16	1	2	2	1	4	5
17	3	2	3	2	2	3
18	2	2	2	2	2	3
19	3	3	1	2	2	1
20	3	0	3	0	2	3
22	2	3	2	3	4	3
23	2	3	2	4	3	5
24	3	2	3	1	2	3
25	2	2	3	1	2	2
36	3	2	3	2	2	3
37	2	1	2	2	2	2
38	3	1	3	2	2	3
39	3	1	3	1	1	3
40	3	2	3	2	2	3
41	3	2	3	2	1	3
49	3	3	2	3	3	3
50	1	3	3	1	0	5
51	3	2	2	2	2	3

Figure D.15: Raw Data - High - Part 7

	Perceived					
Subject	Agreement	Missing Aspects	Accurate Description	Mistakes	Result Satisfaction	Mental Effort
52	4	2	2	2	2	4
53	2	2	2	2	2	3
54	3	3	3	1	1	3
55	2	2	2	2	2	3
56	3	0	3	1	1	3
57	3	1	3	2	1	2
58	3	2	3	2	3	3
59	3	2	3	3	4	2
60	3	2	3	1	1	4
61	4	0	4	0	0	2
74	3	2	3	2	2	4
75	1	3	1	2	3	3
76	2	2	2	1	3	2
77	2	2	2	2	3	4
78	1	4	1	4	4	5
79	3	1	3	1	1	3
80	3	2	3	1	3	4
81	3	1	3	2	1	2
88	3	3	2	2	3	3
89	4	2	0	0	3	2
90	3	3	2	3	2	3
91	2	1	3	1	2	4
92	2	3	2	2	2	4

Figure D.16: Raw Data - High - Part 8

E

Experimental Results

Figure E.1-E.3 visualize the results as bar charts. Therefore, each bar chart consists of three classes (i.e. low, high, total) and each class represents median values for low and high social distance as well as the median value of both groups together.
Figure E.4-E.12 visualize the results as scatter plots. The x-axis of scatter plots indicate the competencies (i.e., competent, confident, and familiar) in BPMN and the y-axis of scatter plots show individual results of subjects.

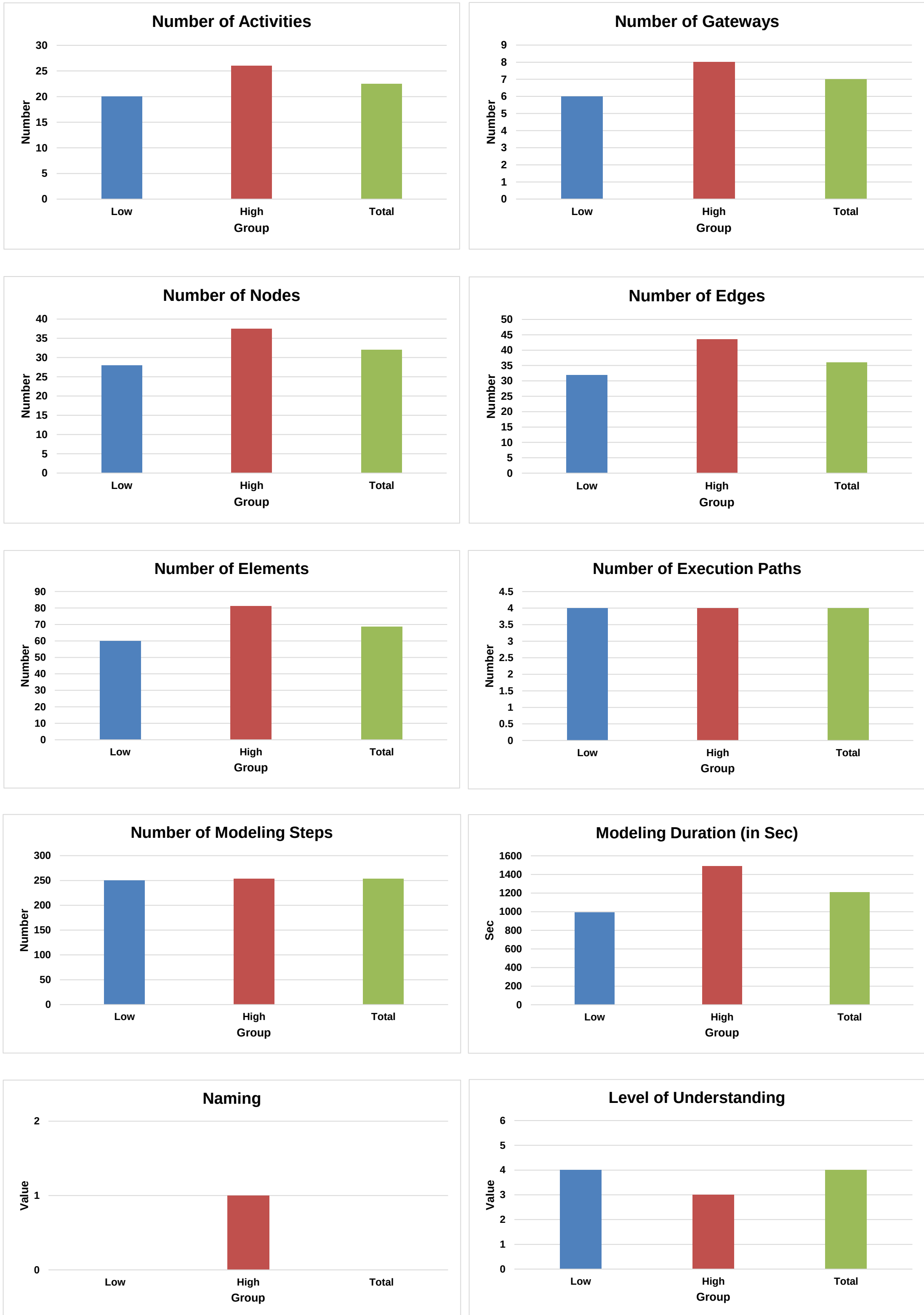

Figure E.1: Bar Charts - Part 1

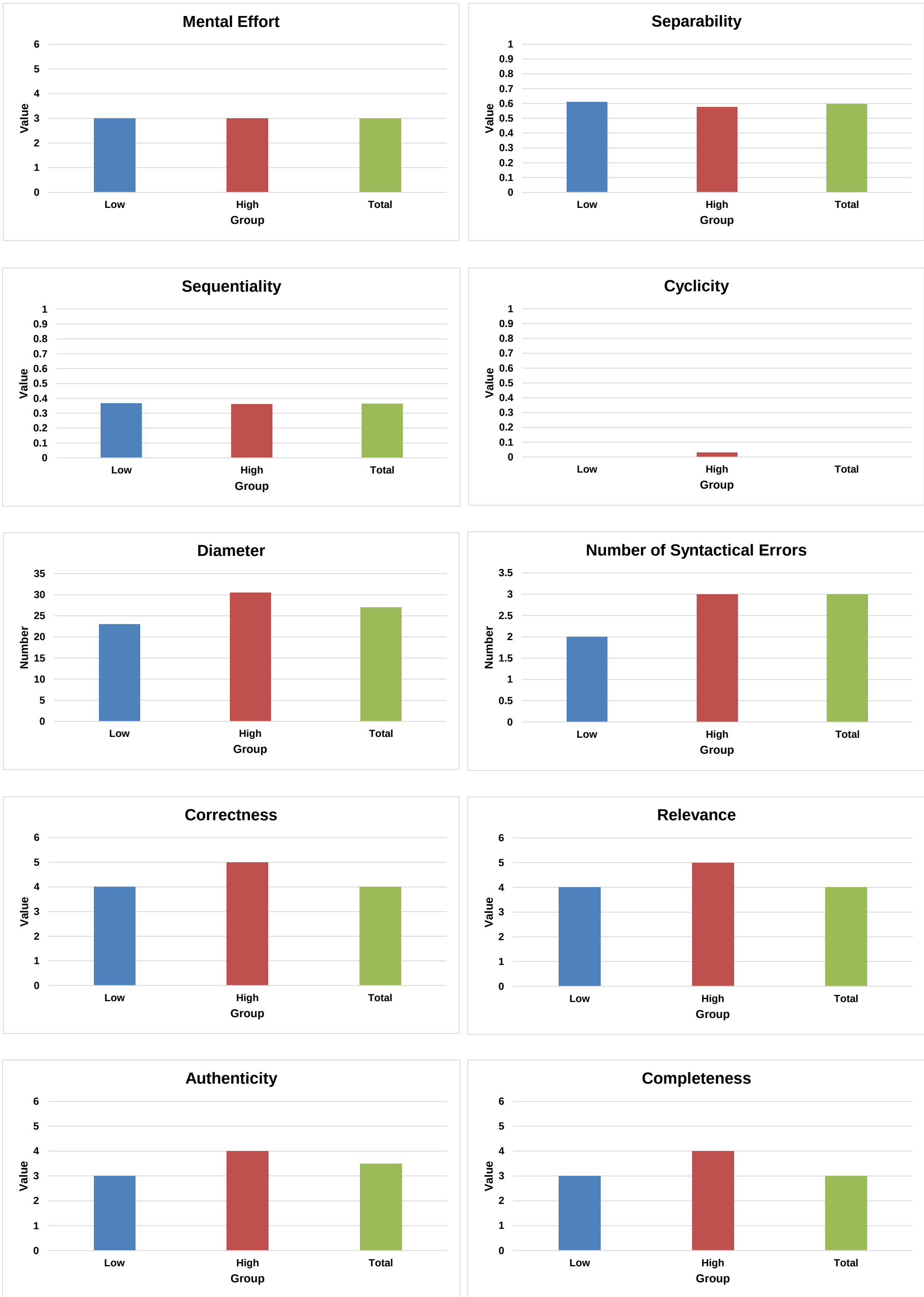

Figure E.2: Bar Charts - Part 2

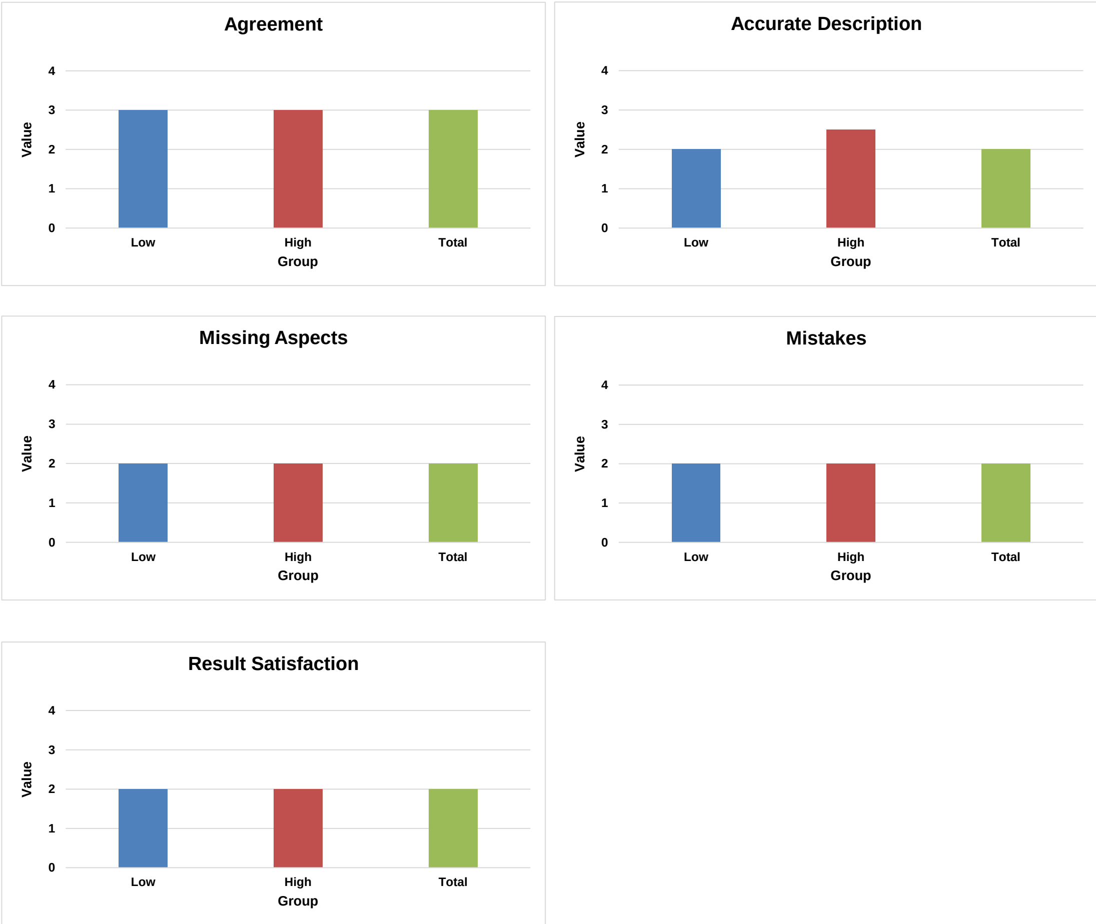

Figure E.3: Bar Charts - Part 3

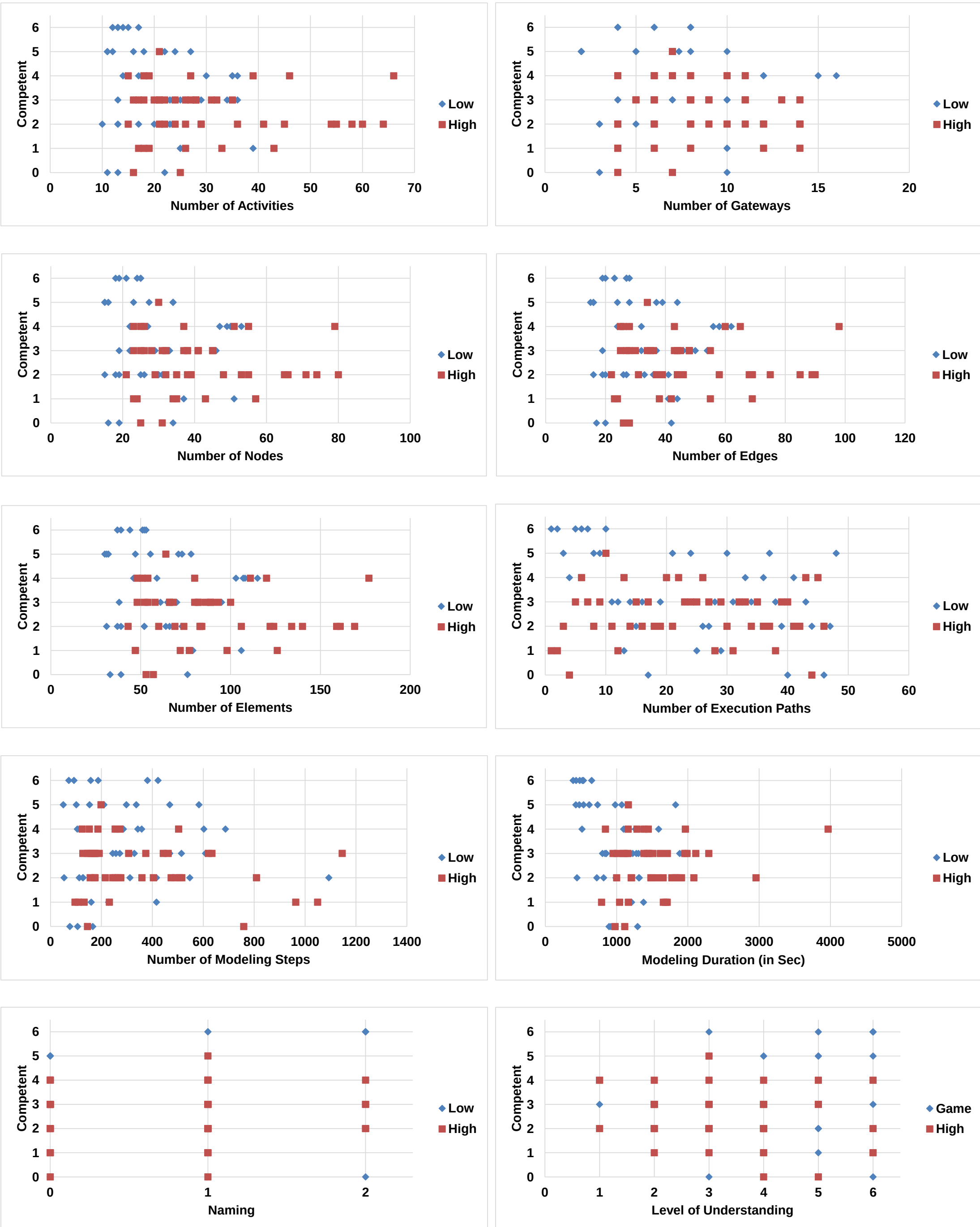

Figure E.4: Scatter Plots - Part 1

Figure E.5: Scatter Plots - Part 2

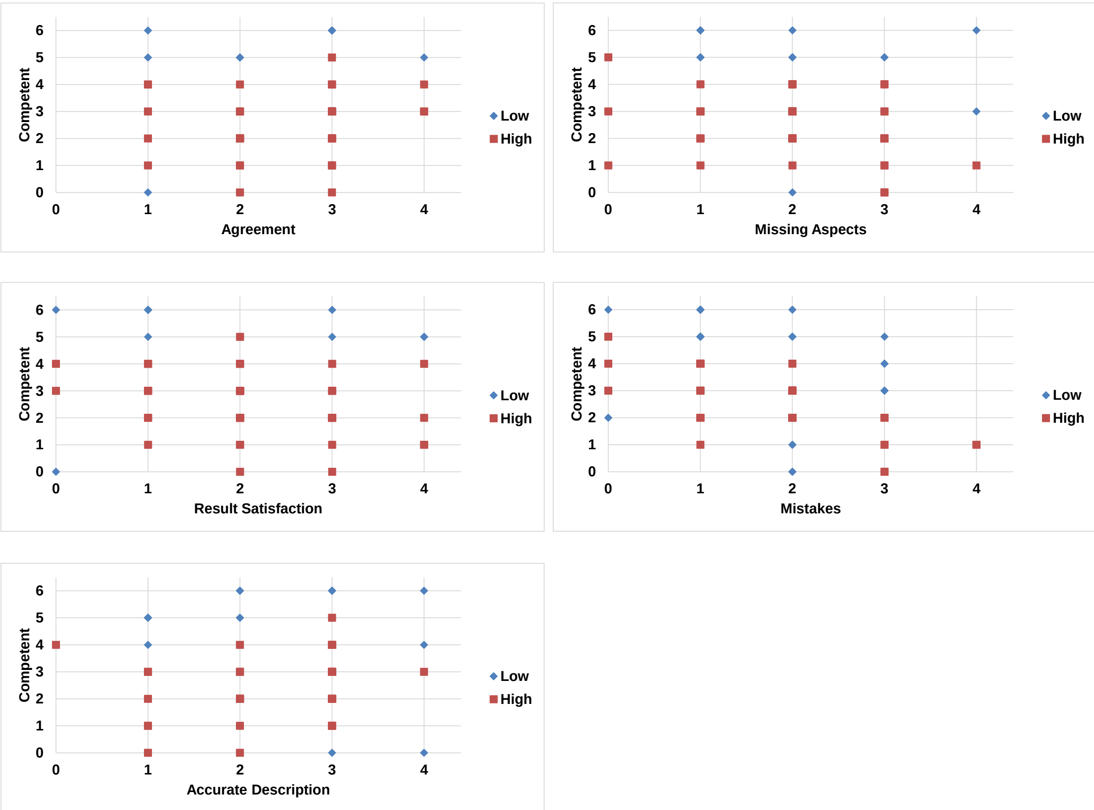

Figure E.6: Scatter Plots - Part 3

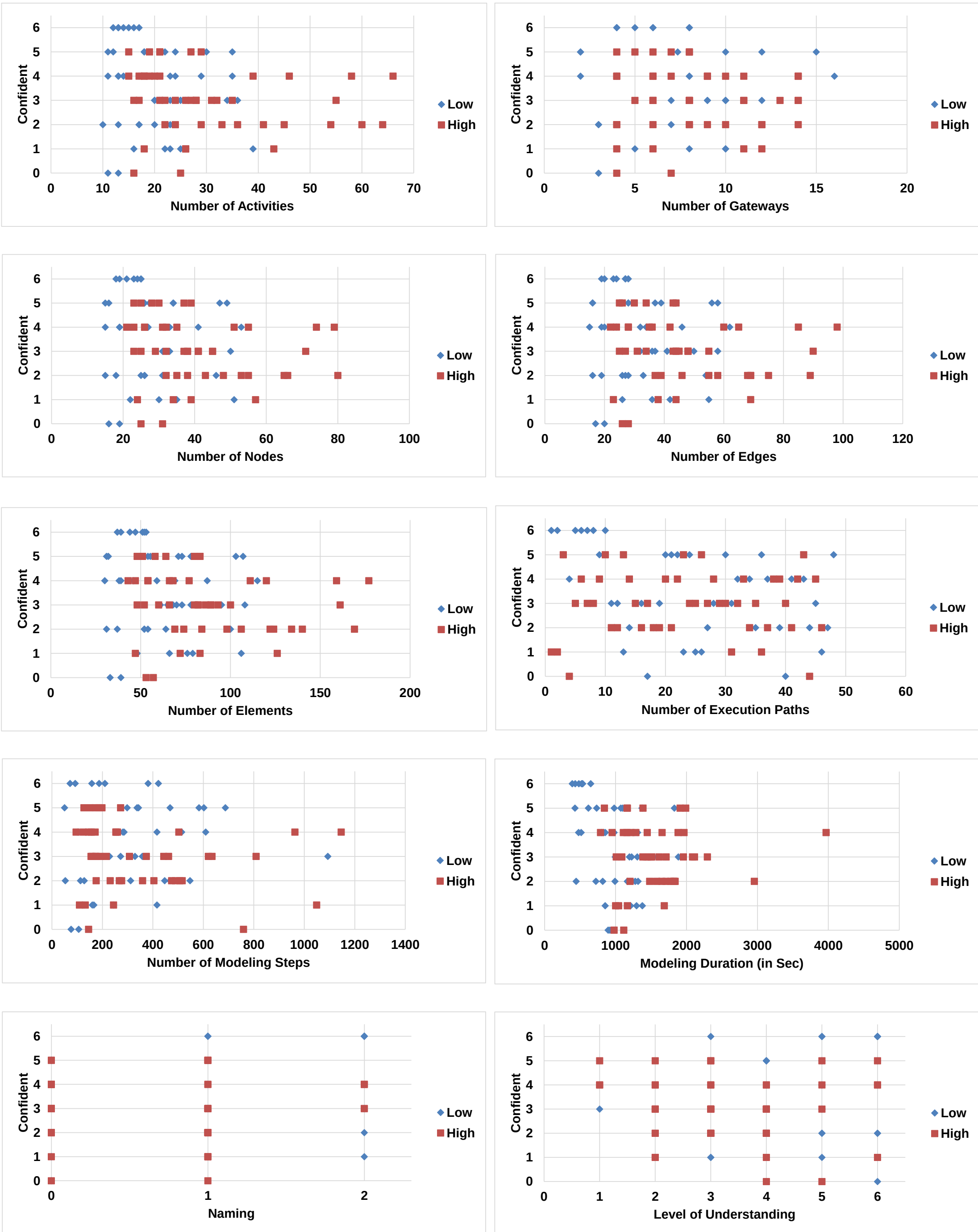

Figure E.7: Scatter Plots - Part 4

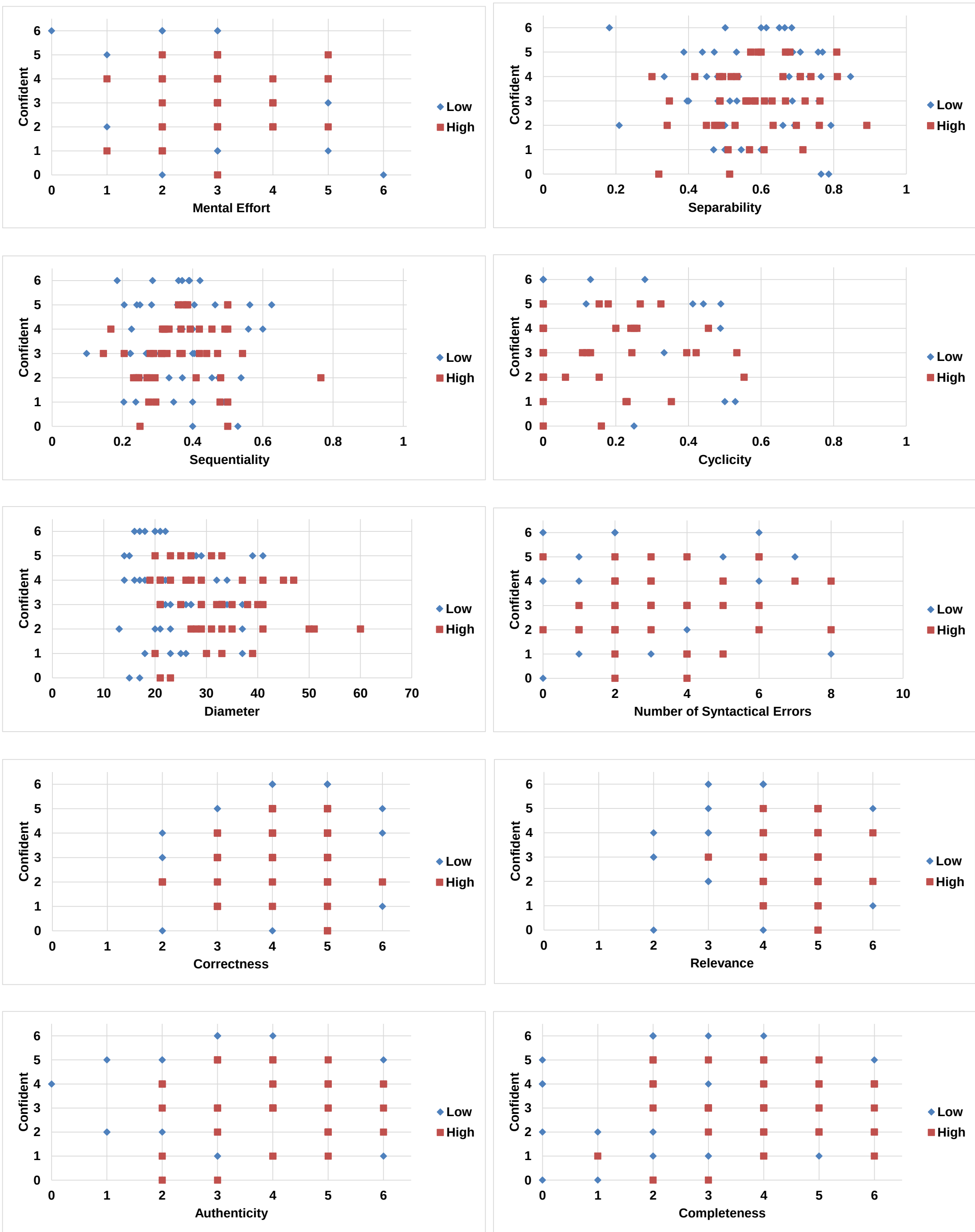

Figure E.8: Scatter Plots - Part 5

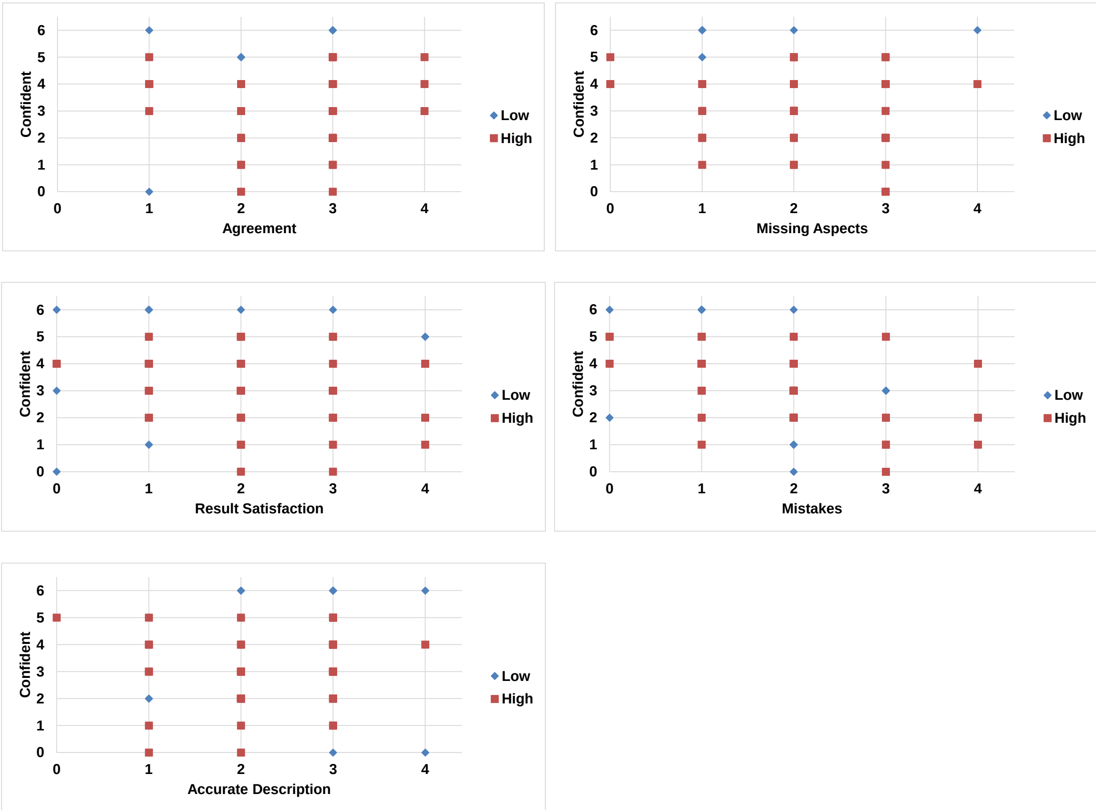

Figure E.9: Scatter Plots - Part 6

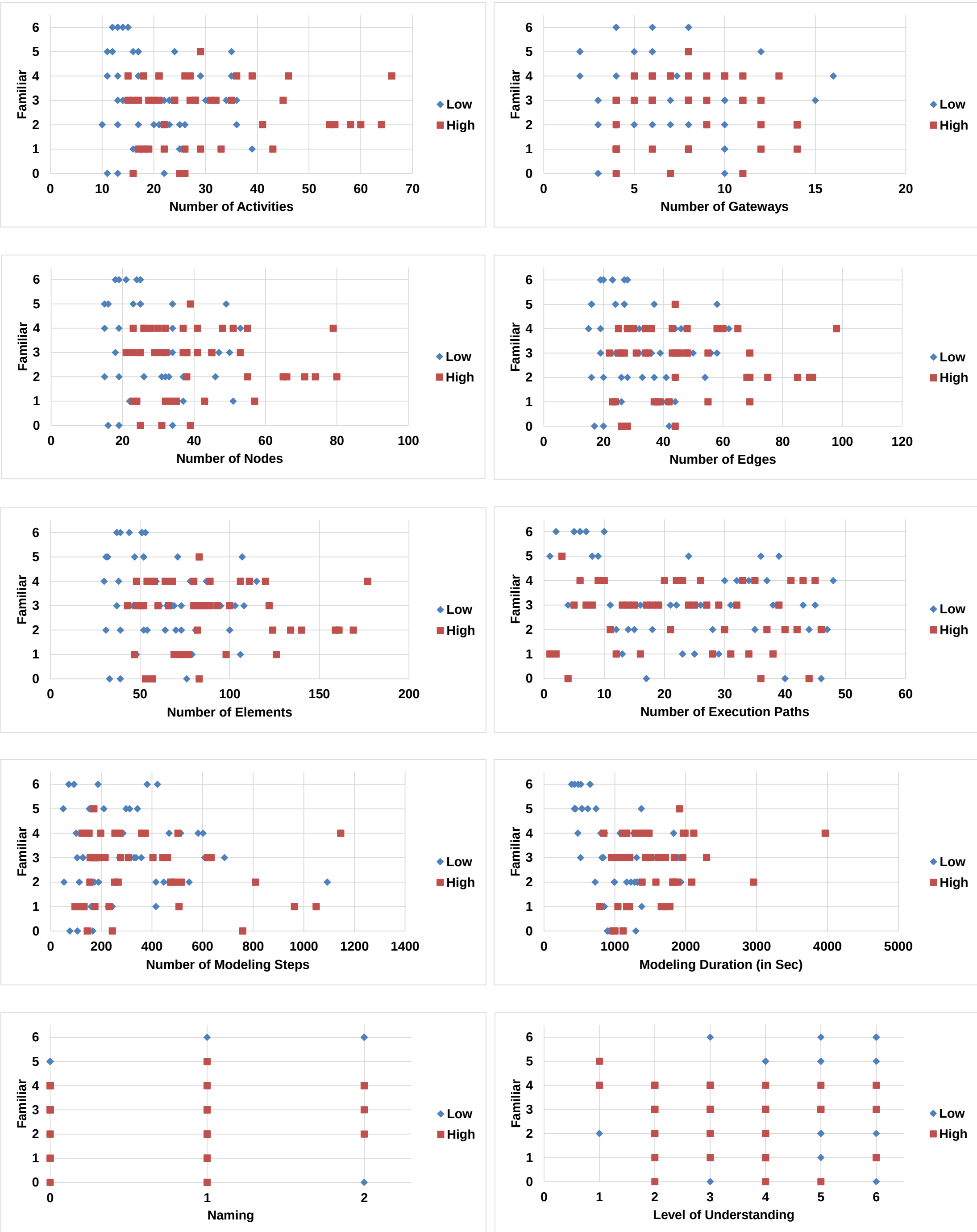

Figure E.10: Scatter Plots - Part 7

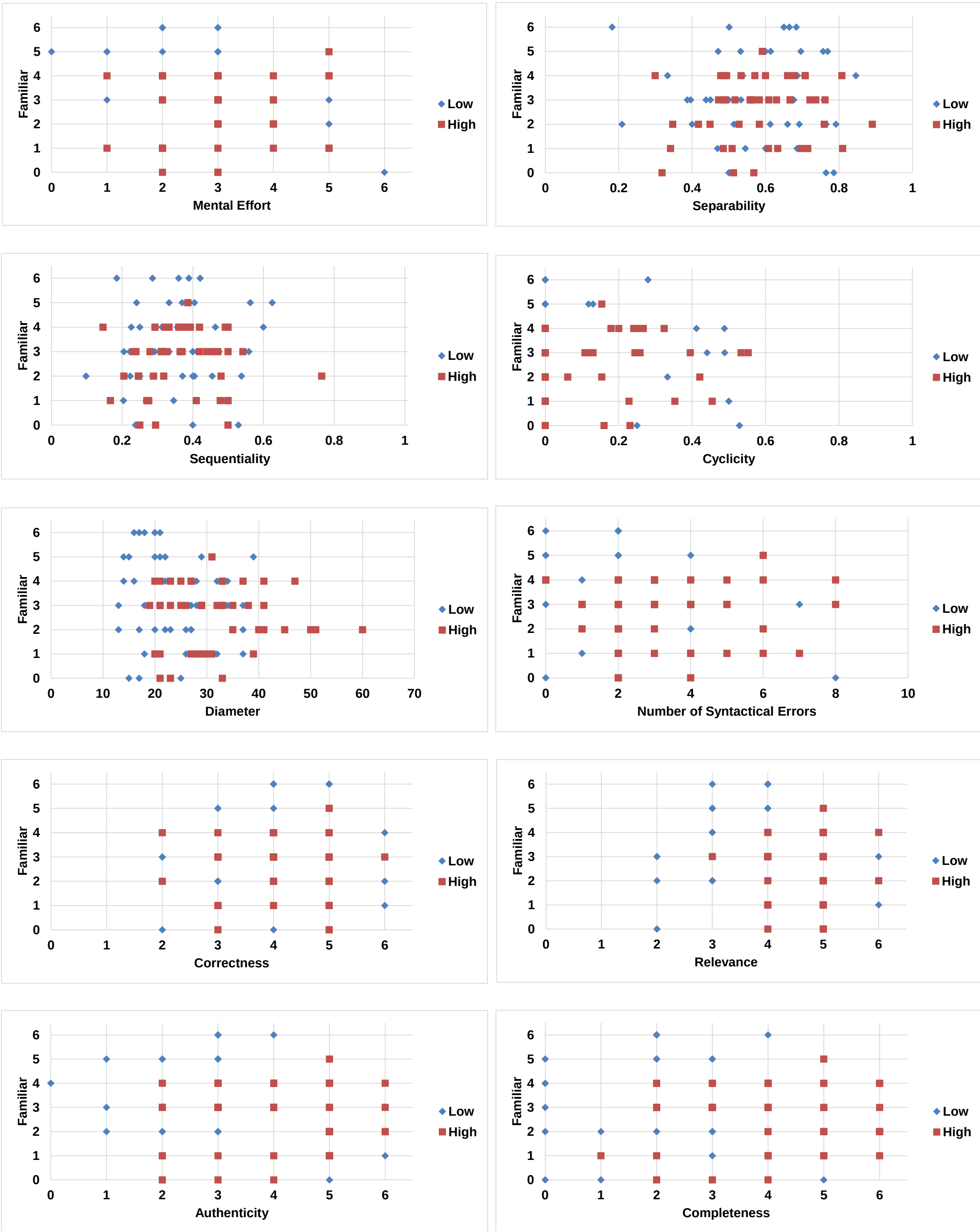

Figure E.11: Scatter Plots - Part 8

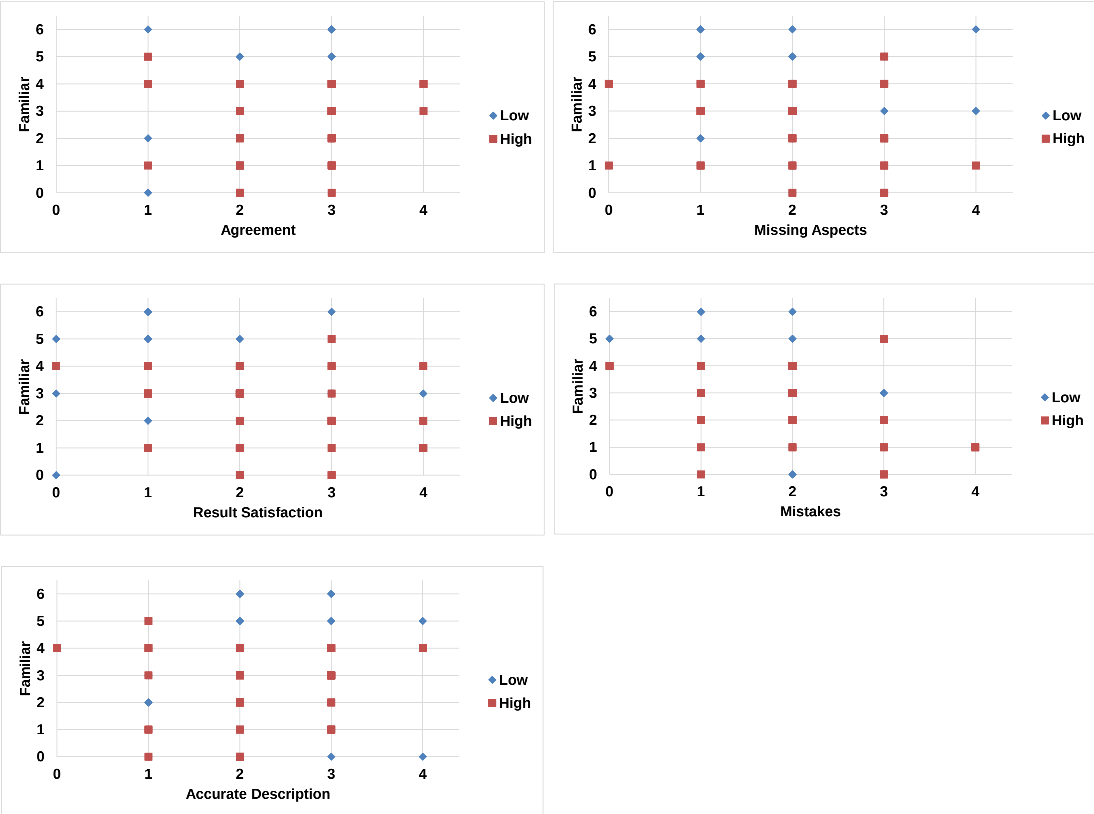

Figure E.12: Scatter Plots - Part 9

F

Detailed Results of Hypothesis Testing

Table F.1-F.25 summarizes the calculated values of testing the hypotheses. The single values are defined as followed:

- Rank $(R_1|R_2)$: Sum of ranks from group one R_1 (i.e., low social distance) and group two R_2 (i.e., high social distance)
- U-Value $(U_1|U_2)$: Specific u-value for group one U_1 (i.e., low social distance) and group two U_1 (i.e., high social distance)
- Mean of Ranks (m_u): Calculated mean of U
- Standard Deviation (σ_u): Standard deviation of U
- Z-Value: Calculated standard score of U
- P-Value: Result of the significance test

Number of Activities		
Rank $(R_1\|R_2)$	1783	2682
U-Value $(U_1\|U_2)$	1601	607
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-3.755	
P-Value	$<$ 0.01	

Table F.1: Number of Activities

Number of Gateways		
Rank $(R_1\|R_2)$	2006.5	2458.5
U-Value $(U_1\|U_2)$	1377.5	830.5
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-2.065	
P-Value	0.039	

Table F.2: Number of Gateways

Number of Nodes		
Rank $(R_1\|R_2)$	1799	2666
U-Value $(U_1\|U_2)$	1585	623
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-3.634	
P-Value	$<$ 0.01	

Table F.3: Number of Nodes

Number of Edges		
Rank $(R_1\|R_2)$	1826	2639
U-Value $(U_1\|U_2)$	1558	650
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-3.430	
P-Value	$<$ 0.01	

Table F.4: Number of Edges

Number of Elements		
Rank $(R_1\|R_2)$	1809	2656
U-Value $(U_1\|U_2)$	1575	633
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-3.559	
P-Value	$<$ 0.01	

Table F.5: Number of Elements

Number of Execution Paths		
Rank $(R_1\|R_2)$	2177	2288
U-Value $(U_1\|U_2)$	1207	1001
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-0.755	
P-Value	0.435	

Table F.6: Number of Execution Paths

Number of Modeling Steps		
Rank $(R_1\|R_2)$	2167	2298
U-Value $(U_1\|U_2)$	1217	991
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-0.851	
P-Value	0.395	

Table F.7: Number of Modeling Steps

Modeling Duration (in Sec)		
Rank $(R_1\|R_2)$	1629	2836
U-Value $(U_1\|U_2)$	1755	453
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-4.920	
P-Value	$<$ 0.01	

Table F.8: Modeling Duration (in Sec)

Number of Syntactical Errors		
Rank $(R_1 \| R_2)$	2014.5	2450.5
U-Value $(U_1 \| U_2)$	1369.5	838.5
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-2.004	
P-Value	0.045	

Table F.9: Number of Syntactical Errors

Sequentiality		
Rank $(R_1 \| R_2)$	2254	2211
U-Value $(U_1 \| U_2)$	1130	1078
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-0.163	
P-Value	0.849	

Table F.10: Sequentiality

Cyclicity		
Rank $(R_1 \| R_2)$	2056	2409
U-Value $(U_1 \| U_2)$	1328	880
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-1.691	
P-Value	0.091	

Table F.11: Cyclicity

Diameter		
Rank $(R_1 \| R_2)$	1755	2710
U-Value $(U_1 \| U_2)$	1629	579
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-3.967	
P-Value	$<$ 0.01	

Table F.12: Diameter

Separability		
Rank $(R_1\|R_2)$	2347	2118
U-Value $(U_1\|U_2)$	1037	1171
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	0.503	
P-Value	0.617	

Table F.13: Separability

Correctness		
Rank $(R_1\|R_2)$	2104.5	2360.5
U-Value $(U_1\|U_2)$	1279.5	928.5
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-1.324	
P-Value	0.186	

Table F.14: Correctness

Relevance		
Rank $(R_1\|R_2)$	1721	2744
U-Value $(U_1\|U_2)$	1663	545
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-4.224	
P-Value	$<$ 0.01	

Table F.15: Relevance

Completeness		
Rank $(R_1\|R_2)$	1822	2643
U-Value $(U_1\|U_2)$	1562	646
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-3.460	
P-Value	$<$ 0.01	

Table F.16: Completeness

Authenticity		
Rank $(R_1 \| R_2)$	1860	2605
U-Value $(U_1 \| U_2)$	1524	654
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-3.173	
P-Value	$<$ 0.01	

Table F.17: Authenticity

Level of Understanding		
Rank $(R_1 \| R_2)$	2720	1745
U-Value $(U_1 \| U_2)$	664	1544
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	3.324	
P-Value	$<$ 0.01	

Table F.18: Level of Understanding

Detailed Naming		
Rank $(R_1 \| R_2)$	2165	2300
U-Value $(U_1 \| U_2)$	1219	989
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-0.866	
P-Value	0.384	

Table F.19: Detailed Naming

Mental Effort		
Rank $(R_1 \| R_2)$	2138.5	2326.5
U-Value $(U_1 \| U_2)$	1245.5	962.5
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-1.067	
P-Value	0.285	

Table F.20: Mental Effort

Agreement		
Rank $(R_1\|R_2)$	2269	2196
U-Value $(U_1\|U_2)$	1115	1093
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-0.079	
P-Value	0.936	

Table F.21: Agreement

Missing Aspects		
Rank $(R_1\|R_2)$	2211	2254
U-Value $(U_1\|U_2)$	1173	1035
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-0.518	
P-Value	0.603	

Table F.22: Missing Aspects

Accurate Description		
Rank $(R_1\|R_2)$	2196	2269
U-Value $(U_1\|U_2)$	1188	1020
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-0.632	
P-Value	0.529	

Table F.23: Accurate Description

Mistakes		
Rank $(R_1\|R_2)$	2173.5	2291.5
U-Value $(U_1\|U_2)$	1210.5	997.5
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-0.802	
P-Value	0.424	

Table F.24: Mistakes

Result Satisfaction		
Rank $(R_1\|R_2)$	2160	2305
U-Value $(U_1\|U_2)$	1224	984
Mean of Ranks (m_u)	1104	
Standard Deviation (σ_u)	132.212	
Z-Value	-0.904	
P-Value	0.368	

Table F.25: Result Satisfaction

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Name: Michael Zimoch Matrikelnummer: 699504

Erklärung

Ich erkläre, dass ich die Arbeit selbstständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel verwendet habe.

Ulm, den ....

Michael Zimoch