A Systematic Literature Review on the Usage of Eye-Tracking in Understanding Process Models

A SYSTEMATIC LITERATURE REVIEW ON THE USAGE OF EYE-TRACKING IN UNDERSTANDING PROCESS MODELS

Abstract

Purpose – Business process modeling can involve multiple stakeholders, so it is natural that problems may occur in building and understanding them. One way to perceive these problems is to evaluate the comprehension of these models through the collection of data related to the readers' awareness with an eye-tracking device. The purpose of this paper is to provide a comprehensive overview of the use of eye-trackers in understanding process models and provide evidence on the contributions of eye-trackers to new empirical studies in this area.

Design/methodology/approach – To achieve this goal, Systematic Literature Review (SLR) was perfomed following the good practices from the Evidence-Based Software Engineering's (EBSE) field.

Findings - This study resulted in 10 primary studies selected for analysis and data extraction, from the 1,482 initially retrieved. The major findings indicate that the business process community still benefits little from the use of eye-tracking, e.g., not offering sufficient support for inexperienced designers and not having an explicit standardization in its use. These and other findings are synthesized in a research roadmap which results would benefit researchers and practitioners.

Originality/value – Performing an SLR is not a simple task. Thus, the SLR process is presented in detail with the descriptions of all activities to register and trace data and decisions along the process. The models presented here may con-tribute to other researchers in need to perform such a similar study for other re-search questions.

Keywords: Business Process Modeling, Understandability, Comprehension, Eye-Tracking, Systematic Literature Review.

1. Introduction

Establishing efficient processes is the goal that all companies must pursue (Vaknin & Filipowska, 2017). Business processes are a set of activities, well determined, coordinated in time and space to achieve goals and organizational objectives (Alotaibi & Liu, 2017). Besides that, they can be represented in models or diagrams composed of visual components. These models are used as an instrument to facilitate the understanding or even to identify points of improvement in an organization (Melcher & Seese, 2008). In this perspective, business process models are essential so that organizations keep control of their flows of activities.

Recent and more innovative researches analyze how these models are explained and perceived by their stakeholders (Mendoza et al., 2018). Hereupon, users understand models differently, resulting in different abstractions (Figl & Recker, 2016). Contrary to this statement, in (Mendling et al., 2007), the authors state that one of the main objectives of a process model is to facilitate communication between stakeholders. However, according to these authors, little is known about the factors that influence the understanding of a process model by human agents. Thus, despite the research that has already been done in this field, there are still unanswered questions about the perception of process models. Besides that, cognitive neuroscience and psychology can also provide valuable information about this field.

There are several alternatives to evaluating the understanding of business process models. These include experimenting with the collection of data, sometimes with the use of biometric sensors, on the performance of designers and other stakeholders in a given modeling task to know their level of understanding and preferences about the use of a modeling artifact to the detriment of another. Biometric sensors have been explored in recent years as data collection devices become more accessible. Additionally, one of the technologies that have deserved particular attention is eye-tracking.

This paper focuses on these pillars (business process, comprehension, and eye-tracking), offering an overview of evaluating the understanding of process models through eye-tracking techniques. Evidence-Based Software Engineering (EBSE) is used to better understand the problem and the field of the research, and to extract and synthesize the results. EBSE provides a rigorous and reliable research methodology, together with auditing tasks to reduce the researchers' bias on the result (Kitchenham et al., 2004). Two of the core tools for evidence-based studies are systematic literature reviews

(SLR) and systematic mapping studies (Petersen et al., 2008).

Thus, between both types of methods, and based on their differences, it was opted to perform an SLR process due to the possibility of having a more rigorous and controlled process, including a protocol definition and validation, and also because this is study is looking for some specific information regarding the mediation of terms: business processes, comprehension, and eye-tracking.

The remainder of this paper is organized as follows: section 2 gives an overview of introductory concepts; section 3 shows the method used in this study describing the planning phase, execution, and findings. The section 4 discusses the threats to validity; and section 5 shows related works. Finally, section 6 summarizes some gaps in a specific investigation area, providing a research roadmap to guide decisions on new research activities, and this paper is concluded in section 7.

2. Background

2.1. Business Process Modeling

Business process modeling is an interdisciplinary area that has adopted a variety of paradigms and methodologies of different areas such as organizational management theory, computer science, business management, information technology, mathematics, linguistics, semiotics, and philosophy (Ko, 2009). Despite the growing importance of business modeling to the success of organizations, its multidisciplinary origins results in a lack of cohesion and understanding of its definition, fundamental concepts, components and taxonomy of business models (Zott et al., 2011). The aim of business process modeling is to build Business Process Diagrams (BPD), which are technical drawings that translate abstract representations of processes (Wahl & Sindre, 2006).

Since the introduction of flowcharts in the 1920s (Indulska et al., 2009) several notations have been developed to represent BPD. However, regardless of the notation used for a process model, its understanding by all stakeholders is of paramount importance to organizations. Moreover, a suitable analysis and verification of processes at the modeling stage would make easier the process maintenance tasks by reducing their implicit costs. This is why efforts should be made to impose quality characteristics to the process models. The next section presents some concepts about understanding.

2.2. Understanding

Since process diagrams are intended to support the activities of stakeholders with different technical backgrounds, they must have their proper understanding, among other purposes, to facilitate the communication among those kinds of stakeholders (Mendoza et al., 2018). Understanding is a criterion that helps measuring whether the information contained in a model can be understood by all stakeholders (Laue & Gadatsch, 2011). The authors also point out that understanding is one of the criteria used to evaluate the quality of a model. This definition implies that the opinion can be investigated from two central angles: personal factors, related to the reader of the model, and the factors that relate to the model itself.

In addition to this definition, in (Mendling et al., 2012), the authors emphasize that the understanding of a process model is a function related to the characteristics of the model and to the users who will interpret it. For these authors, the understanding of the models by the stakeholders is a prerequisite for several tasks related to the model, such as communication, design, organizational reengineering, project management, end-user queries, etc.

2.3. Eye-tracking

Eye-tracking is a mechanism for collecting cognitive data from its users. This mechanism is used to conduct empirical studies and to study models comprehension (Sharafi et al., 2015a), to realize what can be improved to facilitate, for instance, the interaction of systems with their users. Beyond the analysis of visual attention and cognitive processes, eye-data can also be examined to measure the workload of a task. Thus, the data can be studied with respect to certain areas of the stimuli, which are called areas of interest (AOI). An AOI can either be relevant or irrelevant for a given task that is being performed by a participant. For instance, when considering a business process model as stimulus, a relevant AOI could be a specific activity that is used by the participant to perform a certain task, while an irrelevant AOI would be any other artifact in the model. Thus, such technology allows analyzing user's performance in reading and interpreting business process models.

2.4. Systematic Literature Reviews (SLR)

An SLR aims at establishing the state of evidence and identifying the best practices based on empirical evidence (Kitchenham & Charters, 2007).

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The typical SLR process illustred in Figure 1 is composed of three main phases with the objectives of planning the SLR, conducting the research and reporting the results. In phase "(A) *Plan the SLR*" the objectives are to identify the need of the review, to commission the review, to specify research questions and to review the protocol. In phase "(B) *Search Studies*" the objectives are to collect the studies, to select primary studies, to apply quality assessment, and to extract and synthetize data. In phase "(C) *Analysis of Studies*" the objective is to format and communicate results.
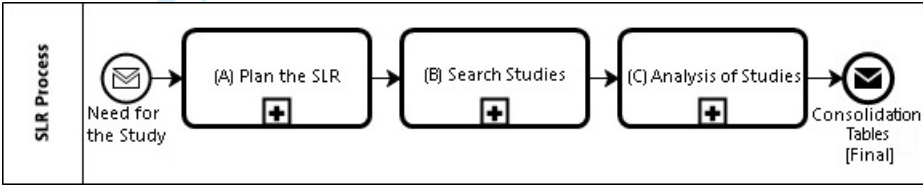

Figure 1: Typical Systematic Literature Reviews Processes.

In general, the complexity and rigor required to conduct an SLR is higher than in a systematic mapping study (Wohlin et al., 2012). A summary of the main differences between both follows:

- Systematic mapping studies typically address broader research questions, and do not require the validation of the process artifacts nor do they impose a quality assessment of primary studies. Their main objective is to classify and summarize the data of some area of interest, with no deeper analysis (Kitchenham et al., 2011).

- SLRs, on the other hand, typically address focused research questions, and require protocol elaboration and validation as well as quality assessment of primary studies. Their main objective is to provide specific evidences based on very specific research questions (Kitchenham & Charters, 2007).

3. SLR Process

This section describes the SLR process performed in this study. The initial intention was to simply apply the method proposed by Kitchenham & Charters (2007). However, as the application of the process evolved, the difficulties of establishing and maintaining a clear SLR strategy, managing

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the amount of data, dealing with a set of non-structured search databases, handling non-standardized papers metadata, supervising changes during the process, ensuring a minimum level of quality of the papers, together with consolidating and classifying data, led us to: defining some control activities to manage data and changes during the execution of the SLR process.

These changes influenced the SLR process defined in Figure 1, where control activities, inputs and outputs were identified. The following subsections present the SLR discussing in detail how the subprocesses, which make up each of the three phases, were here performed.

3.1. Plan the SLR

This subprocess is composed of another subprocess and four activities (Figure 2). Two of those activities (*Review Protocol* and *Define Templates and Rules*) and an additional subprocess (*Define Protocol*) are assigned to the researchers' team in charge and other two (*Analyze Protocol* and *Provide Feedbacks*) are assigned to the reviewers for the execution of the study.
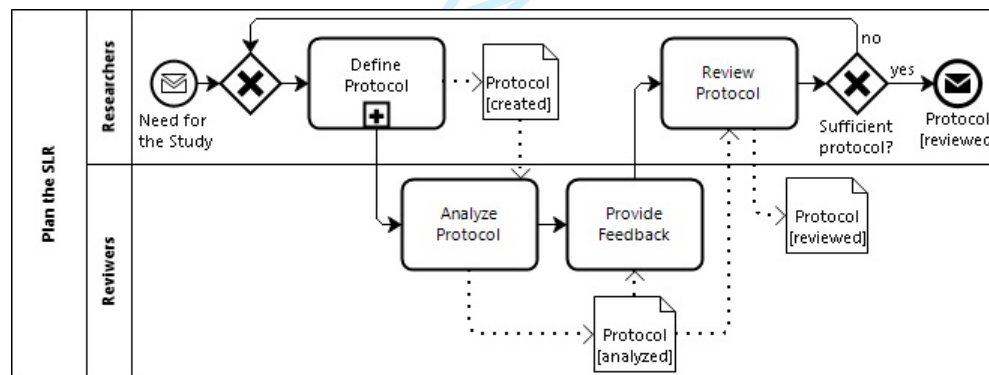

Figure 2: Subprocess (A) Plan the SLR.

3.1.1. Define Protocol

In the *Define Protocol* subprocess the research protocol is formed by the composition of the following elements: research question list, research sources list, research query list, inclusion/exclusion criteria list, data extraction form and quality assessment form. The following subsections describe each activity for the formation of these elements.

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3.1.1.1. Define Research Questions.

The objective of this activity is to determine the scope of the study, defining one or more research questions. It is usually difficult to define the right research question, as it needs to be wide enough to include all relevant studies, but yet focused enough to be effective and selective in the size of the search space. According to Kitchenham & Charters (2007), it is useful to consider the PICOC method. The results of applying PICOC helped focusing on what matters for the study in hand, also guiding the extraction phase of the process. PICOC analysis follow:

- **P**opulation: works that use eye-tracking to analyze the understanding of process models;

- **I**ntervention: the use of eye-tracking in understanding analysis;

- **C**omparison: it doesn't apply, as the analysis or the use of eye-tracking won't be compared, this study just collects as much information as possible to build a catalog that contains a thorough analysis of approaches that use eye-tracking with the intention of measuring how much a model of business process is understandable;

- **O**utcome: relating factors of interest to professionals, e.g., the metrics used to analyze understanding, the notations used to map processes, when and where studies were published and which researchers are using eye-tracking to analyze model understanding of processes;

- **C**ontext: works that highlight the scope of using eye-tracking to analyze the understanding of process models.

In summary, this piece's goal is to identify the quality attributes and factors that are used by eye-tracking which can aid in understanding models. Hopefully future research can use our findings to help business designers build their business process models. Thus, allowing the construction of more intuitive process models for all readers. Hence, the research questions defined in this SLR were:

- RQ1: Is eye-tracking technology being used in the analysis of the understanding of business process models?

- RQ2: What metrics are used to measure the visual comprehension of eye-tracking business process models?

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- RQ3: Which business process model's notations are evaluated in the studies?

- RQ4: What contributions have been reported about the application of the eye-tracker device to evaluate the understanding of the process models?

3.1.1.2. Define Search Sources.

The objective of this activity is to identify sources to perform searches, as well as the kind of search that should be performed. The search can be automatic in digital libraries, where the results are collected through a search query execution, or manual, where the results are collected manually in the selected conferences and journals databases. Typically, both alternatives are selected. The digital libraries sources selected for this study were: Web of Science, ACM Digital library, IEEE Explore, Science Direct (Elsevier), Scopus, Springer Link, and Engineering Village.

The manual searches included conferences and journals related to business process. In both cases, DBLP[1] and Google Scholar were used to support the searches with additional information on each paper, such as number of citations and author information.

3.1.1.3. Define Search Queries.

The objective of this activity is to define keywords and *boolean* expressions to per-form automatic searches in digital libraries. The first step to define the search queries was the identification of keywords. The list of keywords was based on a preliminary *ad-hoc* search, with the purpose of guaranteeing that relevant terms would not be omitted from the very beginning. Table 1 shows the keywords used in the final queries, already grouped with *boolean* operators.

Table 1: Search queries.

	Queries
Web of Science	TS=(("*eye-tracker*" **OR** "*eye tracker*" **OR** "*eye-tracking*" **OR** "*eye tracking*" **OR** "*restricted focus viewer*") **AND** ("*BPM*" **OR** "*business process model*" **OR** "*business process*" **OR** "*process model*") **AND** ("*understanding*" **OR** "*comprehension*" **OR** "*comprehensibility*"))

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[1]https://dblp.org/

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ACM Digital Library	[[Abstract: *eye-tracker*] **OR** [Abstract: *eye tracker*] **OR** [Abstract: *eye-tracking*] **OR** [Abstract: *eye tracking*] **OR** [Abstract: *restricted focus viewer*]]] **AND** [[Abstract: *BPM*] **OR** [Abstract: *business process model*] **OR** [Abstract: *business process*] **OR** [Abstract: *process model*]] **AND** [[Abstract: *understanding*] **OR** [Abstract: *comprehension*] **OR** [Abstract: *comprehensibility*]]
IEEExplore	(("Abstract":*eye-tracker* **OR** "Abstract":*eye tracker* **OR** "Abstract":*eye-tracking* **OR** "Abstract":*eye tracking* **OR** "Abstract":*restricted focus viewer*) **AND** ("Abstract":*BPM* **OR** "Abstract":*business process* **OR** "Abstract":*process models* **OR** "Abstract":*business process models*) **AND** ("Abstract":*understanding* **OR** "Abstract":*understandability* **OR** "Abstract":*comprehension* **OR** "Abstract":*comprehensibility*))
Science Direct	(("*eye-tracker*" **OR** "*eye tracker*" **OR** "*eye-tracking*" **OR** "*eye tracking*" **OR** "*restricted focus viewer*") **AND** ("*BPM*" **OR** "*business process*" **OR** "*process models*" **OR** "*business process models*") **AND** ("*understanding*" **OR** "*understandability*" **OR** "*comprehension*" **OR** "*comprehensibility*"))
Scopus	TITLE-ABS-KEY (("*eye-tracker*" **OR** "*eye tracker*" **OR** "*eye-tracking*" **OR** "*eye tracking*" **OR** "*restricted focus viewer*") **AND** ("*BPM*" **OR** "*business process*" **OR** "*process model*" **OR** "*business process model*") **AND** ("*understanding*" **OR** "*understandability*" **OR** "*comprehension*" OR "*comprehensibility*"))
Springer Link	(("*eye-tracker*" **OR** "*eye tracker*" **OR** "*eye-tracking*" **OR** "*eye tracking*" **OR** "*restricted focus viewer*") **AND** ("*BPM*" **OR** "*business process*" **OR** "*process models*" **OR** "*business process models*") **AND** ("*understanding*" **OR** "*understandability*" **OR** "*comprehension*" **OR** "*comprehensibility*"))
Engineering Village	(("*eye-tracker*" **OR** "*eye tracker*" **OR** "*eye-tracking*" **OR** "*eye tracking*" **OR** "*restricted focus viewer*") **AND** ("*BPM*" **OR** "*business process*" **OR** "*process models*" **OR** "*business process models*") **AND** ("*understanding*" **OR** "*understandability*" **OR** "*comprehension*" **OR** "*comprehensibility*"))

3.1.1.4. Define Inclusion and Exclusion Criteria.

The objective of this activity is to establish a set of criteria to filter out unnecessary studies. Here it is interesting to highlight that even after refining the search queries, the resulting number of papers can still be refined through a set of inclusion and exclusion criteria, to guarantee minimal quality of the results. We included peer-reviewed papers from journals, conferences and workshops which included eye-tracking technology in the analysis of understanding process models (I1), and relevant studies cited by authors of the papers were read during the conduction process obtained by forward snowball search (I2). On the other hand, we excluded papers with unavailable access (E1), papers with only abstract available; extended abstracts or short papers (less than six pages) (E2), duplicated papers (E3), papers that did

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not apply to research questions (E4), papers written in other than the English language (E5), and Papers not meeting some quality criteria (regarding quality criteria, more details are given in the section 3.1.1.6) (E6). Given that not all the criteria are mutually exclusive and the execution order matters, it is suggested the following criteria priority: I1, I2, E1, E2, E3, E4, E5, and E6. This sequence was particularly important in our case with four people executing the SLR.

3.1.1.5. Define Data Extraction Strategy.

The objective of this activity is to define a strategy to extract data from selected primary studies. In our case a template was defined to record the relevant information related to the research questions. The five sections of this template should be filled according to the following indications:

- Section 1 (mandatory): records basic information on the paper - paper identifier, title, conference or journal, year, number of citations, digital library;

- Section 2 (optional): records the metrics used to measure the visual comprehension of eye-tracking business process models;

- Section 3 (optional): records the business process model notation that was used in the study;

- Section 4 (optional): records the information directly associated with the contributions that have been reported about the application of the eye-tracker device;

- Section 5 (optional): records the profile of the subjects who used the eye-tracking device.

The data extraction form must be filled with the mandatory section, and at least one of the optional sections. This is necessary because not all the papers answer all the research questions.

3.1.1.6. Define Quality Assessment.

The objective of this activity is to define the criteria to measure the quality of each primary study. However, there isn't an agreed definition of what a high-level quality study is; there is, though, a common agreement

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that the quality of the selected primary studies is fundamental to obtain more reliable results (Kitchenham & Charters, 2007).

Thus, four quality assessment criteria (QA1–QA4) were defined to be considered when applying the excluding criteria E6, using an approach similar to that in Jamshidi et al. (2012) and based on bibliometric impact information. While QA1 uses four general and four specific criteria (Table 4), QA2 uses the ranking of the publications forums, QA3 uses the papers' citations and QA4 relaxes QA3. Each of these criteria is discussed next.

QA1 is calculated using the *QualityScore* given by Equation 1, where the General (G) and Specific (S) assessment factors are summarized in Table 2. The result is a numerical quantification to rank the selected studies. The quality assessment checklist, with G and S composed of four items each and each one with a maximum score of 1, shows a weighted average, where S weights 3 times more than G, as the specific contributions (S) of a study are more important than the general contributions (G). Papers with an overall score $>= 2.5$ were considered "*high*" quality studies; papers with a score $>= 1.5$ and < 2.5 were considered "*medium*" quality; and papers with a score < 1.5 were considered of "*lower*" quality and were excluded from the analysis. It is important to highlight that there is no evaluation of the paper's quality itself with this criterion, but only its contributions' alignment with this study's purpose.

$$QualityScore = [\frac{\sum_{G=1}^{4}}{4} + (\frac{\sum_{S=1}^{4}}{4} \times 3)] \tag{1}$$

Table 2: Quality Assessment Checklist.

General Items (G) = 25%	Specific Items (S) = 75%
G1: Problem definition and motivation: a) Explicit Definition (1.0) b) General Definition (0.5) c) No definition (0.0)	S1: Evaluation of the study: a) Formalized evaluation (1.0) b) Some informal evidences are provided (0.5) c) Non-justified or *ad-hoc* validation (0.0)

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G2: Research methodology: a) An empirical methodology (1.0) b) A generalized analysis (0.5) c) Lacks any proper methods (0.0)	S2: Definition of the experimentation method: a) Formalized experimentation method (1.0) b) Some informal evidences are provided (0.5) c) Non-justified or *ad-hoc* experimentation method (0.0)
G3: The study contributions refer to the study results: a) Explicitly correlates contributions to results (1.0) b) There isn't correlation between contributions and results (0.5) c) There isn't description of contributions or results (0.0)	S3: Metrics to validate comprehension characteristics: a) Formalized definition of metrics (1.0) b) Some informal definition of metrics (0.5) c) Non-justified or *ad-hoc* definition of metrics (0.0)
G4: Limitations and future implications of the study: a) Formalized empirical evaluations (1.0) b) Some informal evidences are provided (0.5) c) Non-justified or *ad-hoc* validation (0.0)	S4: Use of another device in addition to eye-tracking: a) Formalized definition of another device (1.0) b) Some informal definition of another device (0.5) c) No definition (0.0)

The second quality assessment criteria (QA2) rates papers according to the forums where they were published. For this assessment CORE[2] was used to determine the rates for conferences and SJR[3] for journals. It considers "*high*" for papers published in conferences rated "A" or in journals rated "Q1", and "*medium*" for papers published in conferences rated "B" or in journals rated "Q2". It considers "*lower*" for papers published in conferences rated "C" or in journals rated "Q3". Forums which have no scores are considered "*lower*" too.

The third quality assessment criteria (QA3) rates papers according to

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[2]http://portal.core.edu.au/conf-ranks/
[3]https://www.scimagojr.com/journalrank.php

their citations. In which, one paper is considered a "*high*" score for articles with more than five citations, a "*medium*" score for articles with less than five citations and "*lower*" score for papers without citations. Google Scholar[4] will be used to verify number of citations.

However, the QA3 will be unfair to recent work for having fewer citations. For these cases, the fourth quality assessment criteria (QA4) analyzes articles from the last five years, which have potentially "*high*" relevance, have at least one citation and articles that have not been cited have potentially "*medium*" relevance. For a paper to be included in the review, an article must obtain $CQ1 >= 1.5$ and its criteria for bibliographic impact CQ2, CQ3 and QA4 must be "*medium*" or higher.

3.1.2. Analyze Protocol, Provide Feedback and Review Protocol

The objective of these activities is to evaluate and validate the SLR protocol. Thus, outcomes from phase (A) where evaluated by Reviewers during a session with two specialists. These specialists are experts in EBSE. For this reviewing session, it was prepared a 30-minute presentation with the objective of the study, the process followed, and the outcomes. After presentation, there was a session to discuss and collect reviewer comments based on the presentation.

3.2. Search Studies

This subprocess is composed of four activities (Figure 3). From these activities, three are assigned to the researchers in charge of the study and one is assigned to the reviewers. The researchers are responsible for the activities *Perform Search in the Sources*, *Analyze Search Results* and *Apply Quality Assessment*; and the reviewers are responsible for the *Review Primary Studies* activity. Each activity will be detailed in next sections.
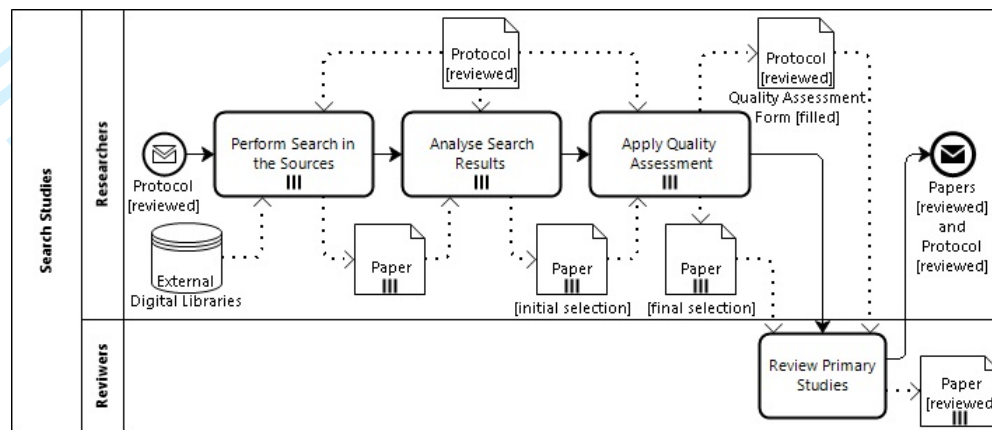
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[4]https://scholar.google.com

Figure 3: Subprocess (B) Search Studies.

3.2.1. Perform Search in the Sources

The objective of this activity is to execute the searches in digital libraries. Hence, some specific configurations were considered during the search in each database, e.g., advanced search with command line was selected in all databases as it demonstrated to be more accurate than a simple advanced search. This said, papers metadata was used to perform the searches.

About the studies, they were automatically collected in digital libraries using the defined search queries (Table 1). In total 1,482 were found, where the majority, 713 (48.27%), came from the Springer Link library. The library Science Direct returned 502 (33.99%), the second-largest number of studies. The remaining libraries returned a much smaller amount of studies, in which: 180 (12.19%) studies were retrieved from the ACM Digital Library, 27 (1.83%) came from Scopus, 23 (1.56%) were retrieved from the IEEE, 20 (1.35%) came from Engineering Village and finally 12 (0.81%) came from Web of Science.

3.2.2. Analyze Search Results and Apply Quality Assessment

The objective of these activities is to analyze the studies to select the list of primary studies and perform quality assessment. In the *Analyze Search Results* activity the initial selection phase is carried out. At this stage, the inclusion and exclusion criteria, with the exception of E6, were applied in all the studies identified, through the evaluation of titles, keywords, and abstracts. However, in some cases, it was difficult to determine whether or not the research was relevant only by reading those data. Thus, whenever

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there was any doubt about the inclusion or not of a particular study, the recommendation adopted - at this stage - was by its inclusion, being the decision of keeping it postponed to the final selection.

Figure 4 shows the amount of studies found, segmented by the selection criteria in the two selection phases. In this initial selection, from the 1,482 studies found, 1,455 were excluded when applying the exclusion criteria. So, based on this first selection, only 27 primary studies were taken to the final selection.
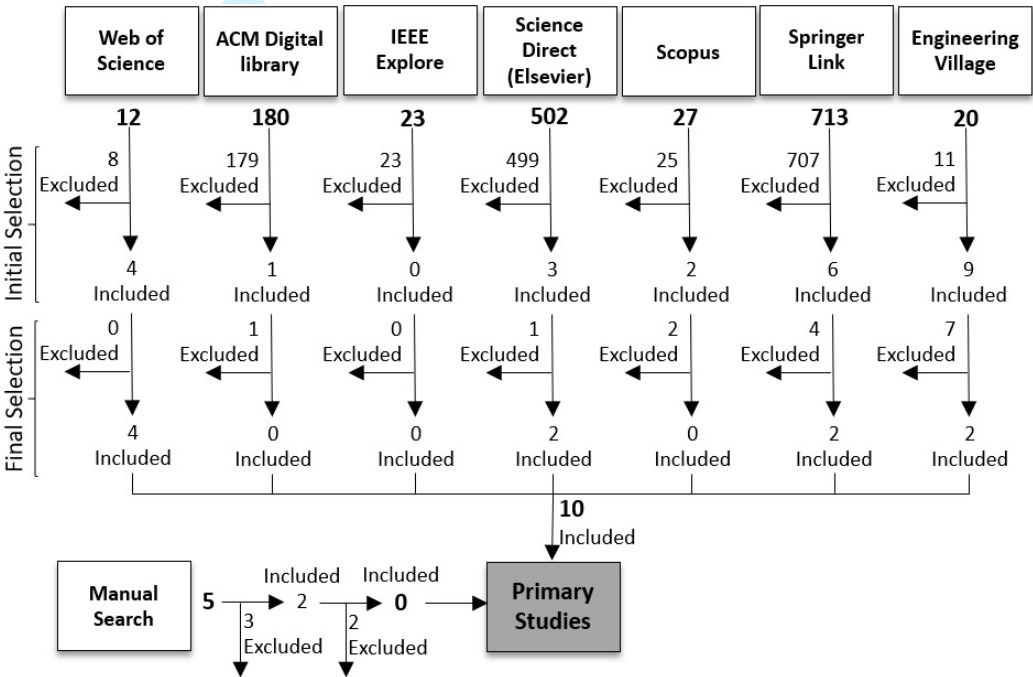
Figure 4: An Overview of the Primary Studies Selection.

Next, the *Apply Quality Assessment* was utilized, in it all the inclusion and exclusion criteria (including the E6) were applied again in the studies included in the first stage, through the evaluation of their complete texts. Thus, for 27 studies selected in the previous phase, 3 were rejected by the exclusion criteria (E1 to E5) after reading the entire text. Therefore, the quality criteria were applied to the 24 remaining studies.

When applying the E6 criteria, 14 papers obtained in the QA1 criterion a value less than 1.5 or were considered "*lower*" by one more of the other

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criteria (QA2, QA3 or Q4) reducing to 10 the number of studies for *Review Primary Studies*.

3.2.3. Review Primary Studies

The objective of this activity is to review lists of selected primary studies. The reviewers' related activity was performed by an expert in EBSE, with experience in business process management, with the objective to decide and confirm included and excluded papers.

Here, it is interesting to highlight that the two selection stages were performed independently and in parallel by two researchers. So, any inconsistency from the re-searchers can be reviewed by a third person in the search for a concession between the selected papers. The product of this activity is a single list of selected and reviewed papers.

3.3. Analysis of Studies

This subprocess is composed of five activities (Figure 5). From these activities, four are assigned to the researchers of the study and one is assigned to the reviewers. The researchers apply the *Data Extraction Strategy*, *Consolidate Results*, *Analyze Consolidated Results*, and *Review Consolidated Results*. The reviewer comments and review the results (*Comment and Review the Results*).
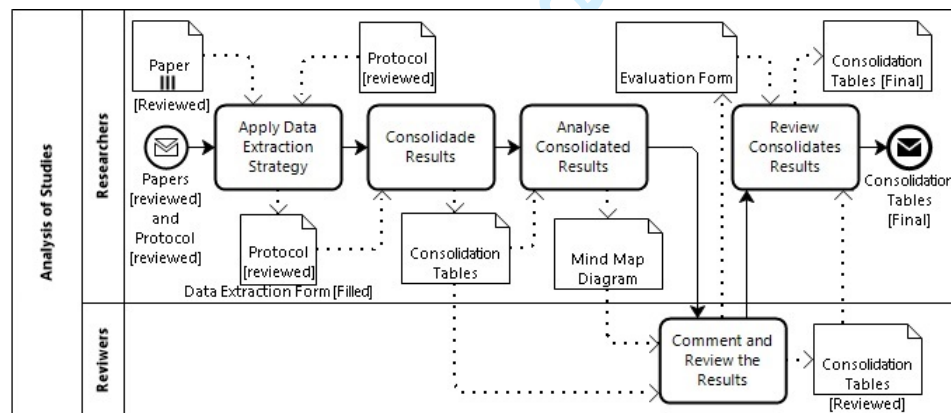

Figure 5: Subprocess (C) Analyze Studies.

3.3.1. Apply Data Extraction Strategy and Consolidate Results

The objective of these activities is to extract data from the selected primary studies and consolidate the findings. Hence, the set of 10 primary

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studies were analyzed for the data extraction process, and a form was filled for each paper. Each paper received a unique identifier in the data extraction form.

3.3.2. Analyze Consolidated Results

The objective of this activity is to analyze the consolidated data to provide a classification and review results. The analysis starts with a summary of the demographic data for the primary studies and proceeds to discussing the results according to the aforementioned research questions.

3.3.2.1. Demographic Data.

This section describes important information such as where, when and who published the selected papers. Table 3 shows the segmented papers by type of publication. Half of the papers are conference articles and half of the studies are journal papers. Still in table it is possible to observe the names of the journals, conferences and workshops with their respective publication numbers. The table also shows that the International Conference on Business Process Management has the largest number of publications, with three studies. On the other hand, there were no repetitions in relation to publications in journals.

Still in the Table 3, we can observe the citations number of the selected studies. From the 10 selected studies there is a total of 125 citations. The studies of the Petrusel et al. (2016, 2017); Petrusel & Mendling (2013); Pinggera et al. (2012) were the most cited accounting for 88% of citations. In this context, it is possible to highlight that perhaps the number of citations in the study by Pinggera et al. (2012) is due to its pioneering nature. Just as importantly, it should also be highlighted the studies by Tallon et al. (2019); Bera et al. (2019); Vermeulen (2018) with just one quote, as they are more recent.

About the authors of the selected studies, out of the 33 authors, 5 (five) Razvan Petrusel and Jan Mendling owning 3 (three) studies, and Barbara Weber, Hajo A. Reijers, Manfred Reichert and Rüdiger Pryss with 2 (two) studies.

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Table 3: Overview of the selected papers.

	Source	Title	Citations	Reference
Journal	Data & knowledge engineering	Learning process modeling phases from modeling interactions and eye tracking data	4	Burattin et al. (2019)
	Decision Support Systems	How visual cognition influences process model comprehension	27	Petrusel et al. (2017)
	Expert systems with applications	Comprehension of business process models: Insight into cognitive strategies via eye tracking	1	Tallon et al. (2019)
	Information and Software Technology	Task-specific visual cues for improving process model understanding	19	Petrusel et al. (2016)
	MIS Quarterly	Using eye tracking to expose cognitive processes in understanding conceptual models	1	Bera et al. (2019)
Conference	International Conference on Business Process Management	Using insights from cognitive neuroscience to investigate the effects of event-driven process chains on process model comprehension	5	Zimoch et al. (2018)
		Business process and rule integration approaches - an empirical analysis	3	Chen et al. (2018)
		Investigating the process of process modeling with eye movement analysis	36	Pinggera et al. (2012)
	International Conference on Advanced Information Systems Engineering	Eye-tracking the factors of process model comprehension tasks	28	Petrusel & Mendling (2013)
Workshop	On the Move to Meaningful Internet Systems: OTM Workshops	Real-time business process model tailoring: The effect of domain knowledge on reading strategy	1	Vermeulen (2018)

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3.3.2.2. Context.

Is eye-tracking technology being used in the analysis of the understanding of business process models? All the studies found used the eye-tracking device to verify comprehension in business process models, each study using the device to evaluate different topics in the understanding of the models. Studies were categorized by topics. Studies Zimoch et al. (2018) and Bera et al. (2019) use the eye-tracking device to evaluate different business process modeling notations to determine which is best understood.

Studies Petrusel et al. (2016) and Chen et al. (2018) assess the understanding of structures or specific elements from which they were added in the notation. The remaining studies evaluate how different readers understand business process models in a particular notation.

What metrics are used to measure the visual comprehension of eye-tracking business process models? Typically, there are many methods for exploring eye-data. The most common one is to analyse the visual path (scan-path) of the participant across a computer screen, where each eye-data observation is translated into pixel coordinates. From there, the presence or absence of eye-data points in different AOIs can be examined (Sharafi et al., 2015b). This type of analysis, found in studies, is used to determine which features are seen, when a particular feature captures attention, how quickly the eye moves, which content is overlooked, among other gaze-related questions.

Therefore, Table 4 presents the metrics used to evaluate the understanding of business process models. Ocular data found in the studies were classified based on 4 (four) indicators.

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Table 4: Metrics used with your descriptions.

Descriptions Metrics	
Fixation	The eye-fixation metric was used in most (70%) of the mapped studies. The fixation consists of the visual attention time of the participant in an area of interest while performing a task (Santos et al., 2016). On average the eyes move to a new fixation position during business process model viewing about three times each second, though there is a good deal of variability in the duration of fixations (Burattin et al., 2019; Bera et al., 2019; Vermeulen, 2018; Petrusel et al., 2017, 2016; Pinggera et al., 2012). Two important issues for understanding eye movements during models perception are: where a fixation tends to be directed; and how long it typically remains there. In this context, researchers in psychology claim that most of the information acquisition and cognitive processing occur during fixations (Irwin, 2004). These eye fixations are intercalated by rapid eye jumps, called saccades, during which vision is suppressed;
Saccade	The saccade metric was used in 20% and consist of the sudden, swift movement that occurs between eye-fixations, it has a duration of about 40 to 50 milliseconds (Santos et al., 2016). Researchers in psychology claim that there is evidence that these saccade-induced shifts of visual attention not only facilitate stimulus processing at the saccade target location, but also influence the contents of mental representations as well (Irwin, 2004). This metric supports the conclusion that attention shifts obligatorily to the location of the saccade target, thereby increasing the likelihood that features near that location will be conjoined and encoded as integrated objects into memory (Vermeulen, 2018; Zimoch et al., 2018). Thus, understanding a business process model involves the sequencing, scan-path, and those saccades;
Scan-Path	A scan-path metric is a set of fixations or AOI, in chronological order. Here, they were used in 30% of the studies. In this context it is interesting to highlight that an AOI is visit-ed if there is at least one fixation in it. Hence, scan-paths and AOI can be connected with the participants' understanding strategies of the business process models. Researchers in psychology showed that scan-paths are representative of the tasks being performed by participants (Sharafi et al., 2015b);
Duration	Also, as a metric the duration was found, used in 50% of the studies. The duration represents the time that the participant takes to complete a given task (Sharafi et al., 2015b). Generally, these tasks involve checking the understanding of the models (what does the model represent?). In other words, checking if the participants have difficulties in performing the tasks (Bera et al., 2019; Tallon et al., 2019; Vermeulen, 2018; Petrusel et al., 2017; Pinggera et al., 2012).

It is interesting to highlight that associated with the metrics, 40% of the studies (Tallon et al., 2019; Chen et al., 2018; Zimoch et al., 2018; Pinggera

et al., 2012) used a questionnaire with questions about the domain of business process models. According to the number of correct answers, the studies indicate whether the participants understood the models or not.

Which business process model notations are evaluated in the studies? All the studies evaluate the comprehension of business process models in BPMN notation (OMG, 2011). Just the study Bera et al. (2019) compares the understanding between models in BPMN (OMG, 2011) and EPC (Scheer & Nüttgens, 2000).

What contributions have been reported about the application of the eye-tracker device to evaluate the understanding of process models? The selected studies present results that show that the application of the eye-tracking device can offer essential contributions to the understanding of the process models. Table 5 presents the contributions of the selected studies.

Table 5: Studies Contributions.

Contributions
The new analysis technique and the exploring of new source data resulted in higher precision at identifying the types of phases in the process of models' creation in relation to the traditional technique. This technique allowed identifying factors such as: problems' comprehension, methods' discovery, semantic and syntactic validation (Burattin et al., 2019).
This study has two experiments. In the first experiment, a sample with 1047 students from school classes was evaluated. The second study had a sample of 21 specialists and 15 beginners in the use of process models. Three process models, in BPMN notation, with increasing complexity levels were used in the experiment. Participants in both samples demanded longer response times with increasing model complexity. For Sample I, Six latent classes with qualitatively differing solution profiles were adequate to classify scholars. These configurative and non-ordered profiles can be interpreted as separate solution patterns, where specific model parts are understood better than others. For the sample could not find significant differences in cognitive solution patterns between experts and novices. Thus, understanding and "solving" process models does not seem to depend too much on visual literacy as defined in this study. Apparently, comprehending the logic behind IF and OR gates as well as recognizing pathways is crucial to follow the information flow in process models (Tallon et al., 2019).

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The authors perform a comparative study between the EPC and EPC-H notation, the latter is a variant of the EPC, proposed by the authors, in which the organizational units and the associated activities in an EPC model are highlight-ed by marking each function with a different color. In addition, the authors carry out a second comparative study between EPC-H and BPMN. The study found that participants viewed EPC models spent significantly more time in terms of fixation and duration than participants viewed EPC-H and BPMN models. In addition, participants viewed the variation in EPC notation proposed by the authors (EPC-H) spent significantly more time than participants who viewed BPMN models. The study indicates that coloring the EPC model has beneficial effects on its understanding, however even without the use of colors, the BPMN notation has better compressibility than colored EPC (Bera et al., 2019).

The results of matched *post-hoc* comparisons show that diagrammatic integration is associated with greater accuracy of comprehension rather than text annotation and link integration. Obviously, there is no significant difference in mental effort between different integration approaches. The presence and quantity of XOR gateways, AND gateways and issues that require navigation of constructions through loop structures, seems to influence understanding (Chen et al., 2018).

It is a work in progress, appearing only the strategy of how a future experiment will run. In the pilot experiment, the visual behavior of 10 participants was analyzed to confirm the theory of the existence of different BPD reading strategies (Vermeulen, 2018).

The performance of participants decreases as the level of difficulty increases. However, regardless of their level of expertise, all individuals have similar standards when faced with process models that exceed a certain level of difficulty. Participants' overall performance demonstrates a better understanding of business process models in EPC notation compared to the BPMN (Zimoch et al., 2018).

There is no influence between the reader's familiarity with business mastery and the proper understanding of the model. They point out that a Visual Cognition Efficiency (measured by Scan Path Precision and Recall) and Visual Cognition Intensity (measured by Total Fixtures and Total Fixture Length) better explain the comprehension performance (higher efficiency, shorter duration) than a model of personal knowledge and model complexity. For them, higher levels of specialization in business process modeling and lower complexity of the model lead to better cognitive efficiency (Petrusel et al., 2017).

The performance in the understanding of the models was better with the collaborative model than the individual, and the layout change of the BPMN models proposed by the experiment (Petrusel et al., 2016).

The elements of the area of interest are fixed for longer than other elements of the model by the subjects who provided the correct answer to the question of understanding. More elements of the area of interest are set than other elements of the model by subjects who provided the correct answer to the question of understanding (Petrusel & Mendling, 2013).

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It can be observed that the average duration is smaller for the fixations in the task description compared to the fixations in the process model. The perceived lower complexity, once, allows the modelers to consider additional features of the model, such as secondary notation of the process model from the outset. It is noticeable that when the average length of fixings is increased by about 30%, the participants are facing a challenging part of the model (Pinggera et al., 2012).

3.3.3. Comment and Review Results and Review Consolidated Results

The objective of these activities is to evaluate and validate the data consolidation files. Thus, classified and consolidated results were evaluated by two reviewers. These reviewers' background was on business process management, software engineering, empirical software engineering and statistics. The final results were validated with the insertion of some suggestions to represent the results of the data.

4. Threats to Validity

The main limitations of this study are related to the manual control process, as well as the subjectivity to classify and consolidate data. To minimize the impact of these limitations, a set of review activities was performed. A validation session with two (2) software engineering specialists was undertaken during phase (A) *Plan the SLR*, with two activities assigned to the reviewers, *Analyze Protocol* and *Provide Feedback*. In phase (B) *Search Studies*, one activity was assigned to the reviewer *Review Primary Studies*. Their feedback was very useful to improve the quality of the process artifacts. For example, quality assessment was applied to primary studies to support the reviewers' evaluation. During phase (C) *Analyze Studies*, the reviewers performed an activity, *Comment and Review Results* and the researchers more a *Review Consolidated Results*.

Regarding our SLR we were so totally immersed in the work that objectivity could be thought as an issue. To mitigate this risk, in addition to choosing only peer-reviewed papers, the *QualityScore* approach was used to reduce the subjectivity of the analysis, and used quality assessment criteria based on bibliometric impact information.

5. Related Works

The studies of the Dikici et al. (2018) and Figl (2017) investigate the factors that in-fluence the understanding of process models but do not specif-

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ically address the use of eye-tracking as a way of measuring comprehension. However, there is the study Sharafi et al. (2015b) that verifies the use of eye-tracking technology in software engineering. This study conducts a comprehensive survey, but that does not explicitly address business process models. Moreover, this research (Sharafi et al., 2015b) is limited until the year 2014 and with only one search source. After the research by similar studies and in the context already mentioned in the present work, it was necessary to perform the systematic mapping to know the aspects involved in the understanding of the business process models through techniques and eye-traking.

In recent work, we performed a systematic literature mapping (SLM) that identifies and analyses primary studies to provide an overview of researches that evaluate the understanding of process models through eye-tracking techniques (Anonymous et al., 2019)[5]. However, the underlying protocol doesn't impose a quality assessment of primary studies. Furthermore, this study only presents a list with studies on using eye-tracking for investigating quality aspect of business process models (or their notations).

In the present paper, it was revisited the SLM described in Anonymous et al. (2019), enriching the process with quality assessment measures to evaluate primary studies list. Quality measure is an important way to classify the primary studies to allow further analysis and prioritization. The quality assessment measures applied during this revisit determines the relevance and impact of the paper. Additionally, as presented in section Threats to Validity, a set of control activities was included in the revisit to add transparency to the execution and management of activities.

Finally, in this revisit several open issues were presented, identifying gaps in current research in order to suggest areas for further investigation. Therefore, we also differentiate ourselves from previous work by providing a structure and background for the proper development of future research activities.

6. Research Roadmap

The previous discussions of the results and major findings highlight several open is-sues, suggesting worthwhile topics for future research. Table 6 illustrated some of these issues.

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[5]Reference omitted to ensure this manuscript is correctly prepared for double-blind peer review.

Table 6: Topics for future research.

Open Issues
To propose a method for the quantitative evaluation of the quality of business process models and their modelling activities: the idea here is to define (bio)metrics, with the aid of eye-tracking, about the models and the way stakeholders interact with them, using scenarios to evaluate their usability (under-standing) in terms of appropriateness recognisability and learnability.
To evaluate the effect of the layout guidelines on the modelling novice stakeholders' ability to understand and review their business process models: the idea here is to perform an experiment where participants are given tasks of the understanding and reviewing. Both tasks must involve a model with a bad layout and another model following layout guidelines with good practices. Thus, with the aid of eye-tracking, it will be possible to evaluate the impact of layouts by combining the success level in those tasks and the required effort to accomplish them.
To define a consistent terminology with metrics' names, and methods: the idea here is to define standard guidelines and terminology while conducting and reporting an eye-tracking experiment. Using standard guidelines to design experiments for mod-elling tasks could reduce the risks of failure and also mitigate threats to validity. Using a uniform way to report an experiment that uses eye-tracking can benefit our community. This standardization can provide valuable information on how to re-view, replicate and analyze the data from an experiment with the eye-tracking. Here it is worth mentioning that conducting an eye-tracking experiment requires further, more specific recommendations with regards to the limitations associated with this technology.
To study the differences in business process models comprehension watching navi-gation strategies between experienced and less experienced business designers in the modelling languages: the idea here is to use eye-tracking technology and have inves-tigated how designers understand business models. That is, to use the eye-tracking technology to study the differences in models comprehension and models reading nav-igation strategies between experienced and less experienced business designers in the notations to represent BPD, e.g., BPMN.
To verify the cognitive effectiveness of business process models: in particular, the business process community is concerned with bridging the perceived gap between sophisticated modelling languages approaches and the stakeholders with whom de-signers need to interact with. As such, devising ways of making these processes languages more accessible is perceived as very important. The idea here is to propose approaches to help improving the understandability of processes models, by improving the concrete syntax of those models through the definition of a set of principles, for designing cognitively effective visual notations. In this case, cognitive effectiveness must be obtained by the speed, ease and precision with which the business model content can be understood by the stakeholders.

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> To use semiotic theory to check the denotations (signs) of the process models notations, for example, BPMN: the process of interpretation, called semiosis, at the pragmatic level necessarily results from and depends on the use of the sign. So, the idea here is to use eye-tracking to validate and verify the three aspects of a sign: syntax (between sign representations), semantics (between a representation and its referent) and pragmatics (between the representation and the interpretation) in semiotic levels. This research can be viewed in terms of its potential in fluence on the stakeholders' subsequent actions as a means of communication, according to the understanding of the process model's artifacts.

7. Conclusions

Performing an SLR is not a simple task. The challenges are several and the skills and time required are not always available in a research group, and hardly in an industry-like set up. This paper presents an enriched SLR process with control activities and discusses how to achieve the prescribed objectives. Also, it shares a set of templates to register and trace data and decisions along the process.

Thus, with this SLR we performed a study to find empirical evidence about how the eye-tracking technology has been applied in the understanding of the business process models. The final result is an overview of the current practice of eye-tracking in business process models, and it can be seen that the business process community takes little advantage from the use of eye-tracking. The evidence found indicates that the selected studies are strongly concerned with the understanding of process models, but none of them are concerned with recognition and the ability to learn modeling itself. Also, it was possible to verify that there is no standardization about the use of eye-tracking technology in the analysis of the process models. Although there is a standardization of terms used in the use of eye-tracking, for instance, ocular, sacral, sweep path, duration and attempt-pill.

These issues identified can be used to offer a research agenda. In works intended for the near future, we will focus our research on the systematization of the manner in which an evaluation with an eye-tracking should be built. Also, we will contribute to improve the state of practice with the conduction of controlled experiments to evaluate the understanding of business process modeling on the fly.

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References

Alotaibi, Y., & Liu, F. (2017). Survey of business process management: challenges and solutions. *Enterprise Information Systems*, *11*, 1119–1153. doi:10.1080/17517575.2016.1161238.

Bera, P., Soffer, P., & Parsons, J. (2019). Using eye tracking to expose cognitive processes in understanding conceptual models. *MIS Quarterly*, *43*, 1105–1126. doi:https://doi.org/10.25300/MISQ/2019/14163.

Burattin, A., Kaiser, M., Neurauter, M., & Weber, B. (2019). Learning process modeling phases from modeling interactions and eye tracking data. *Data Knowledge Engineering*, *121*, 1–17. doi:https://doi.org/10.1016/j.datak.2019.04.001.

Chen, T., Wang, W., Indulska, M., & Sadiq, S. (2018). Business process and rule integration approaches - an empirical analysis. In M. Weske, M. Montali, I. Weber, & J. vom Brocke (Eds.), *Business Process Management Forum* (pp. 37–52). Cham: Springer International Publishing.

Figl, K., & Recker, J. (2016). Exploring cognitive style and task-specific preferences for process representations. *Requir. Eng.*, *21*, 63–85. doi:10.1007/s00766-014-0210-2.

Indulska, M., zur Muehlen, M., & Recker, J. (2009). Measuring method complexity : The case of the business process modeling notation.

Irwin, D. E. (2004). Fixation location and fixation duration as indices of cognitive processing. In J. M. Henderson, & F. Ferreira (Eds.), *The interface of language, vision, and action: Eye movements and the visual world* (pp. 105–133). Psychology Press.

Jamshidi, P., Ghafari, M., Ahmad, A., & Pahl, C. (2012). A protocol for systematic literature review on architecture-centric software evolution research. Technical Report, Lero - The Irish Software Engineering Research Centre, Dublin City University, Oct.

27

Kitchenham, B., & Charters, S. (2007). Guidelines for performing systematic literature reviews in software engineering. Technical Report, EBSE 2007-001, Keele University and Durham University Joint Report.

Kitchenham, B. A., Dyba, T., & Jorgensen, M. (2004). Evidence-based software engineering. In *Proceedings of the 26th International Conference on Software Engineering* ICSE '04 (p. 273–281). USA: IEEE Computer Society.

Kitchenham, K., Budgen, D., & Brereton, P. (2011). Using mapping studies as the basis for further research - a participant-observer case study. *Inf. Softw. Technol.*, *53*, 638–651.

Ko, R. K. L. (2009). A computer scientist's introductory guide to business process management (bpm). *XRDS*, *15*. doi:10.1145/1558897.1558901.

Laue, R., & Gadatsch, A. (2011). Measuring the understandability of business process models - are we asking the right questions? In M. zur Muehlen, & J. Su (Eds.), *Business Process Management Workshops* (pp. 37–48). Berlin, Heidelberg: Springer Berlin Heidelberg.

Melcher, J., & Seese, D. (2008). Towards validating prediction systems for process understandability: Measuring process understandability. In *10th International Symposium on Symbolic and Numeric Algorithms for Scientific Computing* (pp. 564–571).

Mendling, J., Reijers, H. A., & Cardoso, J. (2007). What makes process models understandable? In G. Alonso, P. Dadam, & M. Rosemann (Eds.), *Business Process Management* (pp. 48–63). Berlin, Heidelberg: Springer Berlin Heidelberg.

Mendling, J., Strembeck, M., & Recker, J. (2012). Factors of process model comprehension—findings from a series of experiments. *Decision Support Systems*, *53*, 195–206. doi:https://doi.org/10.1016/j.dss.2011.12.013.

Mendoza, V., da Silveira, D. S., Albuquerque, M. L., & Araújo, J. (2018). Verifying bpmn understandability with novice business managers. In *Proceedings of the 33rd Annual ACM Symposium on Applied Computing* SAC '18 (p. 94–101). New York, NY, USA: Association for Computing Machinery. doi:10.1145/3167132.3167139.
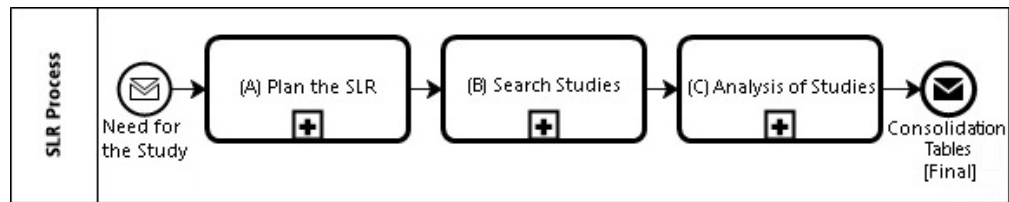
28

OMG (2011). Business process model and notation (bpmn), version 2.0. http://www.omg.org/oceb-2/.

Petersen, K., Feldt, R., Mujtaba, S., & Mattsson, M. (2008). Systematic mapping studies in software engineering. In *Proceedings of the 12th International Conference on Evaluation and Assessment in Software Engineering* EASE'08 (p. 68–77). Swindon, GBR: BCS Learning Development Ltd.

Petrusel, R., & Mendling, J. (2013). Eye-tracking the factors of process model comprehension tasks. In C. Salinesi, M. C. Norrie, & O. Pastor (Eds.), *Proceedings of the 25th International Conference on Advanced Information Systems Engineering* (pp. 224–239). Berlin, Heidelberg: Springer Berlin Heidelberg.

Petrusel, R., Mendling, J., & Reijers, H. A. (2016). Task-specific visual cues for improving process model understanding. *Information and Software Technology*, *79*, 63–78. doi:https://doi.org/10.1016/j.infsof.2016.07.003.

Petrusel, R., Mendling, J., & Reijers, H. A. (2017). How visual cognition influences process model comprehension. *Decision Support Systems*, *96*, 1–16. doi:https://doi.org/10.1016/j.dss.2017.01.005.

Pinggera, J., Furtner, M., Martini, M., Sachse, P., Reiter, K., Zugal, S., & Weber, B. (2012). Investigating the process of process modeling with eye movement analysis. In M. La Rosa, & P. Soffer (Eds.), *Business Process Management Workshops* (pp. 438–450). Berlin, Heidelberg: Springer Berlin Heidelberg.

Santos, M., Gralha, C., Goulão, M., Araújo, J., Moreira, A., & Cambeiro, J. (2016). What is the impact of bad layout in the understandability of social goal models? In *IEEE 24th International Requirements Engineering Conference (RE)* (pp. 206–215).

Scheer, A. W., & Nüttgens, M. (2000). Aris architecture and reference models for business process management. In W. van der Aalst, J. Desel, & A. Oberweis (Eds.), *Business Process Management: Models, Techniques, and Empirical Studies* (pp. 376–389). Berlin, Heidelberg: Springer Berlin Heidelberg.

29

Sharafi, H., Shaffer, T., Sharif, B., & Guéhéneuc, Y. (2015a). Eye-tracking metrics in software engineering. In *Asia-Pacific Software Engineering Conference (APSEC)* (pp. 96–103).

Sharafi, Z., Soh, Z., & Guéhéneuc, Y. G. (2015b). A systematic literature review on the usage of eye-tracking in software engineering. *Information and Software Technology*, *67*, 79–107. doi:https://doi.org/10.1016/j.infsof.2015.06.008.

Tallon, M., Winter, M., Pryss, R., Rakoczy, K., Reichert, M., Greenlee, M. W., & Frick, U. (2019). Comprehension of business process models: Insight into cognitive strategies via eye tracking. *Expert Systems with Applications*, *136*, 145–158. doi:https://doi.org/10.1016/j.eswa.2019.06.032.

Vaknin, M., & Filipowska, A. (2017). Information quality framework for the design and validation of data flow within business processes - position paper. In W. Abramowicz, R. Alt, & B. Franczyk (Eds.), *Business Information Systems Workshops* (pp. 158–168). Cham: Springer International Publishing.

Vermeulen, S. (2018). Real-time business process model tailoring: The effect of domain knowledge on reading strategy. In C. Debruyne, H. Panetto, G. Weichhart, P. Bollen, I. Ciuciu, M. E. Vidal, & R. Meersman (Eds.), *On the Move to Meaningful Internet Systems. OTM 2017 Workshops* (pp. 280–286). Cham: Springer International Publishing.

Wahl, T., & Sindre, G. (2006). An analytical evaluation of bpmn using a semiotic quality framework. In *Advanced Topics in Database Research*. volume 5. doi:10.4018/978-1-59140-935-9.ch006.

Wohlin, C., Runeson, P., Hst, M., Ohlsson, M. C., Regnell, B., & Wessln, A. (2012). *Experimentation in Software Engineering*. Springer Publishing Company, Incorporated.

Zimoch, M., Mohring, T., Pryss, R., Probst, T., Schlee, W., & Reichert, M. (2018). Using insights from cognitive neuroscience to investigate the effects of event-driven process chains on process model comprehension. In E. Teniente, & M. Weidlich (Eds.), *Business Process Management Workshops* (pp. 446–459). Cham: Springer International Publishing.

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Zott, C., Amit, R., & Massa, L. (2011). The business model: Recent developments and future research. *Journal of Management*, *37*, 1019–1042. doi:10.1177/0149206311406265.

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Typical Systematic Literature Reviews Processes.

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Subprocess (A) Plan the SLR.

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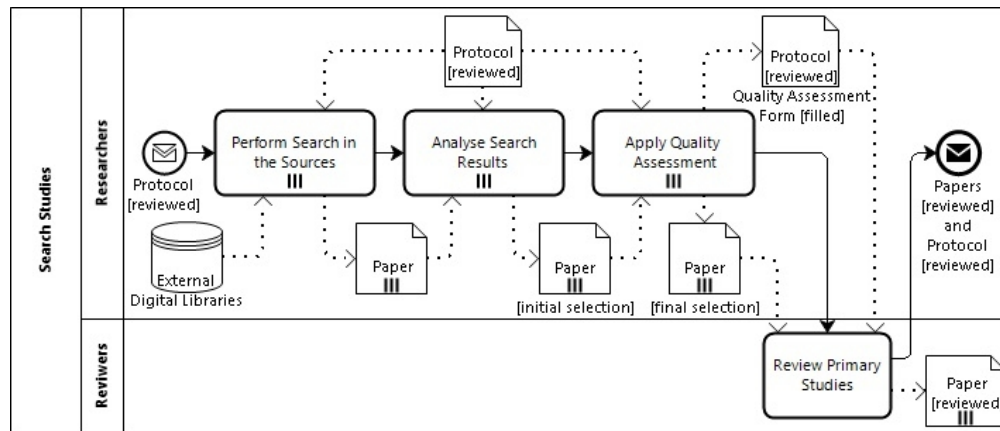
Subprocess (B) Search Studies.

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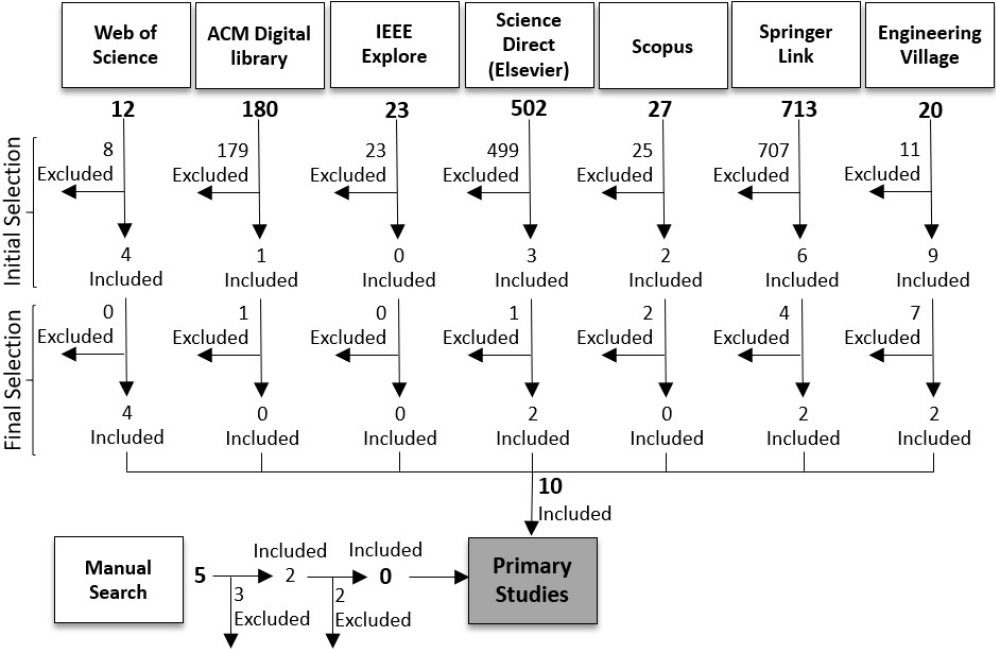
An Overview of the Primary Studies Selection.

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Subprocess (C) Analyze Studies.
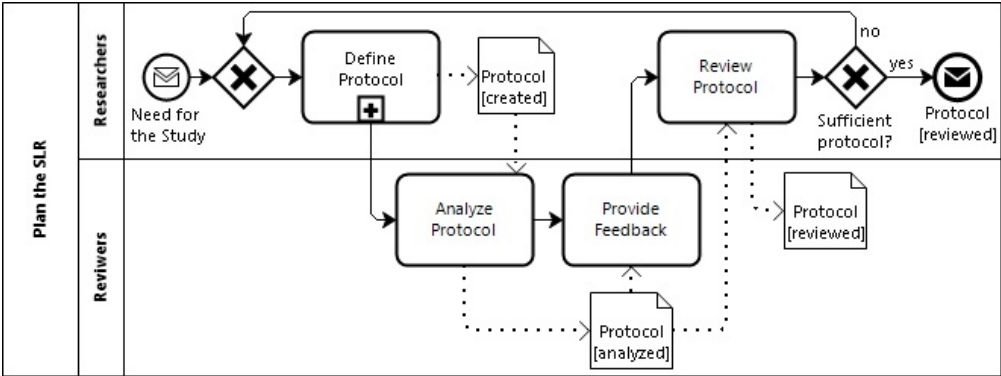
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Table 1: Search queries.

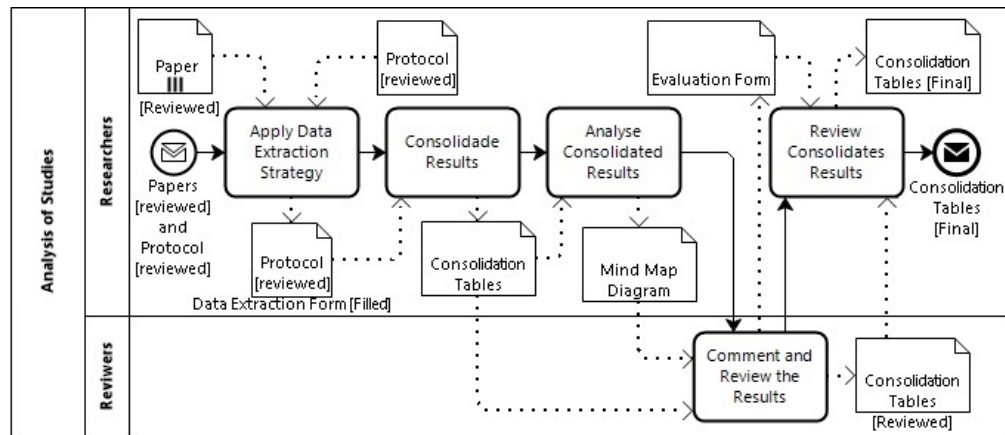|	Queries
Web of Science	TS=((*"eye-tracker"* **OR** *"eye tracker"* **OR** *"eye-tracking"* **OR** *"eye tracking"* **OR** *"restricted focus viewer"*) **AND** (*"BPM"* **OR** *"business process model"* **OR** *"business process"* **OR** *"process model"*) **AND** (*"understanding"* **OR** *"comprehension"* **OR** *"comprehensibility"*))
ACM Digital Library	[[Abstract: *eye-tracker*] **OR** [Abstract: *eye tracker*] **OR** [Abstract: *eye-tracking*] **OR** [Abstract: *eye tracking*] **OR** [Abstract: *restricted focus viewer*]]] **AND** [[Abstract: *BPM*] **OR** [Abstract: *business process model*] **OR** [Abstract: *business process*] **OR** [Abstract: *process model*]] **AND** [[Abstract: *understanding*] **OR** [Abstract: *comprehension*] **OR** [Abstract: *comprehensibility*]]
IEEExplore	((*"Abstract":eye-tracker* **OR** *"Abstract":eye tracker* **OR** *"Abstract":eye-tracking* **OR** *"Abstract":eye tracking* **OR** *"Abstract":restricted focus viewer*) **AND** (*"Abstract":BPM* **OR** *"Abstract":business process* **OR** *"Abstract":process models* **OR** *"Abstract":business process models*) **AND** (*"Abstract":understanding* **OR** *"Abstract":understandability* **OR** *"Abstract":comprehension* **OR** *"Abstract":comprehensibility*))
Science Direct	((*"eye-tracker"* **OR** *"eye tracker"* **OR** *"eye-tracking"* **OR** *"eye tracking"* **OR** *"restricted focus viewer"*) **AND** (*"BPM"* **OR** *"business process"* **OR** *"process models"* **OR** *"business process models"*) **AND** (*"understanding"* **OR** *"understandability"* **OR** *"comprehension"* **OR** *"comprehensibility"*))
Scopus	TITLE-ABS-KEY ((*"eye-tracker"* **OR** *"eye tracker"* **OR** *"eye-tracking"* **OR** *"eye tracking"* **OR** *"restricted focus viewer"*) **AND** (*"BPM"* **OR** *"business process"* **OR** *"process model"* **OR** *"business process model"*) **AND** (*"understanding"* **OR** *"understandability"* **OR** *"comprehension"* OR *"comprehensibility"*))
Springer Link	((*"eye-tracker"* **OR** *"eye tracker"* **OR** *"eye-tracking"* **OR** *"eye tracking"* **OR** *"restricted focus viewer"*) **AND** (*"BPM"* **OR** *"business process"* **OR** *"process models"* **OR** *"business process models"*) **AND** (*"understanding"* **OR** *"understandability"* **OR** *"comprehension"* **OR** *"comprehensibility"*))
Engineering Village	((*"eye-tracker"* **OR** *"eye tracker"* **OR** *"eye-tracking"* **OR** *"eye tracking"* **OR** *"restricted focus viewer"*) **AND** (*"BPM"* **OR** *"business process"* **OR** *"process models"* **OR** *"business process models"*) **AND** (*"understanding"* **OR** *"understandability"* **OR** *"comprehension"* **OR** *"comprehensibility"*))

Table 2: Quality Assessment Checklist.

General Items (G) = 25%	Specific Items (S) = 75%
G1: Problem definition and motivation: a) Explicit Definition (1.0) b) General Definition (0.5) c) No definition (0.0)	S1: Evaluation of the study: a) Formalized evaluation (1.0) b) Some informal evidences are provided (0.5) c) Non-justified or *ad-hoc* validation (0.0)
G2: Research methodology: a) An empirical methodology (1.0) b) A generalized analysis (0.5) c) Lacks any proper methods (0.0)	S2: Definition of the experimentation method: a) Formalized experimentation method (1.0) b) Some informal evidences are provided (0.5) c) Non-justified or *ad-hoc* experimentation method (0.0)
G3: The study contributions refer to the study results: a) Explicitly correlates contributions to results (1.0) b) There isn't correlation between contributions and results (0.5) c) There isn't description of contributions or results (0.0)	S3: Metrics to validate comprehension characteristics: a) Formalized definition of metrics (1.0) b) Some informal definition of metrics (0.5) c) Non-justified or *ad-hoc* definition of metrics (0.0)
G4: Limitations and future implications of the study: a) Formalized empirical evaluations (1.0) b) Some informal evidences are provided (0.5) c) Non-justified or *ad-hoc* validation (0.0)	S4: Use of another device in addition to eye-tracking: a) Formalized definition of another device (1.0) b) Some informal definition of another device (0.5) c) No definition (0.0)

Table 3: Overview of the selected papers.

	Source	Title	Citations	Reference
Journal	Data & knowledge engineering	Learning process modeling phases from modeling interactions and eye tracking data	4	Burattin et al. (2019)
	Decision Support Systems	How visual cognition influences process model comprehension	27	Petrusel et al. (2017)
	Expert systems with applications	Comprehension of business process models: Insight into cognitive strategies via eye tracking	1	Tallon et al. (2019)
	Information and Software Technology	Task-specific visual cues for improving process model understanding	19	Petrusel et al. (2016)
	MIS Quarterly	Using eye tracking to expose cognitive processes in understanding conceptual models	1	Bera et al. (2019)
Conference	International Conference on Business Process Management	Using insights from cognitive neuroscience to investigate the effects of event-driven process chains on process model comprehension	5	Zimoch et al. (2018)
		Business process and rule integration approaches - an empirical analysis	3	Chen et al. (2018)
		Investigating the process of process modeling with eye movement analysis	36	Pinggera et al. (2012)
	International Conference on Advanced Information Systems Engineering	Eye-tracking the factors of process model comprehension tasks	28	Petrusel & Mendling (2013)
Workshop	On the Move to Meaningful Internet Systems: OTM Workshops	Real-time business process model tailoring: The effect of domain knowledge on reading strategy	1	Vermeulen (2018)

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Table 4: Metrics used with your descriptions.

Descriptions Metrics	
Fixation	The eye-fixation metric was used in most (70%) of the mapped studies. The fixation consists of the visual attention time of the participant in an area of interest while performing a task (Santos et al., 2016). On average the eyes move to a new fixation position during business process model viewing about three times each second, though there is a good deal of variability in the duration of fixations (Burattin et al., 2019; Bera et al., 2019; Vermeulen, 2018; Petrusel et al., 2017, 2016; Pinggera et al., 2012). Two important issues for understanding eye movements during models perception are: where a fixation tends to be directed; and how long it typically remains there. In this context, researchers in psychology claim that most of the information acquisition and cognitive processing occur during fixations (Irwin, 2004). These eye fixations are intercalated by rapid eye jumps, called saccades, during which vision is suppressed;
Saccade	The saccade metric was used in 20% and consist of the sudden, swift movement that occurs between eye-fixations, it has a duration of about 40 to 50 milliseconds (Santos et al., 2016). Researchers in psychology claim that there is evidence that these saccade-induced shifts of visual attention not only facilitate stimulus processing at the saccade target location, but also influence the contents of mental representations as well (Irwin, 2004). This metric supports the conclusion that attention shifts obligatorily to the location of the saccade target, thereby increasing the likelihood that features near that location will be conjoined and encoded as integrated objects into memory (Vermeulen, 2018; Zimoch et al., 2018). Thus, understanding a business process model involves the sequencing, scan-path, and those saccades;
Scan-Path	A scan-path metric is a set of fixations or AOI, in chronological order. Here, they were used in 30% of the studies. In this context it is interesting to highlight that an AOI is visit-ed if there is at least one fixation in it. Hence, scan-paths and AOI can be connected with the participants' understanding strategies of the business process models. Researchers in psychology showed that scan-paths are representative of the tasks being performed by participants (Sharafi et al., 2015b);
Duration	Also, as a metric the duration was found, used in 50% of the studies. The duration represents the time that the participant takes to complete a given task (Sharafi et al., 2015b). Generally, these tasks involve checking the understanding of the models (what does the model represent?). In other words, checking if the participants have difficulties in performing the tasks (Bera et al., 2019; Tallon et al., 2019; Vermeulen, 2018; Petrusel et al., 2017; Pinggera et al., 2012).

Table 5: Studies Contributions.

Contributions
The new analysis technique and the exploring of new source data resulted in higher precision at identifying the types of phases in the process of models' creation in relation to the traditional technique. This technique allowed identifying factors such as: problems' comprehension, methods' discovery, semantic and syntactic validation (Burattin et al., 2019).
This study has two experiments. In the first experiment, a sample with 1047 students from school classes was evaluated. The second study had a sample of 21 specialists and 15 beginners in the use of process models. Three process models, in BPMN notation, with increasing complexity levels were used in the experiment. Participants in both samples demanded longer response times with increasing model complexity. For Sample I, Six latent classes with qualitatively differing solution profiles were adequate to classify scholars. These configurative and non-ordered profiles can be interpreted as separate solution patterns, where specific model parts are understood better than others. For the sample could not find significant differences in cognitive solution patterns between experts and novices. Thus, understanding and "solving" process models does not seem to depend too much on visual literacy as defined in this study. Apparently, comprehending the logic behind IF and OR gates as well as recognizing pathways is crucial to follow the information flow in process models (Tallon et al., 2019).
The authors perform a comparative study between the EPC and EPC-H notation, the latter is a variant of the EPC, proposed by the authors, in which the organizational units and the associated activities in an EPC model are highlight-ed by marking each function with a different color. In addition, the authors carry out a second comparative study between EPC-H and BPMN. The study found that participants viewed EPC models spent significantly more time in terms of fixation and duration than participants viewed EPC-H and BPMN models. In addition, participants viewed the variation in EPC notation proposed by the authors (EPC-H) spent significantly more time than participants who viewed BPMN models. The study indicates that coloring the EPC model has beneficial effects on its understanding, however even without the use of colors, the BPMN notation has better compressibility than colored EPC (Bera et al., 2019).
The results of matched *post-hoc* comparisons show that diagrammatic integration is associated with greater accuracy of comprehension rather than text annotation and link integration. Obviously, there is no significant difference in mental effort between different integration approaches. The presence and quantity of XOR gateways, AND gateways and issues that require navigation of constructions through loop structures, seems to influence understanding (Chen et al., 2018).

It is a work in progress, appearing only the strategy of how a future experiment will run. In the pilot experiment, the visual behavior of 10 participants was analyzed to confirm the theory of the existence of different BPD reading strategies (Vermeulen, 2018).

The performance of participants decreases as the level of difficulty increases. However, regardless of their level of expertise, all individuals have similar standards when faced with process models that exceed a certain level of difficulty. Participants' overall performance demonstrates a better understanding of business process models in EPC notation compared to the BPMN (Zimoch et al., 2018).

There is no influence between the reader's familiarity with business mastery and the proper understanding of the model. They point out that a Visual Cognition Efficiency (measured by Scan Path Precision and Recall) and Visual Cognition Intensity (measured by Total Fixtures and Total Fixture Length) better explain the comprehension performance (higher efficiency, shorter duration) than a model of personal knowledge and model complexity. For them, higher levels of specialization in business process modeling and lower complexity of the model lead to better cognitive efficiency (Petrusel et al., 2017).

The performance in the understanding of the models was better with the collaborative model than the individual, and the layout change of the BPMN models proposed by the experiment (Petrusel et al., 2016).

The elements of the area of interest are fixed for longer than other elements of the model by the subjects who provided the correct answer to the question of understanding. More elements of the area of interest are set than other elements of the model by subjects who provided the correct answer to the question of understanding (Petrusel & Mendling, 2013).

It can be observed that the average duration is smaller for the fixations in the task description compared to the fixations in the process model. The perceived lower complexity, once, allows the modelers to consider additional features of the model, such as secondary notation of the process model from the outset. It is noticeable that when the average length of fixings is increased by about 30%, the participants are facing a challenging part of the model (Pinggera et al., 2012).

Table 6: Topics for future research.

Open Issues
To propose a method for the quantitative evaluation of the quality of business process models and their modelling activities: the idea here is to define (bio)metrics, with the aid of eye-tracking, about the models and the way stakeholders interact with them, using scenarios to evaluate their usability (under-standing) in terms of appropriateness recognisability and learnability.
To evaluate the effect of the layout guidelines on the modelling novice stakeholders' ability to understand and review their business process models: the idea here is to perform an experiment where participants are given tasks of the understanding and reviewing. Both tasks must involve a model with a bad layout and another model following layout guidelines with good practices. Thus, with the aid of eye-tracking, it will be possible to evaluate the impact of layouts by combining the success level in those tasks and the required effort to accomplish them.
To define a consistent terminology with metrics' names, and methods: the idea here is to define standard guidelines and terminology while conducting and reporting an eye-tracking experiment. Using standard guidelines to design experiments for mod-elling tasks could reduce the risks of failure and also mitigate threats to validity. Using a uniform way to report an experiment that uses eye-tracking can benefit our community. This standardization can provide valuable information on how to re-view, replicate and analyze the data from an experiment with the eye-tracking. Here it is worth mentioning that conducting an eye-tracking experiment requires further, more specific recommendations with regards to the limitations associated with this technology.
To study the differences in business process models comprehension watching navi-gation strategies between experienced and less experienced business designers in the modelling languages: the idea here is to use eye-tracking technology and have inves-tigated how designers understand business models. That is, to use the eye-tracking technology to study the differences in models comprehension and models reading nav-igation strategies between experienced and less experienced business designers in the notations to represent BPD, e.g., BPMN.
To verify the cognitive effectiveness of business process models: in particular, the business process community is concerned with bridging the perceived gap between sophisticated modelling languages approaches and the stakeholders with whom de-signers need to interact with. As such, devising ways of making these processes languages more accessible is perceived as very important. The idea here is to propose approaches to help improving the understandability of processes models, by improving the concrete syntax of those models through the definition of a set of principles, for designing cognitively effective visual notations. In this case, cognitive effectiveness must be obtained by the speed, ease and precision with which the business model content can be understood by the stakeholders.

To use semiotic theory to check the denotations (signs) of the process models notations, for example, BPMN: the process of interpretation, called semiosis, at the pragmatic level necessarily results from and depends on the use of the sign. So, the idea here is to use eye-tracking to validate and verify the three aspects of a sign: syntax (between sign representations), semantics (between a representation and its referent) and pragmatics (between the representation and the interpretation) in semiotic levels. This research can be viewed in terms of its potential in fluence on the stakeholders' subsequent actions as a means of communication, according to the understanding of the process model's artifacts.