MASTER

The influence of modularity representation on the understandability of business process models
an investigation into the factors that contribute to an understandable business process model

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The influence of modularity representation on the understandability of business process models

An investigation into the factors that contribute to an understandable business process model

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"The goal is not to make the model easy to understand but to ensure that it is understood" (Lindland, Sindre, & Solvberg, 1994)

I. Abstract

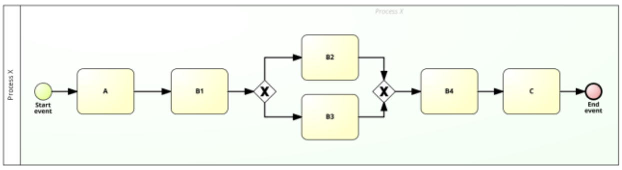
Many factors are of influence on the creation of understandable business processes for the appropriate audience. This study investigates a large extent of factors that contribute to an understandable and usable business process model. This results in an understandability reference framework and an understandability factors model (which shows a considerable number of influencing factors on process models). The foundation for modeling 2 real-life business processes is provided by this theoretical framework. The aim for modeling two processes is to investigate which modularity representation serves best for the understandability of business processes. An online experiment compares 3 different modularity representations applied on these process models. A total of 61 process participants participated in the experiment. Half of the participants in the experiment received the process models in an A3 paper format and the other half received a fully online computer format. With this additional experimental characteristic the presentation medium was investigated as a proposed influencing understandability factor. The practical data resulting from the experiment are analyzed with the help of statistical tests. We conclude from our analysis that for business practitioners to optimally understand the process model, it is best to show the process model in a fully-flattened way (without defined sub-processes). The large size of a process model causes less trouble than the split-attention effect of reintegrating hidden sub-processes. Nevertheless, the split-attention effect is easiest to overcome when the sub-processes are not hidden in the main process model but when separate views or windows are used to represent the main process model and the sub-process. The presentation medium also influences the understandability of process models. Paper process representations seem to be more understandable compared to computer representations.

II. Executive Summary

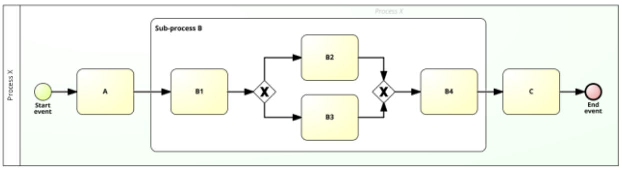
Introduction

A graphical representation of a business process is called a business process model and has been used already by many companies to represent their business processes. A process is a chain of events, activities and decisions (Dumas, La Rosa, Mendling, & Reijers, 2013). In order for these business process models to be usable, it is necessary to know how to represent process models in an understandable and usable way. All model-related and personal factors that influence and contribute to a better understandability and usability of process models are captured in an understandability reference framework (Table 2, Page 16) and an understandability factors model (Figure 3, Page 17). In order to contribute to this understandability factors model, a specific area is chosen to study in more depth. Since realistic business processes are large and complex in general, a certain representation of modularity (hierarchy or decomposition with the use of sub-processes) might be required. An empirical study with the help of an experiment has been used to find out (*1) which modularity representation supports the understandability of business process models best*. Also, there might be an influencing effect of the presentation medium on the process model. Therefore another objective to investigate results in the research question: (2) *does the presentation medium influence the understandability of business process models?* For the execution of this empirical study Philips Health Tech (PH) MR is closely involved. Two of their Quality Management System (QMS) processes are used in the experiment. A QMS is an information system that helps the organization to manage the quality of a product (ANSI/AAMI/ISO, 2004). In order to be compliant to the described process (model), users have to understand the process first. The modularity representation that facilitates this understanding best should be used in practice.

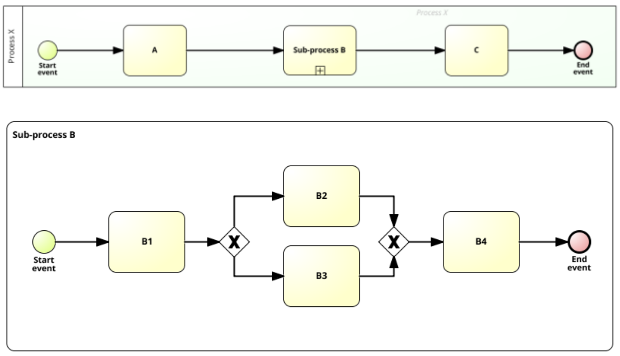
Research Approach



Copy of REPR1: Fully-flattened (Page 27)



Copy of REPR2: fully-flattened with a division of sub-processes (Page 28)



Copy of REPR3: sub-process hidden and located in a separate view (Page 28)

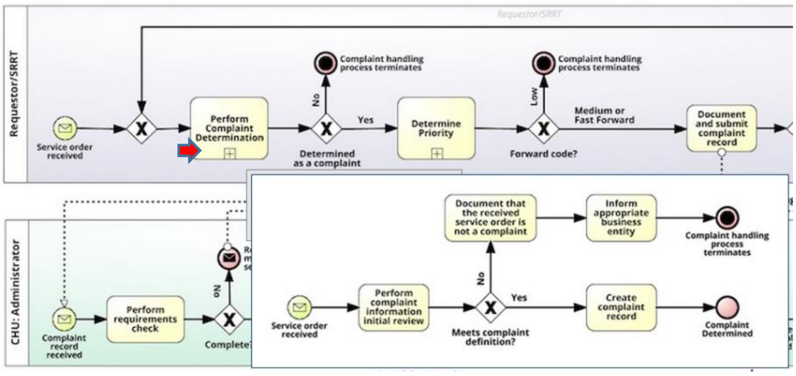
The two PH MR processes that have been modelled are the *Corrective and Preventive Action (CAPA-) process* and the *Complaint Handling (CH-) process*. This study used three different representations. Representation (REPR) 1 is a fully-flattened version of the process model. REPR2 combines REPR1 with an additional division of the process into sub-processes with colored boxes. The last representation (REPR3) separates and hides the sub-processes from the main view. Five dependent measures have been defined to measure the understandability of these process representations: score (correctly answered model questions), time (efficiency), perceived usefulness (PU), perceived ease of use (PEOU) and intention to use (ITU). A number of personal factors were recorded as well to serve as control variables.

The experimental setup existed out of a block design of six different blocks (Table 3). As displayed, every process model representation was either presented on A3 paper (P) or on a computer screen (C). Every participant received one representation of the CAPA process and one of the CH process. A total of 61 PH employees completed the experiment. A proportion of those employees was experienced in either the CAPA process or in the CH process.

*Copy of Table 3: Block design of the experiment (*P=paper and C=Computer Screen, Page 34)*

Block	CAPA Representation	CH Representation	Presentation Medium*: P or C
Block 1	1	2	P
Block 2	1	3	C
Block 3	2	1	C
Block 4	2	3	P
Block 5	3	1	P
Block 6	3	2	C

The business process models of the two processes are attached in Appendix A. The questionnaire (Appendix C) first addressed the personal characteristics of the participants. Thereafter, content knowledge about the models was requested. The model content questions contained an equal distribution of global, local, control flow, resources and message flow (or information) questions among the two different processes. A further comparison between both the CAPA and the CH process models shows that the two processes were fairly comparable in terms of their structural characteristics (Table 6, page 39). In the analysis of the experimental data they are considered as similar and interchangeable. Therefore, the dataset is organized in groups divided on representation type instead. At last, the subjective measures of PU, PEOU and ITU were addressed. The whole experiment was implemented in an online environment hosted by www.bpmresearch.net. Only participants who were allocated to the paper group received the models on paper upfront. Another difference was manifested between REPR3 on paper (REPR3P) and computer (REPR3C).



Sub-processes on a computer medium were hidden until the mouse hoovered over the sub-process. The details of the sub-processes became visible while all context content stayed intact (Figure 7, Page 37 and Figure 8)

Copy of Figure 8: CH REPR3, mouse hoovering over sub-process "Perform Complaint Determination" (sub-process pop-up)

Results

Based on the research objectives, we posed a set of hypotheses to structure the analysis of the experiment. These hypotheses are summarized and answered in Table 8. All the hypotheses are partially or completed accepted. The representation did not highly influence the score or time needed to answer the questions. On the other hand, the subjective measures (PU, PEOU and ITU) were highly (significantly) influenced by the different representations. Besides this, an initial resistance towards business process models was bend into positivity for specifically REPR1 on paper.

Copy of Table 8: summary of hypotheses

SUMMARY		
Hypothesis	**Result**	**Proposition**
H1: Representation type has an influence on the a) score, b) time, c) perceived usefulness (PU), d) perceived ease of use (PEOU), and e) intention to use (ITU).	Partially Accepted	*REPR1 is more understandable compared to REPR2 (Based on a paper medium and PEOU) and REPR3 (Based on PU, PEOU and ITU).*
H2: Presentation medium has an influence on the a) score, b) time, c) perceived usefulness (PU), d) perceived ease of use (PEOU), and e) intention to use (ITU).	Partially Accepted	*A paper presentation medium is a more understandable presentation medium compared to a computer screen for at least REPR1 (based on PU) and REPR3 (based on score/time, PU and ITU).*
H3: The Representation type and Presentation medium have a combined effect on the a) score, b) time, c) perceived usefulness (PU), d) perceived ease of use (PEOU), and e) intention to use (ITU).	Partially Accepted	*REPR1P is more understandable compared to REPR3C (based on PU, PEOU and ITU). As well, REPR2P is more understandable compared to REPR3C (based on PU). Furthermore, REPR1P is more understandable compared to REPR2C (based on PU and PEOU)*
H4: The influence of the representation will be different for different types of understandability questions: a) Global & Local, b) Ctr/Res/Inf	Accepted	*The local questions are most understandable for REPR1 and REPR2 (based on score). Next, Ctr/Res/Inf questions are most understandable on a paper medium, especially on REPR1 and REPR3 (based on score and score/time)*

Conclusion and Practical Implications

From a time perspective, there is no reason to choose one modularity representation over the other. On the other hand, the understandability measured in this experiment is different among the different representations in terms of effectiveness and the subjective measures. A fully-flattened version of a process model (without sub-processes) supports the understandability of business process models best. Apparently, size has a lower positive impact on the understandability compared to the negative split-attention effect of the use of hidden sub-processes. Besides, the method used to represent representation 3 on the computer is undesirable. Representation 3 on paper excludes the sub-processes from the main view and does not have a measurable lower understandability than the fully-flattened process models. It seems easier to integrate the sub-processes into the overall process model when they are represented in separate views or windows. Furthermore, the extra feature to divide processes into sub-processes with the help of colored boxes but without losing any overview and size, does not create a higher understandability. Likewise, for business practitioners to optimally understand local parts of the process model, it is best to show the process model in a fully-flattened way without sub-processes (preferably on paper). This all it suggests that the main process model should contain the least extra information possible per process view.

Secondly, the presentation medium in itself also seems to influence the understandability of process models. A process model on a paper presentation medium is more understandable for at least a fully-flattened process representation and a representation that divides and hides sub-processes from the main process view. Especially, a first contact with these kind of process representations is perceived highly useful and easy to use in a fully-flattened format, on a paper medium. Of course it is not achievable to present a whole QMS on paper; it is not practical, durable, environmentally unfriendly and a waste of money. Though, for certain business purposes it might be useful to print the process model in order to increase the understandability.

At last, a high perceived usefulness and perceived ease of use of specific groups, shows that an initial resistance can be bend towards a positive attitude. The first contact with BPMN process models should not be in a REPR3C-like visualization because of its low perceived understandability. This asks for more resistance in the perceived usefulness and perceived ease of use of this type of process models after using it. A fully-flattened representation on paper supports the understandability best. For future implementations of business process models, the use of sub-processes is probably inevitable. Another online representation which makes use of separate views should be used.

III. Preface

You are about to read the end product of the development and the transformation of being a clueless student into a person who is ready for the next phase in life; working life. I executed this master thesis project in the area of the understandability of business process models in order to conclude the (Industrial Engineering) master Innovation Management.

To start with, I would like to thank Jan van Moll and Zouhair Bedawi for the opportunity to do my master project in the Quality and Regulatory department of Philips Health Tech. More importantly, I would like to thank them for the time, enthusiasm and knowledge that they were willing to share with me. I felt welcome at all times, and our daily informal walks during the break made me feel part of their team very soon. It is very unique in my opinion to have such a close line with your supervisors during the duration of a master thesis project, and it worked out definitely in favor of my project. Next to that, I would like to thank all other colleagues on the floor of the Quality and Regulatory department for their kindness, the good atmosphere and the laughter. By showing interest in my project and involving me into the group I always enjoyed going to "work".

I would also like to thank my supervisor at the university Oktay Türetken. At first, I am very grateful for the opportunity to graduate in a large, Dutch company and this would not have been possible without his help and arrangements. Next to all the extra knowledge and experience I was able to gather for these past 7 months, my self-confidence in the industry was able to evolve. Within the project, I would like to show my gratitude for all the time and energy he has invested in my project to make sure that I could succeed. I was able to grow in many research aspects simply because he would ask me the right questions at the right moments. I would also like to thank my second supervisor Irene Vanderfeesten for her time, helpful ideas and feedback.

Maybe even the most important contribution comes from all company employees and friends who have participated in the (pilot) experiment. Without their time and effort this master thesis would *literally* not have been the same. I truly appreciate every individual contribution in this aspect and I would like to thank them all very much!

For the last acknowledgements, I saved the people who are closest to me. Thanks to my father and mother† I was able to study Industrial Engineering for the past 6 years. They have always believed in me through my whole study career and lived up through my potential at times I could not care less. They learned me about persistence and to never give up and I am very thankful for that. I would also like to say thanks to my friends and family for their understanding, patience and desirable distraction during the lead time of my master thesis project. At last, special recognition goes out to Noud Ackermans, for his excitement and continuous interest in my project. By supporting me and unconditionally believing in me he delivered the most valuable help, wherefore my special thanks.

Tessa Rompen
Eindhoven, 2015

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Abbreviations

BPM	Business Process Management
BPMN	Business Process Modeling and Notation
BU	Business Unit
CAPA	Corrective Actions and Preventive Action
CH	Complaint Handling
CHU	Complaint Handling Unit
FDA	Food and Drug Administration
ISO	International Organization for Standardization
ITU	Intention to Use
MEM	Method Evaluation Model
MR	Magnetic Resonance
MRI	Magnetic Resonance Imaging
OEM	Original Equipment Manufacturer
PEOU	Perceived Ease of Use
PU	Perceived Usefulness
QMS	Quality Management System
Q&R	Quality and Regulatory
REPRnm	Representation (n=1-6) and (m=P,C)
	P = A3 Paper
	C = Computer
SRRT	Service Record Reviewer Team

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1. Introduction

Every organization consists of a series of processes. A process is a chain of events, activities and decisions (Dumas et al., 2013). Even the smallest or merely service related company contains processes formally or informally. Depending on the company, these business processes can be represented in words, described on paper, in a graphical way or not even at all. A graphical representation of a business process is called a business process model and has been used already by many companies for their process representations. These process models or other representation formats can be established with the help of an information system.

The larger and more complex an enterprise is, the more advantageous it becomes to store all main business processes in order to keep the organization among other things maintainable and transparent. Besides, towards the creation of a competitive asset an enterprise must be aware of its structures, processes and information systems to create a mindset that is focused on innovation, productivity and process optimization (Lantow, 2014). Innovation, productivity and process optimization are well known terms in nowadays businesses and research, since it is highly important to keep up with the rapidly changing and dynamic business environments.

Furthermore, in order for an information system with business process models to be usable, it is important to know how to use process models in an understandable and usable way first. A Quality Management System (QMS) is an example of an information system that is used to record and communicate processes throughout the whole company. A QMS is an information system that helps the organization to manage the quality of a product (ANSI/AAMI/ISO, 2004). Processes from a QMS will be leading for this research paper because the most important feature of a QMS is to execute the process compliant to the description of the process. Evidently, employees are only able to execute the process compliant to the description if they are perfectly able to understand and use the represented process (model). The literature review was therefore focused on the identification of factors that influence the understandability and usability of business process models. Besides that, business processes are large and complex in general. With this characteristic it will be difficult to present process models in full extend and it is inevitable to anticipate in the modeling process on this given. The process model could be decomposed or separated in diverse sub-processes of the main higher level process (modularity) to minimize the process information at once. Furthermore, it seemed that there is not much known in current literature about the influence of the presentation medium on the understandability of business process models. The empirical study will focus on these particular facets of the understandability factors to find out which modularity representation supports the understandability of business process models best.

1.1 Company involvement

The Quality and Regulatory department of Philips Health Tech MR is closely involved in the execution of this study. The Business Unit (BU) MR develops Medical Resonance Imaging (MRI) scanners. Philips is situated in a very dynamic time during the maturity of this project. With a few setbacks in 2014 and a new start as Philips Health Tech, separated from Philips Lighting (previously as one Philips), it is time for a whole new century. The Quality Management System (QMS) has received more emphasized attention in the last couple of years, whereas all employees have to commit to the processes and procedures described in the QMS in order to secure the quality of the end products. Philips MR displays the QMS with the help of a sharepoint, were all employees have access to. The sharepoint consists of a high level quality manual, quality procedures, work instructions, forms, and records.

The implemented Quality Management System is based and certified on the international standard ISO 13485:2003 (ISO, 2003). This standard provides the organization with guidance related to the management of quality for the design, development, production, installation and service of medical devices (ANSI/AAMI/ISO, 2004). The QMS is process-based and this is represented in Figure 1. This process-based approach is defined as "the application of a system of processes within an organization, together with the identification and interactions of these processes, and their management" (ISO:9001, 2000). According to ISO, the process-based approach should emphasize the importance of understanding and meeting requirements, obtaining results of process performance and effectiveness, and continual improvement of processes based on objective measurement.

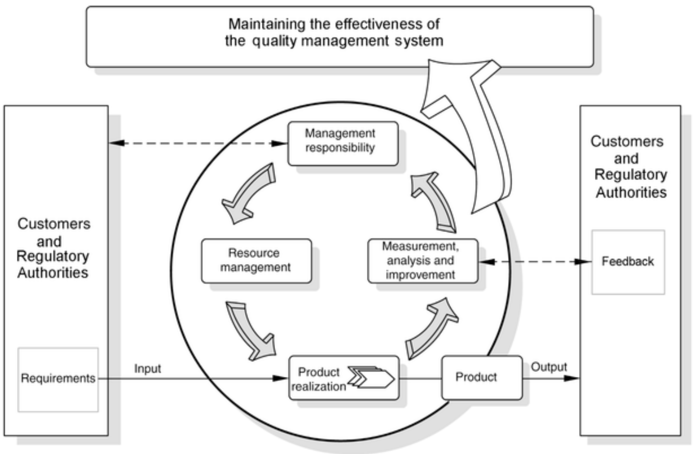


Figure 1: Model of a ISO 13485 process-based quality management system (ANSI/AAMI/ISO, 2004)

Nevertheless, the main motive for the implementation of the QMS at Philips Health Tech (PH) is the external or market related motive. This means that the ISO certification and FDA approval is essential for the company to access international markets and to be known for their high quality (Piskar & Dolinsek, 2006). There are regulatory authorities that oversee and assure the quality of these (medical) products. They have to make sure that everything happening within the company is compliant to the process description captured in the QMS. Especially, the American 'Food and Drug Administration' (FDA) has the legal force to take drastic actions towards the American market whenever there are any inconsistencies found between the processes described and the process execution. Internal motives are intrinsic and consist for example of productivity improvement or the simplification and standardization of a set of processes (Piskar & Dolinsek, 2006). Even though the reason for implementing a QMS is at first highly external, all the benefits accompanied with the internal motive (process and productivity improvement or the simplification and standardization of a set of processes) can be reached automatically as well (Piskar & Dolinsek, 2006). There is still a lot of potential for Philips Health Tech regarding the internal advantages.

A preview into the future shows that the prospective PH will make use of one QMS for all business units. The current situation is different for every separate BU. This is a large ongoing project with an innovative approach towards the representation of processes with the help of business process models. The modeling notation and style will be similar to the one notation and style (called BPMN 2.0) used in this research project.

1.2 Motivation

As mentioned implicitly before, one of the many reasons to use process models is to use them for communication purposes. An information system like a QMS is also used to communicate the processes throughout the whole organization to guarantee the quality and compliance over the whole process. Nowadays, many businesses use process models. These process models are only effective and efficient if people are able to understand the model (and subsequently the process). There are multiple scientific resources addressing *understandability* and *usability* of business process models as a dependent variable. Even though these subjects and terminologies are used interrelated in research topics addressing business process models, there was not much stated about their direct relationship and overlap. Many researchers also studied the behavior of business process models and what makes them more or less understandable to its users. The literature review resulted in a framework that integrates the existing knowledge about understandable and usable business process models. Business practitioners who are willing to model their processes need to know how to design and represent a process model best to be successful in communicating the processes and procedures throughout the company.

Thereupon, not much is known about the usability of quality management systems in general. How processes should be represented in an understandable and usable manner to the people who are supposed to use it is no common topic in research. Most processes in the QMS are large and complex. With this in mind it would be useful to know how these processes could be represented best. Many organizations, especially the ones concerned with medical devices, have to deal with regulatory authorities who actually control the quality. The use of a QMS in those organizations is not an optional feature that you may or may not use in your strategic plan. The QMS becomes an obligatory asset necessary to access areas of distribution. Compliance to the processes described in the QMS will be facilitated best when the most understandable way of representing processes is chosen. Gathering more knowledge towards the optimal use of process models of QMS-processes is therefore convenient for multiple business environments. More specifically, Philips Health Tech is going towards the use of a business process management tool that makes use of process model representations in the near future. By studying the behavior of their own processes and their own employees, relevant knowledge will be gathered regarding these intended transformations. These findings are valuable input for this ongoing project.

1.3 Research objectives

This empirical study considers a sub-area of the foundational framework of understandability factors. A business environment and a QMS consists of large, complex processes, which go through many layers within the organization. Also Philips Health Tech has to deal with these large and complex processes on a daily basis. Modeling these processes is not always easy, because it is difficult to take all identified understandability model factors into account for the same process model. A process representation in a fully flattened version is often very large and unclear for example. It will become as well clear that there is a common trade-off between the one model factor and the other model factor that influences the understandability of business process models. From the model factors that were found in the literature review, it seems that the *model structure and the visual layout* covers the biggest part of the influencing model factors on the understandability as well. Complexity in terms of size and structure, in this regard, have a major impact on the understandability of process models. This means that a certain degree of modularity is often necessary to improve the understandability and keep the model maintainable. By making use of sub-processes (i.e. applying hierarchy or decomposing the model), the process model advantageously decreases in size and becomes more structured in general, but other forces come into place as well. The ability to hide information (and therefore reduce the complexity) facilitates understanding (Reijers & Mendling, 2011). On the other hand, the cognitive load increases because of the fragmented pieces of the process model that have to be integrated again (Figl, Koschmider, & Kriglstein, 2013). It is therefore not yet clear what the total and moderating effects of modularity (the use of sub-processes) are and whether they do increase the understandability in an absolute sense (Figl, Koschmider, et al., 2013). In short, the way a process model applies modularity influences the understandability (Burton-Jones & Meso, 2008). Furthermore, one of the factors that has not yet been investigated is the presentation medium of the process model. The presentation medium might have an influence on the understandability of a certain modularity representation. The research objective will therefore contribute to this elaborated field of business process model understandability with as a main focus:

To identify which modularity representation and presentation medium supports the understandability of business process models best.

1.4 Report outline

This report will start with the theoretical background coming from the literature review. This is the foundation of the subsequent empirical study. The research methodology explains what has been done to collect the data from practice. An experiment conducted in the company is the main method used to gather field knowledge. The experimental setup will therefore be explained next. All the information that has been collected with this experiment is captured in the results section. At last, this report will conclude with an overall discussion of the results and with a summary of this study in the format of an end conclusion.

2. Theoretical Background

The main goal of the literature review was to integrate all the identified factors that contribute to a usable and understandable business process model into one framework. The *focus* of the literature review was therefore two sided (Randolph, 2009). At first, it is of importance to know what theories already exist on the understandability and usability of process models and the relationship and overlap between especially the concepts *"understandability"* and "*usability"* of business process models. Furthermore, the literature review lays a focus on previous research outcomes and the relationship between the different findings within the papers about the understandability of process models. This outcome-oriented review also facilitated the identification of factors that had not been investigated yet (Randolph, 2009). The general issues that were found are identified and included as well, to find out which problems were caused regarding the usability of the research outcomes in practice. The main literature research questions is focused on the overall influencing understandability factors.

From the previous literature, which factors contribute to an understandable and usable business process model?

Of first interest here, is to know what is meant by the understandability and usability of business process models and to know in which context these constructs are used. This is of relevance, since researchers in this field use numerous terms as a dependent variable (e.g. quality, comprehension, understandability, usability etc.) in order to increase the quality of use of business process models. Prior to any integration of different factors, a certain consensus on all the different defining constructs is needed. In order to establish a certain consensus *usability* and *understandability* have been compared as different concepts. It seems understandability is only a fraction of usability, though they have a lot in common in the research context of business process models. Apparently there is a high overlap and strong relationship between the usability and understandability of business process models. In addition, the usefulness of process models is interrelated with usability and understandability. In fact a useful model must be at least understood well and be efficient. As a result the understandability and usability of business process models can be best described as a combination of different constructs. Most of the elements of the different constructs are captured in the "understandability measures", which can therefore be used as a main construct to measure the understandability and usability of business process models.

2.1 Business process model (process models)

Business process models (or conceptual models) are graphical representations which "communicate knowledge about the work performed in organizations" (Kunze, Luebbe, Weidlich, & Weske, 2011). In other words they describe the aspects of a defined business domain (Burton-Jones & Meso, 2008). The modeling of processes is not a purpose in itself, but belongs to the much broader field called Business Process Management (BPM). The field of BPM focusses mainly on the improvement of the processes that create products and services in order to optimally configure the processes with the performance objectives of the company (Dumas et al., 2013). Organizational concepts like resources, actors, activities and goals, have to collaborate with each other in order to achieve the stated performance objectives of the company (Caetano, Silva, & Tribolet, 2005). These organizational concepts are captured by business process models and are able to represent the business relationships as well (Caetano, Silva, et al., 2005). Hence, business processes can be represented graphically, including activities or tasks, events or stages, decision points and control flow logic (Dumas et al., 2013; Reijers, Recker, & Wouw, 2010). This graphical representation of a real-life business process is often created with the help of a modeling technique and has to be supported by an information system, in order to communicate the models throughout the company (Burton-Jones & Meso, 2008; Davies, Green, Rosemann, Indulska, & Gallo, 2006).

As mentioned before, one of the main motives to model processes is for communication purposes. Other motives may be to facilitate the understanding of the process, to overcome problems, to coordinate work and to discover and realize opportunities (Houy, Fettke, & Loos, 2014; Rittgen, 2010; Sánchez-González, Ruiz, García, & Piattini, 2013). Besides that, information regarding the execution data is a useful asset, to capture and monitor performance metrics of the process (Jan Mendling, Strembeck, & Recker, 2012). At last, Mturi and Johannesson (2013) summarize several other explicit benefits of process models, captured from several researchers namely: a maintained focus on business needs, automated enactment and easy change management. To succeed in any of the positive outcomes of these purposes, the process models have to be usable for all users. Usability and its meaning towards business process models will therefore be the next topic to address.

2.1.1 Usable Process Models

Usability is defined in a number of ways and in a number of disciplines. Bevan (1995) mentions that there are two complementary ways to look at usability. The first perspective is the bottom-up product-oriented view. Usability is then linked to the ease of use of the product or service (i.e. business process model). The second perspective is a broader top-down approach whereas usability is defined as "the ability to use a product for its intended purpose" (Bevan, 1995). Nielsen (1993) defines usability as multiple measurable components with the following five usability attributes: *learnability, efficiency, memorability, errors and satisfaction.* Again another viewpoint states that *"usability is the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use"* (ISO:9241; as well defined as "quality of use measures" by Bevan, 1995). This ISO:9241 standard is also used by Birkmeier, Klöckner, & Overhage (2010) in their research and is process-oriented in nature (Abran, Khelifi, Suryn, & Seffah, 2003). Surprisingly, the International Organization for Standardization (ISO) also makes a different statement on *usability* in the ISO standard ISO:9126. This standard is product-oriented and claims that usability is a combination of five usability attributes*: understandability, learnability, operability, attractiveness and usability compliance* (Abran et al., 2003).
As a last addition to all the different usability attributes, Bevan (1995) emphasizes the importance of the *context of use* (technical, physical, social and organisational environment). The interactions between basically all these usability attributes are visualized in Figure 2.

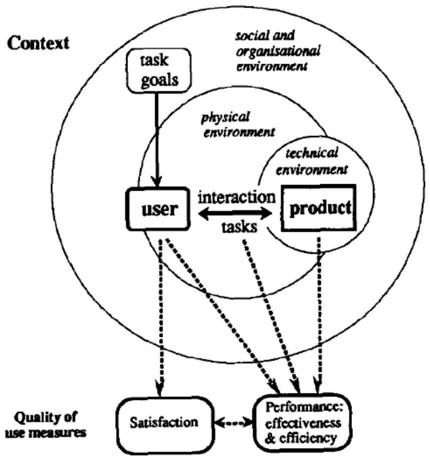


Figure 2: Usability measures determined by the context of use (Bevan, 1995)

Continuing on the different definitions, there is a big overlap. For example, between the ISO definitions, a major overlap exists once we know that *efficiency* and *effectiveness,* are also indicated as the pragmatic quality of a system by several researchers (e.g. Moody, 2003). *Pragmatic quality* is often used to measure the *understandability* and the *facilitation of learning* of models (Rittgen, 2010; Krogstie et al., 2006). Likewise, *learnability* could also be substituted by relative user *efficiency* (Bevan, 1995). A system must have a high usability in order for users to use the system. Without the system being used or underutilized, not all potential benefits can be realized despite technological superiority (Agarwal, De, & Sinha, 1999; Moody, 2003). This leads to again another way to capture part of this phenomenon namely *Perceived Usefulness* (PU). PU is "a person's subjective probability that using a particular system would enhance his or her job performance (Moody, 2003). PU is used to measure the actual usefulness of a product or process (Rittgen, 2010). Not entirely coincidentally, usefulness is the major driving factor that decides whether business analysts are willing to keep using process models (Davies et al., 2006). Davies et al. (2006) used questions like "does conceptual modeling take too much time?" and "does conceptual modeling make my job easier?" to find out more about the usefulness of process models. These questions are similar to questionnaires based on the Method Evaluation Model (MEM). The MEM can be used to measure usefulness in information systems (IS-) design research (Moody, 2003). Just like "*PU"*, "*satisfaction*" is a subjective measurement, which is used to measure whether a system is pleasant to use and if people are willing to use the system from an intrinsic motivation (Moody, 2003; Nielsen, 1993). Furthermore, Mendling, Strembeck and Recker (2012) claim that in order for a model to be useful the model must be at least *understood well* and *efficient*. This adds up to the broader definition of usability proposed by Bevan (1995). He explains that in terms of this definition, the product must be usable and useful and cannot be either of the two since they are not mutually exclusive. In conclusion, there is a big overlap between "usefulness" and "usability" as well as for the different definitions of usability itself.

After defining usability and explaining a bit more about process models, it is good to know more about one major quality criteria that contributes to a good usability of process models. Making process models usable for the users goes together with making these models understandable. Process models should be understandable first, in order to succeed in its purpose to communicate and to facilitate a thorough understanding of the process (Dumas, Rosa, Mendling, & Raul, 2012; Recker, Reijers, & van de Wouw, 2014; Reijers et al., 2010). Besides that, questions about understanding are used in order to measure usability (Birkmeier et al., 2010). Since understandability is only part of usability it is important to know that it is one of the most important contributing factors, and therefore highly relevant. Understandability is considered by Houy, Fettke and Loos (2012) as one of the most important quality criteria of process models. Other researchers use understandability even as a proxy for model quality (Fettke, Houy, Vella, & Loos, 2012; Mendling, Reijers, & Cardoso, 2007a). Besides, considering systematic reviews on business process model quality, approximately 60% (42/72) of the researchers use 'understandability' as the dependent variable for the measurement of the quality of process models. Understanding process models is thus essential to them actually being used (Reijers et al., 2010). It is therefore relevant to keep in mind that model understandability is of high importance but, only as a means to achieve the purpose of realizing an information system with a highly usable business process models (Rittgen, 2010). An extra advantage to this purpose is that the understandability of a process model also influences the maintainability of the process in a positive way (García, Piattini, Ruiz, & Visaggio, 2005), which is highly wishful in the current dynamic environment of many businesses.

There are numerous researchers whom address understandability issues in relation to business process models. Reijers and Mendling (2011) describe understandability as "the degree to which information contained in a process model can be easily understood by a reader of that model". Houy et al. (2012) covers all the identified understandability dimensions that where included in the papers that were used for their systematic literature review. His framework shows the number of different understandability dimensions (effectiveness, efficiency and subjective effectiveness) that are, and can be tested. As mentioned before, this framework shows that again there is a large overlap between measuring *usability* and *understandability*. The framework is included in Table 1.

Table 1: Conceptual model understandability reference framework (Houy et al., 2012)

Conceptual model understandability					
Objectively measurable dimensions of understandability					**Subjective dimension of understandability**
Effectiveness				**Efficiency**	**Effectiveness**
1. Recalling model content	2. Correctly answering questions about model content	3. Problem-solving based on the model content	4. Verification of model content	5. Time needed to understand a model	6. Perceived ease of understanding a model

At last, there are three possible perspectives to look at the understandability of process models, which will be discussed subsequently. Reijers et al. (2010) contend that the understandability of process models is not only depending on factors intrinsic to the model but also dependent on the characteristics of the user. Besides that, there is literature that discusses understandability with the modeler as a starting point of the modeling process (e.g. Claes et al., 2012). Apperently, Claes et al. (2012) found out that a structured modeling style creates a better outcome in terms of understandability. In addition, they found that the best readable models are created by more experienced and therefore faster modelers. In conclusion, the three perspectives are the perspective of (1) the model itself, (2) the user and (3) the modeler. Combinations of these perspectives are considered as well (Mendling et al., 2007; Reijers & Mendling, 2011; Weitlaner et al., 2013). Nevertheless, perspective (3) is left out of scope further on, even though the understandability of the created models is significantly dependent on the person who models the process (Weitlaner et al., 2013). More in the interest of the *literature research questions* are the factors that increase the understandability of the process model, from the process model perspective itself, and from the user perspective. The modeler perspective is left out of scope under the assumption that the modeler is an expert in modeling the process and therefore models according to the model factors that increase the understandability.

2.2 Understandability of Business Process Models

After this theoretical introduction of the topic, the next step is to identify all factors that are already found to be of influence. The usability of these influencing factors were integrated in the dependent variable *"understandability".* An elaborated literature review was conducted on the different factors that make process models understandable to its users. The research into the understandability of process models is very diversified and addresses many underlying theories without a unified agreement on these different theories yet (Fettke et al., 2012; Houy et al., 2014). Though, the influencing factors that were found, are indeed improving the overall understandability of process models, so the research that is done is of good use (Saghafi & Wand, 2014). As a result, Houy et al. (2012) states that "experimental research on model understandability should put a stronger focus on the pool of different understandability dimensions identified in related work and use them in order to further our understanding of model understandability regarding all its possible dimensions". This is the main motivation to find out what factors are investigated in research regarding business process model understandability. Process model understandability is defined by Reijers and Mendling (2011) as "the degree to which information contained in a process model can be easily understood by a reader of that model". Gruhn & Laue (2006) introduce complexity therefore as the opposite of understandability, i.e. the difficulty to understand a model. In addition, Houy et al. (2014) found in a systematic literature review that the subject matters of the research on understandability of process models is focused (among other things) on the investigation of general model quality and complexity and on the study of cognitive factors influencing model understanding. This again suggest that the understanding of a business process model is highly reliant on the intrinsic model and user (personal) characteristics.

A total of 31 papers has been analyzed in order to extract all understandability factors. The included papers either address model factors, personal factors, or both. All identified influencing understandability factors are summarized in the reference framework in Table 2.

Table 2: Reference framework of the understandability factors of process models

Paper	Reference	Year	Model factor	Personal factor	Understandability Factor	Description	significant /relevant
1	Bera, Burton-Jones and Wand	2014		x	Domain Knowledge	Following ontological guidelines and domain knowledge as interacting effect	Yes
2	Haisjackl and Zugal	2014	x		Presentation Format	Graphical representation compared to textual: in nr of errors, duration and mental eff	Yes
3	Johannsen, Leist and Braunnagel	2014	x		Model Structure and Visual Layout	Decomposing with Wand and Weber's decomposition model increases understandabi	Yes
4	Lantow	2014	x		Model Structure and Visual Layout	Level of detail.	Yes
5	Recker, Reijers and van de Wouw	2014		x	Dynamic Characteristics	Cognitive skills	Yes
				x		Learning strategy	Yes
6	Figl, Mendling and Strembeck	2013	x		Modeling Notation	Symbol design, based on cognitive load and context of the conceptual model	Yes
			x		Model element Labelling	Textual labels flatten the influence of the modelling notation	Yes
7	Figl, Koschmider and Kriglstein	2013	x		Model Structure and Visual Layout	Subprocess representation. Overview+Detail strategy is preferred over focus+context	Yes
			x			Linking process visualization. Node-link, Treemap or Nested graphs	No
8	Figl, Recker and Mendling	2013	x		Model element Labelling	The routing symbol design of the gateways: "perceptual discriminality", "pop out"	Yes
9	Koschmider, Kriglstein and Ullrich	2013	x		Model Content	Including context information like objects and roles	Yes
10	Mturi and Johannesson	2013	x		Navigation and Searching	The influence of a context-based process semantic annotation model	Yes
11	Recker	2013	x		Model Structure and Visual Layout	Use of gateway constructs	Yes
12	Sánchez-González, Ruiz, García and Cardoso	2013	x		Model Structure and Visual Layout	number of nodes, reducing sequence and message flow, reducing decision nodes, reducing number of events	yes
13	Stitzlein, Sanderson and Indulska	2013	x		Presentation Format: Modeling Notation	Representation sequences and task allocations	Yes
				x	Practical Experience: Modeling Expertise	Experience with abstract models	No
14	Weitlaner, Guettinger and Kohlbacher	2013	x		Modeling Notation	Concurrency, Order, Repetition	Yes, No, No
				x	Theoretical Knowledge	Level of education, Focus of education	Yes, No
				x	Practical Experience	Knowledge of Business Process Modeling	No
15	Dumas, La Rosa, Mendling et al.	2012	x		Model Structure and Visual Layout	Structuredness (trade-off with compactness)	Yes
16	Mendling, Strembeck and Recker	2012	x		Model element Labelling	Abstract labels realize syntax comprehension better	Yes
				x	Theoretical Knowledge	Formal process knowledge	Yes
				x	Practical Experience: Modeling Expertise	Modelling experience	No
				x	Practical Experience: Modeling Expertise	Modelling intensity	No
17	Ottensooser, Feteke, Reijers et al.	2012	x		Presentation Format: Textual Support	Textual descriptions of the process are understood by everyone	Yes
						Textual descriptions complement graphical (process modelling) notations	Yes
18	Recker & Dreiling	2011		x	Practical Experience	Prior experience in the modeling language	No
				x	Practical Experience	Business process management work experience	Yes
			x		Model element Labeling	Native Language	Yes
19	Reijers, Freytag, Mendling and Ecklede	2011	x		Coloring Model Elements	use of color to highlighting process model elements (syntax highlighting)	Yes
				x	Modeling Expertise	Difference between novices and experts of the effect of highlighting	Yes
20	Reijers and Mendling	2011	x		Model Structure and Visual Layout	12 Complexity measures: influence only of average connector degree and density	Yes
				x	Theoretical and Practical Knowledge	As combined dimension personal factors: Theory, Practice and Education	Yes
21	Reijers, Mendling and Dijkman	2011	x		Model Structure and Visual Layout	Subprocess representation/modularity	Yes
						A fully automated approach of the modularization of process models is not possible	Yes
22	la Rosa, Wohed, Mendling et al.	2011	x		Model Structure and Visual Layout	Managing Complexity by adjusting model parts to increase usability	Yes
						Inceased structuredness and decrease in size improve understandability	Yes
23	Birkmeier, Klöckner and Overhage	2010	x		Modeling notation	Comparing the usability (effectiveness, efficiency, user satisfaction) of BPMN and UM	No
24	Mendling, Reijers and Recker	2010	x		Model element Labelling	Verb-object labels are most understandable, next Action-noun labels, next others	Yes
				x	Domain Knowledge	The moderating effect of application domain knowledge between labeling style and P	No
				x	Theoretical Knowledge	The moderating effect of modelling notation knowledge between labeling style and I	No
25	Peters and Weidlich	2009	x		Model element Labelling	Impact of labelling on the understandability	Not tested
	Burton-Jones and Meso	2008	x		Presentation Format: Textual Support	Multiple forms of information	Yes
			x		Model Structure and Visual Layout	Decomposition with Wand and Weber's decomposition rules (quality decomposition)	Yes
26	Mendling and Strembeck	2008	x		Model element Labelling	Larger text labels decease the understandability of the model	Yes
				x	Model Structure and Visual Layout	Separability relates the numger of cut-vertices to the number of nodes	Yes
				x	Theoretical knowledge	Theoretical pcoess modeling knowledge increases the process understandability	Yes, partly
26	Mendling, Reijers and Cardoso	2007	x		Model Structure and Visual Layout	Size: high number of arcs/average connector degree and density	Yes
				x	Theoretical and Practical Knowledge	As combined dimension personal factors: Theory and Practice	Yes
28	Recker and Dreiling	2007	x		Modeling Notation	Differences in understanding two process-oriented languages.	No
29	Caetano, Silva and Tribolet	2005	x		Model Content	Business Objects (object oriented) and Role model Framework	Not tested
30	Caetano, Zacarias, Silva and Tribolet	2005	x		Model Content	Object oriented framework including role-based business process modelling	Not tested
31	Agarwal, De and Sinha	1999	x		Model Emphasis	Process-oriented is easier to understand in comparison to Object-oriented notation	Yes

Most of the understandability factors were empirically tested and influence the understandability significantly. Despite that, there is also a number of factors that are not significant in the currently existing experiments or are not tested yet. Especially the factors that are not empirically tested have a high theoretical power and are therefore included in the reference framework. The factors that are not of influence (enough) should not be addressed again in research in a similar setup, and are neither of interest in the modeling process.

Subsequently, the conceptualized understandability factors of the reference framework are all graphically represented in the *understandability factors model* (Figure 3). This model explains the possible relationships between these understandability factors. Not only the reference framework factors are included, but also a new dimension is created. Personal factors are suggested to be a subdivision of the *context* of the process model. As can be derived, also the *presentation medium* is part of this environment or context of the process model. Modeling purpose, domain knowledge, presentation medium and modeling expertise are white or arced in the model. Their contribution is not fully clear, or at least the literature does not provide clear evidence for the inclusion or exclusion of these factors within the introduced model. The other factors are somehow validated to have an effect on the understandability of process models, even though this effect may be ambiguous. Both the *modularity* and *presentation medium* are colored in orange. These factors are the main focus of the empirical study.

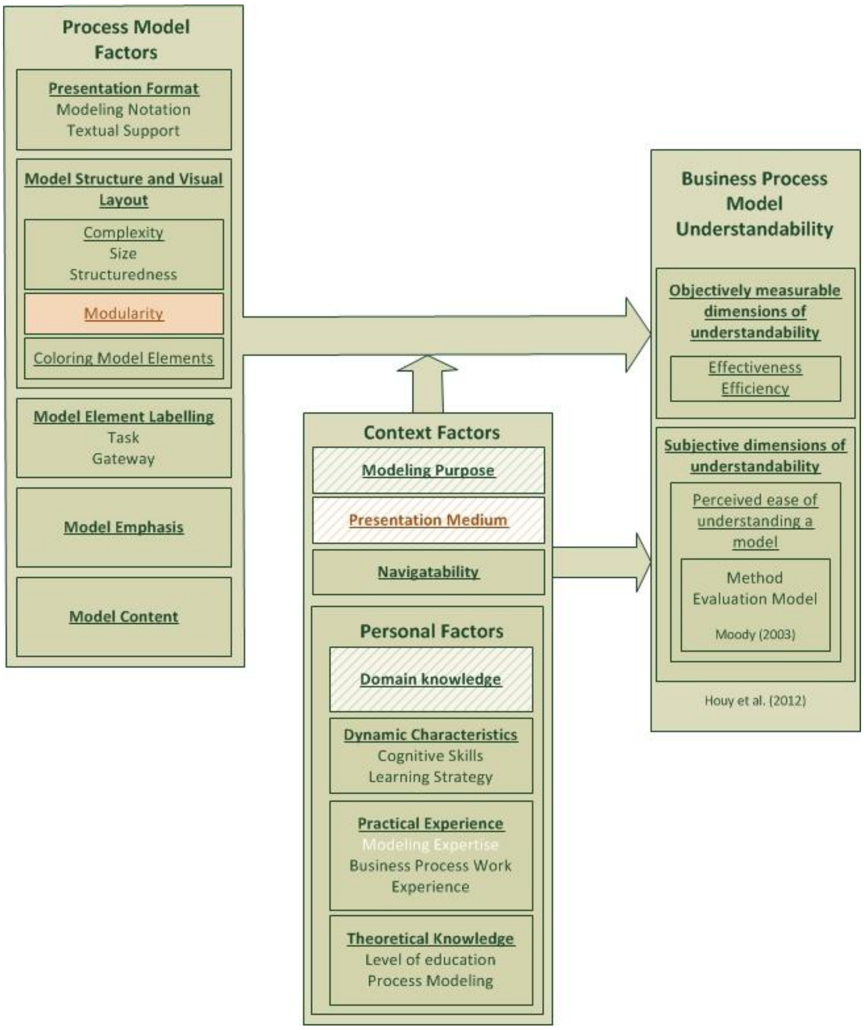


Figure 3: Understandability Factors Model

Note that despite of the existence of the framework and model, taking all the different understandability factors into consideration is difficult. The reason for this is that the intention to make the process model more understandable with the inclusion of one factor could on the other hand decrease the understandability by a side effect of that factor (Dumas et al., 2012). Structuredness and size are two of these contradicting factors. These shortcomings are not represented in the understandability framework. Though, the understandabililty framework could be used as an input for quality treshold measures that still have to be created and as input for the model areas that have not yet been investigated in enough detail. It also shows clearly which factors are quite elaborately and thoroughly investigated already. In this way a certain saturation can be reached in time.

How both the reference framework and the understandability factors model were originated will be explained next. The specific influence of the understandability factor will also be explained here. To start with, process models should be *simple, intuitive, easy to interpret* (Mendling et al., 2007; Reijers & Mendling, 2011; Stitzlein, Sanderson, & Indulska, 2013) and designed in a way that serves its *purpose* best (Schrepfer, Wolf, Mendling, & Reijers, 2009). The understandability of process models is thus related to the "ease of use and the effort for reading and correctly interpreting a model" (Houy et al., 2014).

2.3 Model Factors

The model factors that seem to influence the understandability of process models in any extent are conceptualized in the next sub-paragraphs. These concepts are either proposed in the papers included in the reference framework (Table 2) or newly created in order to be consistent about the influencing understandability factors. The discussion about these factors includes the presentation format, model structure and visual layout, model element labelling, model emphasis, model content and at last the navigation of process models.

2.3.1 Presentation format: Modeling Notation

A number of modeling notations can be used to model processes. This modeling notation exists out of a set of graphical symbols, which shape the visualization of the elements of the process (Dumas et al., 2013; Schrepfer et al., 2009). A number of mostly used modeling notations are UML activity diagrams (UML ADs), Event driven Process Chains (EPCs) and Business Process Modeling Notation (BPMN) and flowcharts. The Business Process Modeling Notation (BPMN) is a mature and standardized modeling language, which can be used to model business processes (Dumas et al., 2013). As being said, BPMN is not the only language that may be used in modeling processes. What language should be used in practice to represent processes is a well-known and ambiguous topic in research. Researchers claim that BPMN (compared to other languages) provides technical advantages and is readily usable for business users (Birkmeier et al., 2010). BPMN is one of the most frequently used notations (Reijers & Mendling, 2011) as well. On the other hand, there is no unambiguous evidence for any superiority. The reason for this inconsistency might have its roots at the many different experimental setups that are used, which leads to fundamentally different outcomes towards understandability and usability aspects (Laue & Gadatsch, 2011). For example, Birkmeier et al. (2010) compare BPMN with UML (Unified Modeling Language) activity diagrams in order to conclude that BPMN nor UML is significantly better from a usability perspective. Afterwards they compared the modeling languages and imply that the modeling elements are very similar.

Despite of this, another representation, EPC, is more difficult to understand in comparison to UML and BPMN in terms of being able to identify simultaneous activities. This is found by Weitlaner, Guettinger and Kohlbacher (2013) regardless of the personal factors of the users of the model. One of the oldest process languages is the flowchart (Dumas et al., 2013). A big difference between BPMN and flowcharts, according to Dumas et al. (2013), is that the flowchart does not make use of event nodes; "an event node tells us that something may or must happen, within the process or in the environment of the process that requires a reaction". BPMN has in this sense the opportunity to model a more complete process in comparison to the possibilities of a flowchart. Though, flowcharts are still mainly used in practice (Weitlaner et al., 2013). Figl, Mendling and Strembeck (2013) reinforced the preference for BPMN by their research on the low cognitive load that the Business Process Modeling Notation uses. Namely, "the limited capacity of human working memory constitutes a bottleneck for cognitive activities involved in understanding process models, and the way information is represented via a specific symbol set may place extra cognitive load on the user" (Figl, Mendling, et al., 2013). BPMN therefore performs significantly better than other modeling notations and has a higher usability.

Despite all these considered differences between process model notations, it seems that process models are understood at an equal level, even though the experience and familiarity with process models is in a different modeling notation (e.g. Mendling, Reijers, & Cardoso, 2007b; Recker & Dreiling, 2011; Reijers, Mendling, & Dijkman, 2011). For example, there has been no significant difference in understanding in a test between the BPMN-language and the EPC-language whereas all participants had knowledge of only one notation (Recker & Dreiling, 2007). This again suggests that the modeling notations share a common ground (similar modeling elements) that serves a common understanding.

2.3.2 Presentation format: Textual Support

As mentioned by process actors as well (Mendling et al., 2007), processes models should always come together with textual support in terms of textual descriptions of the processes (Ottensooser, Fekete, Reijers, Mendling, & Menictas, 2012). Textual descriptions of the process improve the understandability of the process and therefore of the process model itself (Ottensooser et al., 2012). The reason is that personal factors like experience in process modeling and analytical insight influence the perceived understandability of process models (Mendling et al., 2007; Ottensooser et al., 2012). It must be possible for a broad audience to absorb information from a process model with the help of text. Next to that, individuals process information better when the brain receives information through auditory (words) and visual (graphical models) channels in parallel (Mendling et al., 2010). Even more critical is the statement that Ottensooser et al. (2012) makes by saying that the benefits of a graphical notation can only be reached when people have received training in process models. Besides, the increase of cognitive load is an unfortunate trade-off of the inclusion of text, whereas graphical notations capture an efficient way of processing information (Ottensooser et al., 2012). Equally, the number of errors, duration of processing the textual descriptions and the mental effort is higher for textual descriptions and this might be the reason that people find graphical representation easier to understand (Haisjackl & Zugal, 2014). The reason for using both textual and graphical notations is because they facilitate different cognitive processes and are therefore complementary in nature (Ottensooser et al., 2012). As a result, the textual descriptions are not meant to be used in isolation but as a support of the graphical representation.

2.3.3 Model Structure and Visual Layout

There are a number of structural and layout factors that influence the understandability. The understandability seems to increase when the models become less complex (Reijers & Mendling, 2011). Size and structuredness of process models are both associated with complexity, whereas a reduced size and a higher structured process model should affect the understandability of the model in a positive way (La Rosa et al., 2011). Besides, the layout could help in designing process models in an understandable way. A few guidelines are enumerated by Gruhn & Laue (2006) considering this layout of a process model:

1. Choosing size and color of the graphical elements in the model with care
2. Modeling time-dependency horizontally from left to right or vertically from top to bottom
3. Aligning the edges of the graphical elements
4. Avoiding intersecting arrows.

2.3.4 Model Structure and Visual Layout: Complexity

As being said already, researchers have shown that size in general has an impact on the understandability, whereas larger models are less easy to understand (Reijers & Mendling, 2011). Though, Reijers and Mendling mention correctly that relevant parts of a model cannot simply be skipped. Leaving out gateways for example already decreases the understandability (Recker, 2013). In line with the above mentioned, the number of arcs in a process model and the density seems to influence the understandability. A high number of arcs in a model and a high density have a negative effect on model understandability (Mendling et al., 2007; Reijers & Mendling, 2011). Reijers and Mendling (2011) also found that a lower variety of connectors in a model may increase the understandability. Both show that complexity factors affects the understandability. Though, more details in the process model actually can result in a higher understandability even though the size (complexity) increases (Lantow, 2014). The suggested reason for this is that there might be important context information included in the details, which fosters understandability to a higher extend then the increase in size hampers the understandability. Saghafi & Wand (2014) have determined this trade-off as well and call it the simplicity-expressivenes trade-off. Because of the high relevance of this trade-off, sub-processes come into place to compromise between these contradicting effects. This topic will be discussed further on.

The other factor that was also mentioned by experts (when understandability was perceived higher) is *structuredness* (Mendling et al., 2007). Besides that, unstructured models have a higher error probability and are therefore less correct, because it is more difficult to understand the control flow (Laue & Mendling, 2010). Dumas et al. (2012) also examined the effects of structuredness on the understandability of process models. They discuss the trade-off between structuredness and the implication of duplicating a specific amount of nodes and gateways (i.e. at the cost of compactness and size). This trade-off is also mentioned by la Rosa et al. (2011). Block-structuredess and the duplication of model elements are methods to achieve structuredness (la Rosa et al., 2011). The application of block-structuredness means that "for every node with multiple outgoing arcs (a split) there is a corresponding node with multiple incoming arcs (a join)" (Dumas et al., 2012). For realizing structuredness, the size increases due to the duplication of nodes, but the complexity attributes decrease (Dumas et al., 2012). Structured models are nonetheless easier to understand (as long as the number of gateways does not increase) and perceived to be less complex (Dumas et al., 2012).

2.3.5 Model Structure and Visual Layout: Modularity

Complexity and size issues can be solved by modularity and decomposition, which can be applied for example by using subprocesses (Reijers, Mendling, et al., 2011). Compacting (removing redundant element without loss of process behavior) is another way to realize a positive effect on the size of the process model (la Rosa et al., 2011), but might not be effective enough. Decomposing means that large process models are divided into smaller subprocesses in order to increase the understandability without leaving out relevant parts of the process(Johannsen, Leist, & Braunnagel, 2014). These sub-processes provide for a hierarchy in the process model (Stefan Zugal, Soffer, Pinggera, & Weber, 2012). The concept of modularity can be found under all these different headings (decomposition, hierarchy, modularity) in literature and has been used interchangeably. The use of subprocesses facilitates understanding because of lower browsing costs and the ability to hide information (la Rosa et al., 2011; Reijers, Mendling, et al., 2011). This reduction of mental effort gets rewarded by the positive effects of *abstraction* (Zugal, Pinggera, Weber, Mendling, & Reijers, 2012). This leads to a limitation in the represented information, which makes the local parts of the process model more understandable (Reijers et al., 2011). In short, the rationale for the advantages of modularity is supposedly based on the reduction of the complexity of a process model and therefore improves the understandability (Johannsen et al., 2014; la Rosa et al., 2011). In contradiction to all the before mentioned, modularity causes also for an increase of cognitive load, since the fragmented pieces of the process model (the subprocesses) have to be cognitively integrated again (Figl, Koschmider, et al., 2013). This negative effect is called the *split-attention effect* (Zugal et al., 2012). It is therefore not yet clear what the total and moderating effects of modularity (the use of sub-processes) are and whether they do increase the understandability in an absolute sense (Figl, Koschmider, et al., 2013). Combining these two opposing forces into one makes the application of modularity or hierarchy an undefined topic regarding the understandability of process models. (Zugal, Pinggera, Reijers, Reichert, & Weber, 2012). Zugal, Pinggera et al. (2012) claim that both *abstraction* and the *split-attention* effect should be taken into account when questions are asked in an experiment on the effect of modularity on the understandability.

Nevertheless, the decomposition of process models is already established in process modeling and conditions are used to make this job easier. It seems that using the decomposition conditions of Wand and Weber significantly increases the understandability of decomposed models compared to decomposing without these conditions (Burton-Jones & Meso, 2008; Johannsen et al., 2014). Wand and Weber's Decomposition Model provides conditions to decompose a model into subprocesses in an understandable way (Johannsen et al., 2014). Especially, the strong cohesion and minimum coupling condition are of influence of this effect. Reijers, Mendling, et al. (2011) also provide five criteria that should be modelled according to when modularity is applied to a process model, despite their recognition that there are no explicit guidelines that can be given. Next to that, they evaluate three types of criteria that provides the insight that automatic modularization is only suitable with the end assessment of an expert. All conditions can still be used in the case of large process models to decrease the size, but Burton-Jones & Meso (2008) gave at least strong support that decomposing according to Wand and Weber's model gives a high quality model with a direct effect on its understandability. Next to the choices that can be made during decomposition, there also a number of representations that can be chosen to present sub-process in a business proces model. The representation of sub-processes can be done in a number of ways, which are described for example by Figl, Koschmider and Kriglstein (2013). They found out that the preferred representation uses multiple windows that separately display a particular (sub-) process model and its relationship (overview+detail representation) in comparison to a focus+context view.

2.3.6 Model Structure and Visual Layout: Coloring model elements

The last factor that has been identified as an important visual layout factor, is the use of color and highlights. This is another feature that can be used within modeling tools to connect model elements that relate to one another. Especially, users with little practical knowledge of modeling, will understand process models more accurately with the help of color (Reijers, Freytag, Mendling, & Eckleder, 2011).

2.3.7 Model element Labelling

Keeping simplicity is one of the important factors that increases understandability (Mendling et al., 2007). This is also one of the reasons that Mendling et al. (2012) finds that abstract labels are easier to understand then textual labels in the process models. Also, the larger the label text, the less understandable the model becomes (Mendling & Strembeck, 2008). As we have seen before, if the cognitive load becomes too high, the understandability decreases. In practice the domain information in the labels cannot be left out, because it contains valuable information of the model. However, especially in the modeling phase it is of relevance to use abstract labels at first (Mendling et al., 2012). The modeling will then cause the lowest complexity. On the other hand, domain information is considered in such a way important that it flattens out the influence of the modeling notation, since people are able to understand the process by focussing merely on the text (Figl, Mendling, et al., 2013). This means that there is a contradiction in the effect of textual labels on the understandability of process models. Next to this, the language of the labels is of influence as well. If the language that is used is not the first language of the reader, the understandability decreases due to an increase in cognitive load (Recker & Dreiling, 2007). It is important to ask for the least cognitive load of labels as possible, so there should be a good balance between the information in the label and the cognitive load of the working memory. This has to be kept in mind with the composition of the labeling conventions. The conventions that can be used best to label the elements are called short “verb-object” labels (Mendling, Reijers, & Recker, 2010). These labels are considered to be the least ambiguous. The modeller itself should still think consiously about the choice of terms within the labels, to avoid any misunderstanding (Mendling et al., 2010). Another recommended approach to increase the understandability of element labels that present the domain information, is the use of a glossary of these labels (Peters & Weidlich, 2009). Unfortunately, Peter and Weidlich (2009) did not emperically validate whether this approach really increases the understandability of the process model.

Another part of the modeling elements considers the routing elements. Convergence and divergence semantics are used to model decisions for either “splitting” or “joining” tasks in a process and can be called routing elements (Figl, Recker, & Mendling, 2013). The most used routing elements are the *AND (both routings have to be followed), XOR (a mutually exclusive choice)* or *OR (one or more routings can be chosen)* decisions (Dumas et al., 2013). The different routing elements have to be easy to discriminate from each other and should be easy to locate, in order for them to be accurately understood and to be perceived as easy to understand (Figl, Recker, et al., 2013). There is no such effect on the speed that model users answer the model content questions.

2.3.8 Model Emphasis

Models and their notation can emphasize different aspects of the process. Within the process model, this focus can be on the structure or on the behavior of the process (Agarwal et al., 1999) in the design of respectively object-oriented models (e.g. Caetano, Silva, et al., 2005) and process-oriented models (e.g. Sánchez-González, Ruiz, García, & Cardoso, 2011). It seems that process-oriented representations (BPMN-like notations) are in general easier to understand and therefore more useful for communication purposes in comparison to object-oriented (UML-like) representations (Agarwal et al., 1999). A possible explanation for this outcome is that people find it easier to understand process representations rather than a model with data (Agarwal et al., 1999).

2.3.9 Model Content

The experiments that are done in the field of the understandability of process models are mainly done with the use of models, where only the control-flow or the activities are included (e.g. Figl, Koschmider, et al., 2013; la Rosa et al., 2011). This means that only the sequence of process elements or tasks are included in the content of the experiment. Representing business objects like resources and actors in the process model, are highly relevant as well though. This is the case since including roles in the process model could improve the understandability as well (Caetano, Silva, et al., 2005; Caetano, Zacarias, Silva, & Tribolet, 2005). The interactions between those roles shows namely the dependencies between the business actors and also organizes the process into sets of operations regarding the actors, which increases the understandability of the process models (Caetano, Silva, et al., 2005). From a comparison between BPMN and EPC it doesn't seem to matter that these languages are message- and control-flow oriented respectively event-function-event oriented in terms of their understandability (Recker & Dreiling, 2007), despite that the inclusion of resources and information flows means an instantaneous increase in the size of the process model. though, the representation of process models separed from roles and used objects is a preferred representation (Koschmider, Kriglstein, & Ullrich, 2013). This suggests that model users do not like to have all this context information included (due to an increased cognitive load) even though they might want to be able to find out more about the interactions between different roles. Koschmider et al. (2013) suggests therefore`1 to foster a purpose-oriented visualization that starts with a main activity flow with the option (in different views) for more.

2.4 Context Factors: Personal Factors

Process models usually need to be understood by a variety of people (Koschmider et al., 2013). The human characteristics of the wide variety of process model users are of significant influence as well, since the understandability of a process model is not a static property but a relation between human and performance (Reijers et al., 2010). Personal factors are even of bigger influence in comparison to the model factors (Reijers & Mendling, 2011). These personal factors determine whether a person finds a business process model understandable. Two streams of literature consider personal factors as an understandability factor. They can be subdivided in papers that consider the personal factor as an emergent learning property of the user, which can be influenced by organizational interventions (e.g. Recker et al., 2014), or secondly, as a static feature of the user (e.g. Stitzlein et al., 2013).

2.4.1 Theoretical Knowledge

Users of process models can differ in their level of knowledge about conceptual modeling and their level of knowledge about the (business) process. Weitlaner et al. (2013) found out that the level of education increases the perceived understandability of a model, with disregard of the focus of this education. This insinuates that the gathered knowledge and intelligence of a person impacts the capability of understanding the graphical representation of a process. Being in the possesion of theoretical, formal process knowledge also contributes significantly to the understandability of process models (Mendling et al., 2012).

2.4.2 Dynamic User Characteristics

Recker et al. (2014) also found out that dynamic traits like cognitive selection skills increase the understandability. This means that searching and selecting the required information in an effective way is a useful skill. Not only did they find positive influencing cognitive skills but also prohibiting negative influencing skills. This means that giving workshops or training (possibly in terms of an education) to the users of process models would be a reasonable influencing intervention to increase the understandability of process models.

2.4.3 Practical Experience: Modeling Expertise

Besides the education level, does not every user possess the same amount of other theoretical, domain and modeling expertise (Mendling et al., 2012; Recker et al., 2014). Modeling expertise is based on trained skills and gained knowledge about process modeling (Schrepfer et al., 2009). These factors are found by a number of researchers to be of relevance in the understanding of process models. Modeling expertise seems to increase the ability to find process models understandable (Recker & Dreiling, 2007; Stitzlein et al., 2013).This is also in agreement with the cognitive load theory (Recker & Dreiling, 2007). It does not matter with which modeling language the familiarity exists in the meantime (Recker & Dreiling, 2007).Though, Mendling et al., (2012) contradicts this viewpoint by showing that theoretical, formal process knowledge is of significant importance for the understandability of process models and neutralizes the earlier significant impact of modeling expertise (modeling or practical experience and intensity).

2.4.4 Practical Experience: Domain Knowledge

Domain knowledge is often kept constant in experiments, in order to rule out that the measures are influenced by this confounding, extraneous variable instead of by the independent variable (Burton-Jones & Meso, 2008; Mendling et al., 2012). Especially since the effectiveness is measured by “correctly answering questions about model content” and the efficiency by the “time needed to understand a model” (Houy et al., 2012) in most experiments. Especially novices in a specific domain could use conceptual models to learn more about the processes in this domain, by reading the process models (Burton-Jones & Meso, 2008). Domain experts will probably be able to answer part of the domain-related questions already without even looking at the model, since they are familiar with the process. Next to that, they must be able to find the answer faster by easier navigation through the model since they already know where specific tasks occur in the process and by whom these tasks should be carried out. Since process modeling also serves the purpose of teaching novice business participants about the domain, and domain knowledge enhances the understandability of process models, it would be interesting to know more about this circular relationship.

Domain knowledge is already considered in relation to semantic factors (Bera, Burton-Jones, & Wand, 2014; Priebe, Keenan, & Miller, 2012). Construct overload is manipulated in an experiment by using the same type of grammatical symbols to model a thing in the domain and a role (Bera et al., 2014). Domain knowledge has an inverted U-shaped effect, whereas users with moderate domain knowledge, profit the most (in comparison to low and high domain knowledge) from semantically correct models. People with high domain knowledge are able to tight the ends together even if the models are not of high quality. Other researchers capture domain knowledge as being useful in the modeling process (e.g. Cherfi, Ayad, & Comyn-Wattiau, 2013; Dhillon & Dasgupta, 2011). Nevertheless, there are not much more experiments done that keep *all* other factors constant instead of domain knowledge. An experiment where people have domain knowledge of one process and no domain knowledge on the other process could be conducted, to see how big the influence of this confounding factor is on either of the understandability factors.

2.5 Other Context Factor

Navigatability is one of the investigated factors which does not fit within the personal factors or model factors. Later on it will become clear why this understandability factor is sub-divided underneath other context factors.

2.5.1 Navigatability

Easy navigation between hierarchy levels (Figl, Koschmider, et al., 2013) and easy navigation mechanisms that enable users to find a relevant process model easily affects understandability of the process models (Mturi & Johannesson, 2013). The understandability of process models is found to be higher when annotated-based navigation is used (Mturi & Johannesson, 2013). This all suggests that the ability to search and navigate yourself between, for example, the different subprocesses or content-views, fullfills a major role as well to increase the understandability of the overal process.

2.6 Suggested Factors

Peters and Weidlich (2009) state that the understandability of process models depends on the context within which the process model operates. The context of a process model exists out of the *purpose* of the model and the audience or *users* (personal factors) of the process models (Peters & Weidlich, 2009). This view is shared by Lantow (2014) who recognizes that the environment and the modeling purpose are of relevance but not yet investigated. This suggests that the personal factor belongs to a bigger concept that considers the contextual factor of a process model. Peters & Weidlich (2009) approach that "depending on the context, many specific factors affect the understandability of a process model, among them the chosen notation, the number of different elements used, as well as the model structure". These contextual conditions influence not only the use of the model but also the creation of the model (Bera et al., 2014). Reijers & Mendling (2011) and Mendling et al., (2007) also mention the *model purpose* as one of the possible factors since the intended use (documentation, communication, automated enactment, process improvement, control, or maintained focus on business needs) could influence how such a model should look like and whether it has to be understandable in the same way. This can also be considered as a different dimension where the question is more whether process models have to be understandable by the same audience and to the same extent for every modeling purpose. Furthermore, the experiments in practice are done either on paper (Reijers, Mendling, et al., 2011) or on a computer. There is no research paper that discusses the influence of the *presentation medium* yet. It is only mentioned as a factor in the experimental setup.

2.7 Discussion on the applied research methods

This literature review also tried to contribute to the development of the maturity of this research topic. Therefore, it is meaningful to document the conspicuous and relevant findings of the different pieces of literature that address factors that influence the understandability. The field of research does not produce completely reliable output. For example, different measures and methods are used and a low number of practical cases are considered. There is no absolute consensus about the way process modeling should be done, and research outcomes are contradicting each other. This is for example the case for modularity. A part of the characteristics of modularity creates an improvement of the understandability. A counter effect creates a decrease in the understandability of the process model. Not much is known about the absolute effect of this understandability factor yet. Despite of these ambiguities, process model factors, context factors and personal factors that influence the understandability of business process models should be taken into account when business processes are modelled.

These conclusions come from a couple of researchers who question or extend the measurements that are used to investigate the understandability of a certain understandability factor (e.g. Laue & Gadatsch, 2011; Zugal, Pinggera, Reijers, Reichert, & Weber, 2012). This is out of the scope of this literature review since Houy et al. (2012) already addressed this subject. Though, it shows that the unambiguous outcomes could be caused by the different measures that have been used to measure understandability. These ambiguous outcomes are hardly comparable and this makes it difficult to create a clear understanding about the conceptualization of process model understandability (Fettke et al., 2012). Not all the right questions are asked to cover the whole spectrum from for example a cognitive psychology point of view (Zugal et al., 2012). This might also explain the contradicting outcomes and results found for the understandability factor *modularity.*

Furthermore, most models are usually validated with the help of students (e.g. Reijers & Mendling, 2011). This means that there is not much data on the applicability of the findings, regarding the understandability of process models, in practice. In other words, most outcomes include merely intangible knowledge (Moreno-Montes de Oca, Snoeck, Reijers, & Rodríguez-Morffi, 2015) and a lack of field study testing (Davies et al., 2006). Besides, most factors are only measured in relative terms. This means that the information has been retrieved by comparing different models with each other rather than creating an independent interpretation (Sánchez-González et al., 2013). A number of researchers has tried to change this relative measure by creating treshold measures for high quality process models in the last couple of years (e.g. Sánchez-González et al., 2013; Sánchez-González, Ruiz, García, & Cardoso, 2011) and by creating measurements to measure the complexity of process models in order to make them less complex (Gruhn & Laue, 2006). This progress is valuable for the maturity of this research topic since there should be prescripiton-driven research, next to description-driven research, to be able to use scientific knowledge in the modeling of processes (van Aken, 2004).

3. Research Methodology

The literature review has resulted in a framework that represents all the factors that contribute to the understandability of business process models up to date. This framework is the input for the further research about the factors that influence the understandability of process models. The main research goal of the empirical study is to contribute to this *framework that has identified the factors that contribute to an understandable business process model.* The aim was also to produce more tangible knowledge about the understandability of business process models by experimenting with real business processes and actual business practitioners. This study will find out more about the trade-off between negative side effects of modularity that could abolish the positive effects. This is in line with the research conducted by Figl et al. (2013), which addresses the role of visualization strategies in modularity hierarchies of processes models. The question they do not address, is which modularity representation actually supports the understandability of process models best. Subsequently, the presentation medium is a newly identified factor in Figure 3. The influence of the presentation medium on a specific representation is unknown and will therefore be assessed as well.

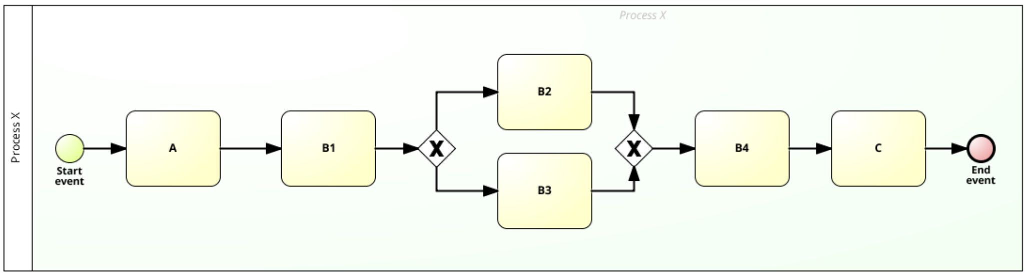
3.1 Research Questions

The first research question that will be addressed in this study is as follows:

1. ***Which modularity representation supports the understandability of business process models best?***

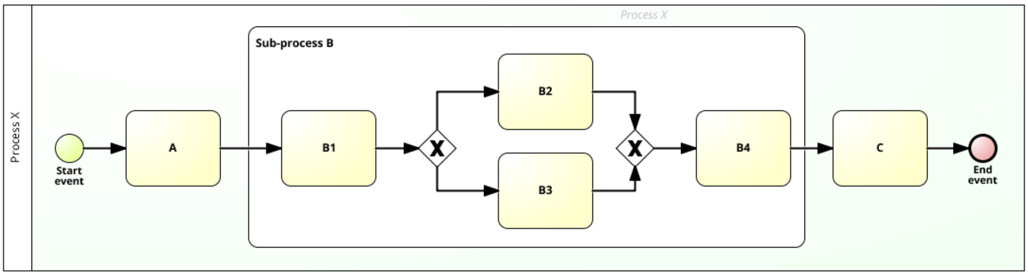
Two highly relevant processes of Philips MR have been modeled. These processes are the *Corrective and Preventive Action (CAPA-) process* and the *Complaint Handling (CH-) process*. Three representations of these processes are chosen. The three process representation can be compared towards each other in order to discover which model representation is preferred for a realistic business process.

The first representation (Representation 1) is a fully-flattened representation of the process model. This representation has been chosen because it offers the possibility to draw conclusions about the absolute outcome of modularity in process models. In other words, the decrease in size may have a lower impact on the understandability of process models in comparison to the modularized process models or vice-versa. This might mean that even though modularity has proven advantages, the negative counter-effects cause that a process model could better be represented in full extend (in terms of the understandability of the process model).



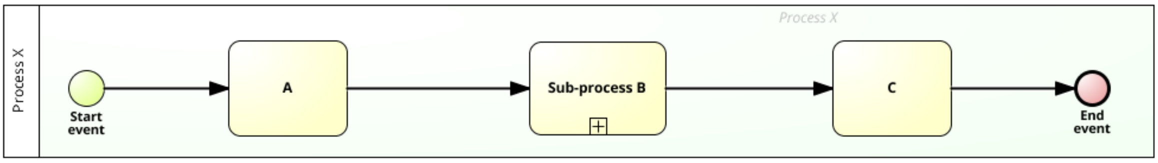
Representation 1: Fully-flattened (REPR1)

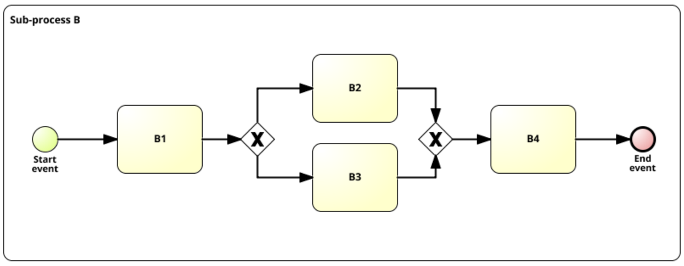
Representation 2 combines the fully-flattened representation with the division of the process into sub-processes with the use of colored boxes. This representation does not ask for an extra cognitive load of the user, who usually has to integrate all the different model parts again, when sub-processes are used. As a result, the size of the model does not decrease either. How and if dividing the process into sub-processes without reducing the size is relevant has not yet been investigated. It might be easier to navigate and search through the process if sub-processes are explicitly mentioned, especially for people with domain knowledge. Therefore this representation will help to figure out if sub-processes in itself realize a more understandable business process model.



Representation 2: fully-flattened with a division of sub-processes (REPR2)

The last representation (Representation 3) combines the decrease in size and complexity with the use of sub-processes. The idea here is to create a representation where the context stays intact. The sub-processes are hidden in the higher level process model, but can be accessed whenever the user is interested in the information it contains.





Representation 3: sub-process hidden and located in a separate view (REPR3)

During the literature review, another factor came up as a potential influencing factor. Softcopy (computer-screen) representations are usually used in experiments to represent the process model. This is probably done because most organizations describe their processes in an online environment. Since most processes are recorded in online information systems it will be valuable to find out if this is the most understandable way of representing process models as well. The question is whether the presentation medium affects the way that business participants perceive the understandability of the process model. There also might be an effect of the presentation medium on the "modularity" representation that is preferred most. The second question that will be addressed in this study is:

> ***2. Does the presentation medium influence the understandability of business process models?***

This information will be used to confirm or dismiss the suspicion that the presentation medium is an influencing factor on the understandability of process models. A paper process model might increase or decrease the understandability of a modeled process. When a difference occurs (especially within representations), this should be taken into account for the design of future research. It might be important for the generalizability of other experiments to make use of computer-based visualizations only. Most processes are communicated in an online environment within organizations and research outcomes should therefore be generalizable to computer-based visualizations.

3.2 Dependent Variables

The understandability of a process model is the dependent variable, which was measured with the *modularity representation* and the *representation medium* as the independent factors. The dependent variables that have been used to evaluate the understandability are well known and used in other studies regarding the understandability of process models (e.g. Houy, Fettke, & Loos, 2012; Moody, 2003; Schrepfer, Wolf, Mendling, & Reijers, 2009). The measurements that were used are:

- The ***score,*** which means the number of correctly answered questions about the model content. The individual scores for different type of content questions were also used as a measurement.
- The ***time*** needed to understand the model (efficiency). In other words, the time that is needed to answer model content questions. The efficiency was also measured by the ***score/time ratio***.
- The subjective dimension of understandability is measured with the help of the Method Evaluation Model (MEM; Moody, 2003). This model tests subjectively the perceived usefulness (***PU***), the perceived ease of use (***PEOU***) and the intention to use (***ITU***). These measures will be a proxy for the perceived ease of understanding the model (Houy et al., 2012).

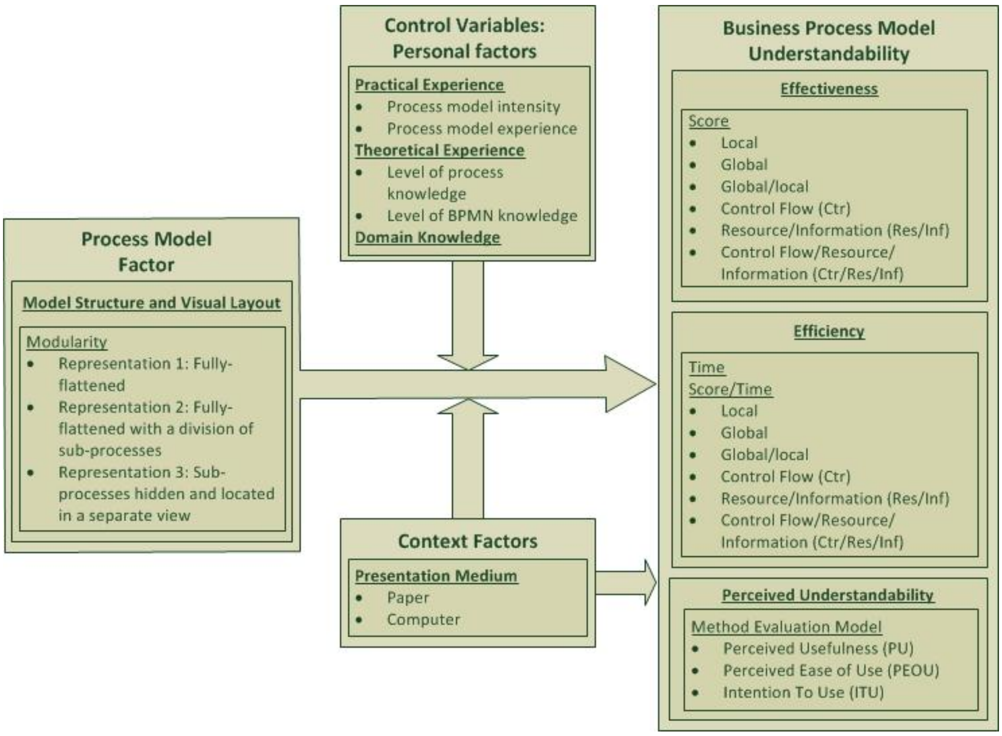


Figure 4: independent-, dependent- and control variables

A number of personal factors from the understandability factors model (theoretical, practical and domain knowledge) were recorded as well to be able to monitor the differences caused by personal factors. These control variables address the *process model intensity* (how often the participant encounters a process model), *process model experience* (when it was the first time that the participant encountered a process model), *level of process knowledge and BPMN knowledge* (the participant's own rating on what level of knowledge they have process modeling in general and about the modeling notation BPMN 2.0) and at last the *domain knowledge* on both processes (the familiarity with both the CAPA-process and the CH-process). We aimed at keeping all other model factors constant. This was, however, difficult between the two process models, since they contained different processes. All other understandability factors (Figure 3) were kept in mind during the modeling process in order to assure an understandable model. All independent-, dependent- and control variables are visualized in Figure 4.

3.3 Hypotheses

Hypotheses that are driven by the research objective would help in structuring the expectations and the analysis of the experiment. We pose a set of hypotheses based on the research objectives, and the expectations drawn from the literature. The hypotheses are subdivided in the dependent variables that will be used to measure the understandability of the process model.

3.3.1 The influence of the representation type

Representations 1 (REPR1) and 2 (REPR2) only differ in the way whether or not they divide the process into sub-processes. REPR1 does not make any division in that extent, whereas REPR2 splits the process into separate sub-processes. Since REPR2 is only an expansion of REPR1 with the help of colored boxes, the expectation is that the second representation has more to offer to understand the process (Reijers et al., 2011). Representation 3 (REPR3) represents the sub-processes defined in REPR2, in a different view. Other researchers (Johannsen et al., 2014; La Rosa et al., 2011; Reijers et al., 2011) have found that the representation of sub-processes, and therefore the decrease in size influences the understandability of process models in a positive extend. Therefore, REPR3 should be better understandable than a fully-flattened version of the process. The objectives towards the subjective feelings of the participants are derived from the objective expectations. It is expected that the PU, PEOU and ITU will be higher for participants who are able to answer the questions with a high correctness and within a relatively low time interval.

H1. Representation type has an influence on the a) score, b) time, c) perceived usefulness (PU), d) perceived ease of use (PEOU), and e) intention to use (ITU).

3.3.2 The (combined) influence of the presentation medium (and the representation type)

The expectation is as well that REPR 1 and 2 on paper (REPR1P and REPR2P) are easier to understand compared to REPR 1 and 2 on a computer screen (REPR1C and REPR2C). This should be the case because the paper versions provide readers with a fully readable oversight of the process. REPR3 captures as a main advantage that the model decreases in size and therefore in complexity. The expectation is that this advantage is the highest when the model is represented on a computer screen. This is expected because it is probably easier to navigate from one part of the model to the other on a fully visible paper based representation (REPR1P and REPR2P). Therefore, a decrease in size might not change the understandability of the process model in a high extend. At least, not in a way that the positive outcome will overcome the negative split-attention effect. On a computer screen (REPR3C) it will be easier to integrate the sub-processes into the high level process. A small difference in objective for the subjective variables might be that the fully-flattened paper versions of the process model are expected to both score higher on the MEM measures. These models are presented with a full overview of the process. This is probably perceived as more useful and easy compared to employees who have to overcome a negative split-attention effect or have to put more energy on navigating themselves through the model on a computer screen.

H2. Presentation medium has an influence on the a) score, b) time, c) perceived usefulness (PU), d) perceived ease of use (PEOU), and e) intention to use (ITU).

H3. The Representation type and Presentation medium have a combined effect on the a) score, b) time, c) perceived usefulness (PU), d) perceived ease of use (PEOU), and e) intention to use (ITU).

3.3.3 The influence of the representation on different type of understandability questions

A limitation in the represented information makes the local parts of the process models more understandable according to Reijers et al., (2011). Based on this, REPR3 should receive a higher score for local questions compared to the other representations. The rationale for the advantages of modularity is supposedly based on the reduction of the complexity of a process model and therefore improves the understandability (Johannsen et al., 2014; la Rosa et al., 2011). This advantage is probably not applicable or similar for all types of understandability questions that will be asked about the business process model. The counterpart of a local questions is called a global question. Also model questions about the control flow (Ctr), resources (Res) and information or message flows (Inf) can be sub-divided. The meaning of all type of questions used, shall be explained further on.

H4: The influence of the modularity representation will be different for different types of understandability questions: a) Global & Local, b) Ctr/Res/Inf

3.4 Research Method

To structure the phases of this research a methodology was necessary. The method that determined the phases and iterations during the project is the *design science methodology*. Design science research solves organizational problems by creating or designing an artefact (constructs, model, method or instantiations) (Mturi & Johannesson, 2013). The design science approach means, according to Van Aken (2004) "that the goal of academic research is to develop scientific knowledge to support the design of interventions or artefacts by professionals and to emphasize its knowledge orientation: a design-science is not concerned with action itself, but with the *knowledge to be used in designing solutions, to be followed by design-based action".* The model that was used to visualize the phases of this research is called the '*integrative cycle' (*Figure 5*)*. This cycle combines the regulative cycle of van Strien (1997) with the reflective cycle of van Aken (2004).

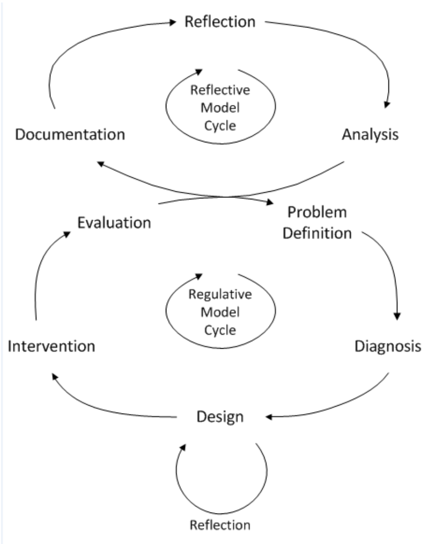


Figure 5: the integrative cycle (van Aken, 2004; van Strien, 1997)

The reflective and regulative cycle took place partly in parallel. An early analysis of the business structure and opportunities took place before an actual problem could be defined in detail. *Analyzing*, *documentation and reflection* have been applied throughout the whole project, especially when important decisions influenced the future of the project. Also, the literature review has contributed to this phase, whereas the review provided an input of a proper problem definition within practice. The project ends with a design and recommendation of the representation that seems to be the most understandable. The intervention-phase in the company was left out of scope of the master thesis, due to time and business constraints. Instead of that, an experiment will resolve and evaluate which representation of a business process model is understood best by the process participants in the company. This phase will be called the implementation-phase instead of the intervention-phase.

3.5 Research Design

The research design already has been represented in the integrative cycle but has to be applied on this specific study. This research design is now partly customized and incorporated into the phases of the integrative cycle. As can be extracted from the information given in Figure 6, most of the tasks had an overlap between the regulative model cycle and the reflective model cycle. This means that during the phase that this task had to be performed, continuous reflection was necessary.

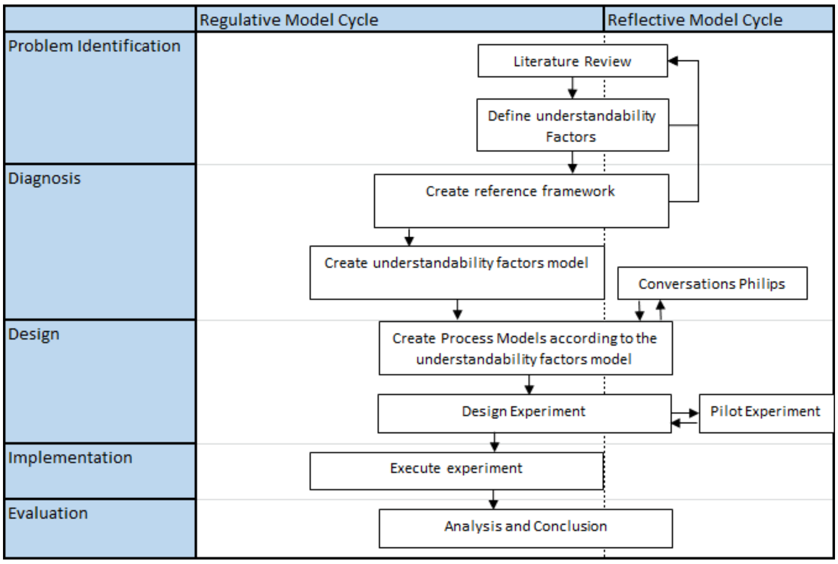


Figure 6: Research Design

3.5.1 Design

The problem identification-phase and the diagnosis-phase were input for the design-phase. The collection of data consisted mainly out of an experiment. Furthermore, un-structured interviews had been conducted with respect to the Quality Management System, to gain more insight into the system and the processes that had to be modelled. Nevertheless, the main method to gather data from the field was with the help of an experiment with the two modelled PH business processes.

Therefore, the design phase existed foremost out of the creation of this experiment and of the execution of the pilot experiment.

The *Corrective and Preventive Action (CAPA-) process* and the *Complaint Handling (CH-) process* were modeled with the business process modeling tool *Signavio for BPM academic initiative* (Signavio, 2015). Within the company, both processes are highly important in terms of the assurance of the quality. The CAPA- and CH process are fully described in the QMS and are of interest of several departments within the organization. Both processes are also relatively large and complex, considering multiple roles during the execution of the process. The business processes are in that sense rather similar. All of this makes these processes the most useful candidates for the creation of business process models. Furthermore, these two processes are not fully interdependent, whereas the CH-process may be the input or the trigger of the CAPA-process. The processes were modelled in a way that this interdependence does not have any influence on the appearance of the process model. Furthermore, the choice for investigating the effect of modularity on two large process models lies in the reasoning that if the large process models are understood best by one modularity representation, this will probably help in the same way in the understanding of small process models either (Reijers et al., 2011). It would be harder to generalize this effect the other way around. Two processes were used in order to gain access to more data to analyze.

The experimental set-up will be considered in more detail further on. A pilot-experiment has been executed before a whole sample of practitioners would be informed and asked to participate. In this way all the possible errors could be identified and enhanced first.

3.5.2 Implementation

The "implementation phase" in this study proceeded in the format of an experiment. The experiment has been executed amongst business practitioners, to find out which representation of their real-life process models will be most understandable.

3.5.3 Evaluation

The collected data had to be analyzed statistically, in order to find out whether a significant difference was perceived between the different representations and to test the hypotheses. The tool called Statistical Package for the Social Sciences (SPSS) has been used for the statistical analysis. This analysis will result into a discussion and conclusion for which representation must be chosen within the business context for these two processes. These two processes were representative for all large and rather complex business process models.

4. Experimental setup

As already stated before, the collection of data mainly consisted of an experiment to examine the understandability of business process models. The experimental setup existed out of a block design of six different blocks (Table 3). All possible combinations of representations existed in the block-design. This is also accounted for the presentation medium, which is attributed for every single representation of the process model. It was not desirable to use more different representations of the same process per participant because the outcome would no longer be reliable due to learning effects.

Table 3: Design of the experiment (block design)

Block	CAPA Representation	CH Representation	Presentation Medium: Paper (P) or Computer Screen (C)
Block 1	1	2	P
Block 2	1	3	C
Block 3	2	1	C
Block 4	2	3	P
Block 5	3	1	P
Block 6	3	2	C

4.1 Business Process models of CAPA and CH

The business process models of the Corrective and Preventive Actions (CAPA) process and the Complaint Handling (CH) process are attached in Appendix A. The CAPA process had been modelled and modified already suitable for an experiment in an earlier research project. Therefore, to be able to use and make this process model comparable, the CH process had to be modelled in a similar way with comparable features and characteristics (i.e. with the same modelling conventions). Consequently, the whole modelling and, verification and validation process has only been conducted for the CH-process. A modification to both processes was desirable for this experiment in order to control the number of roles and to avoid using advanced modelling techniques. The original processes might contain more separate roles and more complex feedback loops or other advanced process characteristics.

4.1.1 Modeling Conventions

Specified modelling conventions were followed in the modelling process to increase comparability, readability and repeatability of this experiment with multiple business processes (Dumas et al., 2013). The conventions will also help with analysing the experimental data of the CAPA process and the CH process. The modelling conventions are summarized in

Table 9, Appendix B.

4.1.2 Verification and validation

A verification was done by the supervising researcher to ensure that the CH models were correct and created with good use of the modelling language BPMN. He checked whether the models (all three representations and the sub-processes) were syntactically correct and therefore of good quality. The syntactic quality refers to the confirmation of the process model to the rules of the modelling notation BPMN 2.0 (Dumas et al., 2013). This check also included the check for structural and behavioural correctness. A few syntactical errors had to be fixed before the models could be released. Validating the models was necessary as well to check whether the business process models represented reality. The CH model is semantically checked by the process owner to make sure that the process model makes true statements about the real-world process domain (Dumas et al., 2013). This also means the process owner checked if the model was complete and correct. A few modifications had to be done in order to be compliant.

4.2 Questionnaire

A questionnaire was used to test the understandability of the process models. At first, some general information was asked to the participant, in order to limit and control the influence of other moderating and influencing factors. Personal factors that might play a role are business process work experience, and the level of theoretical knowledge in general- and about process models. Especially, the experience in business process work is assumed to be variable among the sample of subjects. Another aspect that would probably influence the perceived understandability of the process model was the domain knowledge that the participant possessed about the particular modelled process. The questions whereof the answers are captured in the model, might be already known from their knowledge about the process. The model-questions that were asked, had to contain an equal distribution of global (Gl-) and local (Lo-) questions. Secondly, the model questions had to realize a similar distribution in sequence flow or control flow (Ctr-) questions, Resource (Res-) questions and message flow or information (Inf-) questions. The answers to *control flow* questions can be found by following the sequence of events, activities and arcs within specific roles and resources. *Resource questions* were used to refer to “anyone or anything involved in the performance of a process activity” and a *message flow question addressed* the flow of information between two or more separate resources (Dumas et al., 2013). In this case the different questions for the different processes addressed the same kind of questions in an equal amount. The distribution of questions can be found in Table 4.

Table 4: Distribution of model questions for each process model

CAPA Question	Global	Local	Ctr	Res	Inf	CH Question	Global	Local	Ctr	Res	Inf
1	x	x	x			**1**	x	x	x		x
2		x	x	x	x	**2**		x	x		
3	x	x		x	x	**3**	x	x	x	x	x
4	x			x	x	**4**	x			x	x
5	x			x	x	**5**		x	x	x	
6		x	x			**6**	x	x	x		
7		x	x	x		**7**	x			x	x
8	x		x	x	x	**8**		x	x	x	x
9	x	x	x	x	x	**9**	x		x	x	x
Total	6	6	6	7	6	**Total**	6	6	7	6	6

4.2.1 Verification and validation

The model questions for both processes models were also verified and validated by business actors and experienced process participants. No potential subjects were chosen for this process. The use of potential participants was undesirable since the business participants are scarce and highly valuable. Hence, it was essential that as many business participants as possible could contribute to the experiment. Therefore, all the business actors that had a deeper insight into the experiment and would bias the results, were asked to help with the verification and validation of the questions about the models. All CAPA questions were used before and were therefore only tested and validated by 2 business actors. Testing consisted of filling out the answers to the questions and discussing the acceptability of the wrongly answered questions. The CH questions were completely new and were never verified or validated before. The same business actors answered the questions for the complaint handling process. In addition, the supervising researcher and 3 other acquaintances with process model knowledge answered the questions, to check for any uncertainties or other problems in the questions. A few semantic corrections were made accordingly.

4.3 Online environment

The process models and the questionnaire were implemented in an online environment to make the experiment easy accessible. The software being used is Sawtooth Software SSI WEB 8.3.10. The created experiment was hosted by www.bpmresearch.net. A print version, belonging to the paper versions (block 1, 4 and 5) of the online environment, is attached in Appendix C.

The participants -regardless of the presentation medium- were asked to answer the questions in the online environment. The only part of the experiment that was represented on paper (for participants in the group with representation medium "paper") were the business process models. The main reason for this is that the experimental conditions should be as equal as possible and the duration per question would be monitored by the software. A total of 4 different routings has been applied in the experimental online environment. One routing for each separate computer block (2, 3 and 6) and one routing for all participants in the "paper presentation medium" group. Evidently, the sequence was the same for all paper block's since the questions were all the same since the online experiment lacks any models linked to the questions.

Representation 1 and 2 looked quite similar in terms of structure for both presentation media. Nevertheless, a few extra features were required for the presentation of the process model on softcopy (i.e. on the computer screen). This was necessary to make the model readable and usable in an online environment. The computer-group questionnaires explained that in order to zoom in on the process model, you had to hoover with the mouse pointer over the figure (displayed process model). Also scrolling your mouse wheel would make it possible to zoom in and out. Due to the size of the process models, navigation across the page or image was possible by the use of the arrow keys on the keyboard.

Representation 3 needed an extra advanced feature to deal with the hidden sub-processes. The sub-process popped up when the mouse pointer hoovered over the sub-process. All details of the sub-process became visible. Figure 7 and Figure 8 display this feature in particular for the first sub-process in the sequence of the CH process "Perform Complaint Determination".

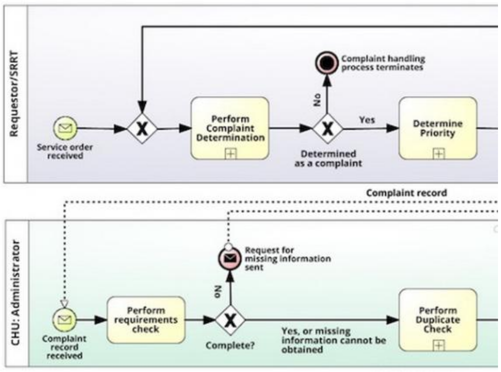


Figure 7: CH Representation 3, mouse is not hoovering over sub-process (sub-process hidden)

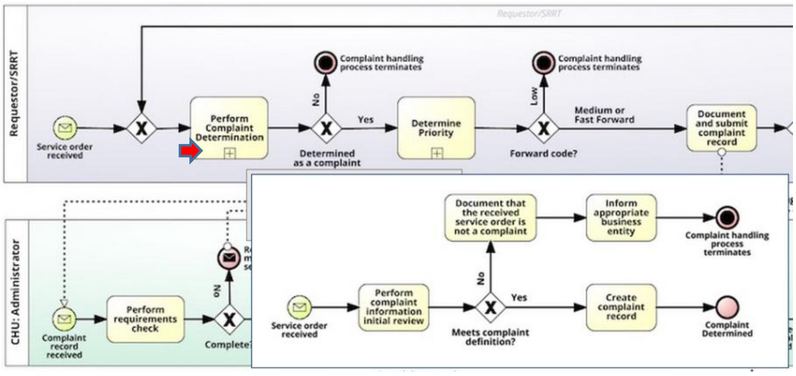


Figure 8: CH Representation 3, mouse hoovering over sub-process "Perform Complaint Determination" (sub-process pop-up)

A usercode (password) was defined for every participant. Participants of ‘block 1’ received the letter ‘A’ combined with a number between 101 and 115 (A101-A115). For ‘block’ 2 the codes laid in between B201-B215. The other blocks were coded accordingly: block 3 » C301-C315, block 4 » D401-D415, block 5 » E501-E515 and block 6 » F601-615. The user codes ensured that the predetermined allocated blocks were connected to the right participants. In other words, participants with usercode B203 received a questionnaire belonging to block 2 with a CAPA representation 1 process model and a CH representation 3 process model.

4.3.1 Pilot experiment in online environment

For the pilot-experiment, again no potential subjects were chosen. Five colleague students have contributed in the pilot version of the experiment. This was deemed sufficient to reveal any small mistakes or ambiguities within the models and questionnaire in the online environment. These students were familiar with processes and process models and received the task to review critically every step in the experiment. This led to the detection of one significant model mistake and multiple minor linguistic and layout flaws, which were corrected before the official launch.

The pilot experiment has been executed only with the codes of the computer blocks in order to make it possible for people to participate on short notice and on different and remote locations. The codes, leading to the paper version of the online experiment, were checked carefully. All technical or quality problems that occurred at the computer version could easily be translated into the related modifications necessary for the paper versions.

4.3.2 Release

All participants allocated to the presentation medium “paper” received an envelope including the corresponding process models prior to the experiment. The email invitation that every participant received is attached in Appendix D.

4.4 Sample

A sample of 64 people (Table 5) within Philips Health Tech were selected to contribute to the experiment. The minimum sample was set on 60. This means that every experimental group contains 10 participants. If too many people dropped out, a further search would have to lead to an additional set of participants. Most of the Philips employees were operating from the BU MR. Also, the majority of selected people worked at the *Quality and Regulatory* department whom are either part of the CAPA process or the CH process. Participants were randomly assigned to the different blocks of process model representation combinations. The only manipulation necessary was the assignment of participants with domain knowledge about the processes equally between the different groups. Also, participants that were not physically able to receive a paper model (due to living abroad) were included in the computer group beforehand. This concerned two of the participants. All participants attributed to the presentation medium “paper” received an envelope including the appointed process models prior to the experiment.

Table 5: Participants of the experiment

Participant	Title	Department	Participant	Title	Department
1	CAPA Leader	Quality & Regulatory	33	Program Manager	Program Management
2	CHU Complaint Handler	Quality & Regulatory	34	Program Manager Customer Service	Customer Services
3	Clinical Application Specialist	Quality & Regulatory	35	Project Leader	Productivity
4	Clinical Marketing Sr. Manager	Quality & Regulatory	36	Project Manager	Order to Cash Improvement
5	Complaint Administrator	Quality & Regulatory	37	Project Manager	PMO & Test Bays
6	Complaint Specialist	Quality & Regulatory	38	Q&R Engineer - Complaint	Quality & Regulatory
7	Complaint Specialist	Quality & Regulatory	39	Q&R Engineer-Complaint Handler	Q&R Post Market Surveillance
8	Complaint Specialist	Quality & Regulatory	40	Q&R Manager	Quality & Regulatory
9	Complaint Specialist	Quality & Regulatory	41	QR-contingent worker	Quality & Regulatory
10	Development Director	R&D	42	Quality Assurance Engineer	Quality & Regulatory
11	Director, Product Management	Product Management	43	Quality Engineer	Quality & Regulatory
12	Domain Expert	Clinical Excellence	44	Quality Engineer	Quality & Regulatory
13	DTE Engineer	PMO & Test Bays	45	Quality Engineer	Quality & Regulatory
14	DTE Project Leader	PMO & Test Bays	46	Quality Engineer	Quality & Regulatory
15	Engineer Quality Assurance	Quality & Regulatory	47	Quality Manager	Quality & Regulatory
16	Engineer Quality Assurance	Quality & Regulatory	48	R&D Project Manager	R&D Program & PfRT team
17	Engineer Quality Assurance	Quality & Regulatory	49	Regulatory Affairs Engineer	Quality & Regulatory
18	FCO Manager	Service Delivery Programs & Operations	50	Regulatory Affairs Engineer	Quality & Regulatory
19	Group Leader Integration & verification	Systems Engineering/Special Projects	51	Regulatory Affairs Manager	Quality & Regulatory
20	Group Leader Patient Handling & Infra	HW/Components	52	SE-contingent worker	Quality & Regulatory
21	Group Leader Systems Engineering	Systems Engineering	53	Senior Configuration Manager	Programs
22	Groupleader	Software	54	Senior Manager Regulatory	Quality & Regulatory
23	Integration Architect	Productivity	55	Senior Software Designer	Software & Platforms
24	Maintenance Architect	Service Innovation	56	Senior Test Engineer	Integration & Verification
25	Manager Analysing & Trending	Customer Services	57	Service Innovation Manager	Customer Services
26	MR Clinical Validation Lead	Clinical Applications	58	Software Configuration Manager	Software & Platforms
27	Operational Engineer	Industrial Operations Engineering	59	Software Designer	Software & Platforms
28	Prodcut Compliance Analyst	Quality & Regulatory	60	Sr Quality Engineer	Quality & Regulatory
29	Prodcut Security/Privacy Lead	Product and Service security	61	SRr Manager, Quality & Regulatory	Quality & Regulatory
30	Product Expert	R&D Program & PfRT team	62	Supllier Quality Manager	Supplier Quality
31	Product Specialist	Service Innovation	63	System Test Architect	Systems Engineering
32	Product Support Manager	Customer Services	64	Training Coordinator	Operations General Factory Support

4.5 Validity

Different representations (Representation 1, Representation 2 and Representation 3) of a process (CAPA or CH) are semantically equal but structurally different. As the research by Agarwal, De, & Sinha (1999) suggests, the information they capture had to be equivalent, allthough this information was represented differently. That means that “the absence or presence of modularity does not affect the business logic in a semantic sense” (Reijers et al., 2011). The content stayed the same, at least for the representations of the same process. The difference between the two processes had to be limited as well. Therefore the process models had to be modified for the experiment, in order to maintain two process models with approximately the same amount of roles, tasks, sub-processes, structuredness and color. This made sure that the visual layout and structural features of the models are considerably similar.

A set of indicators was used to measure and compare the structural properties and to demonstrate that the two models were comparable in terms of their structural complexity. This was necessary since otherwise it is difficult to compare the model representations of the different processes in statistical terms. Table 6 summarizes the number of nodes, arcs and sub-processes for each process model. The number of nodes and arcs are derived from representation 1, while the sub-process information comes from representation 3. Nodes exist out of three types of nodes: activity nodes, control nodes and event nodes (Dumas et al., 2013). Activity nodes indicate a task or unit of work that may be performed. Control nodes (gateways) capture the flow of execution between activities. At last, "an event node tells us that something may or must happen, within the process or in the environment of the process, that requires a reaction, like for example the arrival of a message from a customer"(Dumas et al., 2013). Arcs were sub-divided in sequence and message arcs. The sequence arc shows the order of event. The message arc is used to represent the message flow, when a message is sent from one role to another. As Table 6 suggests, the processes were considerably similar. The only major difference concerns the number of arcs, which is a bit higher for the CAPA process. Due to the large number of arcs in both processes, we assume that the effect of the difference is marginal. To sum, the two processes are considered structurally similar, and consequently the data produced by the experiment regarding these processes can be considered comparable without threatening the validity of the research significantly.

Table 6: CAPA and CH comparison

Process	**CAPA**		**CH**	
#Activity nodes/tasks	**47**		**46**	
#Control nodes/gateways	#AND-Split	4	#AND-Split	4
	#AND-Join	4	#AND-Join	4
	#XOR-Split	13	#XOR-Split	15
	#XOR-Join	9	#XOR-Join	12
	#Excl. Event-Based	4	#Excl. Event-Based	3
	Total	**34**	**Total**	**38**
#Event nodes	**52**		**38**	
#Nodes	**133**		**122**	
#Sequence arcs	**146**		**134**	
#Message arcs	**27**		**18**	
#Arcs	**173**		**152**	
#Sub-processes	**15**		**14**	
#avg nodes/sub-process	**7,53**		**8,14**	
#avg arcs/sub-process	**9,53**		**9,71**	

5. Results

The results of the experiment will be subdivided in three parts starting with the descriptive statistics of the data. Thereafter, a statistical check on the control variables will provide useful information for the actual hypotheses testing. The hypotheses testing is the third and most important part of this section and provides the largest input for the further discussion.

5.1 Descriptive statistics

The first round of invitations included 64 PH MR employees. After 7 working days a reminder was sent to 37 employees to encourage their participation. At last, a more personal approach was chosen to emphasize the importance of every individual contribution. A total of 56 participants was accomplished within this original sample size. This means that the response rate was 87.50%. A second group of 10 PH employees has been approached in order to fulfill the minimum sample size. Due to the time limit of this second group, the response rate was (only) 50%. The total amount sums up to a number of 61 final respondents. The division of these respondents is visualized in Figure 9 and in more detail per function and department (subdivided in blocks) in Appendix E, Table 10.

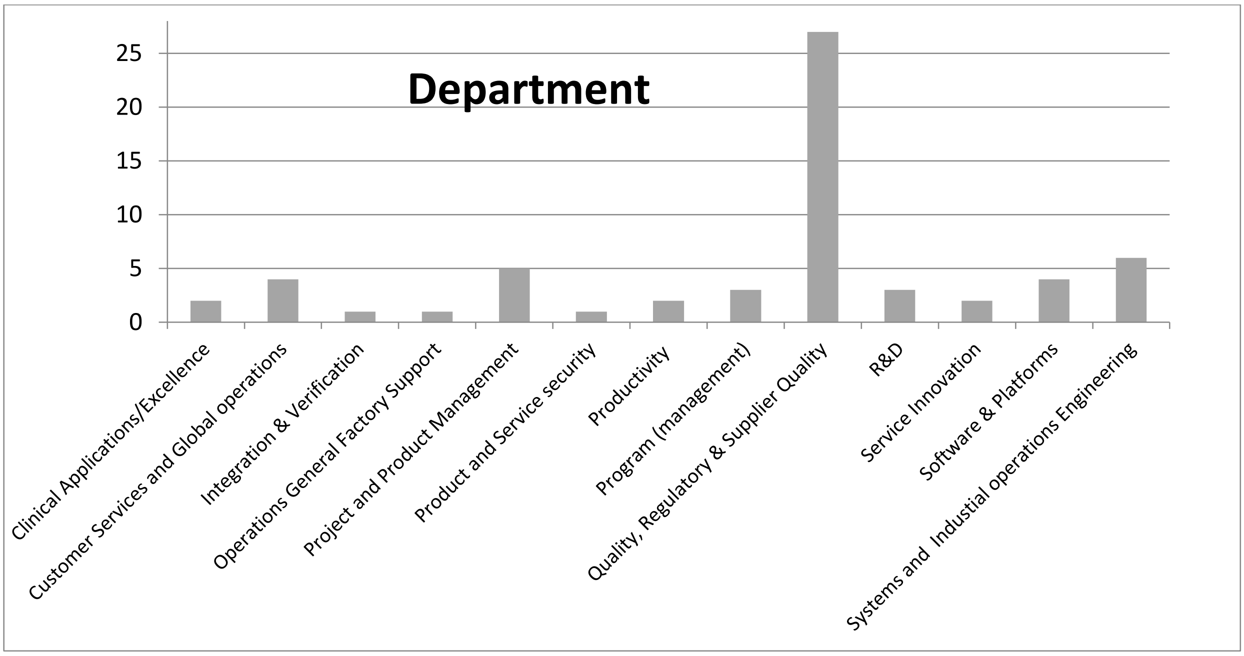


Figure 9: Division of participant per department

The original data set included 61 data entries from 61 participants who filled out the questionnaire for one CAPA representation and one CH representation. The block distribution was almost equal, with one exception whereas block 4 occupied one more participant. A definite outlier in the dataset had only 1 answer correct from a total of 18 questions. A further examination shows also a very low and unrealistic time span for answering the questions. Furthermore, most questions were answered with "I don't know". This data entry (originating from block 2) did not provide valuable information about the representation and presentation medium and would bias the other gathered information. The participant was very resistant to the way of modelling and did not want this to become the company standard. Therefore, this single data entry has been deleted from any further analysis. This left block 2 with 9 respondents (Figure 10).

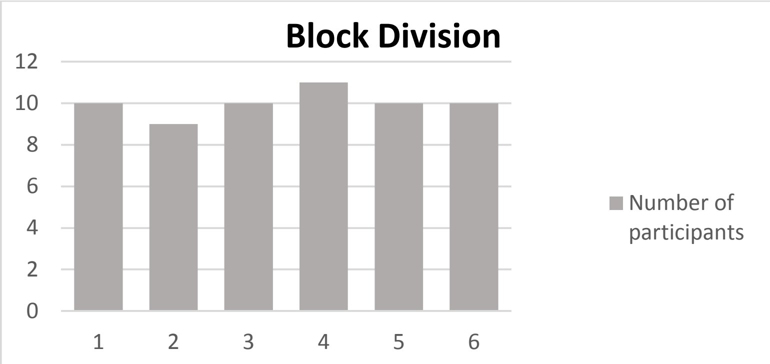


Figure 10: Sample occupation in blocks

5.1.1 Data set

The CAPA process was created in a similar and comparable way as the CH process on purpose. This means that de 60 remaining data entries each existed of data for two different representations with the same presentation medium. These 60 single data entries were split into two data entries per participant. The most important reason for doing this was the same as for assigning two process models to the experiment. The sample of 60 made it possible to create a dataset of 120, which shows significant differences more likely and more accurate. The dataset from this point on was no longer organized based on the respondent number, but on the representation type and presentation medium. All data collected for the CAPA and CH model were now assumed to be equal. According the before mentioned reason, the subdivision took place in newly created groups for the analysis of the data. The groups indicated in Table 7 were used further on.

Table 7: Group division for analysis

Group	Representation	Presentation Medium	Display
1	1	Paper (P)	REPR1P
2	1	Computer (C)	REPR1C
3	2	P	REPR2P
4	2	C	REPR2C
5	3	P	REPR3P
6	3	C	REPR3C

5.1.2 Data Transformation

Despite a warning at the beginning of the experiment, not all participants had the opportunity to participate in the experiment without interruption(s). This caused a number of outliers in the time measurements, large enough to bias the whole dependent variable *time*. Under the assumption that everyone should have been able to answer a single question within 10 minutes, all outliers > 600 (seconds) are transformed into the average of the question of that specific group (e.g. group 1 REPR1P) and process (i.e. CAPA or CH). A distinction between CAPA and CH was required because they contain different questions (with different mean times). A total of 17 out of 1080 measurements have been transformed accordingly. In the analysis, only the total time for all 9 questions have been considered to minimize individual biases.

Another data transformation took place for half of the questions asked for PU, PEOU and ITU. Half of the subjective questions were formulated in a *positive* way (e.g. Learning to use this way of modelling business processes would be *easy* for me) and the other half of the questions was formulated in a *negative* way (e.g. I found the way the process is represented as *unclear and difficult* to understand). This was known already beforehand. Both type of questions used the same Likert-scale (1=strongly disagree and 7=strongly agree). To create variables that represent PU, PEOU and ITU, all outcomes had to be in the same direction. Because of that, all negative questions were inversed in order that for example all answers 1 become number 7 and vice versa.

5.2 Control variables

The dependent variables should in an ideal situation (leading to the factor understandability) only be predicted by the independent variables *representation type* and *representation medium*. A number of control variables were monitored to ensure that the control variables did not predict whether a participant understands the model (instead of the independent variables as predictors). A stepwise regression (Appendix F) was used to check which independent variables could be considers as the predictors of all dependent variables. The independent variables that served as input for the regression are: *process (CAPA/CH), process model intensity, process model experience, level of process knowledge, level of BPMN knowledge, domain knowledge* and *group.* A short explanation of the mentioned personal factors was given in paragraph 3.2.

5.2.1 Effect of control variables on Score

The foremost important check has been done between the two processes. The CAPA process should not significantly differ from the CH process in any of the dependent variables. A significant difference could be a threat to the dataset because it would mean that the processes cannot be treated as one and the same dataset. An independent samples t-test (Appendix F, Table 11) already shows that on average, participants answered more questions correct for the CH-process (M = 6.13, SE = 0.20) than to the CAPA-process (M = 5.42, SE = 0.20). A stepwise regression confirmed this effect with an R^2 = .053 for step 1, $p < 0.05$ (Appendix F, Table 12). The reason for this could be due to a learning effect, but with a further investigation it seems that this inequality has probably to do with question 1 of the CAPA-process. This question was answered incorrect by 91.7% of the participants. The specific question contained multiple feedback loops which was overlooked often by the participants. All other control variables were not of any significant influence and are therefore not of a concern. The difference in score between the CAPA- and the CH process does not have to be a problem. The processes are allowed to have a different average score (because of inconsistencies in the difficulty of the model questions) as long as the pattern for different representations is still similar. The further analysis should be done with a certain suspicion in mind towards this finding.

5.2.2 Effect of control variables on Time

Next, the performed stepwise regression on the dependent variable *time* shows again that the type of process (CAPA or CH) influences the dependent variable R^2 = 0.057, $p < 0.01$ with a negative β (Appendix F, Table 13 and Table 14). This means that answering the questions about the CH process took less time than answering the questions regarding the CAPA process. Since all participants filled out the CAPA process at first, this difference in time can be explained by a learning effect. All participants are fairly new to the modelling language BPMN (102/120 are not knowledgeable about the business process modelling notation 2.0), and may have become faster and more experienced the longer they were exposed to this way of representing process models in general with BPMN. Next, there is also a step 2, R^2 = 0.099, $p < .01$, which considers ‘process model experience’ as a significant predictor of the time as well. The higher *the process model experience,* the least time it took to answer the questions (β=-0.204). Though, 75% of the participants first worked with process models more than three years ago, so the participants are quite equal on this aspect. It makes sense that it took less time to answer the model questions when the participant's process model experience was higher. Though this questions seemed to be not very relevant for the particular group that participated in the experiment. The other control variables showed no influence on the time it took to answer the model questions. However, the predicting power of the process on the time has to be kept in mind though for further analysis.

5.2.3 Effect of control variables on PU, PEOU and ITU

Only the group predicted the Perceived Usefulness, the Perceived Ease of Use and the Intention to Use the model. No other control variables had a significant effect on both PU, PEOU and ITU (Appendix F, Table 15, Table 16, Table 17 and Table 18). For purposes that become clear later on, "*ITU question 1*" has been controlled here as well. The predicting power of the group on the ITU was, $R^2 = 0.054$ and for ITU question 1 inverse, $R^2 = 0.083$, $\Delta R^2 = 0{,}029$. The R^2 is very low in the first place, but the group had at least a higher predicting power for ITU question 1. Recurrent to the effect of the control variables on the PU, PEOU and the ITU, there seems to be no major impact.

5.3 Hypotheses testing

The outcome of testing the control variables shows where caution is required. The result that showed a difference in correctly answered questions between the CAPA- and CH process was kept in mind during the analysis of the hypothesis. With the regression analysis, the R square (predictive power) appeared to be very low for the representation types (group). This low R square for the groups does not come as a surprise. The literature review already presented that there are many independent factors that contribute to the understandability of a process model. It is logical that the representation and the medium only account for a limited portion of this variance. The following hypotheses were tested with the help of statistical tests:

H1. Representation type has an influence on the a) score, b) time, c) perceived usefulness (PU), d) perceived ease of use (PEOU), and e) intention to use (ITU).
H2. Presentation medium has an influence on the a) score, b) time, c) perceived usefulness (PU), d) perceived ease of use (PEOU), and e) intention to use (ITU).
H3. The Representation type and Presentation medium have a combined effect on the a) score, b) time, c) perceived usefulness (PU), d) perceived ease of use (PEOU), and e) intention to use (ITU).
H4: The influence of the modularity representation will be different for different types of understandability questions: a) Global & Local, b) Ctr/Res/Inf

5.3.1 Assumptions check

The dependent variables *score* and *time* were analysed with ANOVA. In order to compare means by using ANOVA the distribution *within* groups had to be normally distributed (or skewed) and the variances had to be equal between different groups (Appendix G, Table 19 and Table 20). The next dependent measurements that had been analysed were the subjective (MEM) measures *perceived usefulness, perceived ease of use* and *the intention to use* (Appendix H, Table 21 and Table 22).

5.3.1.1 Score and Time

The Kolmogorov-Smirnov (K-S) test for normality shows a significant effect for the *Score* within 4 groups. REPR1P, D(20) = 0.29, $p < 0.001$, REPR2P, D(21) = 0.19, $p < 0.05$, REPR2C, D(20) = 0.24, $p < 0.005$ and REPR3C (19) = 0.24, $p < 0.01$ were all significantly non-normal. A follow up on this finding was the exploration of the Q-Q-plots of the four non-normal distributed representations. Since the lines of all four graphs had a S-shaped curve the problem of the distribution was most likely skewness (Field, 2009). Luckily, a skewed distribution has still little effect on the error rate and power in this case (Field, 2009). The Levene's statistic shows that there was no problem regarding the homogeneity of variances of the Score, F(5, 114) = 0.18, *ns.* The outcome for the K-S test for Time was positive, $p > .05$ (*ns*) for all groups. Therefore, violations of normality were not a concern for the dependent variable Time. Also the variances were equal for all six groups, F (5, 114) = 1.83, *ns.*

5.3.1.2 PU, PEOU and ITU

An exploratory analysis has been performed to find out more about the normality and equality of variances of these data. The K-S test displays that the Perceived Usefulness (PU), D(120) = 0.09, $p < .05$, the Perceived Ease of Use (PEOU), D(120) = 0.14, $p < .001$, and the Intention to Use (120) = 0.11, $p < .005$ were all three significantly non-normal. In addition, the results of the Levene's test shows that for PU the groups had homogeneous variances, F(5, 114) = 0.76, *ns*. Likewise, the variances were equal between groups for the ITU, F(5, 114) = 0.35, *ns,* but for PEOU the variances were significantly different, F(5, 114)=2.53, $p < .05$. The assumption of homogeneity of variance has been violated by PEOU and the data are not normally distributed. Therefore, it was not an option to use ANOVA to analyse these data. Meanwhile, the non-parametric Kruskal-Wallis test is based on ranked data and is very useful in a situation where assumptions are violated and suitable for data that can be ordered from lowest to highest (Field, 2009). The 7-point Likert-scale (ordinal variable ranging from "strongly disagree" to "strongly agree") has been used to measure PU, PEOU and ITU. This scale already delivers a pre-ranked dataset where for example, 1 (strongly disagree) has been assigned to the lowest PU and 7 (strongly agree) to the highest PU.

5.3.2 The influence of the representation type

By splitting the data file in two, based on the presentation medium, it was possible to find out if there was a direct influence of the representation type. The results of the score and time are available in Appendix I1 and the results of the PU, PEOU and ITU in Appendix I2. Table 29 (Appendix P) presents a summary of the statistics that show a direct influence of the representation type.

5.3.2.1 Score

For the computer medium the *score* was not different between representation types F(2, 55) = 2.00, *ns*. This also accounted for the paper medium F(2,59) = 1.90, *ns.* This means that H1a is not true.

5.3.2.2 Time

The dependent measure *time* resulted in the same outcome. Also H1b cannot be accepted because none of the representation types were of direct influence. The influence of the representation type on the time needed to answer the mdel questions on a computer medium was F(2, 55) = .03, *ns* and on a paper medium F(2, 59) = .33, *ns.* Neither does the representation type show any influence on the score/time ratio.

5.3.2.3 Perceived usefulness

According to the Kruskal-Wallis test, the PU was significantly affected by the representation on a paper medium, H(2) = 8.81, $p < .05$. Pairwise comparisons were used to find out which representation type was perceived significantly different in terms of usefulness. On a paper medium representation 1 was perceived more useful compared to representation 3 ($p < .05$). In consequence, H1c was true on paper. On the other hand, on the computer there was no measurable difference in the perceived usefulness. Therefore, H1c could not be accepted for a computer medium.

5.3.2.4 Perceived ease of use

Again, only on the paper medium an influence of the representation type was pointed out H(2) = 10.58, $p < .01$. Representation 1 was as well perceived as more easy to use compared to both representation 2 ($p < .05$) and representation 3 ($p < .05$). The PEOU was not different among the participants that received the computer models. So again, H1d was accepted for a paper medium, but had to be rejected for the computer medium.

5.3.2.5 Intention to use

The Intention to use for all groups was H(5) = 8.98, ns. This means that there were no measurable differences for the accumulated variable ITU. Not only were PU and PEOU significantly different for the groups, but all individual questions that set up PU and PEOU were significant as well (Appendix L1 and L2 respectively). ITU exists only out of two questions. Question 1(Q1) H(5) = 14.47, $p < 0.05$ and Question 2 (Q2) H(5) = 2.77, ns. Q2 mediated the significant effect of Q1 in the accumulated variable ITU. Moreover, the independent grouping variable predicted ITU Q1 ("I would definitely not use this method to model business processes") with a higher power (i.e. a higher r square) than ITU. This became clear during the regression analysis of the control variables. Therefore ITU Q1 has been analysed and considered representative for the participant's intention to use this business process model. Subsequently, a different pattern was found regarding the ITU (ITU Q1). It seems that there was an influence of the representation type on the intention to use these type of models H(2) = 7.50, $p <. 05$ on only the computer screen. The participants were less intended to use process models represented like representation 3 compared to process models represented fully-flattened, like representation 1 ($p < .05$). There was no significant effect between representations for the participants who received the process models on paper. This means that also H1e could be partly accepted, this time only for the computer medium.

5.3.3 The influence of the presentation medium

In order to find out what influence the presentation medium has on every individual representation type, the data file has been split into the three representation types. The statistics that show the influence of the presentation medium are summarized in Table 29 (Appendix P).

5.3.3.1 Score

Appendix J1 shows the ANOVA outcome of this analysis. None of the score measures were significantly different between the computer and paper medium for one single representation type. Therefore, H2a was not supported.

5.3.3.2 Time

None of the time measures were significantly different between the computer and paper medium for one single representation type. H2b was not supported. Despite of this, representation 3 scored higher on the score/time ratio for the paper medium, $F(1,38) = 4.27$, $p < .05$. Relatively more answers in representation 3 were correct on a lower timer interval on paper (M=0.38) compared to the computer medium (M=0.27). Unfortunately Levene's statistic showed that there was a violation of the homogeneity of variances which weakens the power of this outcome (Appendix J1).

5.3.3.3 Perceived usefulness,

Next, the PU was different among representation media within at least representation 1 $H(1) = 5.75$, $p < .05$ and within representation 3 $H(1) = 4.78$, $p < .05$. Both models were perceived more useful on a paper medium compared to a computer medium. This means that for at least representation 1 and 3 hypothesis 2c was supported.

5.3.3.4 Perceived ease of use

Nevertheless, the same effect as in PU was not visible for the perceived ease of use of the representations. No differences in presentation media were significant for individual representations and H2d was rejected.

5.3.3.5 Intention to Use

The intention to use business process representation 3 was higher for a paper presentation medium $H(1) = 5.05$, $p < .05$ (Appendix J2) . Here again, H2e could only be partly accepted for only representation 3.

5.3.4 The combined influence of the representation type and presentation medium

After the investigation of the direct effects of the representation type and medium, the combined groups (Table 7) were analysed. The six groups existed out of the fully flattened process representation on paper and computer (REPR1P and REPR1C), the fully flattened representation with defined sub-processes with the help of coloured boxes on paper and a computer (REPR2P and REPR2C), and third the processes representation which hides the sub-processes from the main process view on paper and computer (REPR3P and REPR3C). This analysis was done more elaborately because there was a lot of information captured in the six groups of modularity representations. A summary of the statistics shows on which dependent measurements the groups have an influence (Table 29, Appendix P).

5.3.4.1 Score

To start with, there was no significant effect of the representation group on the number of questions that were answered correctly (*score*), $F(5, 114) = 1.97$, *ns*, $\omega = 0.20$. Despite of that, $p = 0{,}089$, which means that the effect was nearly significant and would have been within a 90% confidence interval. Subsequent Tukey's post hoc test shows that REPR1P was significantly different from REPR3C (Figure 11) at $p < 0.1$ while Bonferroni's post hoc test could not confirm this, whereas $p = ns$ on a 90% confidence interval. Therefore, the score was not consistently different between groups (Appendix K, Table 23 and Table 24). The CAPA process and the CH process produce different means for score supposedly caused by question 1 of the CAPA process. Evidently, there was a difference between groups for the CH process $F(5, 54) = 3.08$, $p < .05$ (Appendix K, Table 25 and Table 26). REPR2P was answered more correctly than REPR3C ($p < .05$). H3a could not be accepted, even though there is enough reason to assume that a further investigation might lead to significant differences. The further investigation into the influence of the different type of questions could offer a solution.

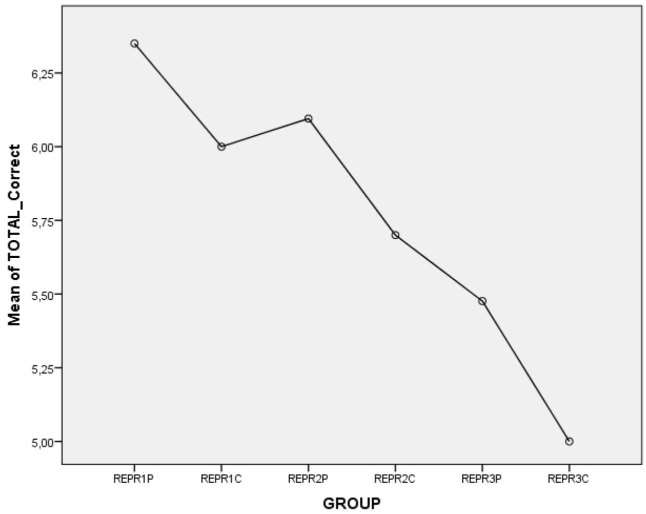


Figure 11: Average Score

5.3.4.2 Time

Subsequently, the representation type and medium do not predict the time that was taken to answer the questions $F(5, 114) = 0.28$, *ns*. The same accounts for the calculated dependent measure Score/Time $F(45, 114) = 1.01$, *ns (*Appendix K, Table 27 and Table 28). In other words, H3b was not supported.

5.3.4.3 Perceived usefulness

According to the Kruskal-Wallis test (Appendix L1), the Perceived Usefulness was significantly affected by the representation and presentation medium (group), $H(5) = 23.29$, $p < .001$. All four separate questions that led to the eventual variable PU were all significantly affected by the group as well. Pairwise comparisons were used to find out which representations were perceived significantly different in terms of their usefulness. The null-hypothesis claims that there was no difference in the distribution across the categories of the group. The pairwise comparison shows that there was only a measurable difference in the PU between representation 1 on paper and representation 3 on the computer, $p < .001$, between representation 2 on paper and representation 3 on the computer, $p < .05$, and at last between representation 1 on paper and representation 2 on the computer, $p < .05$. Figure 12 displays the direction of the significant effect (e.g. REPR1P has on average a higher PU in comparison to REPR3C). This means that H3c was supported.

5.3.4.4 Perceived ease of use

The Perceived Ease of Use was also affected by the group $H(5) = 20.16$, $p < 0.01$. All separate PEOU questions were also significantly affected. The results for these tests can be found in Appendix L2. The differences in Figure 13 were only significant between REPR1P and REPR3C, $p < 0.001$, and between REPR1P and REPR2C, $p < 0.05$. This means that there is only a minor support for H3d. Furthermore, the variances of PEOU were heterogeneous (according to Levene's statistic) and therefore not equal between the groups. A split off of the dataset generated by the CAPA process and the CH process gave some new insights (Appendix L3 and Appendix L4). Both CAPA $H(5) = 22.61$, $p < 0.001$ and CH $H(5) = 23{,}69$, $p < 0.001$ show significant differences between groups. The CAPA-dataset shows that REPR1P was perceived easier to use than REPR2P, $p < 0.05$, and that REPR2P and REPR3C were less easy to use compared to REPR3P, $p < 0.005$ respectively $p < 0.01$. Alternatively, within the CH-process, REPR1P was perceived easier to use then REPR2C, $p < 0.05$, REPR3P, $p < 0.001$ and REPR3C, $p < 0.05$. At last, REPR1C, $p < 0.05$ and REPR2P, $p < 0.005$ were perceived easier to use then REPR3P. There were some remarkable (and even contradicting) differences between the two process models regarding the PEOU. These differences were mediated in the overall dataset as the processes are considered structurally similar.

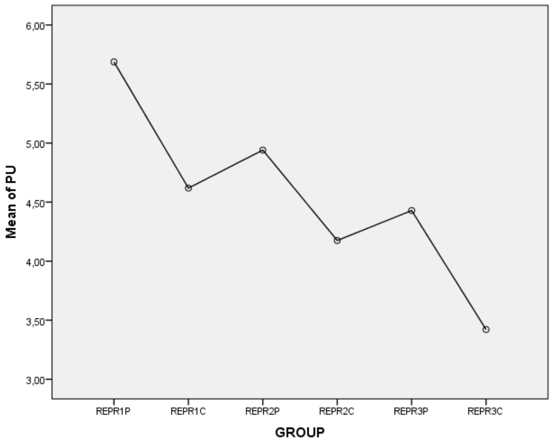


Figure 12: Mean of Perceived Usefulness (PU)

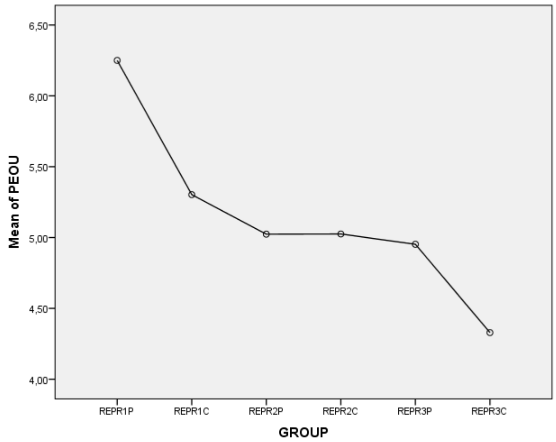


Figure 13: Mean of Perceived Ease of Use (PEOU)

5.3.4.5 Intention to use

It seemed that the intention to use this method of modelling business processes was higher for REPR1P then for REPR3C, $p < 0.01$ (Figure 14). Again, the influence of the modularity representation was stronger for PU and PEOU (which should in general lead to a similar effect on the ITU). This means also that H3e was only slightly supported.

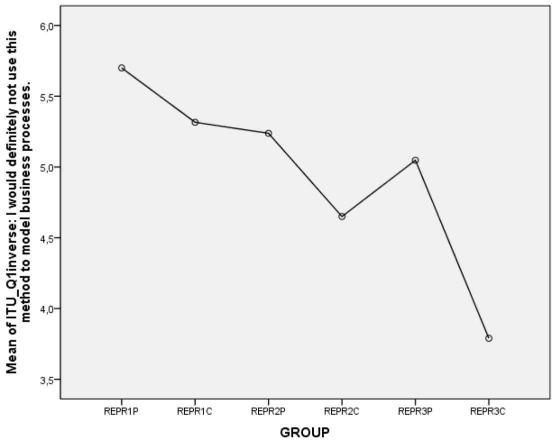


Figure 14: Mean of Intention to Use (ITU) question (Q) 1

5.3.4.6 PU, PEOU and ITU on average

As shown in Figure 12, Figure 13 and Figure 14, the average PU, PEOU and ITU question 1 was above 5.5 (and even above 6 for PEOU) for at least REPR1P. An average rating between 5 and 6 reflects that participants somewhat or moderately agreed on a good perceived usefulness, perceived ease of use and a high intention to use the process model. The average rating for REPR3C is between 3.5 and 4.5, which means that these participants answered the questions with a higher disapproval with respect to the PU, PEOU and ITU.

5.3.4.7 Split off difference CAPA and CH for Score, PU, PEOU and ITU

Because of an extra analysis (due to a significant Levene's statistic) that was performed for the PEOU, an awareness arose of a considerable difference between the PEOU measured for CAPA representations and CH representations. Likewise, the regression analysis showed already that there was a difference in score between the CAPA and the CH process. To understand this difference, the other two subjective measurements (PU and ITU) and the *score* have been visually inspected as well. The same pattern occurred for all three subjective measures (Appendix M, Figure 21, Figure 22 and Figure 23) and for the *score* (Appendix M, Figure 24 and Figure 25). Especially CAPA representation 2 on paper and CH representation 3 on paper scored lower, were perceived not useful, not easy to use and with a low intention to use. It appeared not to be a coincidence that both processes belonged to experimental block D. On average, the participants in this block encountered the least often a process model (compared to the average of other blocks). Besides, they also rated their knowledge on process modelling and their domain knowledge lower than the averages of the other blocks (Appendix Q, Table 30). It became also visible for the PU, PEOU and the ITU that group F scored relatively low on the subjective measures (CAPA representation 3 on the computer and CH representation 2 on the computer). Again, the participants in this block rated their knowledge on process modelling very low and the average knowledge on BPMN 2.0 was even the lowest average of all blocks. These personal factors influence the understandability of the process model (Figure 3) and are therefore very likely to influence the PU, PEOU, ITU and score of a process model representation in general. Therefore, a separation of the dataset would not be a good idea, since the dataset becomes too small and control variables have a relatively higher influence on the measured outcome (understandability) of a specific representation. By balancing this effect caused by the different blocks, the significant effects were more representative for the produced effect of the modularity representation and representation medium. In line with this, the check of control variables on the total dataset of 120 data entries showed that these effects have been minimalized.

5.3.5 The influence of the representation on Local (Lo) and Global (Gl) questions

The last hypothesis investigated the influence of the representation on the different type of understandability questions. Table 29 (Appendix P) presents a summary of the statistics that show the difference between the different types of questions. The set of model questions consisted of 3 local, 3 global, and 3 global/local combination questions (Table 4). Since the same participants were used for the measurement of all three conditions, a one-way repeated-measures ANOVA design was chosen for the measurement of the within-subjects effects. Cases were split between all 6 groups, in order to find out which within-subject effects could be determined between the local, global and the global/local combination questions.

5.3.5.1 Score

The results (Appendix N1) show that there was a difference between the questions for at least four of the groups. Mauchly's test of sphericity has been violated for REPR2P, χ^2 (2) = 6.13, $p < .05$. Therefore, Huynh-Feldt's corrected degrees of freedom has been used ($\varepsilon = .89$) to show the effect of REPR2P. RERPR1P, $F(2, 38) = 4.62$, $p < .05$, REPR1C, $F(2, 36) = 18{,}45$, $p < .001$, REPR2P, $F(1.68, 33.547) = 13.24$, $p < .001$ and REPR 2C, $F(2, 38) = 3.69$, $p < .05$ produce a difference in the average correctness of the answers on local, global and combination questions. On the other hand, these different type of questions were not answered distinctively better or worse for REPR3P, $F(2, 40) = 1.53$, $p > .05$ and REPR3C, $F(2, 36) = 0.73$, $p > .05$. For REPR1P, the number of correct answers was significantly higher for local questions compared to global questions ($p = .02$) and global/local combination questions (p

= .03). REPR1C and REPR2P both showed a higher correctness for local questions in comparison to global (*p = .00)* and combination questions (*p* = .00). At last, REPR2C only showed significantly higher correctness for local questions compared to the combination questions (*p* = .03). As a result, H4a could be already accepted based on the score.

Based on the descriptive statistics of REPR3P and REPR3C, the reason for a non-identified difference in correctly answered local and global questions is due to a lower mean of local questions answered correctly compared to the other representations. These average scores are represented in Figure 15. A one-way ANOVA in Appendix N2 shows that the number of local questions correctly answered was significantly different among groups, $F(5, 114) = 3.26$, $p < .01$. The post-hoc test shows that local questions were answered on average at least more correctly on REPR1C compared to REPR3C ($p < .05$) and with a higher average for REPR2P compared to REPR3C ($p < .05$). Global questions and Global/Local questions did not differ among groups, $F(5, 114) = 0.25$, *ns,* respectively, $F(5,114) = 0.50$, *ns*. It is not surprising that when the same analysis was executed based on solely the representation (so without a distinction in the presentation medium), representation 1 and 2 both produce higher outcomes for local questions in comparison to representation 3. For local questions s, $F(2, 117) = 6.76$, $p < .01$ with post-hoc test REPR1 - REPR3 ($p < .01$) and REPR2 – REPR3 ($p < .05$).

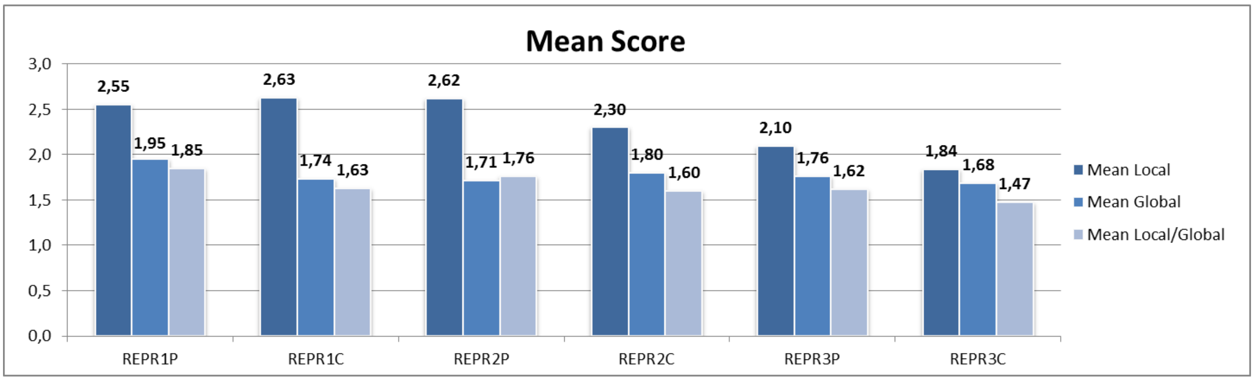


Figure 15: Average score of local, global and local/global combination questions

5.3.5.2 Time

The same procedure was applicable for the time it took to fill out the 3 different kind of questions (local, global and local/global). Mauchly's test of sphericity was violated for REPR1C $\chi^2(2) = 7.73$, $p < 0.05$. For this representation the Huynh-Feldt correction would have been used again, would it not be that this measure shows no within-subjects effect. However, there was a difference in time for the different kind of questions within REPR1P $F(2, 38) = 11.87$, $p < .001$, REPR2P $F(2, 40) = 6.28$, $p < .01$, REPR3P $F(2, 40) = 7.26$, $p < .01$ and within REPR3C $F(2, 36) = 3.97$, $p < .05$ (Appendix N3). The post-hoc test shows that it took in general more time to answer global/local questions in REPR1P ($p < .01$) and in REPR2P ($p < .05$). REPR3P only showed a higher time for global/local questions compared to the global questions ($p < .01$) and REPR3C shows a higher time for global/local questions compared to the local questions ($p < .05$). The average time needed for the global/local combination questions was larger when all representations were included in the analysis ($p < .001$) and also all other times were on first sight rather equal among groups (Figure 16). In line with this, there were no measurable time-variances between groups for local questions $F(5, 114) = 0.27$, *ns,* for global questions $F(5, 114) = 0.89$, *ns*, nor for combination questions $F(5, 114) = 0.40$, *ns* (Appendix N4). It is more important to find out whether there are differences in the score/time ratio in agreement to the findings of the dependent variable *score*. Here again, a few groups do not meet the condition of sphericity. Mauchly's test is violated by REPR1P $\chi^2(2) = 9.21$, $p < .05$, REPR1C $\chi^2(2) = 12.60$, $p < .01$, REPR2P $\chi^2(2) = 15.35$, $p < .001$, REPR3P $\chi^2(2) = 15.80$, $p < .001$. This violation is only a concern for REPR1C (ε =

.69), F(1.38, 24.75) = 18.37, *p* < .001 and for REPR2P (ε = .67), F(1.34, 26.74) = 21.27, *p* < .001, since all other groups do not show any within-subject effects (*ns).* In Figure 17 it is visualized how the score/time ratio was for all groups. It shows that REPR3C shows a different pattern compared to the other groups. Unfortunately though, this was not confirmed statistically. The statistics between groups for local questions were F(5, 114) = 1.31, *ns,* for global questions F(5, 114) = 1.16, *ns*, and lastly for combination questions F(5, 114) = 0.63, *ns (*Appendix N5). There is a general effect whereas the score/time ratio was significantly higher for local questions compared to both global and combination questions (*p* < .001*).* This effect was also found individually for REPR1C and REPR2P between local questions and global questions (*p* < .01) and between local and combination questions (*p* < .001*)* (Appendix N6).

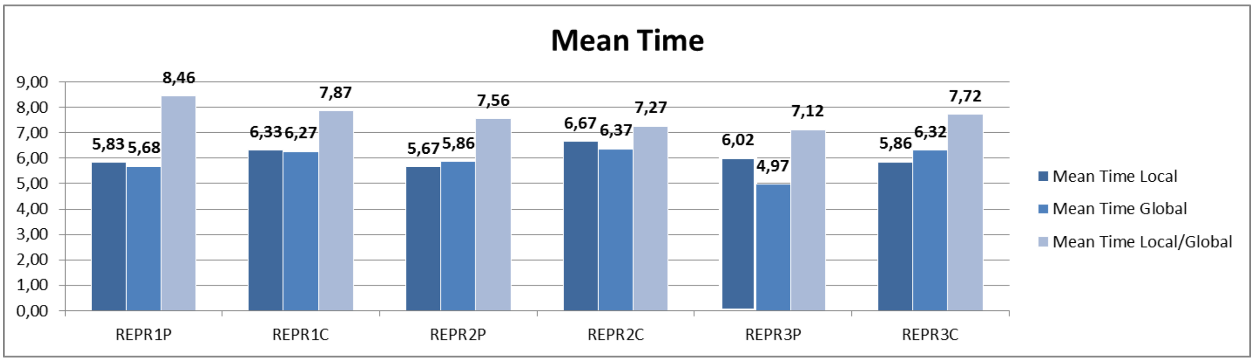


Figure 16: Average time of local, global and local/global combination questions

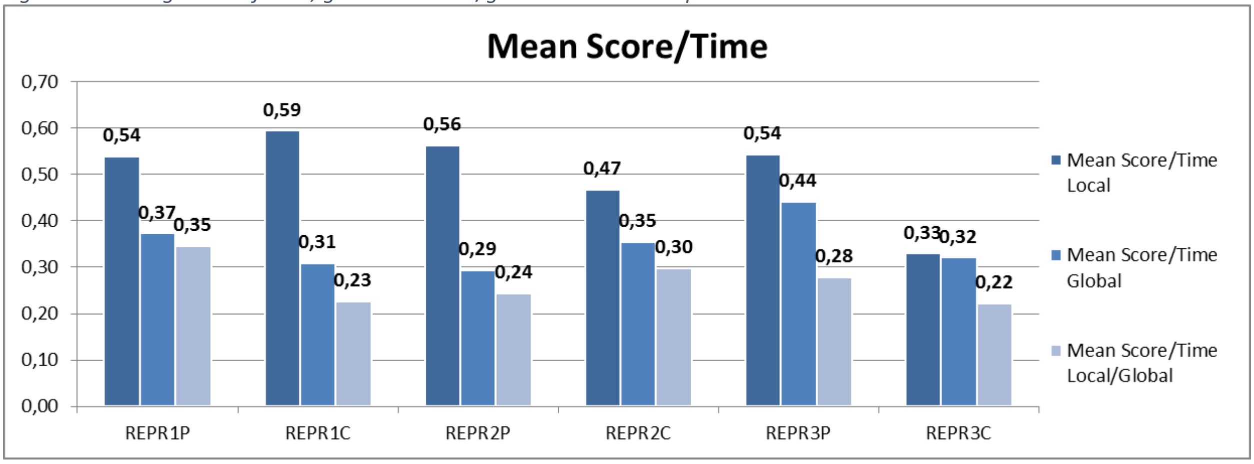


Figure 17: Average Score/Time ratio of local, global and local/global combination questions

5.3.6 The influence of the representation on Control flow (Ctr), Resource (Res) and Information (Inf) questions.

The division for the Ctr/Res/Inf questions is a little more complicated compared to the global/local questions. These type of questions consists of more individual combinations of different characteristics per questions. In order to draw any conclusions about these type of questions, the choice has been made to create three statistical groups. The questions that contain a (1) Ctr/Res/Inf combination questions will be compared among each other with (2) Ctr questions and with (3) Res/Inf questions. The score and time are both divided by the number of questions asked for this type. For the *score* the measurement is a percentage of correct answers and for the time the average time per question being used*.* Again a one-way repeated-measures ANOVA design was used.

5.3.6.1 Score

The results in Appendix O1 show that there was a difference between these type of questions for REPR1C, $F(2, 36) = 7.53$, $p < .01$, REPR2C, $F(2, 38) = 5.94$, $p < .01$ and REPR3C $F(2, 36) = 7.31$, $p < .01$, with no violations of Mauchly's test of sphericity. For representation 1C there was a significant difference between Ctr/Res/Inf questions and Ctr flow questions ($p = .005$), but also between Ctr/Res/Inf questions and Res/Inf questions ($p = .021$). Furthermore, REPR2C and REPR3C both showed a difference in correctness between Ctr/Res/Inf questions and Res/Inf questions ($p < .01$). A pairwise comparison, disregarding the representation type and medium, shows that there was also a general effect where Ctr/Res/Inf questions score lower compared to Ctr questions ($p < .001$). Also Control flow questions scored in general lower than the Res/Inf questions ($p < .01$). A one-way ANOVA between (Appendix O2) groups pointed out that there was a significant difference ($p < .05$) between groups for the questions that contain all areas (Ctr/Res/Inf). Though, Bonferroni's post-hoc test did not support this. On the other hand, a simple ANOVA between the two representation media shows that on average 59% of the Ctr/Res/Inf was answered correctly on paper, against 42% on the computer ($p = .001$). For the individual representation this difference was only significant for REPR1 $F(1,37) = 4,43$, $p < .05$ and for REPR3, $F(1, 39) = 4.53$, $p < .05$. The difference was not high enough for representation 2, $F(1, 39) = 3.25$, *ns.* Figure 18 shows the averages of each of the score of each of these questions. H4b was partly statistically supported for the Ctr/Res/Inf combination questions.

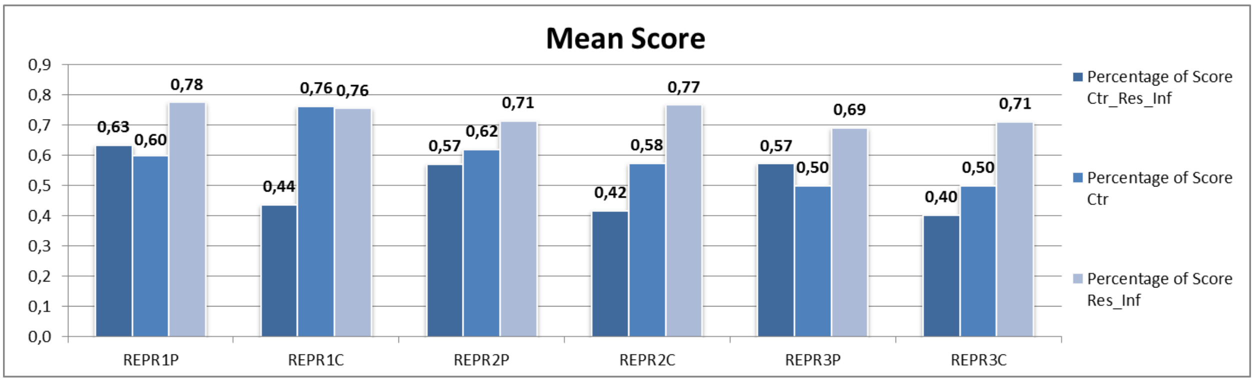


Figure 18: Average score of Control flow, Resource and Information questions

5.3.6.2 Time

The dependent variable *time* violated Mauchly's test for REPR1P and REPR2P so Huynh-Feldt will be used again for these representations ($\varepsilon = .77$ respectively $\varepsilon = .80$). REPR1P $F(1.53, 29,12) = 13.32$, $p < .001$, REPR1C $F(2, 36) = 4.50$, $p < .05$, REPR2P $F(1.60, 32.08) = 8.46$, $p < .01$, REPR2C $F(2, 38) = 3.79$, $p < .05$ and REPR3P $F(2, 40) = 3.26$, $p < .05$ show a difference between the different groups of questions (Appendix O3). For representation 1P and 2P this difference is manifested between Ctr/Res/Inf and Ctr questions ($p < .01$), and between Ctr and Res/Inf questions ($p < .01$). For representation 1C and 2C this difference is manifested between only Control flow questions and Resource/Information questions (Figure 19). For REPR3P there was no longer a measurable significant effect. In general, Ctr- questions take longer compared to Ctr/Res/Inf and Res/Inf questions ($p < .001$) and Ctr/Res/Inf questions take longer compared to Res/Inf questions ($p < .05$). At last, the control flow questions take longer in representation 1 compared to representation 3 (ANOVA, $p < .05$, Appendix O4).

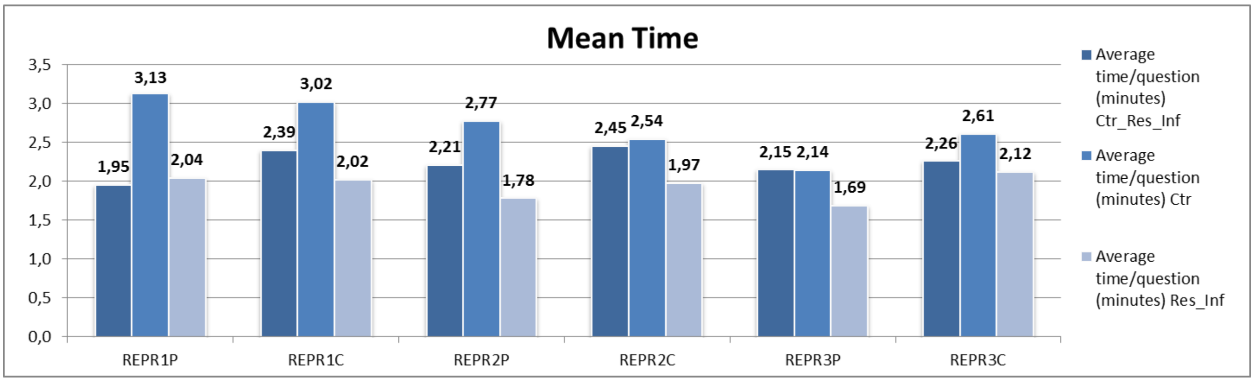


Figure 19: Average time in minutes per Control flow-, Resource- and Information questions

The *score/time* ratio gave some insight again in how the two previous dependent variables are interrelated to each other (Appendix O5). Within the groups that show a within-subject effects, REPR2C ($\varepsilon = .78$, $p < .01$), REPR3P ($\varepsilon = .82$, $p < .05$) and REPR3C ($\varepsilon = .73$, $p < .01$) violated the assumption of non-sphericity and will be reported according to the Huyn-Feldt criterion. There is a general difference between Ctr/Res/Inf questions and Res/Inf questions ($p < .001$), and also between Ctr questions and Res/Inf questions ($p < .001$). This is visible for REPR1C $F(2,36) = 7.00$, $p < .01$ between Ctr/Res/Inf and Res/Inf questions ($p < .01$), for REPR2C $F(1.47, 29.71) = 9.62$, $p < .01$, between Ctr/Res/Inf and Res/Inf ($p < .001$) questions, for REPR3P $F(1.64, 32.77) = 4.93$, $p < .05$, between Ctr and Res/Inf questions ($p < .05$) and for REPR3C $F(1.46, 2.52) = 4.73$, $p < .05$ between Ctr/Res/Inf and Res/Inf ($p < .05$) (Figure 20). Especially due to a simple ANOVA analysis (Appendix O6) it appeared that the ratio for Ctr/Res/Inf questions significantly differed between groups $F(5, 114) = 4.63$, $p < .01$. REPR1P scores better on this type of questions compared to all three computer representations, i.e. REPR1C ($p < .01$), REPR2C ($p < .05$) and REPR3C ($p < .05$). Also the ANOVA analysis between representation media shows a significant effect for the Ctr/Res/Inf questions, where the ratio for a paper medium is on average .37 and on a computer screen .20 with a $F(1, 119) = 19.71$, $p < .001$. This is in line what was found before, which means that questions requiring information from the control flow, resources and information flows were more understandable on a paper based medium.

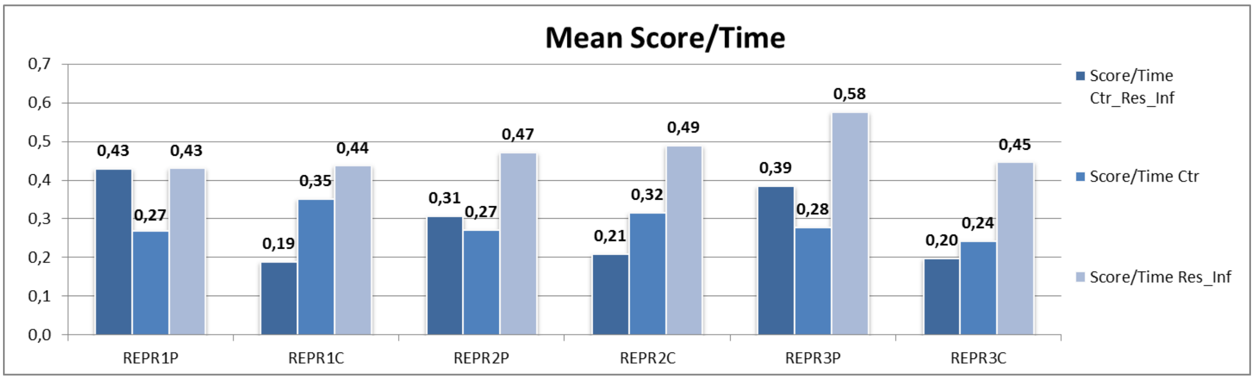


Figure 20: score/time per Control flow-, Resource- and Information questions

5.4 Participant feedback

The design of the experiment did not cover an option to record any open feedback regarding their (first) experience with business process models modelled with BPMN. Nevertheless, there were a few participants who provided feedback voluntarily via email or in person. This feedback also contained valuable information and should be addressed briefly. Usually the feedback had to do with the general expression of a feeling about the process models regardless of the representation type.

A general complaint was about the size of the letters in the models. Participants perceived the text as very small and uneasy to read. This complaint occurred for all groups in both representation media. The zooming function in the softcopy version facilitates this by enlarging the entire model, but it also decreased the oversight of the process model overall. Besides this, multiple people mentioned a delay (interruption) in the completion of the experiment. Other participants even had to quit the experiment halfway and had to finish it another day or time. Another remarkable observation was the resistance to the models in front of the experiment. The first contact with the (paper and computer) models caused a certain abomination by a number of participants. One participant, for example, felt highly reluctant to participate in the experiment after opening the envelope and having a first look at the process models. In a short evaluation after the experiment the participant was optimistic, enthusiastic and recognized many potentials coming from de process models. The opinion had changed 180 degrees simply by spending an approximate 45 minutes with this type of models. A notable comment was the participants' conclusion that it was not the model that was complex, but the process itself. This positivity afterwards was also reflected by most of the participants who provided a few lines of feedback. Another participant also perceived an increase in difficulty for the second process (the CH-process) because of a lower familiarity with this process. The difficulty mainly existed in the search and navigation process, whereas it was difficult to know where to search for the answers to the questions.

One of the participants (*P0*) expressed a motivation on one specific question in the questionnaire. The question is described as "the question about my commitment to use this way of describing processes". The participant refers to one of the questions measuring intention to use. *P0* states that "while I would not have any issue (far from it – this is a very clear way of describing), I had to answer no". The reasoning behind it has to do with a feeling of empowerment regarding BPMN process models ("while I would feel able to do so, I do not feel empowered for it – our current QMS system utilizes a certain way of describing processes"). P0 explained that if the QMS standard templates were the ones as shown in the experiment, BPMN would be the preferred method to use.

6. Discussion

This section shall discuss the statistical results in order to accept or reject the hypotheses. The hypotheses discussed the influence of the *representation type, the representation medium*, *the*ir *combined effect*, and the influence of the *modularity representation* on the *different types of understandability questions*.

6.1 The influence of the representation type

There was no direct measurable difference in the ability to answer questions correctly between the three representations. Also, the average time that is needed to answer the questions for the process representations is quite equal among groups. Because of this, it is not a problem that the process model experience of the participants had an influence on this measure as well. Apparently, the navigation through the model, either with (on the computer screen) or without zooming fuctions does not cost more time in regard to finding the putative answer to the question. On the other hand, representation 1 is perceived as more useful, more easy to use (on paper) and rated with a higher intention to use (on the computer) compared to representation 3. Furthermore, on the contrary of earlier expectations, the first and second representation do not differ in terms of score and time. Therefore, there is no reason to define sub-processes in a process model if the aim is not to hide these sub-processes from the higher level model. The business practitioners were exposed to extra information (the colored boxes titled with the sub-process), which they did not need in order to create a higher understandability of the process. Despite of this, users with low practical knowledge of modeling are supposed to understand process models more accurately with the help of color (Reijers et al., 2011). In this case it looks like the use of color is probably helpful in order to distinguish different roles, but there is no good reason to use colored boxes to distinguish between sub-processes of a process. The differences between the first and the second representation were not high enough to conclude whether the differentiation of sub-processes even harmed the understandability of the process model. Though, participants perceive representation 2 as less easy to use compared to representation 1 (on a paper medium). This means that at least in the perception of people, the models become less understandable when colored boxes are used to divide a process into sub-processes. All of this leads to a *partial acceptation of H1* which claims that the representation type has an influence on the understandability of business process models.

6.2 The influence of the presentation medium

Also *H2 can only be partially accepted*. The presentation medium did not show any difference within representation types for the dependent variables score and time. Nevertheless, in terms of subjective measures we found an effect for the presentation medium within representation 1 and representation 3. Participants indicated that representation 1 and representation 3 were more useful on a paper medium compared to their computer counterparts. A remarkable output shows that the paper version of REPR3 was even rated with a higher *intention to use* compared to its computer counterpart. A possible explanation could be that REPR3P uses an ‘overview+detail view’ whereas the sub-processes are represented on multiple A3 papers (i.e. on multipe windows). This presentation is perceived as more understandable compared to a view that makes it possible to focus on the sub-processes while the context stays visible in the meantime (Figl, Koschmider, et al., 2013). This so called ‘focus+context view’ was used in the computer version of representation 3 (REPR3C). The results of this experiment are therefore in alignment with the findings of Figl, Koschmider, et al. (2013). It is too soon though to state whether this agreement exists for the same reasons or that other forces cause this effect.

6.3 The combined influence of the representation type and presentation medium

Once again, based on the *score* and *time* there was no difference between groups. Participants were not able to answer questions more correctly or faster for any modularity representation. Luckily, the subjective measures did produce some outcomes, partly in agreement with earlier findings. According to all MEM questions, REPR1P is more preferred compared to REPR3C. In addition, REPR1P is perceived more useful compared to REPR2C and REPR2P is more useful compared to REPR3C. Subsequently, the participants preferred representation 1 on paper above representation 2 and 3 on the computer in terms of the perceived ease of use. The high (significant) difference between REPR1P and REPR2C for PU and PEOU might again point out that it is less understandable to have a fully-flattened process model on a computer screen compared to an A3 paper format, due to the size. Also the sub-processes in coloured boxes are not of any help for the way process participants perceive the process models. Furthermore, those subjective questions were used to measure whether people were willing to use process models from an intrinsic motivation (Moody, 2003). Dependent variables PU and PEOU show a reoccurring pattern which does not come back as strong in the ITU. A plausible explanation for this deviation is that a number of participants may not have answered the question about their “intention to use” BPMN process models from an intrinsic motivation but within the context and situation of the company. This was the outcome of the feedback of one participants in the experiment. In conclusion, the representation type and medium have a combined influence on at least the PU, PEOU and ITU. *H3 can therefore be partially accepted.*

6.4 The influence of the modularity representation on different types of understandability questions

It seems that the modularity representation has an influence on local and global questions, and on questions with control flow, resource and information characteristics. According to this, *H4 will be accepted*.

6.4.1 Local and Global questions

In general, participants outperformed on answering local questions in comparison to questions attributing a global aspect for the fully flattened versions (REPR1 and REPR2) of the process models. It seems that REPR1C and REPR2P facilitate accuracy of answering the local oriented questions better than REPR3C does. Subsequently, when the presentation medium is not taken into account, representation 1 and 2 are more understandable when it comes to answering local questions about a process model. Apparently, by dividing a process into several sub-processes it becomes harder to accurately find answers to local content questions. Reijers et al. (2011) stated that the use of sub-processes and the limitation in the represented information should make local parts of the process model more understandable on the contrary. They found this effect within a sample of 28 experienced process modelers. This sample creates a crucial differce in the experimental set-up by all means. Process modelers, and therefore process modeling experts are probably able to handle the split-attention effect (Zugal et al., 2012), caused by modularity, more easily. They are simply more familiar with business process models. The business practitioners of our experiment rated their process modeling knowledge rather low. These business practitionars are the ones targeted to use these type of process models in the current business context and are therefore a more credible sample to test the understandability of process models. Nevertheless, both REPR3P and REPR3C do not show the same weight on this objective measurement of the understandability. REPR3P shows a clearly lower correctness of local questions compared to the fully-flattened models of the process. However, the difference has not been identified as significant (in contast to REPR3C). Therefore no clear conclusions can be drawn towards the understandability of process representations with sub-processes on paper. A possible explanation could be that it becomes more difficult to find local information in the process model when the participant does not know the process or the modeling notation very well. The information stayed hidden in REPR3C until the participant placed the mouse at the right sub-process. In REPR3P, at least all sub-processes are visible on different papers. Less pre-knowledge is requested to find the right sub-process since one can see all sub-processes by simply scanning through them as often as required. This is again in line with the non preferance of the 'focus+context view' (Figl, Koschmider, et al., 2013).

The process information that appears to be most time-consuming to find contained both global and local information about the process. The answers to these particular questions seemed most difficult to find regardless of the representation type. On the other hand, our experiment shows that local model aspects have the highest score/time ratio. This means that the local aspects of the model are replied relatively with a high correctness on a low time interval. Noteworthy, the local score/time ratio is really low for the third representation on a computer screen. This only increases the suspicion that it is more difficult to find the answers to local questions in the 'focus+context view' of REPR3C.

6.4.2 Control Flow, Resource and Information questions

The most valuable information comes from the questions that contain control flow, resource and information elements. These questions are more understandable on a paper medium. Especially representation 1 and representation 3 are more understandable for this type of questions on paper compared to their match on the computer. It also took people longer to answer the control flow question in representation 1 compared to representation 3. This is not very relevant since the score/time ratio shows that the extra time that is used in representation 1 has led to answering the questions more correctly.

6.5 General findings

At last, the personal factors considered as control variables did not have a large influence on the outcomes. However, it seemed that the personal factors (the control variables) of the participants had a stronger impact on the subjective outcomes compared to the objective (score and time) measures. This might mean that the tested personal factors are not of large influence on the absolute ability to read and understand the content and notation of a process model. In the meantime, they might influence the subjective feelings of an employee towards the business process models. One participant also mentioned that it was more difficult to read and navigate through a rather unknown process in comparison to a known process (domain knowledge). This might lead to a certain resistance towards process models. An unneglectable resistance occurred already for part of the participants who were exposed to this type of process representations for the first time. In the end, the subjective measures show a positive and hopeful result towards the PU, PEOU and ITU BPMN process models. REPR3C shows the lowest figure for all three subjective measures, and employees would on average not agree on the proposed usefulness, ease of use and intention to use. On the other hand, it looks like employees feel a rather high connectivity towards the business process models when they are exposed to a paper version that shows the whole process in one overview (fully-flattened representation 1).

7. Conclusions

The aim of the research project was to find the answer to the following questions: *which modularity representation supports the understandability of business process models best in practice?* In addition, we also wanted to examine if *the presentation medium influences the understandability of business process models.*

An experiment has been performed with two real life business process models to find out which representation suits the understandability of these process models best. Looking from a time perspective, there is no reason to choose one modularity representation over the other. That makes it easy to exclude this variable from a rational decision between the different modularity representations. Therefore, all other understandability measurements play a key role even more. The understandability measured in this experiment is different among the different representations in terms of effectiveness and the subjective measures. The presentation medium also seems to influence the understandability of process models. A number of hypotheses were answered and the outcomes to the investigated hypotheses are summarized in Table 8.

Table 8: Summary of hypotheses

SUMMARY		
Hypothesis	**Result**	**Proposition**
H1: Representation type has an influence on the a) score, b) time, c) perceived usefulness (PU), d) perceived ease of use (PEOU), and e) intention to use (ITU).	Partially Accepted	*REPR1 is more understandable compared to REPR2 (Based on a paper medium and PEOU) and REPR3 (Based on PU, PEOU and ITU).*
H2: Presentation medium has an influence on the a) score, b) time, c) perceived usefulness (PU), d) perceived ease of use (PEOU), and e) intention to use (ITU).	Partially Accepted	*A paper presentation medium is a more understandable presentation medium compared to a computer screen for at least REPR1 (based on PU) and REPR3 (based on score/time, PU and ITU).*
H3: The Representation type and Presentation medium have a combined effect on the a) score, b) time, c) perceived usefulness (PU), d) perceived ease of use (PEOU), and e) intention to use (ITU).	Partially Accepted	*REPR1P is more understandable compared to REPR3C (based on PU, PEOU and ITU). As well, REPR2P is more understandable compared to REPR3C (based on PU). Furthermore, REPR1P is more understandable compared to REPR2C (based on PU and PEOU)*
H4: The influence of the representation will be different for different types of understandability questions: a) Global & Local, b) Ctr/Res/Inf	Accepted	*The local questions are most understandable for REPR1 and REPR2 (based on score). Next, Ctr/Res/Inf questions are most understandable on a paper medium, especially on REPR1 and REPR3 (based on score and score/time)*

A fully-flattened version of a process model (without sub-process) supports the understandability of business process models best. The fully-flattened version of a process model was mainly used to be able to tell something about the absolute value of the understandability with the application of modularity. Apparently, the decrease in size clearly has a lower positive impact on the understandability compared to the negative (split-attention) effect of the use of sub-processes. Also the extra feature to divide processes into sub-processes with the help of colored boxes but without losing any overview (and thus size), does not create a higher understandability. Besides, the method used to represent representation 3 on the computer (focus+context view) is undesirable. Representation 3 on paper excludes the sub-processes from the main view (overview+detail view) and does not have a measurable lower understandability than the fully-flattened process models. Representation 3 on the computer happened to be the only representation that scored low on all factors in comparison to at least the first representation on paper. It seems easier to integrate the sub-processes into the overall process model when they are represented in separate views or windows. This result has not been tested in this experiment specifically on the computer though. In combination with a higher understandability for the paper sub-process representation (REPR3P) it suggests that the main process model should contain the least information that is possible per process view.

A process model on a paper presentation medium is more understandable for at least a fully-flattened process representation and a representation that divides and hides sub-processes from the main process view. It might be best for the understandability to represent the whole process fully-flattened on a paper medium. Especially, a first contact with these kind of process representations is perceived highly useful and easy to use when the representation is presented in this format. Our data from the experiment indicate that the use of sub-processes does not make large and complex process models more understandable. Apparently, the large size of a process model causes less trouble than the split-attention effect of reintegrating hidden sub-processes. The split-attention effect is easiest to overcome when the sub-processes are not hidden in the main process model but when separate views or windows are used to represent the main process model and the sub-process.

7.1 Limitations and implications for future research

A threat to the validity of the before mentioned conclusions originates from the already identified difference between the CAPA- and the CH-process. There was a difference between the two processes within the number of correctly answered questions and within the time needed to answer these questions. This makes it more difficult to consider the two processes as similar. On the other hand, arguing from the visible patterns in the dependent variables between the different representations, it would create only more significant results between the different representations. Within this experiment there were not enough data per group to analyze both processes separately because the personal factors caused a higher impact on the understandability. It would be helpful to create an experiment with a similar setup within different companies and with different process models (with comparable characteristics and modeling conventions). More data on this specific aspect causes many benefits in this regard. The second representation in a new setup could be replaced by another format to represent the sub-processes separated from the main process. In this similar experiment it would be helpful to find out if the identified negative effects of REPR3C ('focus+context view') would possibly fade out if REPR3C would make use of separate views to represent the sub-processes ('overview+detail view'). If this is not the case, a number of conclusions could be drawn from this, which includes that the presentation medium has a higher influence then could be drawn from the results of this experiment. In line with this, we have already a better judgement on which process representations cause substantial problems in the understandability of business process models. In the meantime there is no exclusive guideline which modularity representation could provide a high understandability with a high practical business value (practically feasible). Also the research of Figl, Koschmider, et al. (2013) was done with a sample of business process modeling experts. These results are therefore not applicable to the broad public of business process actors who are not as experienced and familiar with process models. They also suggest further research on the influence of modularity representations on large process models in practice. This study made a good start but more research is necessary with real business practitioners included to find out how real business process models could be used in practice in a highly understandable manner. Future research can also address and compare the data originating from the experiment conducted with different business environments and domains, as well as with students.

Another limitation occurred mostly within the computer group. The choice has been made to make the experiment available to the participant on a completely remote basis. Every individual was free to participate on its own best suitable time and location. This means that there was no control on the size or resolution of the computer screen. A difference between the size of the computer screen (and therefore variance in the size of the process models) might account for differences within this group in the *score, time, PU, PEOU and ITU*. Besides, for all participants applies that interruptions by colleagues or other urgent events might have led to a lower concentration and engagement in the experiment. Except for the corrections that were taken for the time measures, there is no control on possible interference on the data.

At last, the use of process participants and real-life models had a positive effect on the external validity of the experiment, which makes it possible to generalize the results better towards practical implications. The random assignment of the subjects into the different blocks also increased the external validity of the experiment. On the other hand, the improvement of the external validity counteracted with the internal validity, since the number of subjects might cause a threat to this internal validity. The sample was set on 60. This is already a difficult and minimum amount to draw statistically significant conclusions upon since every block (group) consists merely of 10 subjects. This is a negative effect of an improvement of the external validity and a generally known trade-off within this research field. A few effects did not become significant but showed a strong trend among all dependent variables. These effects might have been significant with double the size of participants.

7.2 Practical implications

Based on all this, there are a few practical implications which are useful for business practitioners. The group of participants was fairly new to this type of business process representations and an initial view at the process models evoked resistance. By being “forced” to work with this kind of process representations for at least half an hour, a positive learning effect occurred. The high perceived usefulness and perceived ease of use of specific groups, shows that an initial resistance can be bend towards a positive attitude if the right representation is used. This indicates that a first contact with BPMN process models should not be on a computer screen with a REPR3C-like visualization because of its low understandability. This asks for more resistance in the perceived usefulness and perceived ease of use of this type of process models after using it. For future implementations of business process models, the use of sub-processes is probably inevitable. Of course it is not achievable to present a whole QMS on paper; it is not practical, durable, environmentally unfriendly and a waste of money. Every update would lead to a new print out of that particular process model. This experiment has demonstrated that a REPR3C representation is not a good idea though. Another online representation (with sub-processes in separate views or windows) should be used preferably.

Usually one role within a process is captured in one or more sub-processes. For business practitioners to optimally understand these local parts of the process model, it is best to show the process model in a fully flattened way. For a person to understand and to adapt to process models, it would be best to provide a training which exposes the process participant to its own process on a paper medium (or potential on a computer medium) without any division into sub-processes. Also, team meetings which are process oriented could be facilitated with a print out of the process model in order to increase the understandability.

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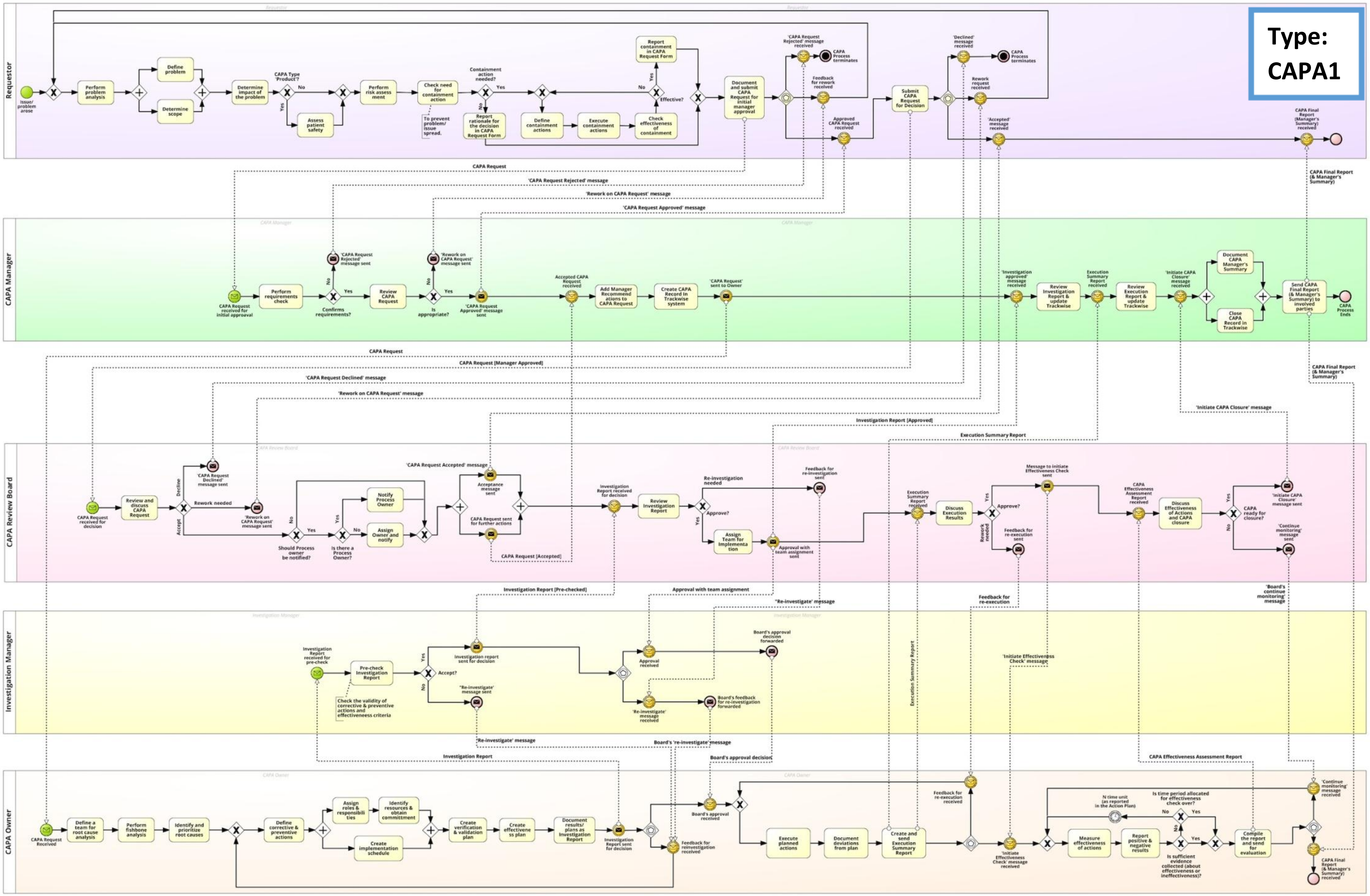
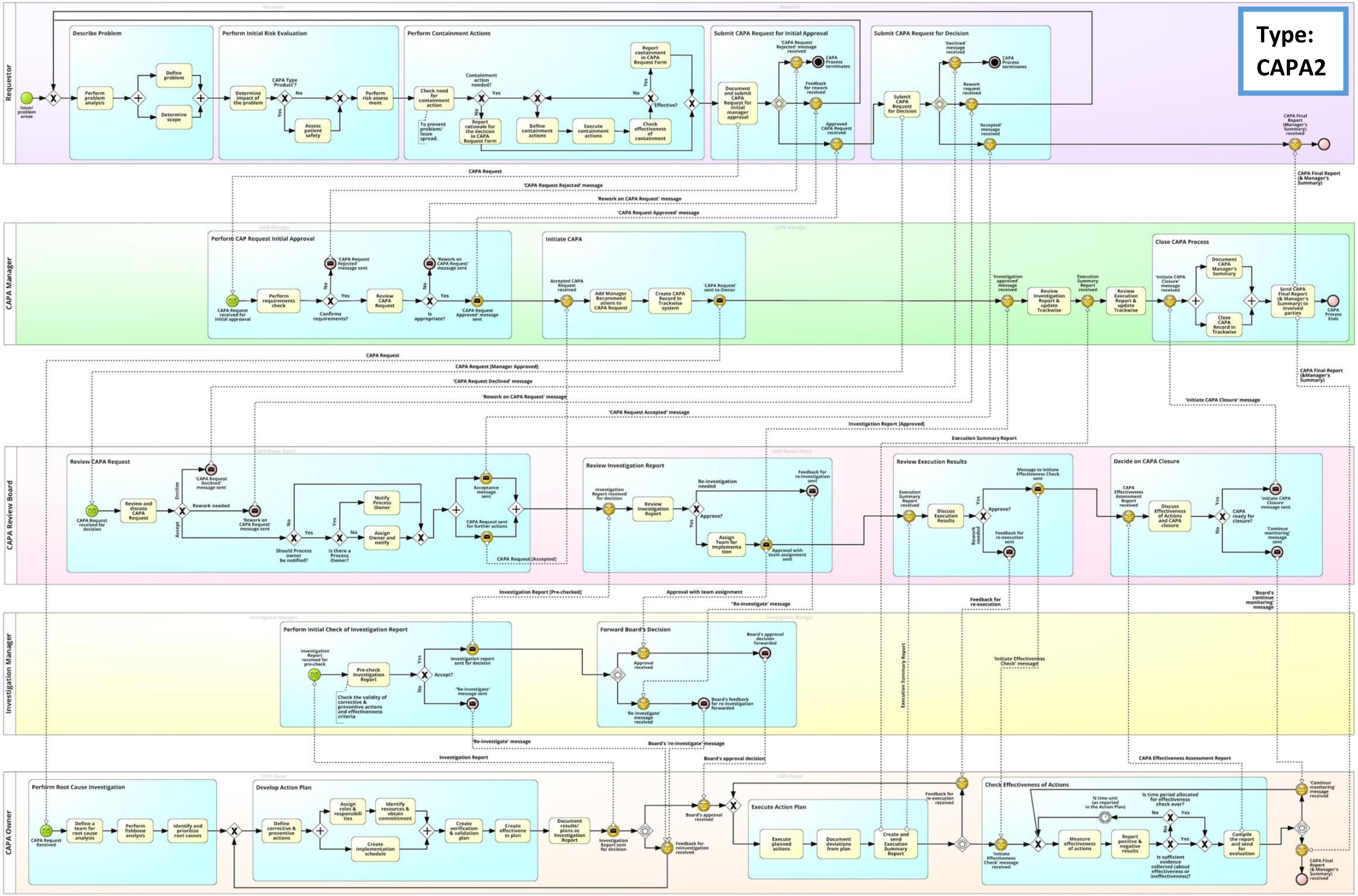
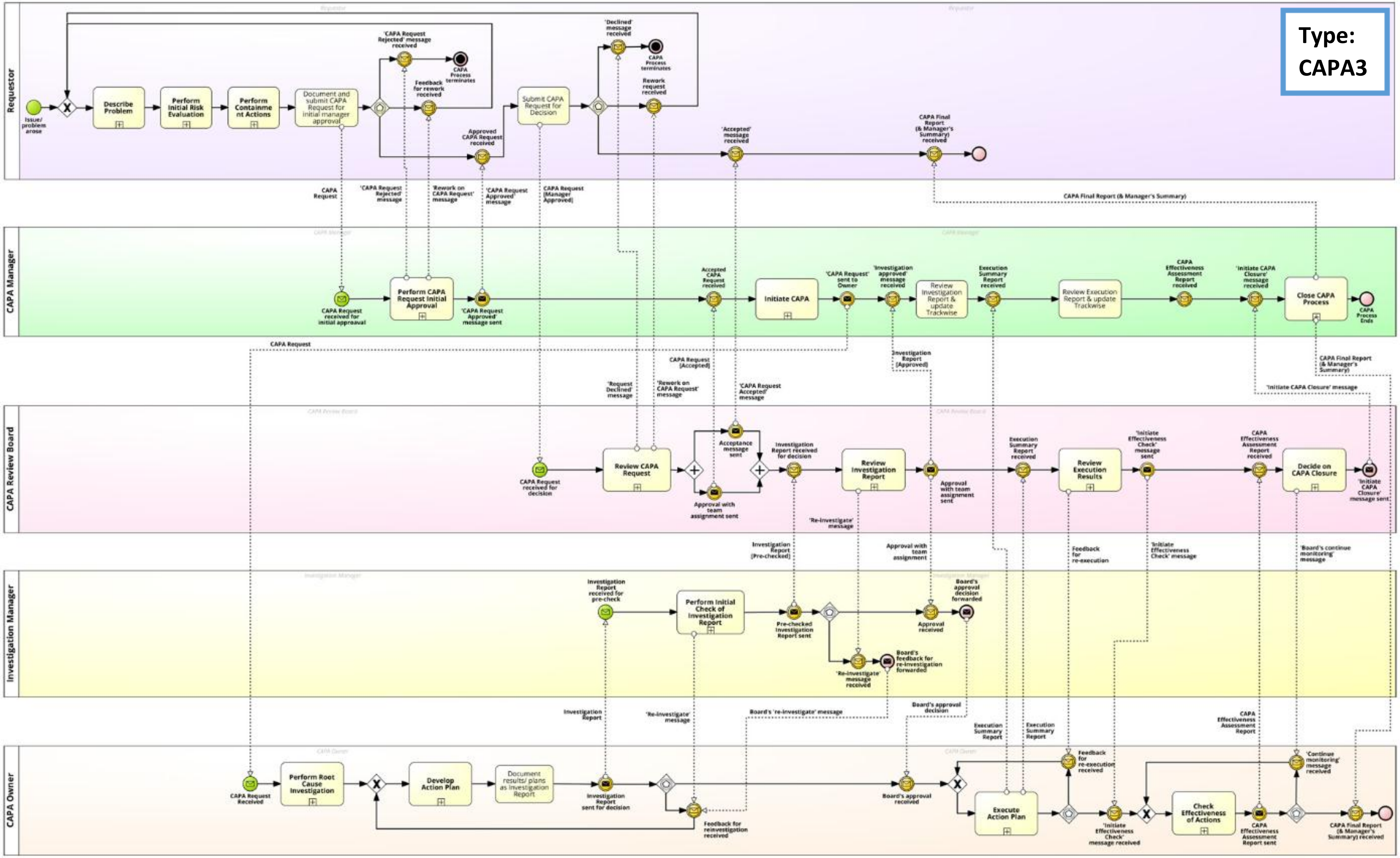
Appendix A: Business Process Models



Corrective and Preventive Actions (CAPA) Process (*Type CAPA1*)



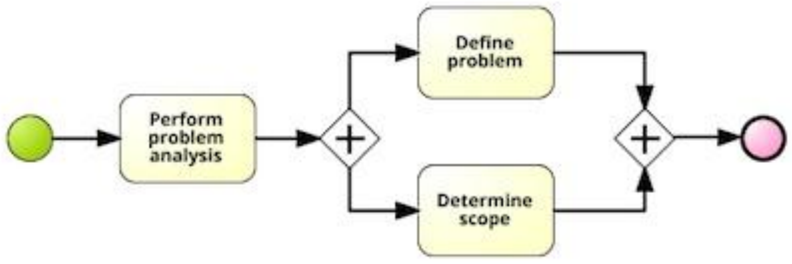
Corrective and Preventive Actions (CAPA) Process (Type CAPA2)



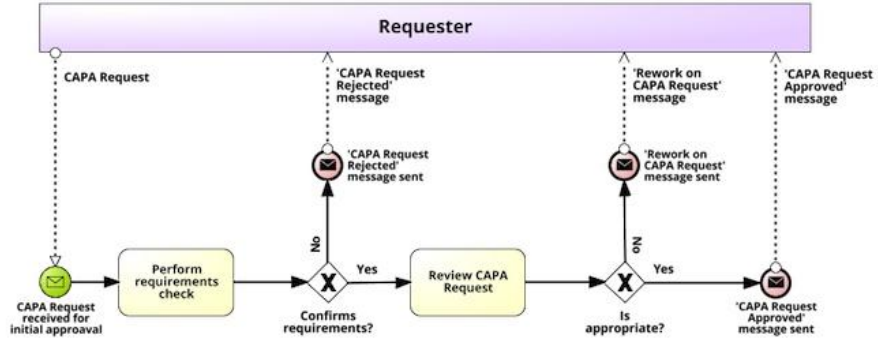
Corrective and Preventive Actions (CAPA) Process (Type CAPA3)

Type: CAPA3

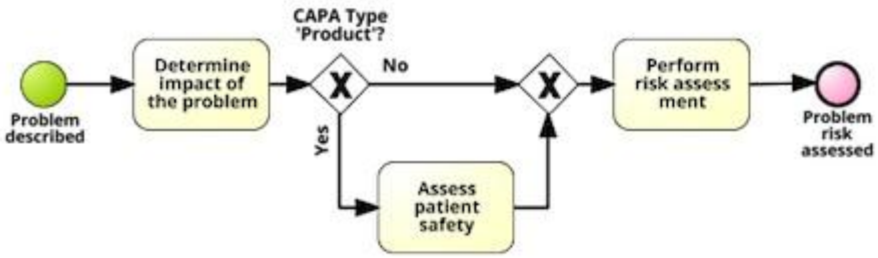
Requestor → Describe Problem



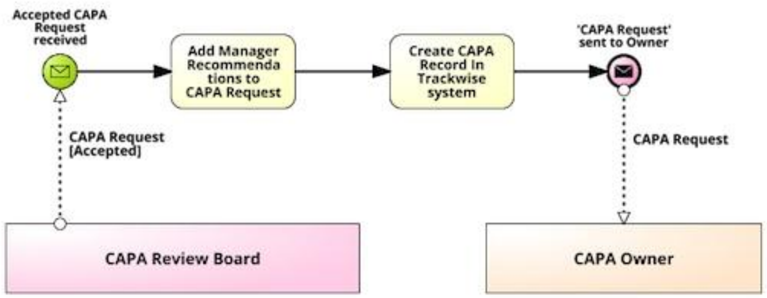
CAPA Manager → Perform CAPA Request Initial Approval



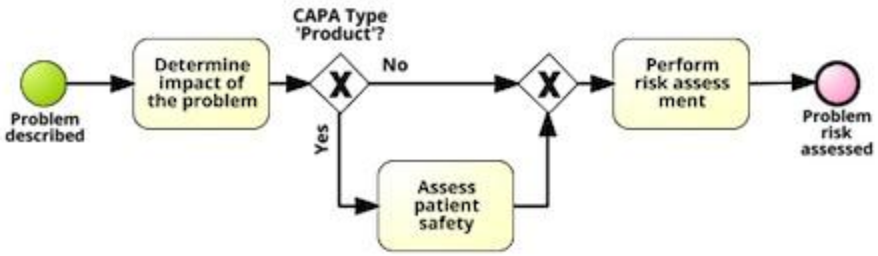
Requestor → Perform Initial Risk Evaluation



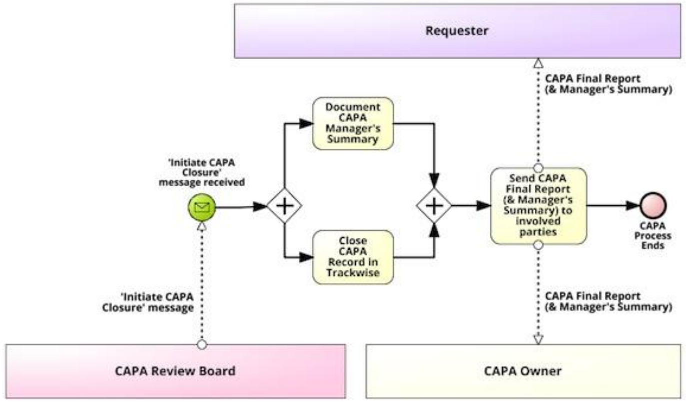
CAPA Manager → Initiate CAPA



Requestor → Perform Initial Risk Evaluation



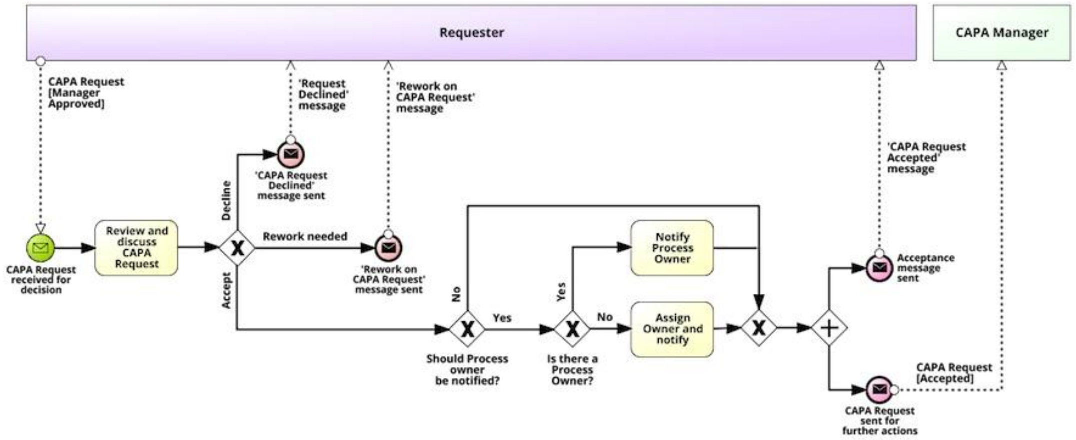
CAPA Manager → Close CAPA Process



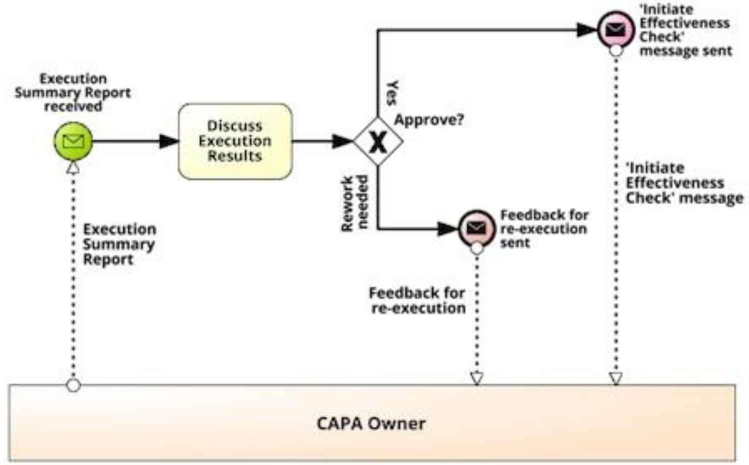
Sub-processes Corrective and Preventive Actions (CAPA) Process (Type CAPA3)

Type: CAPA3

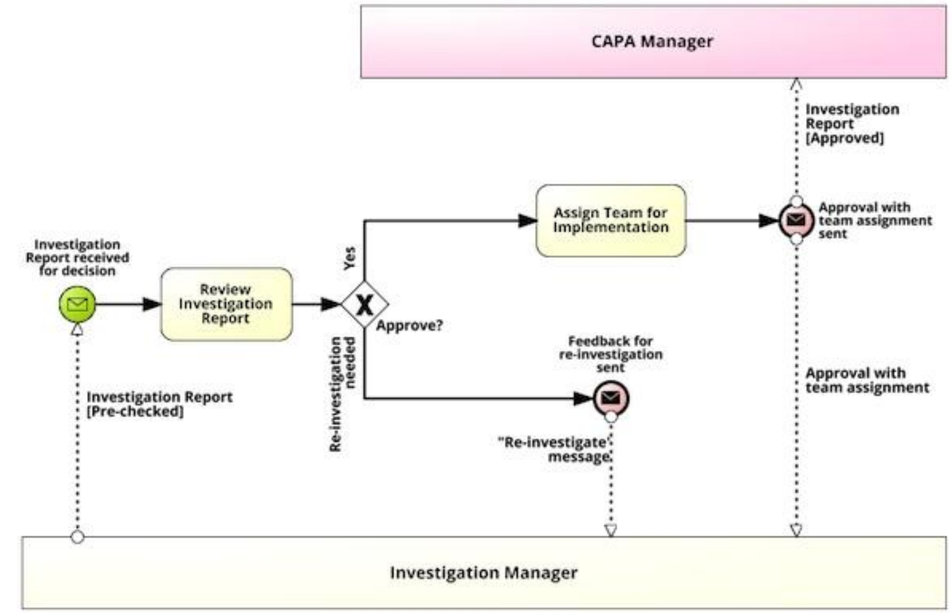
CAPA Review Board → Review CAPA Request



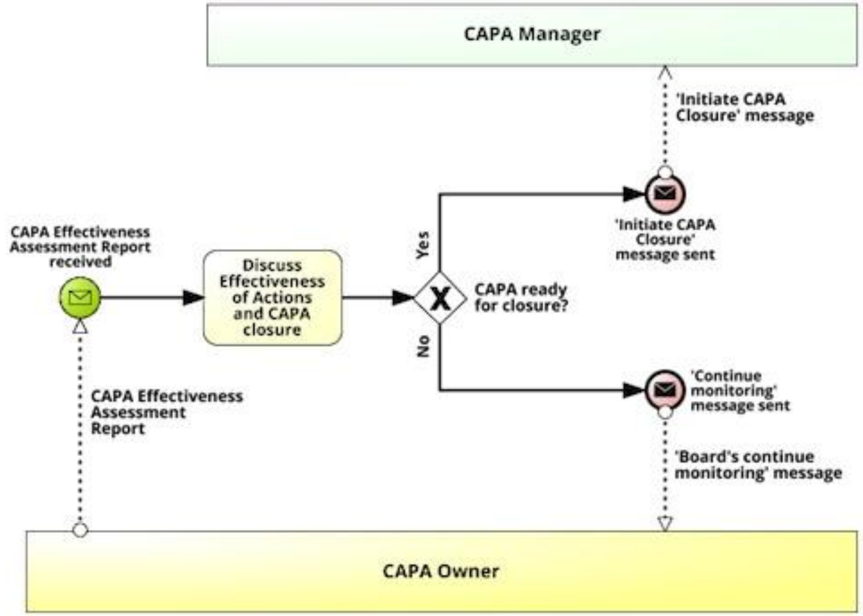
CAPA Review Board → Review Execution Results



CAPA Review Board → Review Investigation Report



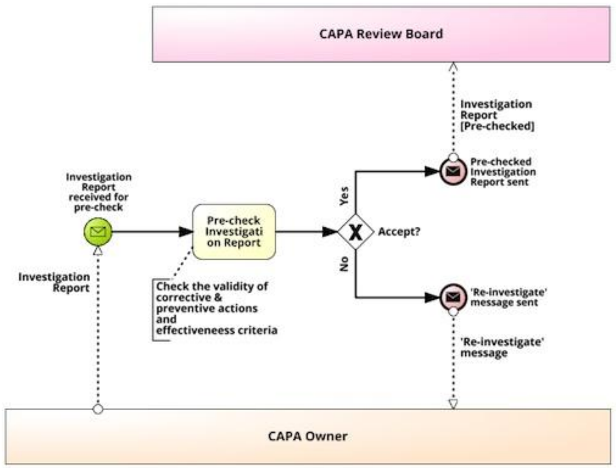
CAPA Review Board → Decide on CAPA



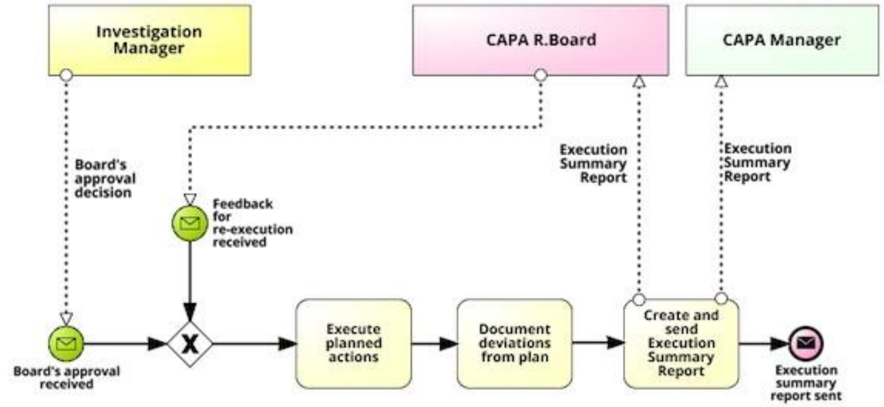
Sub-processes Corrective and Preventive Actions (CAPA) Process (Type CAPA3)

Type: CAPA3

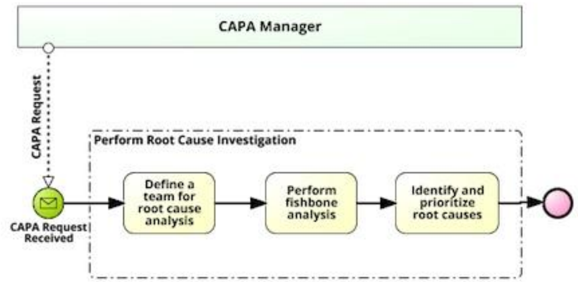
Investigation Manager → Perform Initial Check of Investigation Report



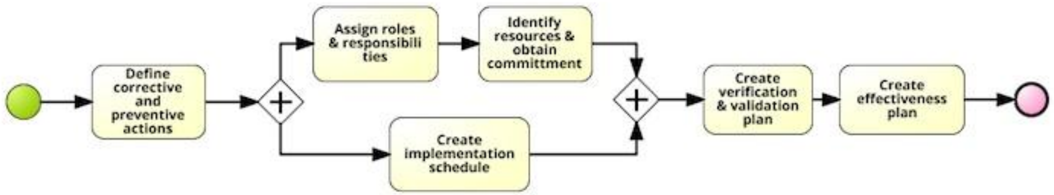
CAPA Owner → Execute Action Plan



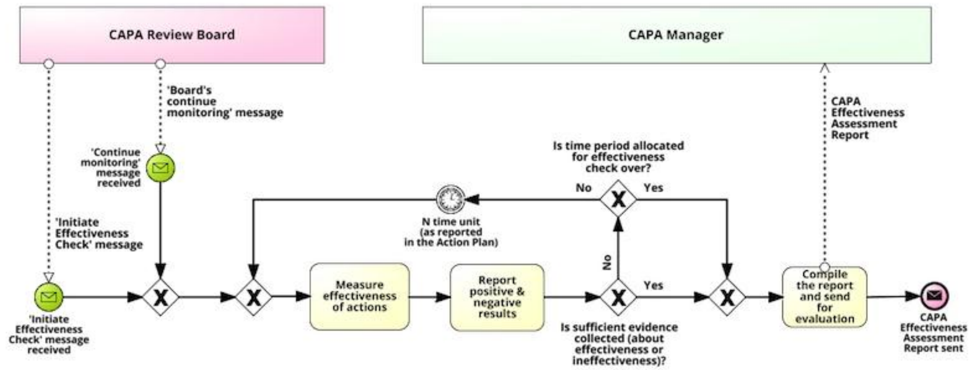
CAPA Owner → Perform Root Cause Investigation



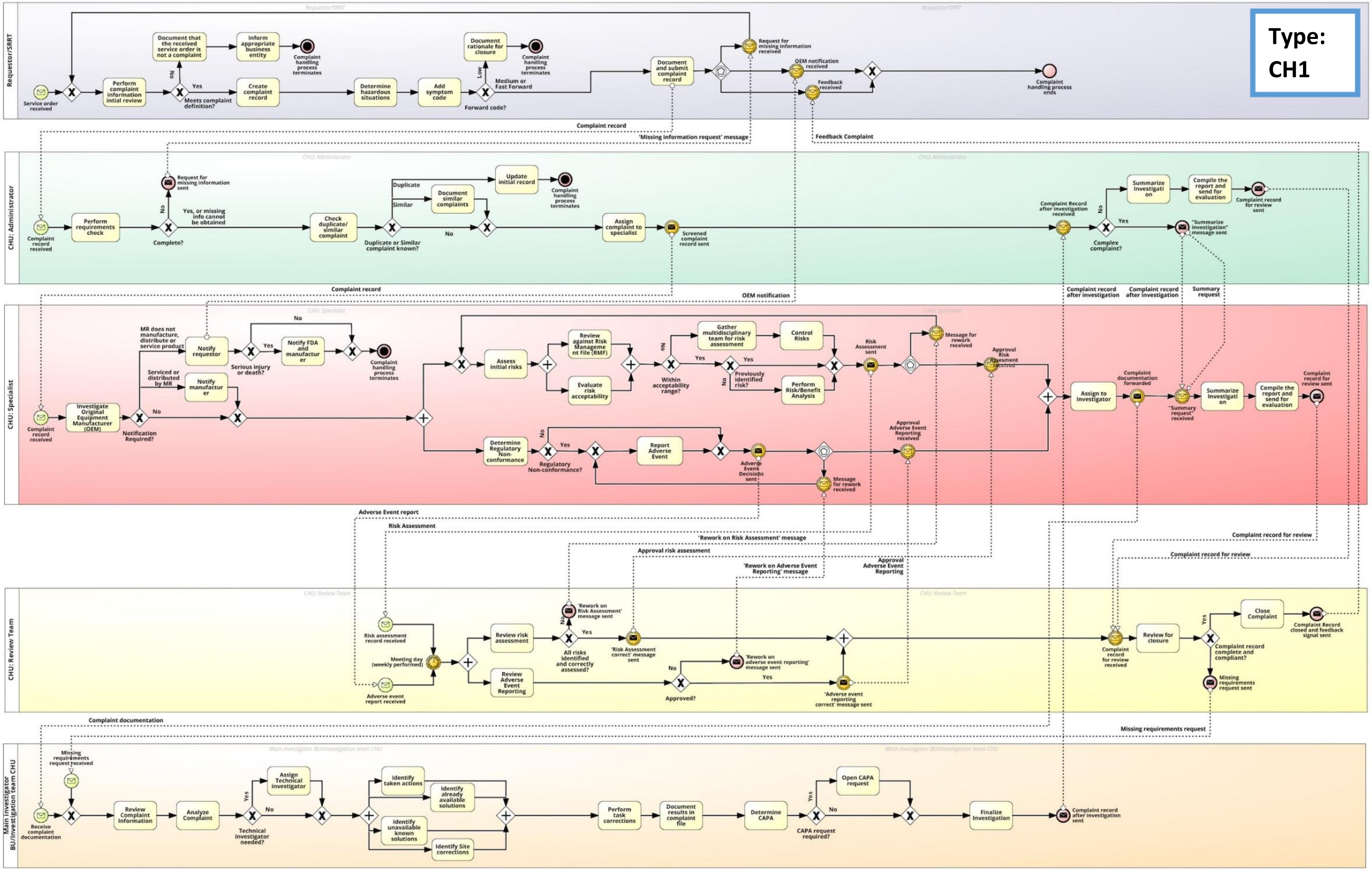
CAPA Owner → Develop Action Plan



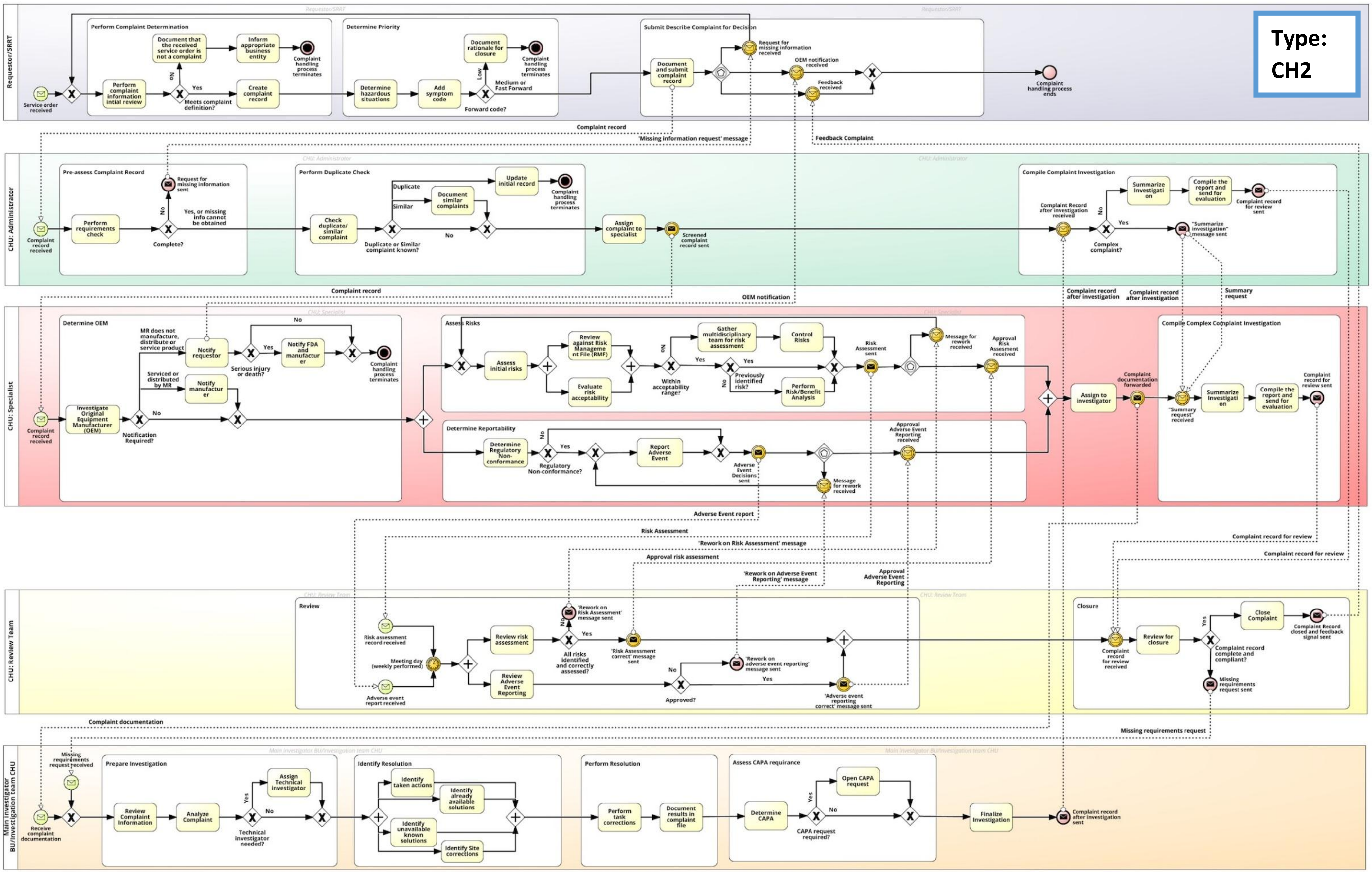
CAPA Owner → Check Effectiveness of Actions



Sub-processes Corrective and Preventive Actions (CAPA) Process (Type CAPA3)

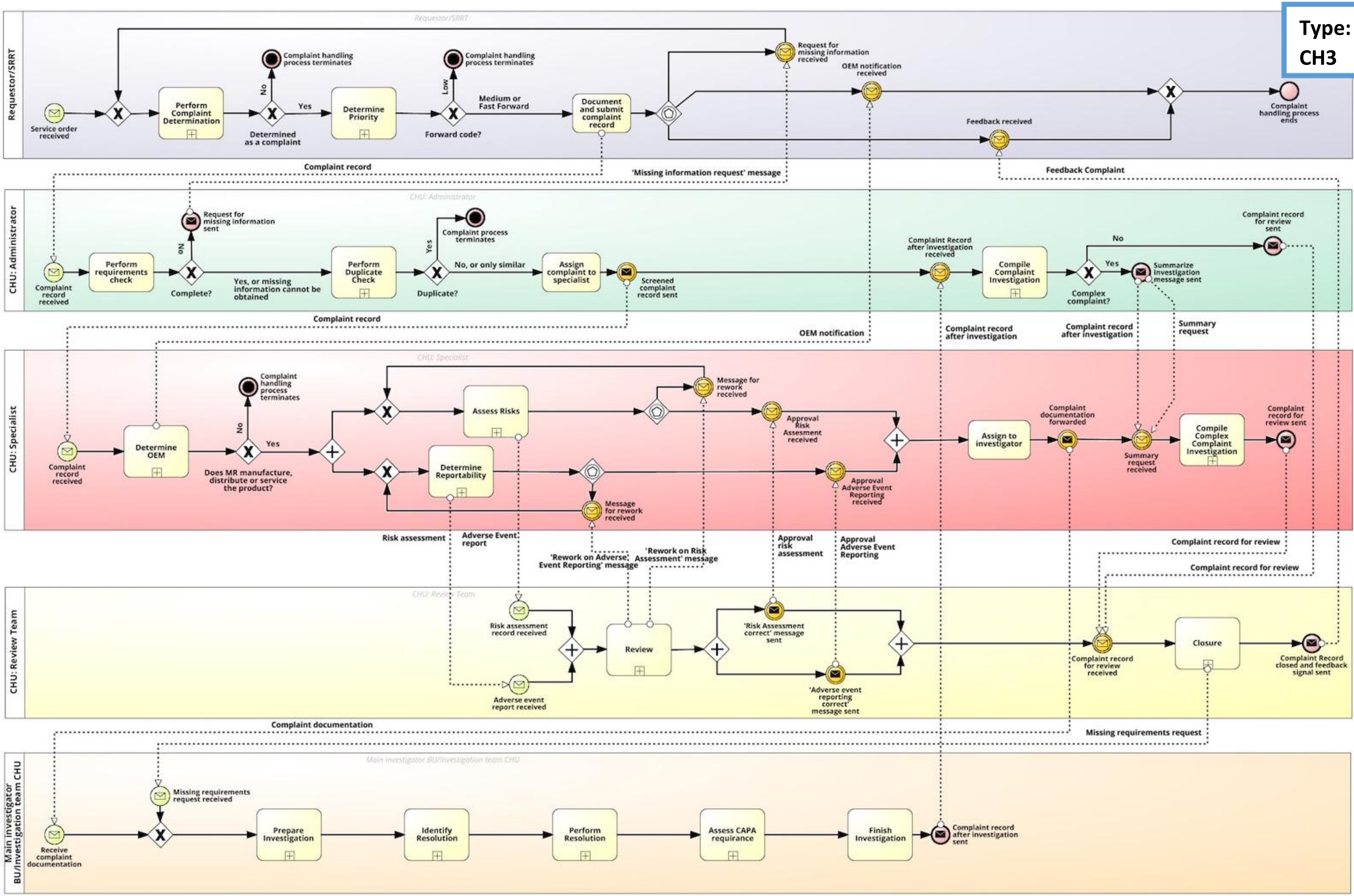


Complaint Handling (CH) Process (Type CH1)



Complaint Handling (CH) Process (Type CH2)

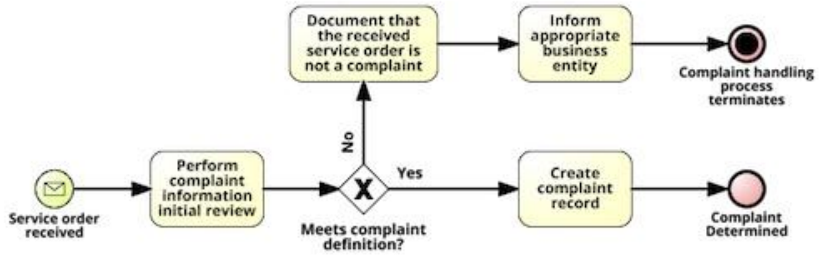
Type: CH3



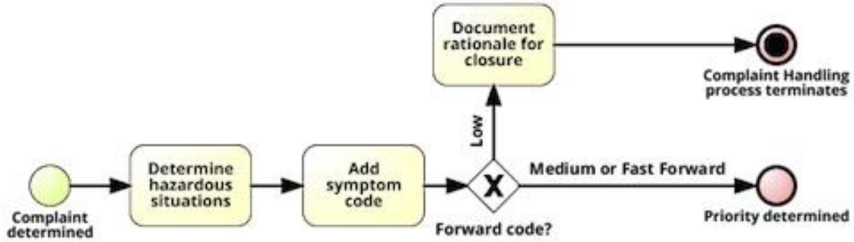
Complaint Handling (CH) Process (Type CH3)

Type: CH3

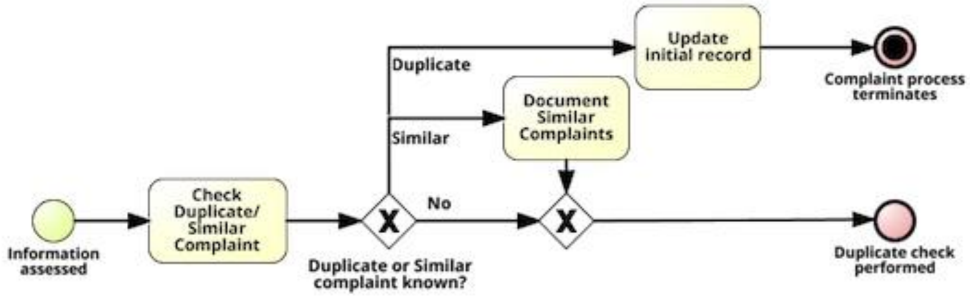
Requestor/SRRT → Perform Complaint Determination



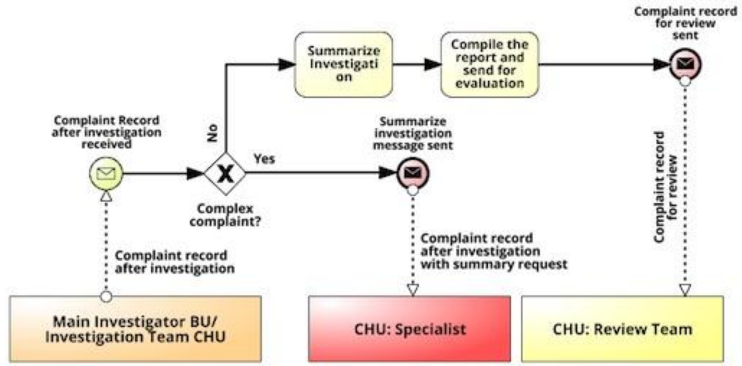
Requestor/SRRT → Determine Priority



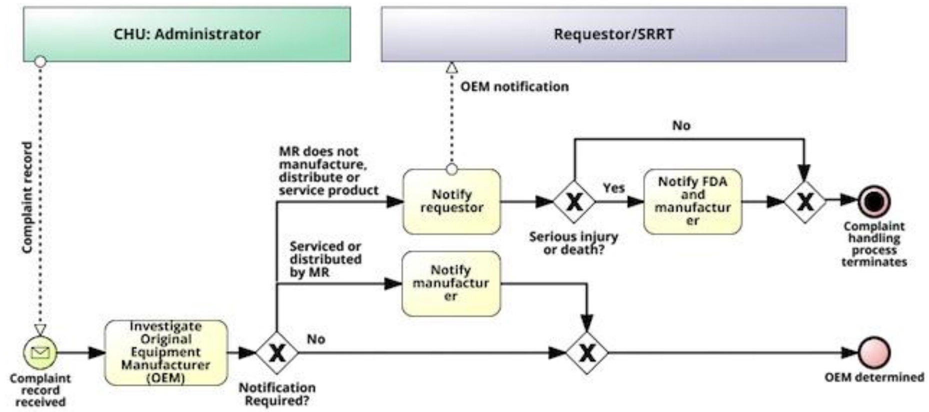
CHU: Administrator → Perform Duplicate Check



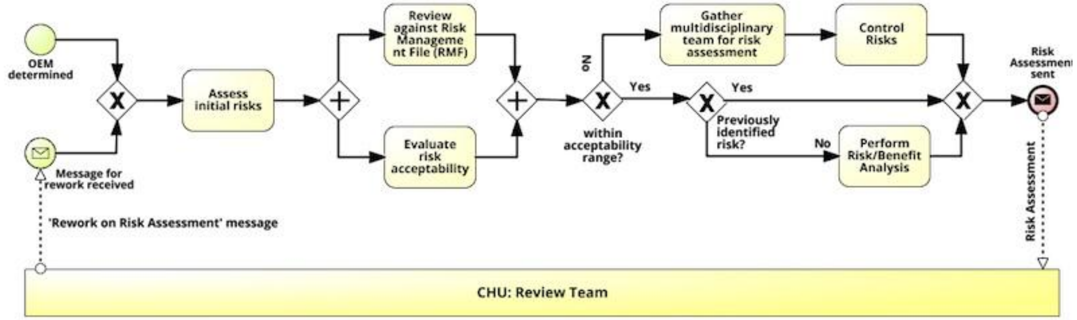
CHU: Administrator → Compile Complaint Investigation



CHU: Specialist → Determine OEM



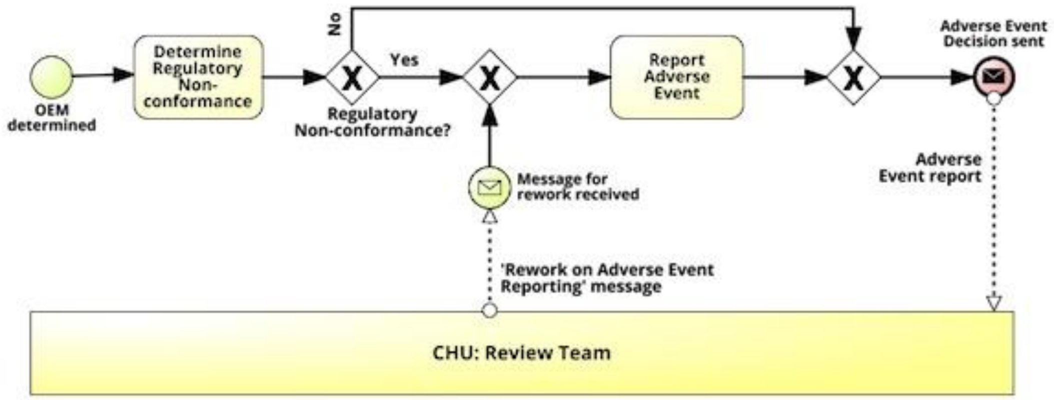
CHU: Specialist → Assess Risks



Sub-processes Complaint Handling (CH) Process (Type CH3)

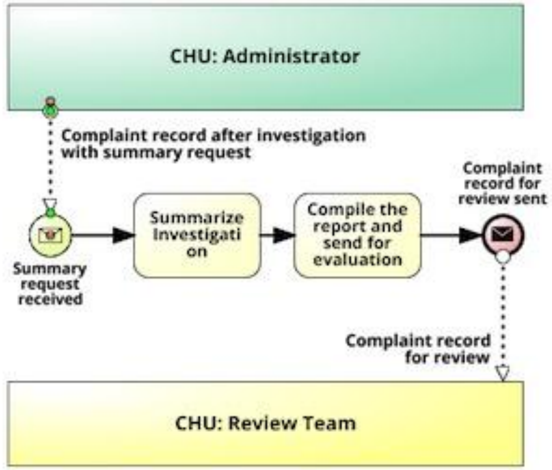
X

CHU: Specialist → Determine Reportability

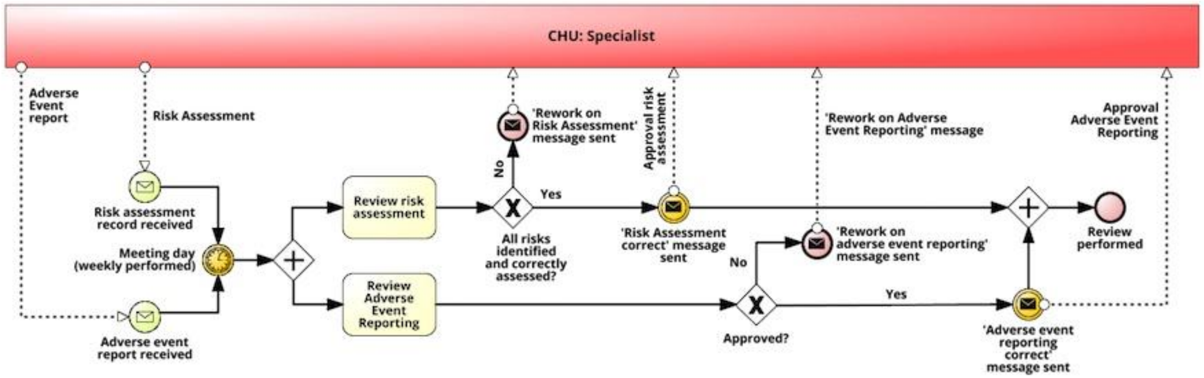


CHU: Specialist → Compile Complex Complaint Investigation

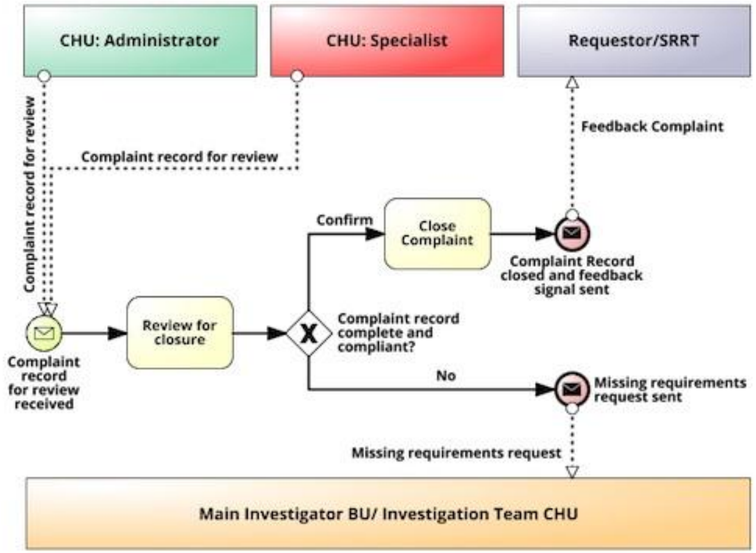
Type: CH3



CHU: Review Team → Review



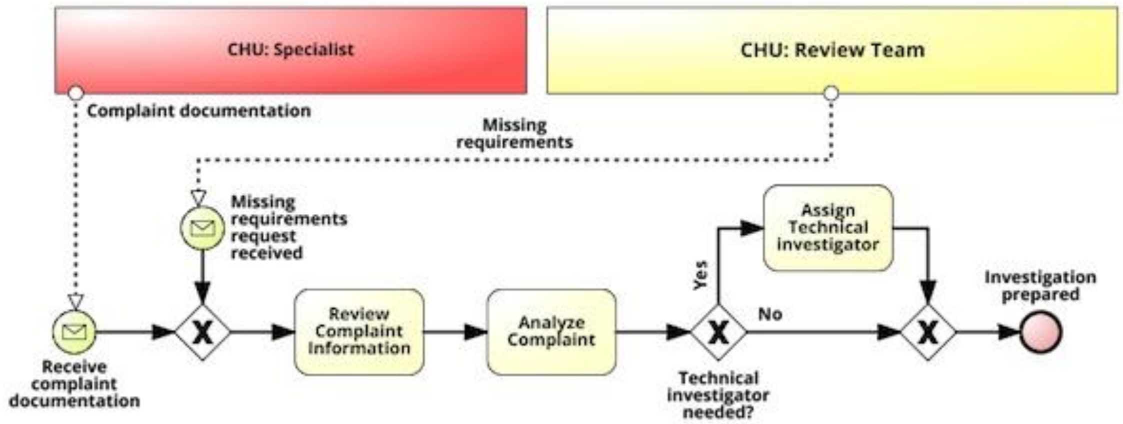
CHU: Review Team → Closure



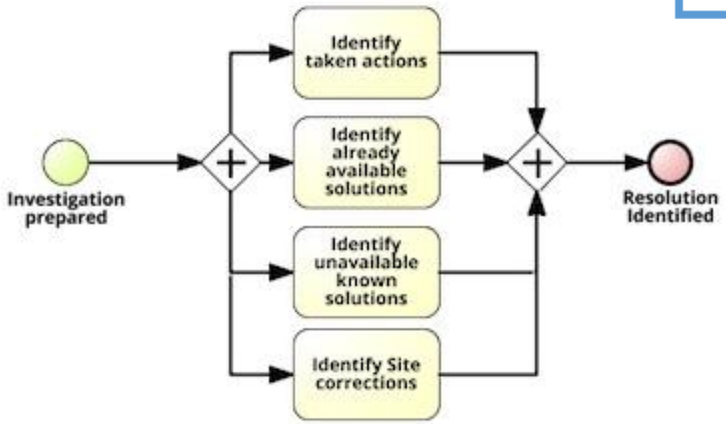
Sub-processes Complaint Handling (CH) Process (Type CH3)

Type: CH3

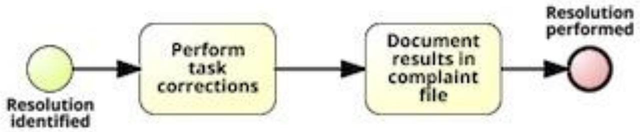
Main investigator BU/Investigation Team CHU → Prepare Investigation



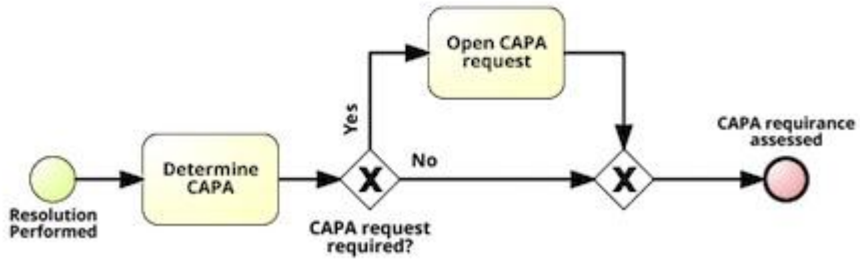
Main investigator BU/Investigation Team CHU → Identify Resolution



Main investigator BU/Investigation Team CHU → Perform Resolution



Main investigator BU/Investigation Team CHU → Assess CAPA requirance



Sub-processes Complaint Handling (CH) Process (Type CH3)

Appendix B: Modeling conventions

Table 9: Modelling conventions business process models (Dumas et al., 2013)

Modelling conventions for	Conventions
Task labelling	Use of verb-object style. The labels should match the own business language and concepts used in the process descriptions of the company.
Event labelling	Use of object-verb style in the past tense. The labels should match the own business language and concepts used in the process descriptions of the company.
Layout task labels	Within (fitted in) the rectangle symbol of a tasks.
Layout event labels	On the right, above or below of the event.
Layout and usage of tasks	Horizontally, from left to right
Layout and usage of events	Horizontally, from left to right
Layout and usage of lanes and pools	A pool will be used to distinct between roles. No lanes will be included in the process model. Message flows are the only flows that connect the pools (and therefore the roles) with each other.
Structuredness	Every split gate-way matches a respective join-gateway
Colour	▪ start events are green ▪ end events are red ▪ intermediate events are yellow (dark) ▪ tasks are yellow (light) ▪ gateways are white ▪ all the roles (presented in pools) are displayed in a different colour ▪ The division of sub-processes happens with a distinguishable colour compared to the colours assigned to the roles.
Tool Restrictions	Use of Signavio
Role Restrictions	A minimum and maximum of 5 roles. The process model should be modified accordingly, and roles have to be suppressed.
Advanced BPMN Restrictions: **Start events** **End event** **Intermediate events** **Gateways**	**The use of advanced BPMN is restricted by the use of a:** (1) Start message event (2) End message event (3) Terminate message event (4) Intermediate message event (5) Intermediate timer event (6) Event-based gateway

Appendix C: Questionnaire printed version experiment

Experiment on Business Process Model Representation

Dear Colleague,

Thank you for your participation in this study.

Your contribution is valuable for improving the quality of processes in Philips and for the research in the business process modeling field in general.

The questionnaire may take about 45mins - 1 hour to complete.

Please note that you will remain anonymous at all times and no individual results will be reported. The results of this questionnaire will NOT be linked to your identity for any reason.

In the invitation email, you have received a "usercode". This is to help ensure online security and reliability. You can enter this information in the fields below and click **'Next'**to start the questionnaire.

Usercode:

Next >>

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PART1. Personal Factors

How often do you encounter process models in practice?

- Never
- Less than once a month
- More than once a month
- Daily

When did you first work with process models in practice?

- Less than a month ago
- Less than a year ago
- Less than three years ago
- More than three years ago
- Never encountered a process model

How would you rate your level of knowledge on process modeling?

- Not knowledgeable about
- Somewhat knowledgeable about
- Knowledgeable about
- Very knowledgeable about

How would you rate your level of knowledge on the business process modeling notation BPMN 2.0?

- Not knowledgeable about
- Somewhat knowledgeable about
- Knowledgeable about
- Very knowledgeable about

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PART1. Personal Factors

How familiar are you in general with the Corrective Action & Preventive Action (CAPA) process in Philips?

- ○ Not at all familiar
- ○ Slightly familiar
- ○ Somewhat familiar
- ○ Moderately familiar
- ○ Extremely familiar

How familiar are you in general with the Complaint Handling (CH) process in Philips?

- ○ Not at all familiar
- ○ Slightly familiar
- ○ Somewhat familiar
- ○ Moderately familiar
- ○ Extremely familiar

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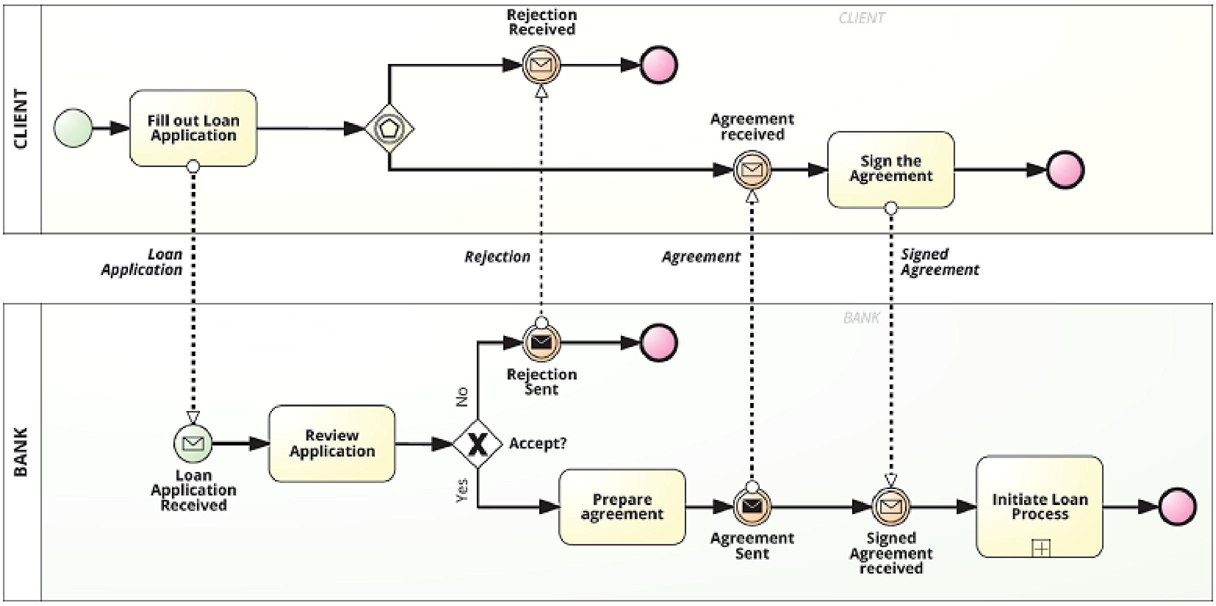
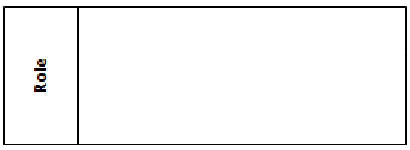
Example Model: Loan Application

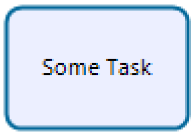
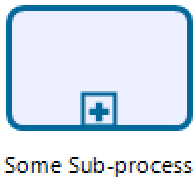
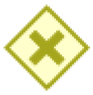
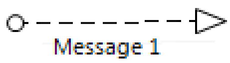


This process consists out of two roles: the "client" and the "bank". The process starts when the client needs a loan and fills out a loan application. When the client has done that, he or she will send the loan application to the bank. Subsequently, the bank receives the loan application and starts the internal process with a review of the application. The bank can either "accept" or "reject" the loan application. If the bank choses to reject the loan application, a message with a rejection is sent to the client. The process will end there. If the bank choses to accept the message, an agreement will be prepared and an agreement message is sent afterwards. The client receives the agreement and signs the agreement. The client sends the signed agreement back to the bank. The signed agreement is the trigger for the bank to start the sub-process "Initiate loan process". After the execution of this subprocess, the total processends.

Process Model Legend:

A process model is a picture of a process. It is very similar to a flowchart and can contain any of the following blocks:

Name	Description	Looks
Role	This long, black rectangle indicates a role within a process. All activities inside this role are considered his/her responsibilities.	

Activity	This blue square indicates some task is being performed. The description or activity of the task is mentioned on its label.	
Sub-Process	It's often useful to group some activities together and put them in a sub-process. This can be recognized by the '+' symbol on the blue square. To view the contents of a sub-process, you can simply place your cursor over the image.	
Sequence	This straight arrow indicates an order of event. The source of the arrow happened before the activity it points to can happen.	
Exclusive Choice	If, at some point, a choice is made, this yellow diamond with the 'X' is used. It means that either one of the outgoing arrows will be chosen. This element can also be used to merge paths. In that case, only one of the incomming arcs has to be active.	
Parallel activities	This element is used to indicate the following activities can happen at the same time. This allows for parallel activities. This element can also be used to merge paths. In that case, all incomming arcs have to be active.	
Exclusive event-based gateway	The proceeding of the process depends on the occurrence of an event that is triggered by one of the outcomes of exclusive choices. The event is delayed or excluded until a message is received.	
Sending information	If an activity results in sending information, this element is used. It means that a message is being sent.	
Receiving information	When someone receives information, this yellow circle is being used. The difference with the previous element is that with a receiving circle the 'envelope' is white rather than black.	
Timer event	This clock shows that there is a certain delay in the process. The label with the clock shows how often something happens or how long it takes before the process proceeds.	
Message Flow	When a message is sent from one role to another, a message flow is used. This is a dashed line with a label.	

While you're answering the questions about the model, you can go back to the process model legend at any time.
Please click **"Next"** to continue the questionnaire.

Next >>

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Part2. Questions about Process Models

In the **second part of the experiment**, you will be given nine multiple-choice questions for each of the two process models depicting activities that take place in Philips MRI.

Please take into account that **not** all the activities in these process models are in line with how the real-life process works, i.e. the way you are used to in Philips MRI. **Do not answer the questions based on your work experience, but always take a closer look at the process models.**

For each question, there will be 5 options to choose from. The last option will always be: "- *I don't know*". When this option is selected, the question will be considered as incorrectly answered.

It is rather important for this study to finish the rest of the questionnaire in one go. There is absolutely no problem with you taking your time to answer a question, but taking a coffee break might influence my results. Therefore, if you'd like to have a cup of coffee, this would be the perfect time to do so.

If you're ready, please click 'Next' to continue.

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Corrective & Preventive Action (CAPA) Process

When a problem/issue occurs with a product in use, the customer company may contact the customer service, which may eventually contact the headquarters if the problem/issue deemed major. If the problem is considered to have large impact for the business or the customer, the headquarter initiates the Corrective & Preventive Action (CAPA) process. When the decision to initiate is given, a requester for the CAPA is assigned on behalf of the customer. The requestor gathers all initial information and subsequently submits a CAPA request. A CAPA review board meets weekly to decide on CAPA requests and monitors progress of current CAPA's. Once a CAPA request is approved, a subject matter expert (SME) is appointed as a dedicated CAPA Owner. This CAPA Owner becomes responsible for performing the root cause analysis and developing actions to mitigate or remove the root cause. At certain control points, the CAPA Review Board provides a decision to either progress to the next phase of the CAPA or ask for rework. After sufficient evidence has been provided that a certain solution solved the root cause of the problem, the CAPA can be closed.

In the pages that follow, you will be asked questions about the process. For each question, you will be referred to the printed version of the process model(s) that were provided to you.

Please take a closer look at the process model(s) and click 'next' to continue when ready.

Next >>

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Click here for the legend.

***Q1*. If the rationale for not performing containment actions is reported in the *CAPA Request Form* for a case, then how many times the *Define containment actions* activity must have been executed for the same case?**

- Zero or more times
- Zero times and not more than that
- At most once
- At least once
- I don't know

Next >>

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Click here for the legend.

***Q2*. Who will know that the *CAPA Request* is accepted after a positive opinion of the *CAPA Review Board*?**

- Only CAPA Manager
- Only CAPA Owner
- Only Requester
- Both CAPA Manager and the Requester
- I don't know

Next >>

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Click here for the legend.

***Q3*. If the planned actions for the CAPA are executed, who will receive the *Execution Summary Report*?**

- Only CAPA Manager
- Only CAPA Review Board
- Either CAPA Manager or CAPA Review Board

- Both CAPA Manager and CAPA Review Board
- I don't know

Next >>

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Click here for the legend.

***Q4*. How does the *CAPA Owner* receive the *CAPA Review Board's 're-investigate'* message?**

- Through the Investigation Manager
- Through the CAPA Manager
- Directly from the CAPA Review Board
- CAPA Owner does not receive such a message
- I don't know

Next >>

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Click here for the legend.

***Q5*. Which messages are exchanged between the *CAPA Requester* and the *CAPA Owner*?**

- CAPA Request
- CAPA Final Report (& Manager's Summary)
- All of above
- None of above
- I don't know

Next >>

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***Q6*. After measuring the effectiveness of actions for a case, under what condition should the *CAPA Owner* _**NOT**_send the *CAPA Effectiveness Assessment Report* for evaluation?**

- When waiting time of N time unit is still not over.
- Only when there is no sufficient evidence collected (about the effectiveness or ineffectiveness of the actions).
- When there is no sufficient evidence collected (about the effectiveness or ineffectiveness of the actions) and the time period allocated for the effectiveness check is not over.
- Only when the time period allocated for the effectiveness check is not over.
- I don't know

Next >>

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***Q7*. Who execute(s) the final activity in the CAPA process for an accepted CAPA case?**

- Requester and CAPA Owner at the same time
- Requester
- CAPA Owner
- CAPA Manager
- I don't know

Next >>

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***Q8*. If the *CAPA Review Board* receives an *Investigation Report*, which was rejected by the board in the first time, how many times should this report have been pre-checked by the *Investigation Manager*?**

- Exactly Zero times
- Exactly Once
- Exactly Two times
- Two or more times
- I don't know

Next >>

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***Q9*. If the *CAPA Owner* is performing a root-cause investigation for a case, which of the following activities of the *CAPA Manager* must have been performed only once for the same case?**

- Sending ‘CAPA Request Rejected’ message
- Sending ‘Rework on CAPA Request’ message
- Sending CAPA Request Approved message
- None of above
- I don't know

Next >>

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--- End of Part 2 Process 1---

Please continue by clicking *'Next'*.

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In the previous part, you were given a process model that is modeled using a particular representation approach. This part of the questionnaire will ask your opinion about this representation approach.

For each of the following statements, please indicate to what extent you agree with them by clicking the circle that corresponds with your opinion.

	Strongly disagree	Moderately disagree	Somewhat disagree	Neutral	Somewhat agree	Moderately agree	Strongly agree
Business process models represented in this way would be difficult for users to understand.	○	○	○	○	○	○	○
I think this presentation approach provides an effective solution to the problem of representing business process models.	○	○	○	○	○	○	○
Using this type of process models would make it more difficult to communicate business processes to end-users.	○	○	○	○	○	○	○
Overall, I found the business process model in this experiment to be useful.	○	○	○	○	○	○	○

Please click the *next* button to continue.

Next >>

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For each of the following statements, please indicate to what extent you agree with them by clicking the circle that corresponds with your opinion.

	Strongly disagree	Moderately disagree	Somewhat disagree	Neutral	Somewhat agree	Moderately agree	Strongly agree
Learning to use this way of modeling business processes would be easy for me.	○	○	○	○	○	○	○
I found the way the process is represented as unclear and difficult to understand.	○	○	○	○	○	○	○
It would be easy for me to become skillful at using this way of modeling business processes.	○	○	○	○	○	○	○
Overall, I found this way of modeling business processes difficult to use.	○	○	○	○	○	○	○

Please click the *next* button to continue.

Next >>

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For each of the following statements, please indicate to what extent you agree with them by clicking the circle that corresponds with your opinion.

	Strongly disagree	Moderately disagree	Somewhat disagree	Neutral	Somewhat agree	Moderately agree	Strongly agree
I would definitely not use this method to model business processes.	○	○	○	○	○	○	○
I would intend to use this way of modeling business processes in preference to another modeling approach, if I have to work with business process models in the future.	○	○	○	○	○	○	○

Please click the *next* button to continue.

Next >>

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Complaint Handling (CH) Process

When a complaint arises with a product in use, the Complaint Handling Unit (CHU) will be notified. When all the needed information is complete, the assigned Complaint Handling Specialist will assess the risks that might be caused by the complaint. The Complaint Handling Specialist is also responsible for the Adverse Event Coordinator role. He or she assures that regulatory non-conformance issues and reporting, attributed to the complaint, are handled well. The Complaint Handling Review Team will monitor all the activities that have to be controlled in order to execute the Complaint Investigation in a comprehensive way. The investigation will be within the responsibility of the main investigator within the Business Unit (BU) where the complaint origins, or within the responsibility of the CHU. This depends on the technical domain knowledge accompanied to the resolution of the complaint. In the end, the complaint might need a root-cause analysis or has to evolve into a CAPA request before closure. Just as well, when the complaint has been handled without any further necessary action, the complaint can be filed and closed.

In the pages that follow, you will be asked questions about the process. For each question, you will be referred to the printed version of the process model(s) that were provided to you.

Please take a closer look at the process model(s) and click 'next' to continue when ready.

Next >>

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Click here for the legend.

***Q1*. If the Requestor/SRRT receives a *request for missing information*, how many times must the *CHU administrator* have sent a request for missing information?**

- Zero or more times
- Zero times and not more than that
- At most once
- At least once
- I don't know

Next >>

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Click here for the legend.

***Q2*. What happens to the submitted *service order* when it does not meet the definition of a complaint?**

- The CHU Administrator sends a request for missing information
- After documentation and informing the appropriate business entity, the process ends
- The complaint process terminates without further actions
- Hazardous situations have to be considered before the case can be closed
- I don't know

Next >>

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***Q3*. Who will be notified if the complaint concerns a product which is *not manufactured, nor distributed or serviced by MR with a serious death or injury* ?**

- Only the Requestor/SRRT of the complaint receives a message
- The Requestor/SRRT and the CHU Review Team
- The Requestor/SRRT of the complaint, the OEM manufcaturer, and the FDA
- The FDA, and the OEM manufacturer
- I don't know

Next >>

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***Q4*. How does the CHU Specialist receive the *complaint record* after the investigation team finishes the investigation?**

- Directly from the CHU Review Team
- Through the CHU Administrator
- Directly from the Investigation Team
- The CHU Specialist does not receive the complaint record
- I don't know

Next >>

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Click here for the legend.

***Q5*. Who is responsible for performing *"task corrections"* during the investigation of the complaint?**

- Main Investigator/Investigation Team
- CHU Specialist
- CHU Review Team
- None of the above
- I don't know

Next >>

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***Q6*. After the *CHU specialist* has completed the *OEM investigation*, what actions have to be completed before the complaint can be assigned to the *investigator*?**

- Only the *Risk Assessment* has to be approved before the assignment to an investigator can take place
- Only the *control of risks*, and the *risk/benefit analysis* have to be completed before the assigment to an investigator can take place

- Only the *Risk Assessment* and the *Adverse Event Reporting* have to be approved before the assignment to an investigator can take place
- Only the *review against Risk Management File (RMF)* has to be completed before the assgnment to an investigator can take place
- I don't know

Next >>

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Click here for the legend.

***Q7*. Which of the following messages is exchanged between the *Main Investator/Investigation Team* and the *CHU Administrator*?**

- The Risk Assessment
- The Complaint feedback
- Missing requerements request
- None of the above
- I don't know

Next >>

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Click here for the legend.

***Q8*. Who will know that the *Adverse Event Reporting* is approved by the CHU Review Team??**

- The CHU Specialist
- Main Investigator/ Investigation Team
- Both CHU Specialist and the Main Investigator/ Investigation Team
- None of the above
- I don't know

Next >>

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Click here for the legend.

***Q9*. If the Risk Assessment conducted by the CHU Specialist has been approved by the CHU Review Team, how often has the CHU Specialist performed a *Risk/Benefit Analysis*?**

- Zero or more times
- Zero times and not more than that
- At most once
- At least once
- I don't know

Next >>

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--- End of Part 2 Process 2---

Please continue by clicking '*Next*'.

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In the previous part, you were given a process model that is modeled using a particular representation approach. This part of the questionnaire will ask your opinion about this representation approach.

For each of the following statements, please indicate to what extent you agree with them by clicking the circle that corresponds with your opinion.

	Strongly disagree	Moderately disagree	Somewhat disagree	Neutral	Somewhat agree	Moderately agree	Strongly agree
Business process models represented in this way would be difficult for users to understand.	○	○	○	○	○	○	○
I think this presentation approach provides an effective solution to the problem of representing business process models.	○	○	○	○	○	○	○
Using this type of process models would make it more difficult to communicate business processes to end-users.	○	○	○	○	○	○	○
Overall, I found the business process model in this experiment to be useful.	○	○	○	○	○	○	○

Please click the *next* button to continue.

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For each of the following statements, please indicate to what extent you agree with them by clicking the circle that corresponds with your opinion.

	Strongly disagree	Moderately disagree	Somewhat disagree	Neutral	Somewhat agree	Moderately agree	Strongly agree
Learning to use this way of modeling business processes would be easy for me.	○	○	○	○	○	○	○
I found the way the process is represented as unclear and difficult to understand.	○	○	○	○	○	○	○
It would be easy for me to become skillful at using this way of modeling business processes.	○	○	○	○	○	○	○
Overall, I found this way of modeling business processes difficult to use.	○	○	○	○	○	○	○

Please click the *next* button to continue.

Next >>

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For each of the following statements, please indicate to what extent you agree with them by clicking the circle that corresponds with your opinion.

	Strongly disagree	Moderately disagree	Somewhat disagree	Neutral	Somewhat agree	Moderately agree	Strongly agree
I would definitely not use this method to model business processes.	○	○	○	○	○	○	○
I would intend to use this way of modeling business processes in preference to another modeling approach, if I have to work with business process models in the future.	○	○	○	○	○	○	○

Please click the *next* button to continue.

Next >>

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Thank you again for your patience and participation!

If you have any interest in the results of this study, you can indicate this by checking the box below. If you do so, you will receive an e-mail with the summarized results of the study. Please note that your e-mail adress will not be used for other purposes, nor will it be shared with third parties.

- Yes, please send me an e-mail with a summary of the results of this study.

Note also that you can contact Tessa Rompen "tessa.rompen@philips.com" for any feedback or any issue regarding the experiment. .

Please click **'Next'** to finalize the questionnaire.

Next >>

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You may now close the browser window.

Appendix D: Email invitation

Dear <<First Name>>,

As you might know already, my name is Tessa Rompen and I'm an Industrial Engineering student at the TU/e, in the final phase of my Master. I'm graduating at the Quality and Regulatory department of Philips MR, with Jan van Moll and Zouhair Bedawi as my supervisors.

I'm currently looking into the *"understandability" of process representations*. I developed an experiment, which aims to find out more about the understandability of these process representations. Some of your own MR QMS processes are used as subjects for the experiment. The results will be a valuable input to the future shaping of QMS's within PH and MR.

The experiment will take approximately 45 minutes - 1 hour. You can start the experiment by clicking on the following link or by copying the link in your browser.

Before you do this, you have to know that you're allocated to the *"paper"-group*. This means that you have to receive an envelope with paper representations of the process first. I will stop by later today, to hand over this envelope to you. Before you start with the experiment, please check **all** the models in the envelope, to make sure that you know which model(s) belong(s) to which process. *

www.bpmresearch.net

You will be asked to enter a usercode.
Your personal usercode is: <<Usercode>>

To make our experiment a success, your participation is crucial.
You will remain anonymous at all times and no individual results will be reported. The results of this questionnaire will NOT be linked to your identity for any reason.

Please be informed that PH privacy and security criteria have been adhered to for this experiment.

Many thanks in advance!
Best regards,

Tessa Rompen
tessa.rompen@philips.com

** This paragraph is excluded in the email invitation for the computer-blocks*

Appendix E: Final sample of completed experiment

Table 10: Final sample of the completed experiment divided in blocks

Block	Title	Department
1	Domain Expert	Clinical Excellence
	Program Manager Customer Service	Customer Services
	Chair Works Council	Global operations
	Operational Engineer/ Manager global operations	Industrial Operations Engineering
	Clinical Application Specialist	Quality & Regulatory
	QR-contingent worker	Quality & Regulatory
	Regulatory Affairs Engineer	Quality & Regulatory
	Senior Software Designer	Software & Platforms
	Group Leader Systems Engineering	Systems Engineering
	System Test Architect	Systems Engineering
2	Senior Test Engineer	Integration & Verification
	Groupleader	Software
	Training Coordinator	Operations General Factory Support
	Prodcut Security/Privacy Lead	Product and Service security
	Project Leader	Productivity
	Quality Assurance Engineer	Quality & Regulatory
	Quality Manager	Quality & Regulatory
	Sr Quality Engineer	Quality & Regulatory
	Quality Engineer	Quality & Regulatory
	Development Director	R&D
3	Quality Systems Engineer	Quality & Regulatory
	Project Manager	Order to Cash Improvement
	DTE Project Leader	PMO & Test Bays
	Integration Architect	Productivity
	Complaint Specialist	Quality & Regulatory
	Engineer Quality Assurance	Quality & Regulatory
	Quality Engineer	Quality & Regulatory
	Engineer Quality Assurance	Quality & Regulatory
	Systems Engineer	Systems Engineering
	Systems Engineer	Systems Engineering
4	DTE Engineer	PMO & Test Bays
	Project Manager	PMO & Test Bays
	Engineer Quality Assurance	Quality & Regulatory
	Complaint Specialist	Quality & Regulatory
	Prodcut Compliance Analyst	Quality & Regulatory
	Quality Engineer	Quality & Regulatory
	Regulatory Affairs Manager	Quality & Regulatory
	FCO Manager	Service Delivery Programs & Operations
	Maintenance Architect	Service Innovation
	Product Specialist	Service Innovation
	Software Configuration Manager	Software & Platforms
5	MR Clinical Validation Lead	Clinical Applications
	Program Manager	Program Management
	Director, Product Management	Product Management
	Regulatory Affairs Engineer	Quality & Regulatory
	Complaint Specialist	Quality & Regulatory
	Q&R Engineer - Complaint	Quality & Regulatory
	SE-contingent worker	Quality & Regulatory
	R&D Project Manager	R&D Program & PfRT team
	Software Designer	Software & Platforms
	Group Leader Integration & verification	Systems Engineering
6	Product Support Manager	Customer Services
	Group Leader Patient Handling & Infra	HW/Components
	Manager Analysing & Trending	Customer Services
	Senior Configuration Manager	Programs
	Complaint Specialist	Quality & Regulatory
	Q&R Manager	Quality & Regulatory
	Quality Engineer	Quality & Regulatory
	Senior Manager Regulatory	Quality & Regulatory
	CAPA Leader	Quality & Regulatory
	Supllier Quality Manager	Supplier Quality

Appendix F: Control variables (Stepwise Regression)

Table 11: Independent samples t-test

Group Statistics

	CAPA(0),CH(1)	N	Mean	Std. Deviation	Std. Error Mean
TOTAL_Correct	CAPA	60	5,42	1,522	,196
	CH	60	6,13	1,535	,198

Table 12: Model summary stepwise regression score

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,230[a]	,053	,045	1,528	
2	,312[b]	,097	,082	1,498	1,820

a. Predictors: (Constant), CAPA(0),CH(1)

b. Predictors: (Constant), CAPA(0),CH(1), GROUP=REPR3C

c. Dependent Variable: TOTAL_Correct

Table 13: Model summary stepwise regression time

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,239[a]	,057	,049	7,3362	
2	,314[b]	,099	,083	7,2032	2,424

a. Predictors: (Constant), CAPA(0),CH(1)

b. Predictors: (Constant), CAPA(0),CH(1), PExperience: When did you first work with process models in practice?

c. Dependent Variable: timeQ1_Q9

Table 14: Coefficients stepwise regression time

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	21,415	,947		22,611	,000		
	CAPA(0),CH(1)	-3,587	1,339	-,239	-2,678	,008	1,000	1,000
2	(Constant)	27,697	2,859		9,688	,000		
	CAPA(0),CH(1)	-3,587	1,315	-,239	-2,727	,007	1,000	1,000
	PExperience: When did you first work with process models in practice?	-1,698	,731	-,204	-2,324	,022	1,000	1,000

a. Dependent Variable: timeQ1_Q9

Table 15: Model summary stepwise regression PU

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,319[a]	,102	,094	1,47677	
2	,364[b]	,132	,118	1,45743	1,989

a. Predictors: (Constant), GROUP=REPR3C

b. Predictors: (Constant), GROUP=REPR3C, GROUP=REPR2C

c. Dependent Variable: PU

Table 16: Model summary stepwise regression PEOU

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,241[a]	,058	,050	1,44704	1,694

a. Predictors: (Constant), GROUP=REPR3C

b. Dependent Variable: PEOU

Table 17: Model summary stepwise regression ITU

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,232[a]	,054	,046	1,54307	2,002

a. Predictors: (Constant), GROUP=REPR3C

b. Dependent Variable: ITU

Table 18: Model summary stepwise regression ITU Question 1

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,288[a]	,083	,075	1,714	1,971

a. Predictors: (Constant), GROUP=REPR3C

b. Dependent Variable: ITU_Q1inverse: I would definitely not use this method to model business processes.

Appendix G: Assumptions check score and time

Table 19: Normality check for score and time

Tests of Normality

	GROUP	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
timeQ1_Q9	REPR1P	,163	20	,175	,945	20	,299
	REPR1C	,136	19	,200*	,957	19	,519
	REPR2P	,090	21	,200*	,982	21	,950
	REPR2C	,192	20	,052	,890	20	,027
	REPR3P	,181	21	,070	,917	21	,074
	REPR3C	,193	19	,061	,895	19	,040
TOTAL_Correct	REPR1P	,290	20	,000	,882	20	,019
	REPR1C	,196	19	,054	,923	19	,131
	REPR2P	,192	21	,043	,947	21	,304
	REPR2C	,238	20	,004	,916	20	,085
	REPR3P	,167	21	,129	,940	21	,218
	REPR3C	,237	19	,006	,889	19	,031

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 20: Homogeneity check for score and time

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
timeQ1_Q9	1,826	5	114	,113
TOTAL_Correct	,182	5	114	,969

Appendix H: Assumptions check PU, PEOU and ITU

Table 21: Normality check PU, PEOU and ITU

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PU	,087	120	,027	,960	120	,001
PEOU	,135	120	,000	,924	120	,000
ITU	,110	120	,001	,941	120	,000

a. Lilliefors Significance Correction

Table 22: Homogeneity check PU, PEOU and ITU

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
PU	,760	5	114	,581
PEOU	2,530	5	114	,033
ITU	,351	5	114	,881

Appendix I: the influence of the representation type

Appendix I1: ANOVA score and time

Test of Homogeneity of Variances

PaperComputer		Levene Statistic	df1	df2	Sig.
Computer	TOTAL_Correct	,201	2	55	,819
	timeQ1_Q9	1,532	2	55	,225
	Score_DIV_Time	3,041	2	55	,056
Paper	TOTAL_Correct	,209	2	59	,812
	timeQ1_Q9	2,583	2	59	,084
	Score_DIV_Time	,518	2	59	,598

ANOVA

PaperComputer			Sum of Squares	df	Mean Square	F	Sig.
Computer	TOTAL_Correct	Between Groups	10,024	2	5,012	1,995	,146
		Within Groups	138,200	55	2,513		
		Total	148,224	57			
	timeQ1_Q9	Between Groups	3,146	2	1,573	,025	,976
		Within Groups	3509,628	55	63,811		
		Total	3512,774	57			
	Score_DIV_Time	Between Groups	,058	2	,029	1,131	,330
		Within Groups	1,413	55	,026		
		Total	1,471	57			
Paper	TOTAL_Correct	Between Groups	8,338	2	4,169	1,898	,159
		Within Groups	129,598	59	2,197		
		Total	137,935	61			
	timeQ1_Q9	Between Groups	35,153	2	17,577	,330	,721
		Within Groups	3146,381	59	53,328		
		Total	3181,534	61			
	Score_DIV_Time	Between Groups	,024	2	,012	,323	,725
		Within Groups	2,225	59	,038		
		Total	2,250	61			

Appendix I2: Kruskal-wallis PU, PEOU and ITU

Descriptive Statistics

PaperComputer	Representation		N	Minimum	Maximum	Mean	Std. Deviation
Computer	1	PU	19	1,00	6,50	4,6184	1,45623
		PEOU	19	1,50	7,00	5,3026	1,57802
		ITU_r1inverse	19	1	7	5,32	1,734
		Valid N (listwise)	19				
	2	PU	20	1,00	6,50	4,1750	1,70352
		PEOU	20	1,50	6,75	5,0250	1,38103
		ITU_r1inverse	20	1	7	4,65	1,872
		Valid N (listwise)	20				
	3	PU	19	1,00	6,25	3,4211	1,50705
		PEOU	19	1,75	6,50	4,3289	1,39207
		ITU_r1inverse	19	1	7	3,79	1,813
		Valid N (listwise)	19				
Paper	1	PU	20	3,25	7,00	5,6875	1,14672
		PEOU	20	5,00	7,00	6,2500	,62828
		ITU_r1inverse	20	1	7	5,70	1,455
		Valid N (listwise)	20				
	2	PU	21	2,50	7,00	4,9405	1,20909
		PEOU	21	1,00	7,00	5,0238	1,44893
		ITU_r1inverse	21	1	7	5,24	1,700
		Valid N (listwise)	21				
	3	PU	21	1,00	7,00	4,4286	1,44080
		PEOU	21	1,50	7,00	4,9524	1,70224
		ITU_r1inverse	21	1	7	5,05	1,687
		Valid N (listwise)	21				

Computer

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of PU is the same across categories of Representation.	Independent-Samples Kruskal-Wallis Test	,053	Retain the null hypothesis.
2	The distribution of PEOU is the same across categories of Representation.	Independent-Samples Kruskal-Wallis Test	,078	Retain the null hypothesis.
3	The distribution of ITU_r1inverse is the same across categories of Representation.	Independent-Samples Kruskal-Wallis Test	,023	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Total N	58
Test Statistic	7,504
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	,023

1. The test statistic is adjusted for ties.

Each node shows the sample average rank of Representation.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
3,000-2,000	7,979	5,318	1,500	,134	,401
3,000-1,000	14,737	5,386	2,736	,006	,019
2,000-1,000	6,758	5,318	1,271	,204	,611

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is ,05.

Paper

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of PU is the same across categories of Representation.	Independent-Samples Kruskal-Wallis Test	,012	Reject the null hypothesis.
2	The distribution of PEOU is the same across categories of Representation.	Independent-Samples Kruskal-Wallis Test	,005	Reject the null hypothesis.
3	The distribution of ITU_r1inverse is the same across categories of Representation.	Independent-Samples Kruskal-Wallis Test	,360	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Total N	62
Test Statistic	8,814
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	,012

1. The test statistic is adjusted for ties.

Total N	62
Test Statistic	10,581
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	,005

1. The test statistic is adjusted for ties.

Each node shows the sample average rank of Representation.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
3,000-2,000	6,119	5,551	1,102	,270	,811
3,000-1,000	16,530	5,620	2,941	,003	,010
2,000-1,000	10,411	5,620	1,853	,064	,192

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is ,05.

Each node shows the sample average rank of Representation.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
2,000-3,000	-1,452	5,547	-,262	,793	1,000
2,000-1,000	16,558	5,616	2,949	,003	,010
3,000-1,000	15,106	5,616	2,690	,007	,021

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is ,05.

Appendix J: The influence of the presentation medium

Appendix J1: score and time

Test of Homogeneity of Variances

Representation		Levene Statistic	df1	df2	Sig.
1	TOTAL_Correct	,391	1	37	,535
	timeQ1_Q9	,194	1	37	,662
	Score_DIV_Time	,471	1	37	,497
2	TOTAL_Correct	,313	1	39	,579
	timeQ1_Q9	7,482	1	39	,009
	Score_DIV_Time	1,953	1	39	,170
3	TOTAL_Correct	,212	1	38	,648
	timeQ1_Q9	,248	1	38	,622
	Score_DIV_Time	4,639	1	38	,038

ANOVA

Representation			Sum of Squares	df	Mean Square	F	Sig.
1	TOTAL_Correct	Between Groups	1,194	1	1,194	,522	,474
		Within Groups	84,550	37	2,285		
		Total	85,744	38			
	timeQ1_Q9	Between Groups	2,423	1	2,423	,051	,823
		Within Groups	1772,834	37	47,914		
		Total	1775,257	38			
	Score_DIV_Time	Between Groups	,028	1	,028	,755	,391
		Within Groups	1,378	37	,037		
		Total	1,406	38			
2	TOTAL_Correct	Between Groups	1,600	1	1,600	,693	,410
		Within Groups	90,010	39	2,308		
		Total	91,610	40			
	timeQ1_Q9	Between Groups	15,480	1	15,480	,276	,603
		Within Groups	2189,891	39	56,151		
		Total	2205,371	40			
	Score_DIV_Time	Between Groups	,001	1	,001	,021	,886
		Within Groups	1,196	39	,031		
		Total	1,197	40			
3	TOTAL_Correct	Between Groups	2,262	1	2,262	,922	,343
		Within Groups	93,238	38	2,454		
		Total	95,500	39			
	timeQ1_Q9	Between Groups	32,032	1	32,032	,452	,505
		Within Groups	2693,283	38	70,876		
		Total	2725,315	39			
	Score_DIV_Time	Between Groups	,119	1	,119	4,268	,046
		Within Groups	1,063	38	,028		
		Total	1,183	39			

Appendix J2: PU, PEOU and ITU

Descriptive Statistics

Representation	PaperComputer		N	Minimum	Maximum	Mean	Std. Deviation
1	Computer	PU	19	1,00	6,50	4,6184	1,45623
		PEOU	19	1,50	7,00	5,3026	1,57802
		ITU_r1inverse	19	1	7	5,32	1,734
		Valid N (listwise)	19				
	Paper	PU	20	3,25	7,00	5,6875	1,14672
		PEOU	20	5,00	7,00	6,2500	,62828
		ITU_r1inverse	20	1	7	5,70	1,455
		Valid N (listwise)	20				
2	Computer	PU	20	1,00	6,50	4,1750	1,70352
		PEOU	20	1,50	6,75	5,0250	1,38103
		ITU_r1inverse	20	1	7	4,65	1,872
		Valid N (listwise)	20				
	Paper	PU	21	2,50	7,00	4,9405	1,20909
		PEOU	21	1,00	7,00	5,0238	1,44893
		ITU_r1inverse	21	1	7	5,24	1,700
		Valid N (listwise)	21				
3	Computer	PU	19	1,00	6,25	3,4211	1,50705
		PEOU	19	1,75	6,50	4,3289	1,39207
		ITU_r1inverse	19	1	7	3,79	1,813
		Valid N (listwise)	19				
	Paper	PU	21	1,00	7,00	4,4286	1,44080
		PEOU	21	1,50	7,00	4,9524	1,70224
		ITU_r1inverse	21	1	7	5,05	1,687
		Valid N (listwise)	21				

Representation 1

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of PU is the same across categories of PaperComputer.	Independent-Samples Kruskal-Wallis Test	,017	Reject the null hypothesis.
2	The distribution of PEOU is the same across categories of PaperComputer.	Independent-Samples Kruskal-Wallis Test	,066	Retain the null hypothesis.
3	The distribution of ITU_r1inverse is the same across categories of PaperComputer.	Independent-Samples Kruskal-Wallis Test	,534	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Total N	39
Test Statistic	5,746
Degrees of Freedom	1
Asymptotic Sig. (2-sided test)	,017

1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because there are less than three test fields.

Representation 2

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of PU is the same across categories of PaperComputer.	Independent-Samples Kruskal-Wallis Test	,178	Retain the null hypothesis.
2	The distribution of PEOU is the same across categories of PaperComputer.	Independent-Samples Kruskal-Wallis Test	,937	Retain the null hypothesis.
3	The distribution of ITU_r1inverse is the same across categories of PaperComputer.	Independent-Samples Kruskal-Wallis Test	,293	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Representation 3

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of PU is the same across categories of PaperComputer.	Independent-Samples Kruskal-Wallis Test	,029	Reject the null hypothesis.
2	The distribution of PEOU is the same across categories of PaperComputer.	Independent-Samples Kruskal-Wallis Test	,158	Retain the null hypothesis.
3	The distribution of ITU_r1inverse is the same across categories of PaperComputer.	Independent-Samples Kruskal-Wallis Test	,025	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Total N	40
Test Statistic	4,783
Degrees of Freedom	1
Asymptotic Sig. (2-sided test)	,029

1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because there are less than three test fields.

Total N	40
Test Statistic	5,051
Degrees of Freedom	1
Asymptotic Sig. (2-sided test)	,025

1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because there are less than three test fields.

Appendix K: The combined influence of the representation type and presentation medium (ANOVA) on score, time and score/time

Table 23: ANOVA score

ANOVA

TOTAL_Correct

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	23,127	5	4,625	1,969	,089
Within Groups	267,798	114	2,349		
Total	290,925	119			

Table 24: Tukey's post-hoc test score

Multiple Comparisons

Dependent Variable: TOTAL_Correct

Tukey HSD

(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
REPR1P	REPR1C	,350	,491	,980	-1,07	1,77
	REPR2P	,255	,479	,995	-1,13	1,64
	REPR2C	,650	,485	,761	-,75	2,05
	REPR3P	,874	,479	,454	-,51	2,26
	REPR3C	1,350	,491	,074	-,07	2,77
REPR1C	REPR1P	-,350	,491	,980	-1,77	1,07
	REPR2P	-,095	,485	1,000	-1,50	1,31
	REPR2C	,300	,491	,990	-1,12	1,72
	REPR3P	,524	,485	,889	-,88	1,93
	REPR3C	1,000	,497	,343	-,44	2,44
REPR2P	REPR1P	-,255	,479	,995	-1,64	1,13
	REPR1C	,095	,485	1,000	-1,31	1,50
	REPR2C	,395	,479	,962	-,99	1,78
	REPR3P	,619	,473	,780	-,75	1,99
	REPR3C	1,095	,485	,221	-,31	2,50
REPR2C	REPR1P	-,650	,485	,761	-2,05	,75
	REPR1C	-,300	,491	,990	-1,72	1,12
	REPR2P	-,395	,479	,962	-1,78	,99
	REPR3P	,224	,479	,997	-1,16	1,61
	REPR3C	,700	,491	,711	-,72	2,12
REPR3P	REPR1P	-,874	,479	,454	-2,26	,51
	REPR1C	-,524	,485	,889	-1,93	,88
	REPR2P	-,619	,473	,780	-1,99	,75
	REPR2C	-,224	,479	,997	-1,61	1,16
	REPR3C	,476	,485	,923	-,93	1,88
REPR3C	REPR1P	-1,350	,491	,074	-2,77	,07
	REPR1C	-1,000	,497	,343	-2,44	,44
	REPR2P	-1,095	,485	,221	-2,50	,31
	REPR2C	-,700	,491	,711	-2,12	,72
	REPR3P	-,476	,485	,923	-1,88	,93

Table 25: ANOVA CAPA and CH score

ANOVA

TOTAL_Correct

CAPA(0),CH(1)		Sum of Squares	df	Mean Square	F	Sig.
CAPA	Between Groups	20,528	5	4,106	1,910	,108
	Within Groups	116,056	54	2,149		
	Total	136,583	59			
CH	Between Groups	30,824	5	6,165	3,079	,016
	Within Groups	108,109	54	2,002		
	Total	138,933	59			

Table 26: Bonferroni posth oc test CH score

Multiple Comparisons[a]

Dependent Variable: TOTAL_Correct
Bonferroni

(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
REPR1P	REPR1C	-,600	,633	1,000	-2,54	1,34
	REPR2P	-1,200	,633	,949	-3,14	,74
	REPR2C	,400	,633	1,000	-1,54	2,34
	REPR3P	,191	,618	1,000	-1,71	2,09
	REPR3C	1,100	,650	1,000	-,90	3,10
REPR1C	REPR1P	,600	,633	1,000	-1,34	2,54
	REPR2P	-,600	,633	1,000	-2,54	1,34
	REPR2C	1,000	,633	1,000	-,94	2,94
	REPR3P	,791	,618	1,000	-1,11	2,69
	REPR3C	1,700	,650	,173	-,30	3,70
REPR2P	REPR1P	1,200	,633	,949	-,74	3,14
	REPR1C	,600	,633	1,000	-1,34	2,54
	REPR2C	1,600	,633	,216	-,34	3,54
	REPR3P	1,391	,618	,428	-,51	3,29
	REPR3C	2,300*	,650	,013	,30	4,30
REPR2C	REPR1P	-,400	,633	1,000	-2,34	1,54
	REPR1C	-1,000	,633	1,000	-2,94	,94
	REPR2P	-1,600	,633	,216	-3,54	,34
	REPR3P	-,209	,618	1,000	-2,11	1,69
	REPR3C	,700	,650	1,000	-1,30	2,70
REPR3P	REPR1P	-,191	,618	1,000	-2,09	1,71
	REPR1C	-,791	,618	1,000	-2,69	1,11
	REPR2P	-1,391	,618	,428	-3,29	,51
	REPR2C	,209	,618	1,000	-1,69	2,11
	REPR3C	,909	,636	1,000	-1,04	2,86
REPR3C	REPR1P	-1,100	,650	1,000	-3,10	,90
	REPR1C	-1,700	,650	,173	-3,70	,30
	REPR2P	-2,300*	,650	,013	-4,30	-,30
	REPR2C	-,700	,650	1,000	-2,70	1,30
	REPR3P	-,909	,636	1,000	-2,86	1,04

*. The mean difference is significant at the 0.05 level.

a. CAPA(0),CH(1) = CH

Table 27: ANOVA time

ANOVA

timeQ1_Q9

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	80,695	5	16,139	,276	,925
Within Groups	6656,009	114	58,386		
Total	6736,704	119			

Table 28: ANOVA score/time

ANOVA

Score_DIV_Time

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	,160	5	,032	1,005	,418
Within Groups	3,638	114	,032		
Total	3,798	119			

Appendix L: Kruskal-Wallis tests

Appendix L1. Perceived Usefulness

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of PU_Q1inverse: Business process models represented in this way would be difficult for users to understand. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,028	Reject the null hypothesis.
2	The distribution of PU_Q2: I think this presentation approach provides an effective solution to the problem of representing business process models. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,001	Reject the null hypothesis.
3	The distribution of PU_Q3inverse: Using this type of process models would make it more difficult to communicate business processes to end-users. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,021	Reject the null hypothesis.
4	The distribution of PU_Q4: Overall, I found the business process model in this experiment to be useful. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,000	Reject the null hypothesis.
5	The distribution of PU is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Total N	120
Test Statistic	23,291
Degrees of Freedom	5
Asymptotic Sig. (2-sided test)	,000

1. The test statistic is adjusted for ties.

Each node shows the sample average rank of GROUP.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
REPR3C-REPR2C	17,904	11,123	1,610	,107	1,000
REPR3C-REPR3P	20,912	10,993	1,902	,057	,857
REPR3C-REPR1C	26,816	11,265	2,381	,017	,259
REPR3C-REPR2P	32,412	10,993	2,948	,003	,048
REPR3C-REPR1P	51,104	11,123	4,594	,000	,000
REPR2C-REPR3P	-3,008	10,848	-,277	,782	1,000
REPR2C-REPR1C	8,912	11,123	,801	,423	1,000
REPR2C-REPR2P	14,508	10,848	1,337	,181	1,000
REPR2C-REPR1P	33,200	10,979	3,024	,002	,037
REPR3P-REPR1C	5,904	10,993	,537	,591	1,000
REPR3P-REPR2P	11,500	10,715	1,073	,283	1,000
REPR3P-REPR1P	30,192	10,848	2,783	,005	,081
REPR1C-REPR2P	-5,596	10,993	-,509	,611	1,000
REPR1C-REPR1P	24,288	11,123	2,184	,029	,435
REPR2P-REPR1P	18,692	10,848	1,723	,085	1,000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is ,05.

Appendix L2. PEOU

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of PEOU_Q1: Learning to use this way of modeling business processes would be easy for me. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,004	Reject the null hypothesis.
2	The distribution of PEOU_Q2inverse: I found the way the process is represented as unclear and difficult to understand. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,005	Reject the null hypothesis.
3	The distribution of PEOU_Q3: It would be easy for me to become skillful at using this way of modeling business processes. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,010	Reject the null hypothesis.
4	The distribution of PEOU_Q4inverse: Overall, I found this way of modeling business processes difficult to use. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,001	Reject the null hypothesis.
5	The distribution of PEOU is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,001	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Total N	120
Test Statistic	20,160
Degrees of Freedom	5
Asymptotic Sig. (2-sided test)	,001

1. The test statistic is adjusted for ties.

Each node shows the sample average rank of GROUP.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
REPR3C-REPR2C	15,345	11,113	1,381	,167	1,000
REPR3C-REPR2P	16,133	10,983	1,469	,142	1,000
REPR3C-REPR3P	17,514	10,983	1,595	,111	1,000
REPR3C-REPR1C	25,342	11,254	2,252	,024	,365
REPR3C-REPR1P	47,620	11,113	4,285	,000	,000
REPR2C-REPR2P	,788	10,838	,073	,942	1,000
REPR2C-REPR3P	-2,169	10,838	-,200	,841	1,000
REPR2C-REPR1C	9,997	11,113	,900	,368	1,000
REPR2C-REPR1P	32,275	10,969	2,942	,003	,049
REPR2P-REPR3P	-1,381	10,705	-,129	,897	1,000
REPR2P-REPR1C	9,209	10,983	,838	,402	1,000
REPR2P-REPR1P	31,487	10,838	2,905	,004	,055
REPR3P-REPR1C	7,828	10,983	,713	,476	1,000
REPR3P-REPR1P	30,106	10,838	2,778	,005	,082
REPR1C-REPR1P	22,278	11,113	2,005	,045	,675

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is ,05.

Appendix L3. PEOU CAPA

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of PEOU_Q1: Learning to use this way of modeling business processes would be easy for me. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,001	Reject the null hypothesis.
2	The distribution of PEOU_Q2inverse: I found the way the process is represented as unclear and difficult to understand. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,004	Reject the null hypothesis.
3	The distribution of PEOU_Q3: It would be easy for me to become skillful at using this way of modeling business processes. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,002	Reject the null hypothesis.
4	The distribution of PEOU_Q4inverse: Overall, I found this way of modeling business processes difficult to use. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,003	Reject the null hypothesis.
5	The distribution of PEOU is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Total N	60
Test Statistic	22,610
Degrees of Freedom	5
Asymptotic Sig. (2-sided test)	,000

1. The test statistic is adjusted for ties.

Each node shows the sample average rank of GROUP.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
REPR2P-REPR3C	-1,223	7,608	-,161	,872	1,000
REPR2P-REPR1C	12,217	7,826	1,561	,118	1,000
REPR2P-REPR2C	-15,323	7,608	-2,014	,044	,660
REPR2P-REPR1P	23,323	7,608	3,066	,002	,033
REPR2P-REPR3P	-28,773	7,608	-3,782	,000	,002
REPR3C-REPR1C	10,994	8,000	1,374	,169	1,000
REPR3C-REPR2C	14,100	7,787	1,811	,070	1,000
REPR3C-REPR1P	22,100	7,787	2,838	,005	,068
REPR3C-REPR3P	27,550	7,787	3,538	,000	,006
REPR1C-REPR2C	-3,106	8,000	-,388	,698	1,000
REPR1C-REPR1P	11,106	8,000	1,388	,165	1,000
REPR1C-REPR3P	-16,556	8,000	-2,069	,039	,578
REPR2C-REPR1P	8,000	7,787	1,027	,304	1,000
REPR2C-REPR3P	-13,450	7,787	-1,727	,084	1,000
REPR1P-REPR3P	-5,450	7,787	-,700	,484	1,000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is ,05.

Appendix L4. PEOU CH

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of PEOU_Q1: Learning to use this way of modeling business processes would be easy for me. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,000	Reject the null hypothesis.
2	The distribution of PEOU_Q2inverse: I found the way the process is represented as unclear and difficult to understand. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,001	Reject the null hypothesis.
3	The distribution of PEOU_Q3: It would be easy for me to become skillful at using this way of modeling business processes. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,000	Reject the null hypothesis.
4	The distribution of PEOU_Q4inverse: Overall, I found this way of modeling business processes difficult to use. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,000	Reject the null hypothesis.
5	The distribution of PEOU is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Total N	60
Test Statistic	28,321
Degrees of Freedom	5
Asymptotic Sig. (2-sided test)	,000

1. The test statistic is adjusted for ties.

Each node shows the sample average rank of GROUP.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
REPR3P-REPR3C	-8,980	7,827	-1,147	,251	1,000
REPR3P-REPR2C	9,891	7,608	1,300	,194	1,000
REPR3P-REPR1C	22,941	7,608	3,015	,003	,039
REPR3P-REPR2P	28,041	7,608	3,686	,000	,003
REPR3P-REPR1P	33,591	7,608	4,415	,000	,000
REPR3C-REPR2C	,911	8,001	,114	,909	1,000
REPR3C-REPR1C	13,961	8,001	1,745	,081	1,000
REPR3C-REPR2P	19,061	8,001	2,382	,017	,258
REPR3C-REPR1P	24,611	8,001	3,076	,002	,031
REPR2C-REPR1C	13,050	7,787	1,676	,094	1,000
REPR2C-REPR2P	18,150	7,787	2,331	,020	,297
REPR2C-REPR1P	23,700	7,787	3,043	,002	,035
REPR1C-REPR2P	-5,100	7,787	-,655	,513	1,000
REPR1C-REPR1P	10,650	7,787	1,368	,171	1,000
REPR2P-REPR1P	5,550	7,787	,713	,476	1,000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is ,05.

Appendix L5. Intention to Use

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of ITU_Q1inverse: I would definitely not use this method to model business processes. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,013	Reject the null hypothesis.
2	The distribution of ITU_Q2: I would intend to use this way of modeling business processes in preference to another modeling approach, if I have to work with business process models in the future. is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,736	Retain the null hypothesis.
3	The distribution of ITU is the same across categories of GROUP.	Independent-Samples Kruskal-Wallis Test	,110	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Total N	120
Test Statistic	14,471
Degrees of Freedom	5
Asymptotic Sig. (2-sided test)	,013

1. The test statistic is adjusted for ties.

Each node shows the sample average rank of GROUP.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
REPR3C-REPR2C	16,413	10,906	1,505	,132	1,000
REPR3C-REPR3P	23,073	10,779	2,141	,032	,485
REPR3C-REPR2P	27,930	10,779	2,591	,010	,143
REPR3C-REPR1C	30,526	11,045	2,764	,006	,086
REPR3C-REPR1P	37,613	10,906	3,449	,001	,008
REPR2C-REPR3P	-6,660	10,636	-,626	,531	1,000
REPR2C-REPR2P	11,517	10,636	1,083	,279	1,000
REPR2C-REPR1C	14,113	10,906	1,294	,196	1,000
REPR2C-REPR1P	21,200	10,765	1,969	,049	,734
REPR3P-REPR2P	4,857	10,506	,462	,644	1,000
REPR3P-REPR1C	7,454	10,779	,692	,489	1,000
REPR3P-REPR1P	14,540	10,636	1,367	,172	1,000
REPR2P-REPR1C	2,596	10,779	,241	,810	1,000
REPR2P-REPR1P	9,683	10,636	,910	,363	1,000
REPR1C-REPR1P	7,087	10,906	,650	,516	1,000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is ,05.

Appendix M: Split off difference CAPA and CH for PU, PEOU and ITU

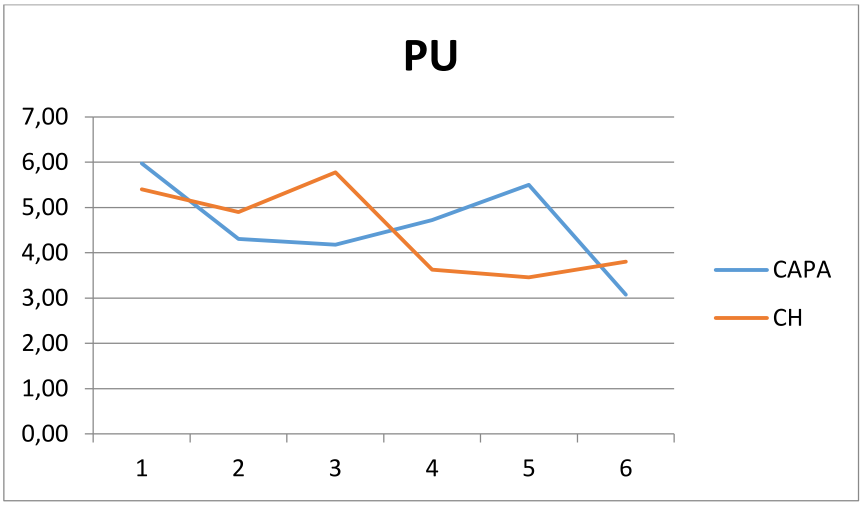


Figure 21: Average Perceived Usefulness

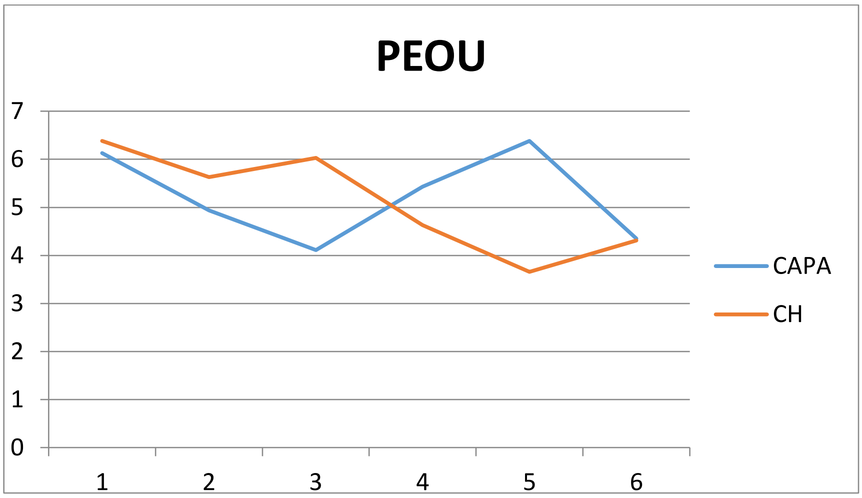


Figure 22: Average Perceived Ease of Use

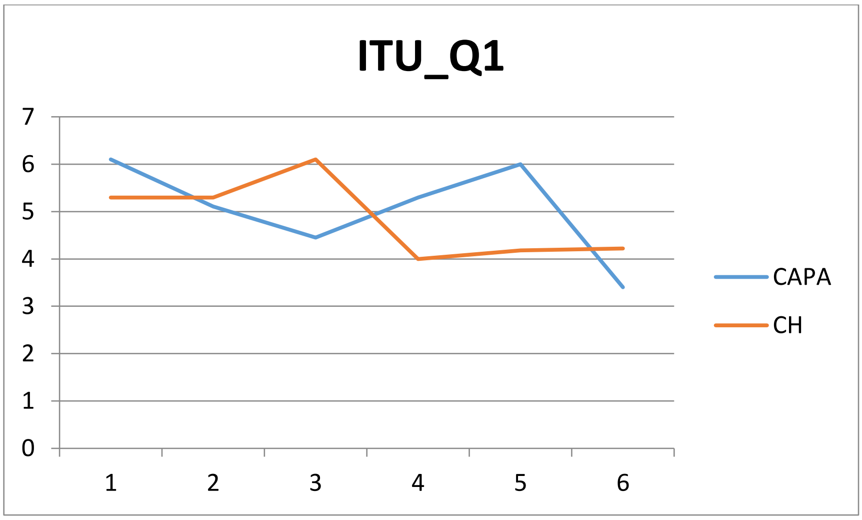


Figure 23: Average Intention to Use Question 1

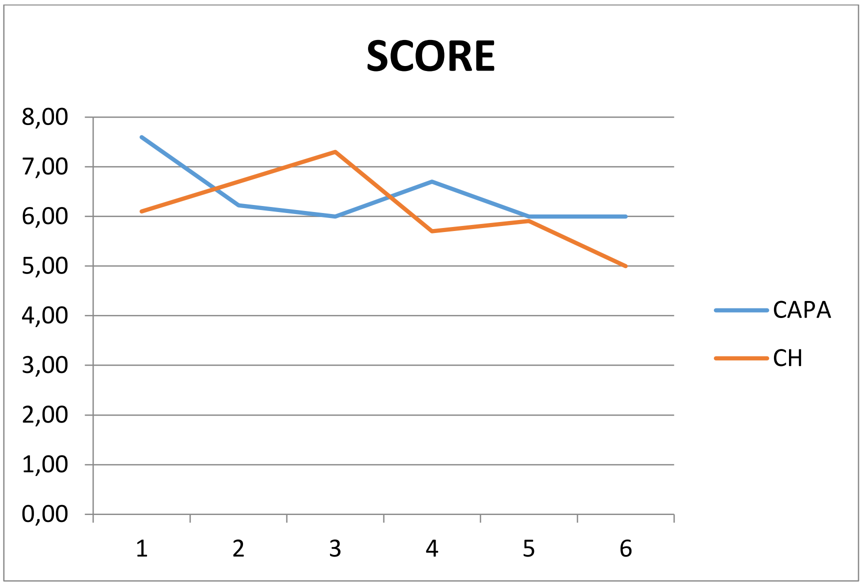


Figure 24: Average Score

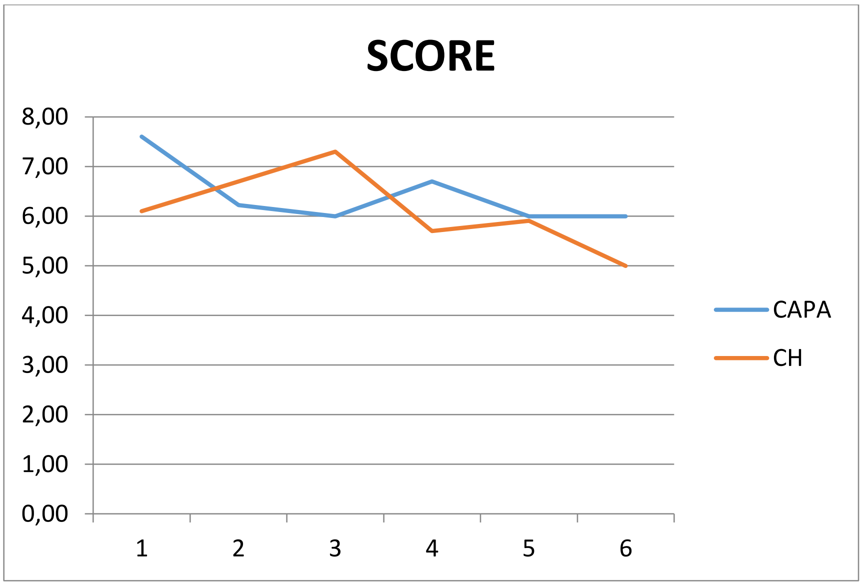


*Figure 25: Average Score (correction of +1 for the CAPA process)**

** In order to have a better visual inspection, it is convenient to correct the score for CAPA with +1 to cover up for the first question of the CAPA process which was answered incorrectly by almost all participants.*

Appendix N: The influence of the representation on Local and Global questions

Appendix N1: one-way repeated-measures ANOVA dependent variable: score

Within-Subjects Factors

Measure: MEASURE_1

Correct	Dependent Variable
1	Local_Correct
2	Global_Correct
3	GLLO_Correct

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

						Epsilon[b]		
GROUP	Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
REPR1P	Correct	,780	4,462	2	,107	,820	,887	,500
REPR1C	Correct	,946	,942	2	,624	,949	1,000	,500
REPR2P	Correct	,724	6,134	2	,047	,784	,839	,500
REPR2C	Correct	,781	4,445	2	,108	,820	,888	,500
REPR3P	Correct	,960	,771	2	,680	,962	1,000	,500
REPR3C	Correct	,972	,485	2	,785	,973	1,000	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: Correct

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

GROUP	Source		Type III Sum of Squares	df	Mean Square	F	Sig.
REPR1P	Correct	Sphericity Assumed	5,733	2	2,867	4,616	,016
		Greenhouse-Geisser	5,733	1,640	3,496	4,616	,023
		Huynh-Feldt	5,733	1,774	3,232	4,616	,020
		Lower-bound	5,733	1,000	5,733	4,616	,045
	Error(Correct)	Sphericity Assumed	23,600	38	,621		
		Greenhouse-Geisser	23,600	31,158	,757		
		Huynh-Feldt	23,600	33,708	,700		
		Lower-bound	23,600	19,000	1,242		
REPR1C	Correct	Sphericity Assumed	11,474	2	5,737	18,451	,000
		Greenhouse-Geisser	11,474	1,898	6,046	18,451	,000
		Huynh-Feldt	11,474	2,000	5,737	18,451	,000
		Lower-bound	11,474	1,000	11,474	18,451	,000
	Error(Correct)	Sphericity Assumed	11,193	36	,311		
		Greenhouse-Geisser	11,193	34,158	,328		
		Huynh-Feldt	11,193	36,000	,311		
		Lower-bound	11,193	18,000	,622		
REPR2P	Correct	Sphericity Assumed	10,889	2	5,444	13,243	,000
		Greenhouse-Geisser	10,889	1,568	6,947	13,243	,000
		Huynh-Feldt	10,889	1,677	6,492	13,243	,000
		Lower-bound	10,889	1,000	10,889	13,243	,002
	Error(Correct)	Sphericity Assumed	16,444	40	,411		
		Greenhouse-Geisser	16,444	31,350	,525		
		Huynh-Feldt	16,444	33,547	,490		
		Lower-bound	16,444	20,000	,822		
REPR2C	Correct	Sphericity Assumed	5,200	2	2,600	3,687	,034
		Greenhouse-Geisser	5,200	1,641	3,169	3,687	,044
		Huynh-Feldt	5,200	1,775	2,929	3,687	,040
		Lower-bound	5,200	1,000	5,200	3,687	,070
	Error(Correct)	Sphericity Assumed	26,800	38	,705		
		Greenhouse-Geisser	26,800	31,177	,860		
		Huynh-Feldt	26,800	33,732	,795		
		Lower-bound	26,800	19,000	1,411		
REPR3P	Correct	Sphericity Assumed	2,508	2	1,254	1,528	,229
		Greenhouse-Geisser	2,508	1,924	1,304	1,528	,230
		Huynh-Feldt	2,508	2,000	1,254	1,528	,229
		Lower-bound	2,508	1,000	2,508	1,528	,231
	Error(Correct)	Sphericity Assumed	32,825	40	,821		
		Greenhouse-Geisser	32,825	38,470	,853		
		Huynh-Feldt	32,825	40,000	,821		
		Lower-bound	32,825	20,000	1,641		
REPR3C	Correct	Sphericity Assumed	1,298	2	,649	,729	,489
		Greenhouse-Geisser	1,298	1,945	,667	,729	,486
		Huynh-Feldt	1,298	2,000	,649	,729	,489
		Lower-bound	1,298	1,000	1,298	,729	,404
	Error(Correct)	Sphericity Assumed	32,035	36	,890		
		Greenhouse-Geisser	32,035	35,016	,915		
		Huynh-Feldt	32,035	36,000	,890		
		Lower-bound	32,035	18,000	1,780		

Pairwise Comparisons

Measure: MEASURE_1

GROUP	(I) Correct	(J) Correct	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
REPR1P	1	2	,600*	,197	,020	,082	1,118
		3	,700*	,242	,028	,066	1,334
	2	1	-,600*	,197	,020	-1,118	-,082
		3	,100	,298	1,000	-,683	,883
	3	1	-,700*	,242	,028	-1,334	-,066
		2	-,100	,298	1,000	-,883	,683
REPR1C	1	2	,895*	,169	,000	,448	1,341
		3	1,000*	,171	,000	,549	1,451
	2	1	-,895*	,169	,000	-1,341	-,448
		3	,105	,201	1,000	-,425	,635
	3	1	-1,000*	,171	,000	-1,451	-,549
		2	-,105	,201	1,000	-,635	,425
REPR2P	1	2	,905*	,136	,000	,549	1,261
		3	,857*	,221	,003	,279	1,435
	2	1	-,905*	,136	,000	-1,261	-,549
		3	-,048	,223	1,000	-,631	,536
	3	1	-,857*	,221	,003	-1,435	-,279
		2	,048	,223	1,000	-,536	,631
REPR2C	1	2	,500	,224	,113	-,087	1,087
		3	,700*	,242	,028	,066	1,334
	2	1	-,500	,224	,113	-1,087	,087
		3	,200	,321	1,000	-,643	1,043
	3	1	-,700*	,242	,028	-1,334	-,066
		2	-,200	,321	1,000	-1,043	,643
REPR3P	1	2	,333	,279	,738	-,395	1,062
		3	,476	,255	,229	-,189	1,142
	2	1	-,333	,279	,738	-1,062	,395
		3	,143	,303	1,000	-,649	,935
	3	1	-,476	,255	,229	-1,142	,189
		2	-,143	,303	1,000	-,935	,649
REPR3C	1	2	,158	,308	1,000	-,656	,972
		3	,368	,326	,821	-,493	1,230
	2	1	-,158	,308	1,000	-,972	,656
		3	,211	,282	1,000	-,533	,954
	3	1	-,368	,326	,821	-1,230	,493
		2	-,211	,282	1,000	-,954	,533

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Descriptive Statistics

GROUP		Mean	Std. Deviation	N
REPR1P	Local_Correct	2,55	,686	20
	Global_Correct	1,95	,887	20
	GLLO_Correct	1,85	,745	20
REPR1C	Local_Correct	2,63	,597	19
	Global_Correct	1,74	,872	19
	GLLO_Correct	1,63	,684	19
REPR2P	Local_Correct	2,62	,590	21
	Global_Correct	1,71	,717	21
	GLLO_Correct	1,76	,944	21
REPR2C	Local_Correct	2,30	,801	20
	Global_Correct	1,80	,768	20
	GLLO_Correct	1,60	,883	20
REPR3P	Local_Correct	2,10	,889	21
	Global_Correct	1,76	,831	21
	GLLO_Correct	1,62	,921	21
REPR3C	Local_Correct	1,84	1,068	19
	Global_Correct	1,68	1,003	19
	GLLO_Correct	1,47	,772	19

Pairwise Comparisons

Measure: MEASURE_1

(I) Score	(J) Score	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	,567*	,094	,000	,339	,794
	3	,683*	,100	,000	,440	,927
2	1	-,567*	,094	,000	-,794	-,339
	3	,117	,111	,880	-,152	,385
3	1	-,683*	,100	,000	-,927	-,440
	2	-,117	,111	,880	-,385	,152

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Appendix N2: one-way ANOVA dependent variable: score

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Local_Correct	Between Groups	10,132	5	2,026	3,260	,009
	Within Groups	70,859	114	,622		
	Total	80,992	119			
Global_Correct	Between Groups	,890	5	,178	,247	,940
	Within Groups	82,035	114	,720		
	Total	82,925	119			
GLLO_Correct	Between Groups	1,722	5	,344	,495	,779
	Within Groups	79,270	114	,695		
	Total	80,992	119			

Multiple Comparisons

Dependent Variable: Local_Correct

Bonferroni

(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
REPR1P	REPR1C	-,082	,253	1,000	-,84	,68
	REPR2P	-,069	,246	1,000	-,81	,67
	REPR2C	,250	,249	1,000	-,50	1,00
	REPR3P	,455	,246	1,000	-,28	1,19
	REPR3C	,708	,253	,089	-,05	1,47
REPR1C	REPR1P	,082	,253	1,000	-,68	,84
	REPR2P	,013	,250	1,000	-,74	,76
	REPR2C	,332	,253	1,000	-,43	1,09
	REPR3P	,536	,250	,507	-,21	1,28
	REPR3C	,789*	,256	,038	,02	1,56
REPR2P	REPR1P	,069	,246	1,000	-,67	,81
	REPR1C	-,013	,250	1,000	-,76	,74
	REPR2C	,319	,246	1,000	-,42	1,06
	REPR3P	,524	,243	,502	-,21	1,25
	REPR3C	,777*	,250	,035	,03	1,53
REPR2C	REPR1P	-,250	,249	1,000	-1,00	,50
	REPR1C	-,332	,253	1,000	-1,09	,43
	REPR2P	-,319	,246	1,000	-1,06	,42
	REPR3P	,205	,246	1,000	-,53	,94
	REPR3C	,458	,253	1,000	-,30	1,22
REPR3P	REPR1P	-,455	,246	1,000	-1,19	,28
	REPR1C	-,536	,250	,507	-1,28	,21
	REPR2P	-,524	,243	,502	-1,25	,21
	REPR2C	-,205	,246	1,000	-,94	,53
	REPR3C	,253	,250	1,000	-,50	1,00
REPR3C	REPR1P	-,708	,253	,089	-1,47	,05
	REPR1C	-,789*	,256	,038	-1,56	-,02
	REPR2P	-,777*	,250	,035	-1,53	-,03
	REPR2C	-,458	,253	1,000	-1,22	,30
	REPR3P	-,253	,250	1,000	-1,00	,50

*. The mean difference is significant at the 0.05 level.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Local_Correct	Between Groups	8,386	2	4,193	6,756	,002
	Within Groups	72,606	117	,621		
	Total	80,992	119			
Global_Correct	Between Groups	,312	2	,156	,221	,802
	Within Groups	82,613	117	,706		
	Total	82,925	119			
GLLO_Correct	Between Groups	,778	2	,389	,567	,569
	Within Groups	80,214	117	,686		
	Total	80,992	119			

Multiple Comparisons

Bonferroni

Dependent Variable	(I) Representation	(J) Representation	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Local_Correct	1	2	,126	,176	1,000	-,30	,55
		3	,615*	,177	,002	,18	1,05
	2	1	-,126	,176	1,000	-,55	,30
		3	,488*	,175	,018	,06	,91
	3	1	-,615*	,177	,002	-1,05	-,18
		2	-,488*	,175	,018	-,91	-,06
Global_Correct	1	2	,090	,188	1,000	-,37	,55
		3	,121	,189	1,000	-,34	,58
	2	1	-,090	,188	1,000	-,55	,37
		3	,031	,187	1,000	-,42	,48
	3	1	-,121	,189	1,000	-,58	,34
		2	-,031	,187	1,000	-,48	,42
GLLO_Correct	1	2	,061	,185	1,000	-,39	,51
		3	,194	,186	,903	-,26	,65
	2	1	-,061	,185	1,000	-,51	,39
		3	,133	,184	1,000	-,31	,58
	3	1	-,194	,186	,903	-,65	,26
		2	-,133	,184	1,000	-,58	,31

*. The mean difference is significant at the 0.05 level.

Appendix N3: one-way repeated-measures ANOVA dependent variable: time

Within-Subjects Factors

Measure: MEASURE_1

TIME	Dependent Variable
1	Local_Time
2	Global_Time
3	GLLO_Time

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

GROUP	Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
REPR1P	TIME	,909	1,722	2	,423	,916	1,000	,500
REPR1C	TIME	,635	7,730	2	,021	,732	,781	,500
REPR2P	TIME	,996	,084	2	,959	,996	1,000	,500
REPR2C	TIME	,795	4,119	2	,128	,830	,900	,500
REPR3P	TIME	,974	,510	2	,775	,974	1,000	,500
REPR3C	TIME	,987	,218	2	,897	,987	1,000	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: TIME

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

GROUP	Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power[a]
REPR1P	TIME	Sphericity Assumed	97,466	2	48,733	11,872	,000	23,743	,991
		Greenhouse-Geisser	97,466	1,833	53,178	11,872	,000	21,758	,987
		Huynh-Feldt	97,466	2,000	48,733	11,872	,000	23,743	,991
		Lower-bound	97,466	1,000	97,466	11,872	,003	11,872	,904
	Error(TIME)	Sphericity Assumed	155,990	38	4,105				
		Greenhouse-Geisser	155,990	34,824	4,479				
		Huynh-Feldt	155,990	38,000	4,105				
		Lower-bound	155,990	19,000	8,210				
REPR1C	TIME	Sphericity Assumed	31,497	2	15,748	2,203	,125	4,406	,420
		Greenhouse-Geisser	31,497	1,465	21,502	2,203	,142	3,227	,354
		Huynh-Feldt	31,497	1,562	20,161	2,203	,139	3,441	,366
		Lower-bound	31,497	1,000	31,497	2,203	,155	2,203	,290
	Error(TIME)	Sphericity Assumed	257,369	36	7,149				
		Greenhouse-Geisser	257,369	26,367	9,761				
		Huynh-Feldt	257,369	28,120	9,152				
		Lower-bound	257,369	18,000	14,298				
REPR2P	TIME	Sphericity Assumed	45,431	2	22,715	6,282	,004	12,563	,873
		Greenhouse-Geisser	45,431	1,991	22,815	6,282	,004	12,508	,872
		Huynh-Feldt	45,431	2,000	22,715	6,282	,004	12,563	,873
		Lower-bound	45,431	1,000	45,431	6,282	,021	6,282	,664
	Error(TIME)	Sphericity Assumed	144,646	40	3,616				
		Greenhouse-Geisser	144,646	39,825	3,632				
		Huynh-Feldt	144,646	40,000	3,616				
		Lower-bound	144,646	20,000	7,232				
REPR2C	TIME	Sphericity Assumed	8,454	2	4,227	,960	,392	1,919	,204
		Greenhouse-Geisser	8,454	1,660	5,092	,960	,379	1,593	,188
		Huynh-Feldt	8,454	1,800	4,697	,960	,385	1,727	,195
		Lower-bound	8,454	1,000	8,454	,960	,340	,960	,154
	Error(TIME)	Sphericity Assumed	167,380	38	4,405				
		Greenhouse-Geisser	167,380	31,547	5,306				
		Huynh-Feldt	167,380	34,196	4,895				
		Lower-bound	167,380	19,000	8,809				
REPR3P	TIME	Sphericity Assumed	48,808	2	24,404	7,256	,002	14,512	,917
		Greenhouse-Geisser	48,808	1,948	25,050	7,256	,002	14,138	,912
		Huynh-Feldt	48,808	2,000	24,404	7,256	,002	14,512	,917
		Lower-bound	48,808	1,000	48,808	7,256	,014	7,256	,727
	Error(TIME)	Sphericity Assumed	134,532	40	3,363				
		Greenhouse-Geisser	134,532	38,969	3,452				
		Huynh-Feldt	134,532	40,000	3,363				
		Lower-bound	134,532	20,000	6,727				
REPR3C	TIME	Sphericity Assumed	35,957	2	17,978	3,967	,028	7,934	,675
		Greenhouse-Geisser	35,957	1,975	18,208	3,967	,028	7,834	,671
		Huynh-Feldt	35,957	2,000	17,978	3,967	,028	7,934	,675
		Lower-bound	35,957	1,000	35,957	3,967	,062	3,967	,470
	Error(TIME)	Sphericity Assumed	163,146	36	4,532				
		Greenhouse-Geisser	163,146	35,547	4,590				
		Huynh-Feldt	163,146	36,000	4,532				
		Lower-bound	163,146	18,000	9,064				

a. Computed using alpha = ,05

Pairwise Comparisons

Measure: MEASURE_1

GROUP	(I) TIME	(J) TIME	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
REPR1P	1	2	,146	,536	1,000	-1,260	1,551
		3	-2,628*	,681	,003	-4,417	-,839
	2	1	-,146	,536	1,000	-1,551	1,260
		3	-2,773*	,693	,002	-4,593	-,954
	3	1	2,628*	,681	,003	,839	4,417
		2	2,773*	,693	,002	,954	4,593
REPR1C	1	2	,059	,899	1,000	-2,312	2,431
		3	-1,546	1,056	,482	-4,334	1,242
	2	1	-,059	,899	1,000	-2,431	2,312
		3	-1,606*	,578	,037	-3,131	-,081
	3	1	1,546	1,056	,482	-1,242	4,334
		2	1,606*	,578	,037	,081	3,131
REPR2P	1	2	-,194	,579	1,000	-1,707	1,319
		3	-1,890*	,575	,011	-3,393	-,388
	2	1	,194	,579	1,000	-1,319	1,707
		3	-1,697*	,606	,033	-3,280	-,114
	3	1	1,890*	,575	,011	,388	3,393
		2	1,697*	,606	,033	,114	3,280
REPR2C	1	2	,301	,496	1,000	-1,000	1,603
		3	-,602	,708	1,000	-2,460	1,257
	2	1	-,301	,496	1,000	-1,603	1,000
		3	-,903	,758	,744	-2,892	1,086
	3	1	,602	,708	1,000	-1,257	2,460
		2	,903	,758	,744	-1,086	2,892
REPR3P	1	2	1,047	,610	,305	-,548	2,641
		3	-1,109	,543	,163	-2,527	,309
	2	1	-1,047	,610	,305	-2,641	,548
		3	-2,156*	,542	,002	-3,572	-,739
	3	1	1,109	,543	,163	-,309	2,527
		2	2,156*	,542	,002	,739	3,572
REPR3C	1	2	-,461	,727	1,000	-2,380	1,458
		3	-1,867*	,662	,034	-3,615	-,120
	2	1	,461	,727	1,000	-1,458	2,380
		3	-1,406	,681	,161	-3,203	,391
	3	1	1,867*	,662	,034	,120	3,615
		2	1,406	,681	,161	-,391	3,203

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Descriptive Statistics

GROUP		Mean	Std. Deviation	N
REPR1P	Local_Time	5,8290	2,52553	20
	Global_Time	5,6835	2,35018	20
	GLLO_Time	8,4570	3,82858	20
REPR1C	Local_Time	6,3268	4,23813	19
	Global_Time	6,2674	1,72639	19
	GLLO_Time	7,8732	2,61176	19
REPR2P	Local_Time	5,6657	2,24435	21
	Global_Time	5,8595	1,65926	21
	GLLO_Time	7,5562	2,47858	21
REPR2C	Local_Time	6,6670	3,63617	20
	Global_Time	6,3655	3,53624	20
	GLLO_Time	7,2685	3,80400	20
REPR3P	Local_Time	6,0157	3,92972	21
	Global_Time	4,9690	2,47543	21
	GLLO_Time	7,1248	3,67166	21
REPR3C	Local_Time	5,8553	2,03585	19
	Global_Time	6,3163	3,12449	19
	GLLO_Time	7,7226	3,68463	19

Pairwise Comparisons

Measure: MEASURE_1

(I) TIME	(J) TIME	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	,160	,262	1,000	-,477	,798
	3	-1,604*	,291	,000	-2,311	-,897
2	1	-,160	,262	1,000	-,798	,477
	3	-1,764*	,264	,000	-2,404	-1,124
3	1	1,604*	,291	,000	,897	2,311
	2	1,764*	,264	,000	1,124	2,404

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Appendix N4: one-way ANOVA dependent variable: time

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Local_Time	Between Groups	13,889	5	2,778	,268	,930
	Within Groups	1179,911	114	10,350		
	Total	1193,801	119			
Global_Time	Between Groups	29,361	5	5,872	,893	,488
	Within Groups	749,527	114	6,575		
	Total	778,888	119			
GLLO_Time	Between Groups	22,950	5	4,590	,398	,849
	Within Groups	1313,088	114	11,518		
	Total	1336,038	119			

* Groups represents: groups

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Local_Time	Between Groups	,947	2	,474	,046	,955
	Within Groups	1192,853	117	10,195		
	Total	1193,801	119			
Global_Time	Between Groups	5,311	2	2,655	,402	,670
	Within Groups	773,578	117	6,612		
	Total	778,888	119			
GLLO_Time	Between Groups	15,215	2	7,608	,674	,512
	Within Groups	1320,823	117	11,289		
	Total	1336,038	119			

* Groups represents: representation type

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Local_Time	Between Groups	6,142	1	6,142	,610	,436
	Within Groups	1187,659	118	10,065		
	Total	1193,801	119			
Global_Time	Between Groups	19,959	1	19,959	3,103	,081
	Within Groups	758,929	118	6,432		
	Total	778,888	119			
GLLO_Time	Between Groups	,218	1	,218	,019	,890
	Within Groups	1335,820	118	11,321		
	Total	1336,038	119			

* Groups represents: presentation medium

Appendix N5. one-way repeated-measures ANOVA dependent variable: score/time

Within-Subjects Factors

Measure: MEASURE_1

SCORE_TIME	Dependent Variable
1	SCORE_DIV_TIME_LOCAL
2	SCORE_DIV_TIME_GLOBAL
3	SCORE_DIV_TIME_GLLO

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

GROUP	Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
REPR1P	SCORE_TIME	,599	9,213	2	,010	,714	,756	,500
REPR1C	SCORE_TIME	,477	12,600	2	,002	,656	,687	,500
REPR2P	SCORE_TIME	,446	15,352	2	,000	,643	,669	,500
REPR2C	SCORE_TIME	,817	3,646	2	,162	,845	,919	,500
REPR3P	SCORE_TIME	,435	15,800	2	,000	,639	,663	,500
REPR3C	SCORE_TIME	,943	1,004	2	,605	,946	1,000	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: SCORE_TIME

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

GROUP	Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power[a]
REPR1P	SCORE_TIME	Sphericity Assumed	,435	2	,217	1,613	,213	3,227	,320
		Greenhouse-Geisser	,435	1,428	,304	1,613	,219	2,304	,268
		Huynh-Feldt	,435	1,511	,287	1,613	,218	2,439	,276
		Lower-bound	,435	1,000	,435	1,613	,219	1,613	,226
	Error(SCORE_TIME)	Sphericity Assumed	5,117	38	,135				
		Greenhouse-Geisser	5,117	27,131	,189				
		Huynh-Feldt	5,117	28,717	,178				
		Lower-bound	5,117	19,000	,269				
REPR1C	SCORE_TIME	Sphericity Assumed	1,420	2	,710	18,369	,000	36,738	1,000
		Greenhouse-Geisser	1,420	1,313	1,082	18,369	,000	24,115	,995
		Huynh-Feldt	1,420	1,375	1,033	18,369	,000	25,256	,996
		Lower-bound	1,420	1,000	1,420	18,369	,000	18,369	,982
	Error(SCORE_TIME)	Sphericity Assumed	1,392	36	,039				
		Greenhouse-Geisser	1,392	23,631	,059				
		Huynh-Feldt	1,392	24,748	,056				
		Lower-bound	1,392	18,000	,077				
REPR2P	SCORE_TIME	Sphericity Assumed	1,244	2	,622	21,268	,000	42,536	1,000
		Greenhouse-Geisser	1,244	1,287	,967	21,268	,000	27,368	,998
		Huynh-Feldt	1,244	1,337	,930	21,268	,000	28,439	,999
		Lower-bound	1,244	1,000	1,244	21,268	,000	21,268	,992
	Error(SCORE_TIME)	Sphericity Assumed	1,170	40	,029				
		Greenhouse-Geisser	1,170	25,736	,045				
		Huynh-Feldt	1,170	26,743	,044				
		Lower-bound	1,170	20,000	,058				
REPR2C	SCORE_TIME	Sphericity Assumed	,299	2	,149	2,927	,066	5,855	,538
		Greenhouse-Geisser	,299	1,690	,177	2,927	,076	4,947	,490
		Huynh-Feldt	,299	1,837	,163	2,927	,071	5,378	,513
		Lower-bound	,299	1,000	,299	2,927	,103	2,927	,369
	Error(SCORE_TIME)	Sphericity Assumed	1,939	38	,051				
		Greenhouse-Geisser	1,939	32,112	,060				
		Huynh-Feldt	1,939	34,907	,056				
		Lower-bound	1,939	19,000	,102				
REPR3P	SCORE_TIME	Sphericity Assumed	,747	2	,374	2,653	,083	5,306	,497
		Greenhouse-Geisser	,747	1,278	,584	2,653	,108	3,391	,389
		Huynh-Feldt	,747	1,327	,563	2,653	,106	3,520	,396
		Lower-bound	,747	1,000	,747	2,653	,119	2,653	,341
	Error(SCORE_TIME)	Sphericity Assumed	5,631	40	,141				
		Greenhouse-Geisser	5,631	25,565	,220				
		Huynh-Feldt	5,631	26,539	,212				
		Lower-bound	5,631	20,000	,282				
REPR3C	SCORE_TIME	Sphericity Assumed	,136	2	,068	1,815	,177	3,630	,354
		Greenhouse-Geisser	,136	1,892	,072	1,815	,180	3,433	,343
		Huynh-Feldt	,136	2,000	,068	1,815	,177	3,630	,354
		Lower-bound	,136	1,000	,136	1,815	,195	1,815	,248
	Error(SCORE_TIME)	Sphericity Assumed	1,351	36	,038				
		Greenhouse-Geisser	1,351	34,047	,040				
		Huynh-Feldt	1,351	36,000	,038				
		Lower-bound	1,351	18,000	,075				

a. Computed using alpha = ,05

Pairwise Comparisons

Measure: MEASURE_1

GROUP	(I) SCORE_TIME	(J) SCORE_TIME	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
						Lower Bound	Upper Bound
REPR1P	1	2	,166	,091	,253	-,073	,404
		3	,193	,101	,217	-,073	,458
	2	1	-,166	,091	,253	-,404	,073
		3	,027	,148	1,000	-,362	,416
	3	1	-,193	,101	,217	-,458	,073
		2	-,027	,148	1,000	-,416	,362
REPR1C	1	2	,286*	,074	,003	,090	,481
		3	,368*	,075	,000	,171	,566
	2	1	-,286*	,074	,003	-,481	-,090
		3	,083	,034	,072	-,006	,171
	3	1	-,368*	,075	,000	-,566	-,171
		2	-,083	,034	,072	-,171	,006
REPR2P	1	2	,269*	,065	,001	,100	,439
		3	,320*	,058	,000	,169	,472
	2	1	-,269*	,065	,001	-,439	-,100
		3	,051	,028	,235	-,021	,124
	3	1	-,320*	,058	,000	-,472	-,169
		2	-,051	,028	,235	-,124	,021
REPR2C	1	2	,114	,085	,581	-,108	,336
		3	,170*	,059	,028	,016	,323
	2	1	-,114	,085	,581	-,336	,108
		3	,056	,069	1,000	-,125	,236
	3	1	-,170*	,059	,028	-,323	-,016
		2	-,056	,069	1,000	-,236	,125
REPR3P	1	2	,101	,153	1,000	-,299	,501
		3	,264*	,098	,041	,009	,519
	2	1	-,101	,153	1,000	-,501	,299
		3	,163	,085	,210	-,060	,386
	3	1	-,264*	,098	,041	-,519	-,009
		2	-,163	,085	,210	-,386	,060
REPR3C	1	2	,009	,069	1,000	-,174	,192
		3	,108	,062	,294	-,055	,271
	2	1	-,009	,069	1,000	-,192	,174
		3	,099	,057	,292	-,050	,248
	3	1	-,108	,062	,294	-,271	,055
		2	-,099	,057	,292	-,248	,050

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

a. Adjustment for multiple comparisons: Bonferroni.

Descriptive Statistics

GROUP		Mean	Std. Deviation	N
REPR1P	SCORE_DIV_TIME_LOCAL	,5385	,28732	20
	SCORE_DIV_TIME_GLOBAL	,3730	,21699	20
	SCORE_DIV_TIME_GLLO	,3460	,53217	20
REPR1C	SCORE_DIV_TIME_LOCAL	,5942	,38260	19
	SCORE_DIV_TIME_GLOBAL	,3084	,16327	19
	SCORE_DIV_TIME_GLLO	,2258	,10585	19
REPR2P	SCORE_DIV_TIME_LOCAL	,5633	,31721	21
	SCORE_DIV_TIME_GLOBAL	,2943	,13456	21
	SCORE_DIV_TIME_GLLO	,2429	,13199	21
REPR2C	SCORE_DIV_TIME_LOCAL	,4680	,37929	20
	SCORE_DIV_TIME_GLOBAL	,3540	,21246	20
	SCORE_DIV_TIME_GLLO	,2985	,26146	20
REPR3P	SCORE_DIV_TIME_LOCAL	,5429	,53442	21
	SCORE_DIV_TIME_GLOBAL	,4419	,34723	21
	SCORE_DIV_TIME_GLLO	,2786	,20318	21
REPR3C	SCORE_DIV_TIME_LOCAL	,3295	,21457	19
	SCORE_DIV_TIME_GLOBAL	,3205	,23253	19
	SCORE_DIV_TIME_GLLO	,2216	,11871	19

Pairwise Comparisons

Measure: MEASURE_1

(I) SCORE_TIME	(J) SCORE_TIME	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	,158*	,039	,000	,063	,253
	3	,238*	,032	,000	,160	,316
2	1	-,158*	,039	,000	-,253	-,063
	3	,080*	,033	,047	,001	,159
3	1	-,238*	,032	,000	-,316	-,160
	2	-,080*	,033	,047	-,159	-,001

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
SCORE_TIME	,926	9,102	2	,011	,931	,945	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: SCORE_TIME

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power[a]
SCORE_TIME	Sphericity Assumed	3,522	2	1,761	24,148	,000	48,297	1,000
	Greenhouse-Geisser	3,522	1,862	1,892	24,148	,000	44,959	1,000
	Huynh-Feldt	3,522	1,890	1,864	24,148	,000	45,645	1,000
	Lower-bound	3,522	1,000	3,522	24,148	,000	24,148	,998
Error(SCORE_TIME)	Sphericity Assumed	17,358	238	,073				
	Greenhouse-Geisser	17,358	221,553	,078				
	Huynh-Feldt	17,358	224,933	,077				
	Lower-bound	17,358	119,000	,146				

a. Computed using alpha = ,05

Appendix N6: one-way ANOVA dependent variable: score/time

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SCORE_DIV_TIME_LOCAL	Between Groups	,887	5	,177	1,306	,266
	Within Groups	15,490	114	,136		
	Total	16,377	119			
SCORE_DIV_TIME_GLOBAL	Between Groups	,303	5	,061	1,155	,336
	Within Groups	5,979	114	,052		
	Total	6,282	119			
SCORE_DIV_TIME_GLLO	Between Groups	,230	5	,046	,632	,675
	Within Groups	8,309	114	,073		
	Total	8,540	119			

* Groups represents: groups

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SCORE_DIV_TIME_LOCAL	Between Groups	,310	2	,155	1,127	,327
	Within Groups	16,067	117	,137		
	Total	16,377	119			
SCORE_DIV_TIME_GLOBAL	Between Groups	,079	2	,039	,742	,478
	Within Groups	6,203	117	,053		
	Total	6,282	119			
SCORE_DIV_TIME_GLLO	Between Groups	,026	2	,013	,175	,839
	Within Groups	8,514	117	,073		
	Total	8,540	119			

* Groups represents: representation type

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SCORE_DIV_TIME_LOCAL	Between Groups	,214	1	,214	1,559	,214
	Within Groups	16,163	118	,137		
	Total	16,377	119			
SCORE_DIV_TIME_GLOBAL	Between Groups	,052	1	,052	,981	,324
	Within Groups	6,230	118	,053		
	Total	6,282	119			
SCORE_DIV_TIME_GLLO	Between Groups	,045	1	,045	,625	,431
	Within Groups	8,495	118	,072		
	Total	8,540	119			

* Groups represents: presentation medium

Appendix O: The influence of the representation on Ctr, Res and Inf.

Appendix O1: one-way repeated measures ANOVA dependent variable: score

Within-Subjects Factors

Measure: MEASURE_1

factor1	Dependent Variable
1	Ctr_Res_Inf
2	Ctr
3	Res_Inf

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

GROUP	Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
REPR1P	Score_RIC	,830	3,345	2	,188	,855	,931	,500
REPR1C	Score_RIC	,962	,654	2	,721	,964	1,000	,500
REPR2P	Score_RIC	,973	,517	2	,772	,974	1,000	,500
REPR2C	Score_RIC	,865	2,609	2	,271	,881	,964	,500
REPR3P	Score_RIC	,816	3,865	2	,145	,845	,914	,500
REPR3C	Score_RIC	,731	5,321	2	,070	,788	,851	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: Score_RIC

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

GROUP	Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power[a]
REPR1P	Score_RIC	Sphericity Assumed	,347	2	,174	1,916	,161	3,833	,373
		Greenhouse-Geisser	,347	1,710	,203	1,916	,168	3,277	,342
		Huynh-Feldt	,347	1,862	,186	1,916	,164	3,569	,358
		Lower-bound	,347	1,000	,347	1,916	,182	1,916	,260
	Error(Score_RIC)	Sphericity Assumed	3,443	38	,091				
		Greenhouse-Geisser	3,443	32,490	,106				
		Huynh-Feldt	3,443	35,384	,097				
		Lower-bound	3,443	19,000	,181				
REPR1C	Score_RIC	Sphericity Assumed	1,313	2	,656	7,534	,002	15,068	,925
		Greenhouse-Geisser	1,313	1,927	,681	7,534	,002	14,521	,918
		Huynh-Feldt	1,313	2,000	,656	7,534	,002	15,068	,925
		Lower-bound	1,313	1,000	1,313	7,534	,013	7,534	,738
	Error(Score_RIC)	Sphericity Assumed	3,136	36	,087				
		Greenhouse-Geisser	3,136	34,691	,090				
		Huynh-Feldt	3,136	36,000	,087				
		Lower-bound	3,136	18,000	,174				
REPR2P	Score_RIC	Sphericity Assumed	,222	2	,111	1,424	,253	2,849	,287
		Greenhouse-Geisser	,222	1,948	,114	1,424	,253	2,774	,283
		Huynh-Feldt	,222	2,000	,111	1,424	,253	2,849	,287
		Lower-bound	,222	1,000	,222	1,424	,247	1,424	,206
	Error(Score_RIC)	Sphericity Assumed	3,120	40	,078				
		Greenhouse-Geisser	3,120	38,955	,080				
		Huynh-Feldt	3,120	40,000	,078				
		Lower-bound	3,120	20,000	,156				
REPR2C	Score_RIC	Sphericity Assumed	1,229	2	,614	5,938	,006	11,876	,851
		Greenhouse-Geisser	1,229	1,762	,697	5,938	,008	10,464	,815
		Huynh-Feldt	1,229	1,929	,637	5,938	,006	11,452	,841
		Lower-bound	1,229	1,000	1,229	5,938	,025	5,938	,638
	Error(Score_RIC)	Sphericity Assumed	3,932	38	,103				
		Greenhouse-Geisser	3,932	33,482	,117				
		Huynh-Feldt	3,932	36,643	,107				
		Lower-bound	3,932	19,000	,207				
REPR3P	Score_RIC	Sphericity Assumed	,388	2	,194	2,253	,118	4,505	,432
		Greenhouse-Geisser	,388	1,689	,230	2,253	,128	3,805	,393
		Huynh-Feldt	,388	1,828	,212	2,253	,124	4,118	,411
		Lower-bound	,388	1,000	,388	2,253	,149	2,253	,298
	Error(Score_RIC)	Sphericity Assumed	3,447	40	,086				
		Greenhouse-Geisser	3,447	33,782	,102				
		Huynh-Feldt	3,447	36,559	,094				
		Lower-bound	3,447	20,000	,172				
REPR3C	Score_RIC	Sphericity Assumed	,941	2	,471	7,314	,002	14,629	,917
		Greenhouse-Geisser	,941	1,576	,597	7,314	,005	11,530	,860
		Huynh-Feldt	,941	1,702	,553	7,314	,004	12,448	,880
		Lower-bound	,941	1,000	,941	7,314	,015	7,314	,725
	Error(Score_RIC)	Sphericity Assumed	2,316	36	,064				
		Greenhouse-Geisser	2,316	28,375	,082				
		Huynh-Feldt	2,316	30,634	,076				
		Lower-bound	2,316	18,000	,129				

a. Computed using alpha = ,05

Pairwise Comparisons

Measure: MEASURE_1

GROUP	(I) Score_RIC	(J) Score_RIC	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
						Lower Bound	Upper Bound
REPR1P	1	2	,033	,096	1,000	-,218	,285
		3	-,142	,076	,230	-,341	,057
	2	1	-,033	,096	1,000	-,285	,218
		3	-,176	,111	,386	-,466	,115
	3	1	,142	,076	,230	-,057	,341
		2	,176	,111	,386	-,115	,466
REPR1C	1	2	-,326*	,089	,005	-,561	-,091
		3	-,318*	,104	,021	-,593	-,042
	2	1	,326*	,089	,005	,091	,561
		3	,008	,093	1,000	-,238	,254
	3	1	,318*	,104	,021	,042	,593
		2	-,008	,093	1,000	-,254	,238
REPR2P	1	2	-,048	,079	1,000	-,254	,158
		3	-,143	,089	,372	-,375	,090
	2	1	,048	,079	1,000	-,158	,254
		3	-,095	,090	,913	-,331	,141
	3	1	,143	,089	,372	-,090	,375
		2	,095	,090	,913	-,141	,331
REPR2C	1	2	-,158	,113	,531	-,454	,138
		3	-,350*	,081	,001	-,563	-,137
	2	1	,158	,113	,531	-,138	,454
		3	-,192	,108	,278	-,477	,093
	3	1	,350*	,081	,001	,137	,563
		2	,192	,108	,278	-,093	,477
REPR3P	1	2	,072	,082	1,000	-,141	,286
		3	-,118	,079	,449	-,324	,088
	2	1	-,072	,082	1,000	-,286	,141
		3	-,190	,108	,281	-,473	,092
	3	1	,118	,079	,449	-,088	,324
		2	,190	,108	,281	-,092	,473
REPR3C	1	2	-,097	,061	,375	-,257	,062
		3	-,308*	,083	,005	-,527	-,088
	2	1	,097	,061	,375	-,062	,257
		3	-,211	,099	,141	-,471	,050
	3	1	,308*	,083	,005	,088	,527
		2	,211	,099	,141	-,050	,471

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

a. Adjustment for multiple comparisons: Bonferroni.

Descriptive Statistics

GROUP		Mean	Std. Deviation	N
REPR1P	Ctr_Res_Inf	,6335	,26428	20
	Ctr	,6000	,34793	20
	Res_Inf	,7755	,28734	20
REPR1C	Ctr_Res_Inf	,4374	,31633	19
	Ctr	,7632	,25649	19
	Res_Inf	,7553	,32545	19
REPR2P	Ctr_Res_Inf	,5714	,24115	21
	Ctr	,6190	,38421	21
	Res_Inf	,7143	,30833	21
REPR2C	Ctr_Res_Inf	,4170	,30494	20
	Ctr	,5750	,33541	20
	Res_Inf	,7670	,25024	20
REPR3P	Ctr_Res_Inf	,5724	,24085	21
	Ctr	,5000	,38730	21
	Res_Inf	,6905	,26566	21
REPR3C	Ctr_Res_Inf	,4026	,26388	19
	Ctr	,5000	,23570	19
	Res_Inf	,7105	,35988	19

Pairwise Comparisons

Measure: MEASURE_1

(I) Score_RIC	(J) Score_RIC	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-,083	,037	,080	-,174	,007
	3	-,227*	,035	,000	-,313	-,141
2	1	,083	,037	,080	-,007	,174
	3	-,143*	,041	,002	-,244	-,043
3	1	,227*	,035	,000	,141	,313
	2	,143*	,041	,002	,043	,244

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Appendix O2: one-way ANOVA depedent variable: score

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Ctr_Res_Inf	Between Groups	,958	5	,192	2,578	,030
	Within Groups	8,472	114	,074		
	Total	9,430	119			
Ctr	Between Groups	,918	5	,184	1,664	,149
	Within Groups	12,574	114	,110		
	Total	13,492	119			
Res_Inf	Between Groups	,123	5	,025	,272	,927
	Within Groups	10,309	114	,090		
	Total	10,432	119			

Multiple Comparisons

Dependent Variable: Ctr

Bonferroni

(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
REPR1P	REPR1C	-,16316	,10640	1,000	-,4822	,1559
	REPR2P	-,01905	,10377	1,000	-,3302	,2921
	REPR2C	,02500	,10502	1,000	-,2899	,3399
	REPR3P	,10000	,10377	1,000	-,2111	,4111
	REPR3C	,10000	,10640	1,000	-,2190	,4190
REPR1C	REPR1P	,16316	,10640	1,000	-,1559	,4822
	REPR2P	,14411	,10515	1,000	-,1712	,4594
	REPR2C	,18816	,10640	1,000	-,1309	,5072
	REPR3P	,26316	,10515	,206	-,0521	,5784
	REPR3C	,26316	,10775	,242	-,0599	,5862
REPR2P	REPR1P	,01905	,10377	1,000	-,2921	,3302
	REPR1C	-,14411	,10515	1,000	-,4594	,1712
	REPR2C	,04405	,10377	1,000	-,2671	,3552
	REPR3P	,11905	,10249	1,000	-,1883	,4264
	REPR3C	,11905	,10515	1,000	-,1962	,4343
REPR2C	REPR1P	-,02500	,10502	1,000	-,3399	,2899
	REPR1C	-,18816	,10640	1,000	-,5072	,1309
	REPR2P	-,04405	,10377	1,000	-,3552	,2671
	REPR3P	,07500	,10377	1,000	-,2361	,3861
	REPR3C	,07500	,10640	1,000	-,2440	,3940
REPR3P	REPR1P	-,10000	,10377	1,000	-,4111	,2111
	REPR1C	-,26316	,10515	,206	-,5784	,0521
	REPR2P	-,11905	,10249	1,000	-,4264	,1883
	REPR2C	-,07500	,10377	1,000	-,3861	,2361
	REPR3C	,00000	,10515	1,000	-,3153	,3153
REPR3C	REPR1P	-,10000	,10640	1,000	-,4190	,2190
	REPR1C	-,26316	,10775	,242	-,5862	,0599
	REPR2P	-,11905	,10515	1,000	-,4343	,1962
	REPR2C	-,07500	,10640	1,000	-,3940	,2440
	REPR3P	,00000	,10515	1,000	-,3153	,3153

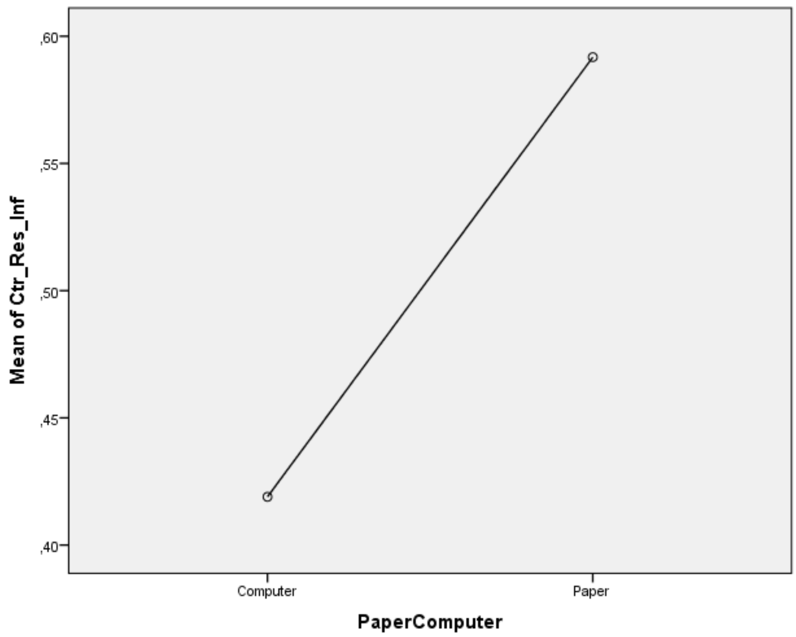
* Groups represents: groups

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Ctr_Res_Inf	Computer	58	,4190	,29118	,03823	,3424	,4955	,00	1,00
	Paper	62	,5918	,24634	,03129	,5292	,6543	,00	1,00
	Total	120	,5083	,28150	,02570	,4574	,5591	,00	1,00
Ctr	Computer	58	,6121	,29681	,03897	,5340	,6901	,00	1,00
	Paper	62	,5726	,37160	,04719	,4782	,6669	,00	1,00
	Total	120	,5917	,33671	,03074	,5308	,6525	,00	1,00
Res_Inf	Computer	58	,7447	,30955	,04065	,6633	,8260	,00	1,00
	Paper	62	,7260	,28515	,03621	,6536	,7984	,00	1,00
	Total	120	,7350	,29608	,02703	,6815	,7885	,00	1,00

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Ctr_Res_Inf	Between Groups	,895	1	,895	12,373	,001
	Within Groups	8,535	118	,072		
	Total	9,430	119			
Ctr	Between Groups	,047	1	,047	,410	,523
	Within Groups	13,445	118	,114		
	Total	13,492	119			
Res_Inf	Between Groups	,010	1	,010	,118	,731
	Within Groups	10,422	118	,088		
	Total	10,432	119			



* Groups represents: presentation medium

ANOVA

Ctr_Res_Inf

Representation		Sum of Squares	df	Mean Square	F	Sig.
1	Between Groups	,375	1	,375	4,433	,042
	Within Groups	3,128	37	,085		
	Total	3,503	38			
2	Between Groups	,244	1	,244	3,252	,079
	Within Groups	2,930	39	,075		
	Total	3,174	40			
3	Between Groups	,287	1	,287	4,525	,040
	Within Groups	2,414	38	,064		
	Total	2,701	39			

Appendix O3: one-way repeated measures ANOVA dependent variable: time

Within-Subjects Factors

Measure: MEASURE_1

Time_RIC	Dependent Variable
1	TimeCtrResInf
2	TimeCtr
3	TimeRes_Inf

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

GROUP	Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
REPR1P	Time_RIC	,616	8,718	2	,013	,723	,766	,500
REPR1C	Time_RIC	,973	,465	2	,793	,974	1,000	,500
REPR2P	Time_RIC	,673	7,515	2	,023	,754	,802	,500
REPR2C	Time_RIC	,945	1,015	2	,602	,948	1,000	,500
REPR3P	Time_RIC	,732	5,921	2	,052	,789	,845	,500
REPR3C	Time_RIC	,908	1,647	2	,439	,915	1,000	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: Time_RIC

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

GROUP	Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power[a]
REPR1P	Time_RIC	Sphericity Assumed	17,095	2	8,547	13,324	,000	26,648	,996
		Greenhouse-Geisser	17,095	1,445	11,829	13,324	,000	19,256	,980
		Huynh-Feldt	17,095	1,533	11,154	13,324	,000	20,420	,985
		Lower-bound	17,095	1,000	17,095	13,324	,002	13,324	,933
	Error(Time_RIC)	Sphericity Assumed	24,377	38	,642				
		Greenhouse-Geisser	24,377	27,459	,888				
		Huynh-Feldt	24,377	29,119	,837				
		Lower-bound	24,377	19,000	1,283				
REPR1C	Time_RIC	Sphericity Assumed	9,668	2	4,834	4,497	,018	8,994	,733
		Greenhouse-Geisser	9,668	1,947	4,964	4,497	,019	8,758	,724
		Huynh-Feldt	9,668	2,000	4,834	4,497	,018	8,994	,733
		Lower-bound	9,668	1,000	9,668	4,497	,048	4,497	,519
	Error(Time_RIC)	Sphericity Assumed	38,696	36	1,075				
		Greenhouse-Geisser	38,696	35,054	1,104				
		Huynh-Feldt	38,696	36,000	1,075				
		Lower-bound	38,696	18,000	2,150				
REPR2P	Time_RIC	Sphericity Assumed	10,399	2	5,199	8,460	,001	16,920	,953
		Greenhouse-Geisser	10,399	1,508	6,898	8,460	,003	12,754	,900
		Huynh-Feldt	10,399	1,604	6,484	8,460	,002	13,568	,913
		Lower-bound	10,399	1,000	10,399	8,460	,009	8,460	,790
	Error(Time_RIC)	Sphericity Assumed	24,583	40	,615				
		Greenhouse-Geisser	24,583	30,151	,815				
		Huynh-Feldt	24,583	32,076	,766				
		Lower-bound	24,583	20,000	1,229				
REPR2C	Time_RIC	Sphericity Assumed	3,756	2	1,878	3,792	,032	7,584	,656
		Greenhouse-Geisser	3,756	1,896	1,981	3,792	,034	7,190	,638
		Huynh-Feldt	3,756	2,000	1,878	3,792	,032	7,584	,656
		Lower-bound	3,756	1,000	3,756	3,792	,066	3,792	,456
	Error(Time_RIC)	Sphericity Assumed	18,820	38	,495				
		Greenhouse-Geisser	18,820	36,025	,522				
		Huynh-Feldt	18,820	38,000	,495				
		Lower-bound	18,820	19,000	,991				
REPR3P	Time_RIC	Sphericity Assumed	2,908	2	1,454	3,260	,049	6,521	,588
		Greenhouse-Geisser	2,908	1,578	1,843	3,260	,062	5,144	,517
		Huynh-Feldt	2,908	1,690	1,721	3,260	,058	5,509	,537
		Lower-bound	2,908	1,000	2,908	3,260	,086	3,260	,405
	Error(Time_RIC)	Sphericity Assumed	17,837	40	,446				
		Greenhouse-Geisser	17,837	31,552	,565				
		Huynh-Feldt	17,837	33,795	,528				
		Lower-bound	17,837	20,000	,892				
REPR3C	Time_RIC	Sphericity Assumed	2,394	2	1,197	,995	,380	1,989	,209
		Greenhouse-Geisser	2,394	1,831	1,308	,995	,374	1,821	,201
		Huynh-Feldt	2,394	2,000	1,197	,995	,380	1,989	,209
		Lower-bound	2,394	1,000	2,394	,995	,332	,995	,157
	Error(Time_RIC)	Sphericity Assumed	43,325	36	1,203				
		Greenhouse-Geisser	43,325	32,957	1,315				
		Huynh-Feldt	43,325	36,000	1,203				
		Lower-bound	43,325	18,000	2,407				

a. Computed using alpha = ,05

Pairwise Comparisons

Measure: MEASURE_1

GROUP	(I) Time_RIC	(J) Time_RIC	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
REPR1P	1	2	-1,175*	,279	,001	-1,909	-,442
		3	-,092	,158	1,000	-,507	,323
	2	1	1,175*	,279	,001	,442	1,909
		3	1,084*	,299	,005	,298	1,869
	3	1	,092	,158	1,000	-,323	,507
		2	-1,084*	,299	,005	-1,869	-,298
REPR1C	1	2	-,624	,356	,290	-1,564	,315
		3	,374	,309	,724	-,441	1,189
	2	1	,624	,356	,290	-,315	1,564
		3	,998*	,342	,028	,095	1,902
	3	1	-,374	,309	,724	-1,189	,441
		2	-,998*	,342	,028	-1,902	-,095
REPR2P	1	2	-,566*	,164	,008	-,994	-,138
		3	,426	,255	,332	-,241	1,093
	2	1	,566*	,164	,008	,138	,994
		3	,992*	,289	,008	,237	1,747
	3	1	-,426	,255	,332	-1,093	,241
		2	-,992*	,289	,008	-1,747	-,237
REPR2C	1	2	-,090	,234	1,000	-,705	,525
		3	,480	,236	,169	-,140	1,100
	2	1	,090	,234	1,000	-,525	,705
		3	,570*	,195	,026	,059	1,081
	3	1	-,480	,236	,169	-1,100	,140
		2	-,570*	,195	,026	-1,081	-,059
REPR3P	1	2	,006	,160	1,000	-,412	,423
		3	,459	,251	,248	-,197	1,115
	2	1	-,006	,160	1,000	-,423	,412
		3	,453	,197	,098	-,062	,968
	3	1	-,459	,251	,248	-1,115	,197
		2	-,453	,197	,098	-,968	,062
REPR3C	1	2	-,348	,406	1,000	-1,420	,724
		3	,139	,322	1,000	-,712	,991
	2	1	,348	,406	1,000	-,724	1,420
		3	,487	,333	,483	-,392	1,367
	3	1	-,139	,322	1,000	-,991	,712
		2	-,487	,333	,483	-1,367	,392

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Descriptive Statistics

GROUP		Mean	Std. Deviation	N
REPR1P	TimeCtrResInf	1,9510	,96849	20
	TimeCtr	3,1265	1,29168	20
	TimeRes_Inf	2,0430	1,03351	20
REPR1C	TimeCtrResInf	2,3916	1,09536	19
	TimeCtr	3,0158	1,61114	19
	TimeRes_Inf	2,0174	,63612	19
REPR2P	TimeCtrResInf	2,2057	,75024	21
	TimeCtr	2,7714	1,00395	21
	TimeRes_Inf	1,7795	,75608	21
REPR2C	TimeCtrResInf	2,4535	1,56837	20
	TimeCtr	2,5435	1,05484	20
	TimeRes_Inf	1,9735	1,10398	20
REPR3P	TimeCtrResInf	2,1452	1,36250	21
	TimeCtr	2,1395	1,21262	21
	TimeRes_Inf	1,6867	,95855	21
REPR3C	TimeCtrResInf	2,2574	1,25386	19
	TimeCtr	2,6053	1,29938	19
	TimeRes_Inf	2,1179	1,04885	19

Pairwise Comparisons

Measure: MEASURE_1

(I) Time_RIC	(J) Time_RIC	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	-,463*	,116	,000	-,743	-,182
	3	,301*	,105	,015	,045	,556
2	1	,463*	,116	,000	,182	,743
	3	,764*	,114	,000	,486	1,041
3	1	-,301*	,105	,015	-,556	-,045
	2	-,764*	,114	,000	-1,041	-,486

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Appendix O4: one-way ANOVA depedent variable: time

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
TimeCtrResInf	Between Groups	3,229	5	,646	,452	,811
	Within Groups	162,838	114	1,428		
	Total	166,067	119			
TimeCtr	Between Groups	12,893	5	2,579	1,637	,156
	Within Groups	179,523	114	1,575		
	Total	192,417	119			
TimeRes_Inf	Between Groups	2,828	5	,566	,643	,668
	Within Groups	100,346	114	,880		
	Total	103,174	119			

* Groups represents: groups

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
TimeCtrResInf	Between Groups	,583	2	,292	,206	,814
	Within Groups	165,483	117	1,414		
	Total	166,067	119			
TimeCtr	Between Groups	10,078	2	5,039	3,233	,043
	Within Groups	182,339	117	1,558		
	Total	192,417	119			
TimeRes_Inf	Between Groups	,581	2	,291	,331	,719
	Within Groups	102,593	117	,877		
	Total	103,174	119			

Multiple Comparisons

Bonferroni

Dependent Variable	(I) Representation	(J) Representation	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
TimeCtrResInf	1	2	-,16094	,26601	1,000	-,8071	,4852
		3	-,03286	,26763	1,000	-,6829	,6172
	2	1	,16094	,26601	1,000	-,4852	,8071
		3	,12809	,26430	1,000	-,5139	,7701
	3	1	,03286	,26763	1,000	-,6172	,6829
		2	-,12809	,26430	1,000	-,7701	,5139
TimeCtr	1	2	,41232	,27923	,427	-,2659	1,0905
		3	,71181*	,28093	,038	,0295	1,3942
	2	1	-,41232	,27923	,427	-1,0905	,2659
		3	,29949	,27744	,848	-,3744	,9734
	3	1	-,71181*	,28093	,038	-1,3942	-,0295
		2	-,29949	,27744	,848	-,9734	,3744
TimeRes_Inf	1	2	,15637	,20945	1,000	-,3524	,6651
		3	,13901	,21073	1,000	-,3728	,6508
	2	1	-,15637	,20945	1,000	-,6651	,3524
		3	-,01735	,20811	1,000	-,5228	,4881
	3	1	-,13901	,21073	1,000	-,6508	,3728
		2	,01735	,20811	1,000	-,4881	,5228

*. The mean difference is significant at the 0.05 level.

* Groups represents: representation type

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
TimeCtrResInf	Between Groups	2,119	1	2,119	1,525	,219
	Within Groups	163,948	118	1,389		
	Total	166,067	119			
TimeCtr	Between Groups	,065	1	,065	,040	,842
	Within Groups	192,352	118	1,630		
	Total	192,417	119			
TimeRes_Inf	Between Groups	1,224	1	1,224	1,417	,236
	Within Groups	101,950	118	,864		
	Total	103,174	119			

* Groups represents: presentation medium

Appendix O5: one-way repeated measures ANOVA dependent variable: score/time

Within-Subjects Factors

Measure: MEASURE_1

Score_Time_RIC	Dependent Variable
1	ScoveDivTimeCtrResInf
2	ScoreDivTimeCtr
3	ScoreDivTimeResInf

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

GROUP	Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
REPR1P	Score_Time_RIC	,722	5,872	2	,053	,782	,840	,500
REPR1C	Score_Time_RIC	,980	,350	2	,839	,980	1,000	,500
REPR2P	Score_Time_RIC	,540	11,692	2	,003	,685	,719	,500
REPR2C	Score_Time_RIC	,640	8,040	2	,018	,735	,782	,500
REPR3P	Score_Time_RIC	,698	6,837	2	,033	,768	,819	,500
REPR3C	Score_Time_RIC	,549	10,179	2	,006	,689	,728	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: Score_Time_RIC

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

GROUP	Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power[a]
REPR1P	Score_Time_RIC	Sphericity Assumed	,347	2	,173	2,373	,107	4,745	,450
		Greenhouse-Geisser	,347	1,565	,222	2,373	,121	3,712	,393
		Huynh-Feldt	,347	1,680	,206	2,373	,117	3,986	,408
		Lower-bound	,347	1,000	,347	2,373	,140	2,373	,310
	Error(Score_Time_RIC)	Sphericity Assumed	2,776	38	,073				
		Greenhouse-Geisser	2,776	29,726	,093				
		Huynh-Feldt	2,776	31,919	,087				
		Lower-bound	2,776	19,000	,146				
REPR1C	Score_Time_RIC	Sphericity Assumed	,602	2	,301	6,993	,003	13,985	,905
		Greenhouse-Geisser	,602	1,960	,307	6,993	,003	13,706	,900
		Huynh-Feldt	,602	2,000	,301	6,993	,003	13,985	,905
		Lower-bound	,602	1,000	,602	6,993	,016	6,993	,706
	Error(Score_Time_RIC)	Sphericity Assumed	1,550	36	,043				
		Greenhouse-Geisser	1,550	35,281	,044				
		Huynh-Feldt	1,550	36,000	,043				
		Lower-bound	1,550	18,000	,086				
REPR2P	Score_Time_RIC	Sphericity Assumed	,483	2	,241	4,429	,018	8,859	,730
		Greenhouse-Geisser	,483	1,370	,352	4,429	,034	6,070	,608
		Huynh-Feldt	,483	1,437	,336	4,429	,032	6,366	,623
		Lower-bound	,483	1,000	,483	4,429	,048	4,429	,517
	Error(Score_Time_RIC)	Sphericity Assumed	2,180	40	,054				
		Greenhouse-Geisser	2,180	27,406	,080				
		Huynh-Feldt	2,180	28,745	,076				
		Lower-bound	2,180	20,000	,109				
REPR2C	Score_Time_RIC	Sphericity Assumed	,796	2	,398	9,620	,000	19,240	,973
		Greenhouse-Geisser	,796	1,470	,542	9,620	,002	14,145	,928
		Huynh-Feldt	,796	1,563	,509	9,620	,001	15,041	,939
		Lower-bound	,796	1,000	,796	9,620	,006	9,620	,837
	Error(Score_Time_RIC)	Sphericity Assumed	1,573	38	,041				
		Greenhouse-Geisser	1,573	27,936	,056				
		Huynh-Feldt	1,573	29,705	,053				
		Lower-bound	1,573	19,000	,083				
REPR3P	Score_Time_RIC	Sphericity Assumed	,954	2	,477	4,929	,012	9,859	,777
		Greenhouse-Geisser	,954	1,536	,621	4,929	,021	7,571	,693
		Huynh-Feldt	,954	1,638	,582	4,929	,018	8,076	,714
		Lower-bound	,954	1,000	,954	4,929	,038	4,929	,561
	Error(Score_Time_RIC)	Sphericity Assumed	3,872	40	,097				
		Greenhouse-Geisser	3,872	30,717	,126				
		Huynh-Feldt	3,872	32,769	,118				
		Lower-bound	3,872	20,000	,194				
REPR3C	Score_Time_RIC	Sphericity Assumed	,663	2	,332	4,733	,015	9,465	,756
		Greenhouse-Geisser	,663	1,379	,481	4,733	,029	6,525	,635
		Huynh-Feldt	,663	1,456	,456	4,733	,027	6,890	,653
		Lower-bound	,663	1,000	,663	4,733	,043	4,733	,539
	Error(Score_Time_RIC)	Sphericity Assumed	2,523	36	,070				
		Greenhouse-Geisser	2,523	24,819	,102				
		Huynh-Feldt	2,523	26,205	,096				
		Lower-bound	2,523	18,000	,140				

a. Computed using alpha = ,05

Pairwise Comparisons

Measure: MEASURE_1

GROUP	(I) Score_Time_RIC	(J) Score_Time_RIC	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
REPR1P	1	2	,160*	,061	,048	,001	,320
		3	-,002	,089	1,000	-,236	,233
	2	1	-,160*	,061	,048	-,320	-,001
		3	-,162	,101	,378	-,428	,104
	3	1	,002	,089	1,000	-,233	,236
		2	,162	,101	,378	-,104	,428
REPR1C	1	2	-,162	,070	,097	-,347	,023
		3	-,248*	,069	,007	-,431	-,065
	2	1	,162	,070	,097	-,023	,347
		3	-,086	,062	,557	-,250	,079
	3	1	,248*	,069	,007	,065	,431
		2	,086	,062	,557	-,079	,250
REPR2P	1	2	,036	,043	1,000	-,076	,148
		3	-,165	,088	,228	-,396	,065
	2	1	-,036	,043	1,000	-,148	,076
		3	-,201	,077	,050	-,402	,000
	3	1	,165	,088	,228	-,065	,396
		2	,201	,077	,050	,000	,402
REPR2C	1	2	-,106	,053	,185	-,246	,034
		3	-,279*	,054	,000	-,422	-,137
	2	1	,106	,053	,185	-,034	,246
		3	-,173	,081	,139	-,387	,040
	3	1	,279*	,054	,000	,137	,422
		2	,173	,081	,139	-,040	,387
REPR3P	1	2	,107	,065	,341	-,062	,276
		3	-,190	,106	,260	-,467	,086
	2	1	-,107	,065	,341	-,276	,062
		3	-,298*	,111	,043	-,587	-,008
	3	1	,190	,106	,260	-,086	,467
		2	,298*	,111	,043	,008	,587
REPR3C	1	2	-,043	,056	1,000	-,192	,105
		3	-,247*	,085	,028	-,472	-,023
	2	1	,043	,056	1,000	-,105	,192
		3	-,204	,108	,227	-,490	,082
	3	1	,247*	,085	,028	,023	,472
		2	,204	,108	,227	-,082	,490

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Descriptive Statistics

GROUP		Mean	Std. Deviation	N
REPR1P	ScoveDivTimeCtrResInf	,4290	,30503	20
	ScoreDivTimeCtr	,2685	,25746	20
	ScoreDivTimeResInf	,4305	,25558	20
REPR1C	ScoveDivTimeCtrResInf	,1889	,13157	19
	ScoreDivTimeCtr	,3511	,27765	19
	ScoreDivTimeResInf	,4368	,25080	19
REPR2P	ScoveDivTimeCtrResInf	,3067	,18709	21
	ScoreDivTimeCtr	,2710	,21741	21
	ScoreDivTimeResInf	,4719	,28899	21
REPR2C	ScoveDivTimeCtrResInf	,2095	,18961	20
	ScoreDivTimeCtr	,3155	,30980	20
	ScoreDivTimeResInf	,4890	,26083	20
REPR3P	ScoveDivTimeCtrResInf	,3852	,27071	21
	ScoreDivTimeCtr	,2781	,25808	21
	ScoreDivTimeResInf	,5757	,42609	21
REPR3C	ScoveDivTimeCtrResInf	,1984	,13255	19
	ScoreDivTimeCtr	,2416	,18842	19
	ScoreDivTimeResInf	,4458	,36251	19

Pairwise Comparisons

Measure: MEASURE_1

(I) Score_Time_RIC	(J) Score_Time_RIC	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	,002	,026	1,000	-,060	,064
	3	-,187*	,035	,000	-,272	-,103
2	1	-,002	,026	1,000	-,064	,060
	3	-,189*	,037	,000	-,280	-,098
3	1	,187*	,035	,000	,103	,272
	2	,189*	,037	,000	,098	,280

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Score_Time_RIC	,831	21,793	2	,000	,856	,867	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: Score_Time_RIC

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power[a]
Score_Time_RIC	Sphericity Assumed	2,836	2	1,418	21,799	,000	43,597	1,000
	Greenhouse-Geisser	2,836	1,711	1,657	21,799	,000	37,306	1,000
	Huynh-Feldt	2,836	1,734	1,636	21,799	,000	37,797	1,000
	Lower-bound	2,836	1,000	2,836	21,799	,000	21,799	,996
Error(Score_Time_RIC)	Sphericity Assumed	15,484	238	,065				
	Greenhouse-Geisser	15,484	203,656	,076				
	Huynh-Feldt	15,484	206,335	,075				
	Lower-bound	15,484	119,000	,130				

a. Computed using alpha = ,05

Appendix O6: one-way ANOVA dependent variable: score/time

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
ScoveDivTimeCtrResInf	Between Groups	1,066	5	,213	4,632	,001
	Within Groups	5,244	114	,046		
	Total	6,310	119			
ScoreDivTimeCtr	Between Groups	,147	5	,029	,455	,809
	Within Groups	7,387	114	,065		
	Total	7,534	119			
ScoreDivTimeResInf	Between Groups	,300	5	,060	,604	,697
	Within Groups	11,333	114	,099		
	Total	11,633	119			

- Groups represents: groups

Multiple Comparisons

Dependent Variable: ScoveDivTimeCtrResInf

Bonferroni

(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
REPR1P	REPR1C	,24005*	,06871	,010	,0340	,4461
	REPR2P	,12233	,06701	1,000	-,0786	,3233
	REPR2C	,21950*	,06783	,024	,0161	,4229
	REPR3P	,04376	,06701	1,000	-,1572	,2447
	REPR3C	,23058*	,06871	,016	,0246	,4366
REPR1C	REPR1P	-,24005*	,06871	,010	-,4461	-,0340
	REPR2P	-,11772	,06791	1,000	-,3213	,0859
	REPR2C	-,02055	,06871	1,000	-,2266	,1855
	REPR3P	-,19629	,06791	,069	-,3999	,0073
	REPR3C	-,00947	,06959	1,000	-,2181	,1992
REPR2P	REPR1P	-,12233	,06701	1,000	-,3233	,0786
	REPR1C	,11772	,06791	1,000	-,0859	,3213
	REPR2C	,09717	,06701	1,000	-,1038	,2981
	REPR3P	-,07857	,06619	1,000	-,2770	,1199
	REPR3C	,10825	,06791	1,000	-,0954	,3119
REPR2C	REPR1P	-,21950*	,06783	,024	-,4229	-,0161
	REPR1C	,02055	,06871	1,000	-,1855	,2266
	REPR2P	-,09717	,06701	1,000	-,2981	,1038
	REPR3P	-,17574	,06701	,149	-,3767	,0252
	REPR3C	,01108	,06871	1,000	-,1949	,2171
REPR3P	REPR1P	-,04376	,06701	1,000	-,2447	,1572
	REPR1C	,19629	,06791	,069	-,0073	,3999
	REPR2P	,07857	,06619	1,000	-,1199	,2770
	REPR2C	,17574	,06701	,149	-,0252	,3767
	REPR3C	,18682	,06791	,104	-,0168	,3904
REPR3C	REPR1P	-,23058*	,06871	,016	-,4366	-,0246
	REPR1C	,00947	,06959	1,000	-,1992	,2181
	REPR2P	-,10825	,06791	1,000	-,3119	,0954
	REPR2C	-,01108	,06871	1,000	-,2171	,1949
	REPR3P	-,18682	,06791	,104	-,3904	,0168

*. The mean difference is significant at the 0.05 level.

- Groups represents: groups

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
ScoveDivTimeCtrResInf	Between Groups	,059	2	,030	,554	,576
	Within Groups	6,251	117	,053		
	Total	6,310	119			
ScoreDivTimeCtr	Between Groups	,047	2	,024	,369	,692
	Within Groups	7,487	117	,064		
	Total	7,534	119			
ScoreDivTimeResInf	Between Groups	,129	2	,064	,654	,522
	Within Groups	11,505	117	,098		
	Total	11,633	119			

* Groups represents: representation type

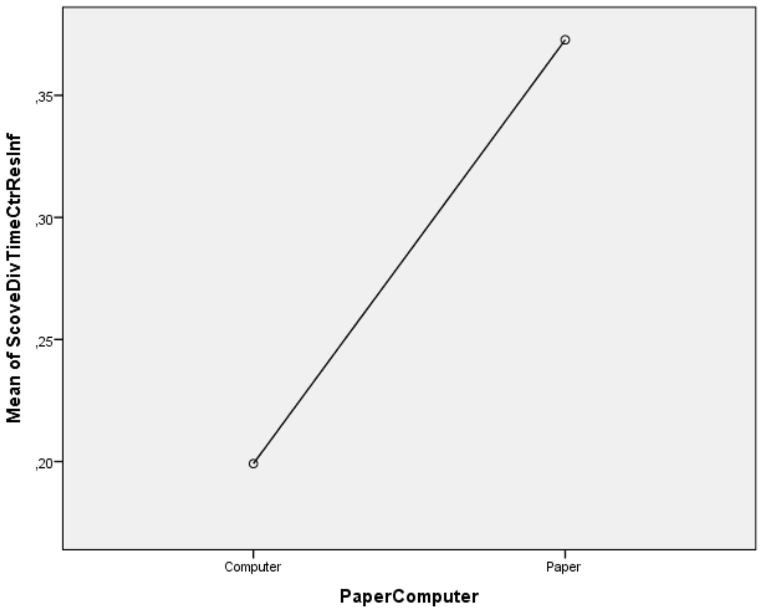
ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
ScoveDivTimeCtrResInf	Between Groups	,903	1	,903	19,710	,000
	Within Groups	5,407	118	,046		
	Total	6,310	119			
ScoreDivTimeCtr	Between Groups	,028	1	,028	,434	,511
	Within Groups	7,507	118	,064		
	Total	7,534	119			
ScoreDivTimeResInf	Between Groups	,039	1	,039	,394	,531
	Within Groups	11,594	118	,098		
	Total	11,633	119			

* Groups represents: representation medium

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
ScoveDivTimeCtrResInf	Computer	58	,1991	,15189	,01994	,1592	,2391	,00	,64
	Paper	62	,3727	,25900	,03289	,3070	,4385	,00	1,18
	Total	120	,2888	,23027	,02102	,2472	,3305	,00	1,18
ScoreDivTimeCtr	Computer	58	,3029	,26387	,03465	,2335	,3723	,00	1,29
	Paper	62	,2726	,24083	,03059	,2114	,3337	,00	1,15
	Total	120	,2873	,25162	,02297	,2418	,3327	,00	1,29
ScoreDivTimeResInf	Computer	58	,4578	,29082	,03819	,3813	,5342	,00	1,35
	Paper	62	,4937	,33323	,04232	,4091	,5783	,00	1,71
	Total	120	,4763	,31266	,02854	,4198	,5328	,00	1,71


Mean of ScoveDivTimeCtrResInf
,35
,30
,25
,20
Computer
Paper
PaperComputer

Appendix P: Summary statistical test results

Table 29: Summary of the statistical results of the one-way ANOVA and the Kruskall-Wallis tests

SUMMARY					
Hypothesis			**F-statistic**	**H-statistic**	***p***
H1: Representation type has an influence on the	**a) score**	Paper	1.90		*ns*
		Computer	2.00		*ns*
	b1) time b2) score/time	Paper	b1) .33, b2) .32		*ns, ns*
		Computer	b1) .03, b2) 1.13		*ns, ns*
	c) perceived usefulness (PU)	Paper		8.81	*.01*
		Computer		-	*ns*
	d) perceived ease of use (PEOU)	Paper		10.58	*.01*
		Computer		-	*ns*
	e) intention to use (ITU)	Paper		-	*ns*
		Computer		7.50	*.02*
H2: Presentation medium has an influence on the	**a) score**	Representation 1	.52		*ns*
		Representation 2	.69		*ns*
		Representation 3	.92		*ns*
	b1) time b2) score/time	Representation 1	b1) .05, b2).76		*ns, ns*
		Representation 2	b1) .28, b2).02		*ns*
		Representation 3	b1) .45, b2) 4.27		*ns, < .05*
	c) perceived usefulness (PU)	Representation 1		5.75	*.02*
		Representation 2		-	*ns*
		Representation 3		4.78	*.03*
	d) perceived ease of use (PEOU)	Representation 1		-	*ns*
		Representation 2		-	*ns*
		Representation 3		-	*ns*
	e) intention to use (ITU)	Representation 1		-	*ns*
		Representation 2		-	*ns*
		Representation 3		5.05	*.03*
H3: The Representation type and Presentation medium have a combined effect on the	**a) score**		1.97		*ns*
	b1) time b2) score/time		b1) .28, b2) 1.01		*ns, ns*
	c) perceived usefulness (PU)			23.29	*.00*
	d) perceived ease of use (PEOU)			20.16	*.00*
	e) intention to use (ITU)			22.61	*.00*
H4: The influence of the representation will be different for different types of understandability questions	**Local**	Score	3.26		*.01*
		1) time, 2) score/time	1) .27, 2) 1.31		*ns, ns*
	Global	Score	.25		*ns*
		1) time, 2) score/time	1) .89, 2) 1.16		*ns, ns*
	Global/Local	Score	.50		*ns*
		1) time, 2) score/time	1) .40, 2) .63		*ns, ns*
	Ctr/Res/Inf	Score	2.58		*.03*
		1) time, 2) score/time	1).45, 2) 4.63		*ns, .00*
	Ctr	Score	1.66		*ns*
		1) time, 2) score/time	1) 3.23*, 2) .45		*.04, ns*
	Res/Inf	Score	.27		*ns*
		1) time, 2) score/time	1) .64, 2) .60		*ns, ns*

* based on the representation type instead of the analysis based on the groups

Appendix Q: Descriptive statistics control variables

Table 30: Descriptive statistics control variables

GROUP				PMIntensity: How often do you encounter process models in practice?	PExperience: When did you first work with process models in practice?	PMKnowledgeLevelPM: How would you rate your level of knowledge on process modeling?	PMKnowledgeLevelBPMN: How would you rate your level of knowledge on the business process modeling notation BPMN 2.0?	PDFamiliarity: How familiar are you in general with the (CAPA) or (CH) process in Philips?
REPR1P	CAPA	N	Valid	10	10	10	10	10
			Missing	0	0	0	0	0
		Mean		2,50	4,30	2,10	1,10	3,10
	CH	N	Valid	10	10	10	10	10
			Missing	0	0	0	0	0
		Mean		2,80	4,70	2,80	1,20	3,20
REPR1C	CAPA	N	Valid	9	9	9	9	9
			Missing	0	0	0	0	0
		Mean		2,44	4,00	2,56	1,00	3,78
	CH	N	Valid	10	10	10	10	10
			Missing	0	0	0	0	0
		Mean		2,60	4,20	2,20	1,20	3,40
REPR2P	CAPA	N	Valid	11	11	11	11	11
			Missing	0	0	0	0	0
		Mean		2,36	4,73	2,09	1,27	2,64
	CH	N	Valid	10	10	10	10	10
			Missing	0	0	0	0	0
		Mean		2,50	4,30	2,10	1,10	3,00
REPR2C	CAPA	N	Valid	10	10	10	10	10
			Missing	0	0	0	0	0
		Mean		2,60	4,20	2,20	1,20	3,50
	CH	N	Valid	10	10	10	10	10
			Missing	0	0	0	0	0
		Mean		2,50	4,20	2,10	1,10	3,70
REPR3P	CAPA	N	Valid	10	10	10	10	10
			Missing	0	0	0	0	0
		Mean		2,80	4,70	2,80	1,20	3,20
	CH	N	Valid	11	11	11	11	11
			Missing	0	0	0	0	0
		Mean		2,36	4,73	2,09	1,27	2,82
REPR3C	CAPA	N	Valid	10	10	10	10	10
			Missing	0	0	0	0	0
		Mean		2,50	4,20	2,10	1,10	3,50
	CH	N	Valid	9	9	9	9	9
			Missing	0	0	0	0	0
		Mean		2,44	4,00	2,56	1,00	3,33

Block 4 (usercode D)
Block 6 (usercode F)