A revisited Systematic Literature Mapping to

Understanding Process Models Using the Eye-Tracking

Rafael Duarte 1, Vinícius Brito1, Charlie Silva Lopes2 and Denis Silva da Silveira1,2

1Department of Computer Engineering, University of Pernambuco, Brazil

2Administrative Sciences Department, Federal University of Pernambuco, Brazil   
{ rbd, vab }@ecomp.poli.br, [charlie1270@gmail.com](mailto:charlie1270@gmail.com), dsilveira@ufpe.br

**Abstract.** The use of business process models in requirements elicitation is a common practice. 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. This device allows collecting data of specific facial reactions of the people, such as the movement of the eyes and dilation of the pupils and the number of blinks in a specified time interval. This paper describes a revisited systematic literature mapping (SLM) that provide an overview of researches that evaluate the under-standing of process models through eye-tracking techniques. In this extended version, the SLM protocol includes paper published in 2019 and the application of quality criteria on studies. Resulting in ten XX studies for analysis and synthesis om the 1,477 studies initially found in the last ten years.

**Keywords:** Business Process Modeling, Understandability, Comprehension, Eye-Tracking, Evaluation, Systematic Mapping Study.

1. Introduction

Establishing efficient processes is the goal that all companies must pursue [1]. Business processes are a set of activities, well determined, coordinated in time and space to achieve goals and organizational objectives [2]. Besides that, they can be represented in models or diagrams composed of visual components [3]. These models are used as an instrument to facilitate the understanding or even to identify points of improvement in an organization [4]. In this perspective, business process models are essential so that the organizations keep control of their flows of activities.

Also, business processes help in specifying the requirements and design of information systems, representing all the data flow of processes. Thus, the path taken by many organizations to produce quality information systems has been to invest in the improvement of business process models. Therefore, processes are expected to result in quality information systems [5]. Studies show that the growth of the models both increases the quality of the information systems produced and the productivity of this development [6, 7, 8].

Recent and more innovative researches analyze how these models are explained and perceived by their stakeholders [9, 10]. Hereupon, users understand models differently, resulting in different abstractions [11]. Contrary to this statement, in [12], 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. Adtionally, 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. We use Evidence-Based Software Engineering (EBSE) 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 method- ology, together with auditing tasks to reduce the researchers’ bias on the results [13]. Two of the core tools for evidence-based studies are systematic literature reviews (SLR), focusing on identifying the best practices on a given topic based on empirical evidence, and systematic mapping studies, aiming at creating a comprehensive overview of a given research area [14].

The goal of this work is to carry out a systematic mapping study of the existing primary studies, and classifying them concerning the information presented. Also, to give an overview of the literature regarding the mediation of terms: business processes, comprehension, and eye-tracking. This paper will provide an adequate position for new research activities in this area, however, it is not its purpose to present a rigid comparison between the studies identified here.

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 and the research questions addressed; section 4 describes its execution, presenting the selected reviews, the classification scheme adopted and reports the findings; while, section 5 discusses related works; finally, section 6 concludes this paper and summarizes directions for further action.

1. Background
   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, mathematics, linguistics, semiotics, and philosophy [15]. The aim of business process modeling is to build Business Process Diagrams (BPD), which are technical drawings that translate abstract representations of processes [16].

Since the introduction of flowcharts in the 1920s [17] 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. The next section presents some concepts about understanding.

* 1. Understanding

In [18], understanding is a criterion that helps to measure whether the information contained in a model can be understood by all stakeholders. 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 [19], 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.

* 1. 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 understanding models [20], to realize what can be improved to facilitate, for instance, the interaction of systems with their users. The systems that use this technology are based on theories of the human physiological system, such as the theory of visual perception, and cognitive theories, such as the visual attention theory [21]. Thus, such technology allows analyzing user’s performance in reading and interpreting business process models.

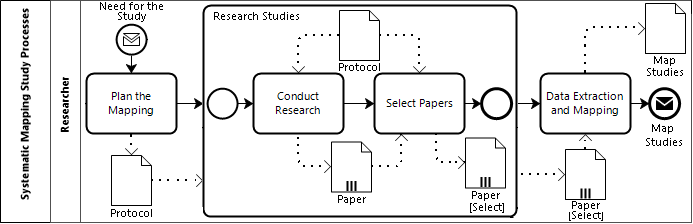
This technology is used for research in several areas of human knowledge, especially in the areas of medicine, cognitive psychology, management and marketing, aeronautics, industrial design, among others. Specifically, in the context of model usability, there has been increasing interest in the application of this technology to empirical studies [22]. Researchers try to understand which cognitive processes underlie the various activities of a business designer, for example.

* 1. Systematic Mapping Study

Systematic mapping study,also referred to as scoping study, is an extensive review of primary studies in a specific subject area that aims at identifying which evidence is available on a particular topic [23]. Hence, a mapping study should review a broader issue, classifying the main research works in that domain. In this context, the research questions for this study are of higher levels [14, 24]. Thus, mapping study may be of great importance to researchers by providing an overview of the research topic. Although, with different results, compared with systematic literature reviews (SLR) they may contain overlapping in their methods [25]. However, there is a significant difference, conventional SLR seeks to aggregate primary studies in terms of the research results, verifying whether these results are consistent or contradictory. On the other hand, a systematic mapping study usually only aims at classifying the relevant studies by categorizing them concerning previously defined categories. These categories are typically based on published information (authors' names, authors' affiliations, source of publication, type of paper, date of publication, etc.) and/or information about the search methods used. Thus, it is not the scope of systematic mapping studies to explicitly aggregate the results of the primary studies.

1. Method

In [14] the authors describe the process that was used as a starting point for this work. However, the ideas were blended and presented in [14] with the right practices defined for the SLR in [23]. Then, we apply a systematic mapping process, including some good practices used in SLRs. An example of this is the use of a search protocol. This artifact defined a plan, which established the necessary mapping procedures presented here.



**Figure 1** Typical Systematic Mapping Study Processes[[1]](#footnote-1) adapted from [14].

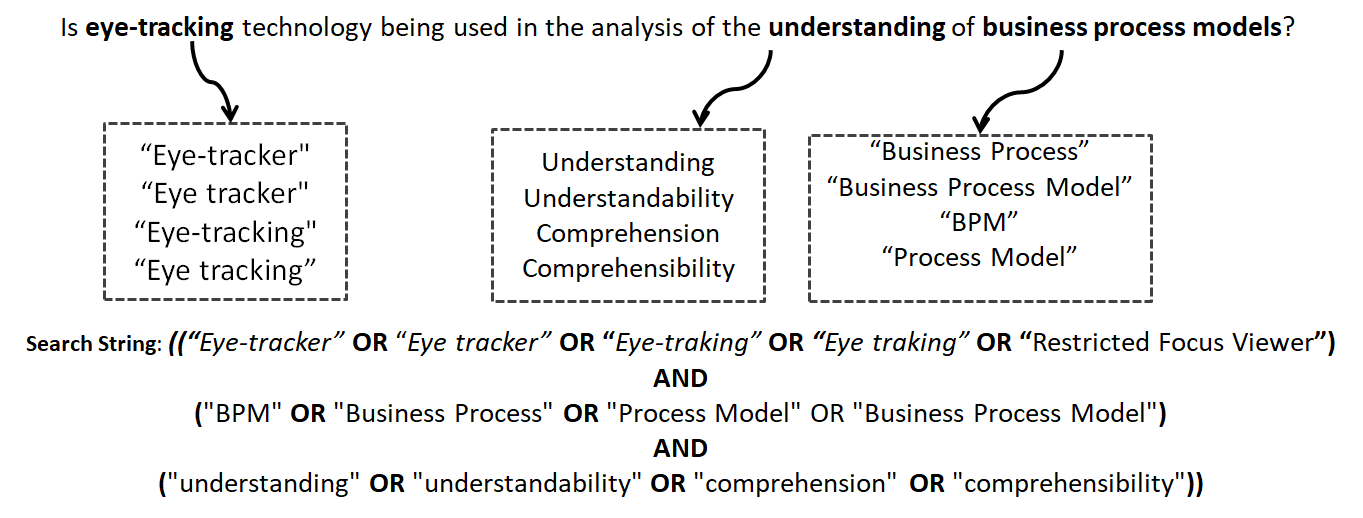
Other activities of the process, as proposed in [14], were also altered and/or rearranged in this study. As can be observed in Figure 1, the process was divided into three main activities: (A) "*Plan the Mapping*", whose objective is to identify the need for the review, defining the research protocol that will be used to conduct the mapping; (B) "research studies", which aims at collecting the studies (Conduct Research) to select the primary studies (Select Papers), applying the inclusion and exclusion criteria; (C) "Data Extraction and Mapping", which aims at formatting and communicating the results.

* 1. Plan The Mapping

To *Plan the Mapping*, it all started by formulating the research questions (Table 1) and the search string to run in the digital libraries (Fig. 2), consequently it was the definition of research sources and, finally, the election of which studies should be selected (included and extracted). (Table 2).

**Table 1.** Research Questions.

|  |  |
| --- | --- |
| ID | Questions |
| RQ1  (MAIN) | 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? |
| RQ3 | Which business process model 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? |
| RQ5 | When and where have the studies been published? |
| RQ6 | How many researchers are using the eye tracking device to evaluate understanding in process models? |



**Fig. 1.**Search string construction based on Silva *et. al.* [27].

* + 1. Search strategies

Regarding the bases of the research, digital databases were chosen to be used, where the results are collected through a search query execution. The research bases selected for this study were: ACM, Engineering Village, IEEExplore, Scopus, Springer Link, Web of Science, and Science Direct (Elsevier).

Over the investigation period, no date restriction was applied because we did not want to risk ignoring useful information that would limit the value of the findings and, after all, we would like to know that it was the first publication using eye-tracking in the analysis of the understanding of the process models. After laying the foundations the next step is identification of keywords. In this mapping, the keywords were extracted from RQ1. Figure 2 illustrates the keywords used in the queries, already grouped with the Boolean operators in the search string.

* + 1. Inclusion and exclusion criteria

It is interesting to emphasize the search on all bases. The resulting number of studies can be reviewed through a set of inclusion and exclusion criteria, which aspireto increase the quality of the resulting studies. Table 2 shows the specific criteria, together with different ones which can be applied in any other study.

**Table 2.** Inclusion and Exclusion Criteria.

|  |  |
| --- | --- |
| Criteria | Detail |
| I1 (inclusion) | Articles that address in the title and/or abstract the use of eye-tracking technology in the analysis of the understanding of process models. |
| I2 (inclusion) | Paper's keywords are among our keywords. |
| E1 (exclusion) | Duplicated papers. |
| E2 (exclusion) | Papers that did not apply to research questions. |
| E3 (exclusion) | Papers with unavailable access. |
| E4 (exclusion) | Papers written in other than the English language. |
| E5 (exclusion) | Papers with only abstract available; extended abstracts or short paper (less than six pages). |

* + 1. Quality criteria

After the inclusion and exclusion criteria are applied to all collected articles, the quality criteria were applied to the remaining articles. The quality criterias here are based on [28], where it is included in our review, an article must obtain **QC1 ≥ 1.5** and criteria for bibliographic impact **QC2** and **QC3** must be *medium* or higher.

**QC1:** The quality assessment checklist, consisting of six General criteria (**GQG**) and four specific criteria (**SQC**). With scores ranging from 0.0 to 1.0. The following is a weighted average, where **SQC** weigh 3 times more than **GQG**, since the specific contributions of a study are more important than the general facts. Articles with a score ≥ 3 were considered *high* quality studies, articles with a score ≤ 1.5 and < 3 were considered acceptable (“medium” quality) and works with a score < 1.5 were considered of *lower* quality.

GCQ - General Quality Criteria:

**GCQ1 - Definition of the study problem:**

(1.0) The authors provide an explicit description of the problem for the study.

(0.5) The authors provide a general description of the problem.

(0.0) There is no description of the problem.

**GCQ2 - In which environment was the study carried out:**

(1.0) The study presents an explicit description of the environment in which the research was carried out (e.g., laboratory, as part of a project, in collaboration with industry, etc.).

(0.5) The study presents a general idea about the environment in which the research was carried out.

(0.0) There is no description about the environment.

**GCQ3 - The methodology presents the method referring to the way the study was organized:**

(1.0) The study explicitly presents the plan (with different steps, deadlines, etc.) that they used to carry out the survey or the way the survey was organized.

(0.5) The study presents a general description about the research plan or the way the research was organized.

(0.0) There is no description of how the research was planned / organized.

**GCQ4 - The study's contributions refer to its results:**

(1.0) The study explicitly presents contributions / results.

(0.5) The study presents its results in general.

(0.0) There is no description of the search results.

**GCQ5 - The study presents insights for new studies:**

(1.0) The study explicitly presents insights and / or lessons learned.

(0.5) The study generally presents some insights and / or lessons learned.

(0.0) There is no description of insights in the study.

**GCQ6 - The authors described the limitations of the study:**

(1.0) The study explicitly lists the limitations / problems found in carrying out the research.

(0.5) The study lists, in general, some limitations / problems in the execution of the research.

(0.0) There is no description of the study limitations

**EQC - Specific Quality Criteria:**

**EQC1 - About the validation of the study:**

(1.0) Some experiment is applied to validate the verification of understanding in the process models.

(0.5) There is application of some case study to validate the verification of understanding in the process models.

(0.0) There is no validation in the study.

**EQC2 - There is definition of the experimentation method:**

(1.0) There is an explicit definition of how the experiment proceeded.

(0.5) There is a general definition of how the experiment proceeded.

(0.0) There is no description of the experiment.

**EQC3 - About metrics to validate comprehension characteristics:**

(1.0) There is a formal definition of metrics.

(0.5) There is a semi-formal definition of metrics.

(0.0) There is an ad-hoc definition of metrics.

**EQC4 - Is there complementary validation in addition to the use of eye-tracking to capture information?**

(1.0) Other complementary validations are used.

(0.0) There is no use of other complementary validations.

**QC2:** About citations, **high** for articles with more than **five** citations, **medium** for articles with **less** than **five** citations and **low** for articles **without citations**. We will use **Google Scholar [[2]](#footnote-2)** to verify citations.

**CQ3:** This quality criterion is intended to be a counterweight to **CQ3**, one that recent articles may have **fewer citations**. For these cases, 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.

* 1. Research Studies

This subprocess consists of two activities: *Conduct Research*, *Select Papers* and *Applying quality criteria*. This section describes how these two activities were performed.

* + 1. Conduct Research

The *Conduct Research* activity, which is responsible for performing the searches in digital libraries, required some specific settings during each search in the databases. Here it is worth noting that the databases used have characteristics and limitations themselves and that their search engines work in different ways. Thus, the resulting strand (Fig. 2) was adapted to rotate appropriately in each of the bases. For example, it was considered whether the database accepts a search with plural terms or whether they should be added to the string, or if the database allows searches to be performed considering only parts of the text, or even if searches are always performed considering the full text.

Figure 3 shows the studies were found distributed by digital libraries. These studies were automatic searched in digital libraries. In total, 1,477 were found, where it uses the majority 713 (48.27%) come from the Springer Link library. The libery Science Di-rect returned 502 (33.99%). The second largest number of estudos. 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.



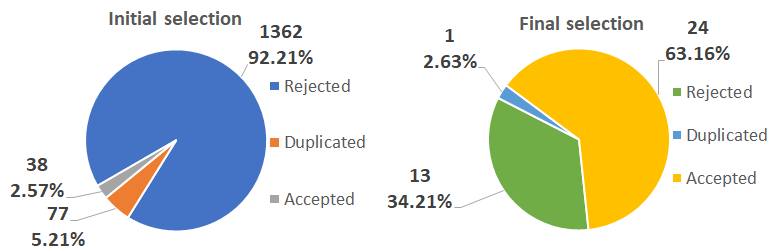
**Fig. 2.** Studies found distributed by digital libraries.

* + 1. Select Papers

In the *Select Papers* activity, the studies were analyzed in two stages: *initial selection* and *final selection*. In the initial range, the inclusion and exclusion criteria 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 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 founded, segmented by the selection criteria in the two selection phases. In this initial selection, of 1,477, 1362 (92.21%) studies were excluded because the research question was not applied, 77 (5.21%) of which were duplicated. Based on this first selection, only 38 (2.57%) primary studies were taken to the final selection.

During the *final selection*, the inclusion and exclusion criteria were applied again in the studies included in the first stage, through the evaluation of their complete texts. For 38 articles selected in the previous phase, 1 of which were duplicated (2.63%), 2 did not have access to reading, 11 were rejected by the rejection criteria after reading the entire text and the article [29] was removed because it is the original version of the present work. Soon the *final selection* phase had a rejection rate of 31.48%. At the end of the two selection phases, we obtained 24 primary studies, which represents an acceptance rate of 63.16% in relation to the universe of articles in the *final selection* phase or 1.62% in relation to the total universe of works found.



**Fig. 3.** Studies found distributed by digital libraries.

This new evaluation resulted in 24 primary studies that fully met all the criteria and would be able to contribute to the results of this work. After each of the two selection stages, initial and final, a review was performed. This review was conducted to increase the reliability and transparency of the selection process, to avoid the exclusion of relevant studies. Here it is interesting to note that the two selection stages were performed independently by two researchers, since the studies can be classified differently. In this happened, a third researcher seeked a consensus between the two previous ones.

* 1. Applying quality criteria

**Table 3.** Quality criteria to selected papers.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

1. Data Extraction and Mapping

This section provides an analysis of the results enables us to present the amount of studies that match each research question addressed in this study.

* 1. RQ1- How is eye-tracking technology applied in understanding 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. Table 3 presents the categorization of studies by these 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.

**Table 3.** Studies Classification.

|  |  |  |
| --- | --- | --- |
| Application | Total | Studies |
| In the comparison between notations | 2 | Zimoch *et al*. 2018,  Bera *et al*. 2019 |
| In addition of new artifacts | 2 | Petrusel *et al*., 2016,  Chen *et al*. 2018 |
| In the evaluation of the models | 6 | Pinggera *et al*., 2012,  Petrusel and Mendling, 2013,  Petrusel *et al*., 2017,  Vermeulen, 2018,  Burattin *et al*., 2019,  Tallon *et al*., 2019 |

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

Table 4 presents the key metrics used to evaluate the understanding of business process models. The *eyefixation* metric, which consists of the visual attention time of the participant in an area of interest while performing a task [52], it is used in most (84.21%) of the mapped studies. The *scan path* were used in 36.84% consist of the way formed by the balconies, in chronological order, between sets of *eyefixations*. The *saccade* were used in 31.58% and consist of the swift movement that occurs between *eyefixations*, it has a duration of about 40 to 50 milliseconds [52]. Meanwhile, the *duration* represents the time the participant takes to complete a task [53] and was used in 47.37% of studies.

*Pupillometry*, which consists of measuring pupillary dilatation, is considered an indication of excitation by the participant to a visual stimulus, was present in 2 (10.53%) of the studies. Finally, 26.32% of the mapped reviews use questionnaires with questions about the domain of business process models, and according to the number of correct answers, the participant understands the business process models.

**Table 4.** Evaluation Metrics.

|  |  |  |
| --- | --- | --- |
| Metrics | Total | Studies |
| Eye Fixation | 6 | Pinggera et al., 2012  Petrusel et al., 2016,  Petrusel et al., 2017,  Vermeulen, 2018,  Zimoch et al. 2018,  Bera et al. 2019,  Burattin et al. 2019 |
| Saccade | 2 | Vermeulen, 2018,  Zimoch *et al*. 2018 |
| Scan Path | 3 | Petrusel et al., 2017,  Vermeulen, 2018,  Zimoch et al. 2018 |
| Duration | 5 | Pinggera et al., 2012,  Petrusel et al., 2017,  Vermeulen, 2018,  Tallon et al., 2019,  Bera et al. 2019 |
| Comprehension Questions | 4 | Pinggera et al., 2012,  Zimoch et al. 2018,  Chen et al. 2018,  Tallon et al., 2019 |

* 1. RQ3 - What business process model notations are evaluated in the studies?

As it can be seen in the Table 5 the majority of 16 studies evaluate the understanding of business process models in BPMN notation [26]. Study [38] compares the understanding between models in BPMN [~~33~~] and EPC [54]. Likewise, the work A11 performs the comparison between the understanding of the models in the notations BPMN [26], EPC [54], Petri Net [55] and eGantt [56]. As well as the study A 17 that makes a comparison between the languages CIAN [57] and CIT [58]. Finally, study [~~34~~] uses the DCR notation to evaluate the understanding of business process models; and studies [~~42~~] did not specify the notation used in the respective studies.

**Table 5.** Notations Assessed by the Studies.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| BPMN | DCR | EPC | Petri Net | eGantt | CIAN | CTT | Not Specified |
| [37, 38, 41, 47, 48, 50, 51] | [] | [] | [] | [] | [] | [] | [] |

* 1. RQ4 - 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 6 presents the contributions of the selected studies.

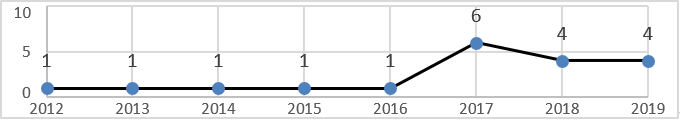
**Table 6.** Studies Contributions.

|  |  |
| --- | --- |
| Reference | Contributions |
| [37] | 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. |
| [38] | 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. |
| [41] | 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. |
| [45] | 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. |
| [47] | 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. |
| [48] | It can be observed that the average duration are 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. |
| [50] | 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. |
| [51] | The results of matched post-hoc comparisons show that diagrammatic integration is associated with greater accuracy of comprehension 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. |

Among the main contributions of the studies, it was observed that the studies [38, ~~43~~] emphasize that the size and complexity of the model influence its understanding. On the other hand, studies [~~39~~, ~~42~~] affirm that complex structures like loops and nestings diminish the understanding of process models. It was also observed in studies [38, ~~43~~] that independently of the level of knowledge, all individuals have similar patterns when faced with process models that exceed a certain level of difficulty. In studies [~~33~~, 45], the addition of complementary elements in the models facilitated the understanding of the participants. Only studies [~~40~~, ~~46~~] evaluate the understanding of process models from the perspective of the designer, and the other studies estimate the understanding from the standpoint of model readers.

* 1. RQ5 - When and where have the studies been published?

Fig. 5 shows the distribution of the studies considering the year of its publication. The first mapped study is [47] of the year 2012. There is a concentration of publications in the last three years, with the year 2017 demonstrating the highest incidence of papers.

****

**Fig. 4.**Distribution of studies per year.

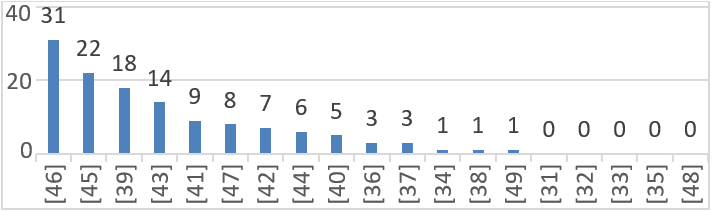
As can it be seen in Fig. 4, the Springer Link research database returned most (78.95%) of the selected studies. Only studies [41, 45] have as source the basis of research Science Direct. No reviews were chosen on the bases: ACM, Engineering Village, IEEE, Scopus and Web of Science.

Among the selected studies 14 (73.68%) were published in conferences. The conferences with the most mapped reviews are International Conference on Business Process Management with three studies [~~34~~, ~~42~~, 47], Information Systems and Neuroscience also with three mapped studies [~~35~~, ~~40~~, ~~46~~] and Enterprise, Business Process and Information Systems Modeling has 2 mapped reviews [~~42~~, ~~43~~]. Also, we outlined 4 (21.06%) studies which published papers in journals and only one study [~~33~~] (5.26%) was released as a chapter of the book Integrating Business Process Models and Rules.

****

**Fig. 5.** Studies per database and types.

To understand which studies are most relevant, we observed the number of citations of the selected papers as it can be seen in Fig. 5, from the 19 chosen reviews there are a total of 129 quotes.

****

**Fig. 6.** Number of citations per study.

Papers [47, ~~46~~, 41, 45] are the most popular accounting for 65.89% of citations. The paper [47] has 31 citations, and this may be due to the pioneering nature of this study, being published in 2012. The works [~~33~~, ~~34~~, ~~35~~] and [37] have no citation, being less popular perhaps because they were published in more recent years.

* 1. RQ6- How many researchers are using the eye-tracking device to evaluate understanding in process models?

Table 7 presents the 42 authors of the 19 mapped studies. Out of the 42 authors, 18 (42.86%) have more than one article included in the mapping. The author with more reviews is Barbara Weber owning five studies. They are followed by the authors Andrea Burattin, Manfred Reichert, Michael Zimoch, RüdigerPryss and Manuel Neurauter with four studies, these studies are what compose a series of experiments of the same research. Study [~~36~~, 45] have the most significant number of authors written by the same seven authors. All the authors of the study [~~36~~] are authors of at least one other study of the present mapping, being thus considered the German University Ulm the most influential for the research area of the mapping in question.

**Table7.** Authors of the mapped studies.

|  |  |
| --- | --- |
| Total | Autors |
| 5 | Barbara Weber |
| 4 | Andrea Burattin, Manfred Reichert, Michael Zimoch, RüdigerPryss, Manuel Neurauter |
| 3 | Thomas Probst, Winfried Schlee, Jakob Pinggera, Razvan Petrusel, Jan Mendling |
| 2 | Johannes Schobel, Marco Furtner, Markus Martini, Pierre Sachse, Stefan Zugal, Christopher J. Davis, Hajo A. Reijers, Michael Kaiser |
| 1 | Georg Layher, Marta Indulska, Shazia Sadiq, Wei Wang, Amine AbbadAndaloussi, Thomas T. Hildebrandt, TijsSlaats, Alan R. Hevner, ÉliseLabonté-LeMoyne, Karl-David Boutin, Pierre-Majorique Léger, Heiko Neumann, Sven Vermeulen, Tim Mohring, Klara Jelinkov, Josef Pavlicek, Petra Pavlickova, Radek Hronza, Katharina Reiter, Ana I. Molina, Miguel A. Redondo, Manuel Ortega, Carmen Lacave |

1. Related Works

The studies [59, 60] investigate the factors that influence the understanding of process models but do not specifically address the use of do eye-tracking as a way of measuring comprehension. However, there is the study [53] that verifies the use of eye-tracking technology in software engineering. This study conducts a comprehensive survey that does not explicitly address business process models.

Moreover, this research [53] 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 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.

1. Conclusions and Future Works

The goal of this paper is to provide a comprehensive overview on the evaluation of understanding process models through eye-tracking techniques. To achieve this, a systematic mapping study was performed to find empirical evidence about how the eye-tracking technology has been applied in the understanding of the business process models. The result is an overview of the current practice of eye-tracking in business process models, both industrially and academically. The evidence found indicates that the selected studies are strongly concerned with the understanding of process models, but few of them [~~40~~, 45] are concerned with the analysis of DBP understanding in the modeling task. 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 [~~33~~, ~~36~~, 37, 38].

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 system atization 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.

References

1. ­­Vaknin, M.; filipowska, A.: Information Quality Framework for the Design and Validation of Data Flow Within Business Processes - Position Paper. In: International Conference on Business Information Systems, vol. 8787, pp. 158–168, Greece, Springer, (2017).
2. Alotaibi, Y.; Liu, F.: Survey of business process management: challenges and solutions. Enterprise Information Systems, 11(8), 1119-1153 (2016).
3. Melcher, J.; Seese, D.: Towards validating prediction systems for process understandability: Measuring process understandability. Proceedingsofthe 2008 10th SYNASC 2008. Anais.Timisoara: IEEE, (2008).
4. Jiménez-ramírez, A.; Weber, B.; Barba, I.; Del Valle, C.: Generating optimized configurable business process models in scenarios subject to uncertainty. Informationand Software Technology, vol. 57, n. 1, pp. 571–594, (2015).
5. Unterkalmsteiner, M.; Gorschek, T.; Islam, A.K.M.M.; Cheng, C. K.; Permadi, R. B.; Feldt, R.: Evaluation and Measurement of Software Process Improvement: A Systematic Literature Review, IEEE Transactions on Software Engineering, vol. 38, p. 398-424 (2011).
6. Gibson, D.L.; Goldenson, D.R.; Kost, K.: Performance results of CMMI-based process improvement. Carnegie-Mellon Univ Pittsburgh Pa Software Engineering Inst (2006).
7. Mohd, N.; Ahmad, R.; Hassan, N.: Resistance factors in the implementation of software process improvement project. Journal of Computer Science, pp. 211-219 (2008).
8. Hani, S. U.: Impact of process improvement on software development predictions, for measuring software development project's performance benefits, In: Proceedings of the 7th International Conference on Frontiers of Information Technology, p 54, (2009).
9. Mendoza, V.; Silveira, D. S.; Albuquerque, M. L.; Araújo, J.: Verifying BPMN Understandability with Novice Business, 33rd Symposium on Applied Computing - ACM/SIGAPP, Pau – France, ACM, pp. 94-101 (2018).
10. Rodrigues, R. D. A.; Barros, M. D. O.; Revoredo, K.; Azevedo, L. G.; Leopold H.: An experiment on process model understandability using textual work instructions and BPMN models, In: 29th SBES, pp. 41-50, (2015).
11. Figl, K., Recker, J.; Exploring cognitive style and task-specific preferences for process representations. Requirements Eng., 21(1), pp. 63–85 (2014).
12. Mendling, J.; ReijersH.; Cardoso, e. J.; What Makes Process Models Understandable?, In: Business Process Management,Springer, Berlin, Heidelberg, pp. 48–63, (2007).
13. Kitchenham, Barbara A.; DYBA, Tore; JORGENSEN, Magne. Evidence-based software engineering. In: Proceedings of the 26th international conference on software engineering. IEEE Computer Society, pp. 273-281 (2004).
14. Petersen, K.; Feldt, R.; Mujtaba, S.; Mattsson, M.: Systematic mapping studies in software engineering, in: EASE ’08: Proceedings of the 12th International Conference on Evaluation and Assessment in Software Engineering, vol. 8, pp. 68-77 (2008).
15. Ko, R. K. L.: A computer scientist’s introductory guide to business process management (BPM), XRDS: Crossroads, The ACM Magazine for Students, vol. 15, n. 4 (2009).
16. Wahl, T.; Sindre, G.: An analytical evaluation of BPMN usi­ng a semiotic quality framework, Advanced topics in database research, vol. 5, pp. 94-105 (2006).
17. Indulska, M.; ZurMuehlen, M.; Recker, J.: Measuring Method Complexity: The Case of the Busi-ness Process ModelingNotation. Technical report, BPM Center Report, n. Apr (2009).
18. Laue, R.; Gadatsch, A. Measuring the understandability of business process models are we asking the right questions? In: SPRINGER. InternationalConferenceon Business Process Management, pp. 37–48 (2010).
19. Mendling, J.; Strembeck, M.; Recker, J: Factors of process model comprehension—findings from a series of experiments. DecisionSupport Systems, Elsevier, vol. 53, n. 1, pp. 195–206 (2012).
20. Sharafi, Z.; Shaffer, T.; Sharif B.: Eye-Tracking Metrics in Software Engineering, In: Asia-Pacific Software Engineering Conference – APSEC, pp. 96–103, (2015).
21. Moody, D.; The “physics” of notations: toward a scientific basis for constructing visual notations in software engineering, In: IEEE Transactions on Software Engineering, 35(6), pp. 756–779, (2009).
22. Santos, M.; Gralha, C.; Goulão, M., Araújo, J.; Moreira, A.; Cambeiro, J.: What is the Impact of Bad Layout in the Understandability of Social Goal Models?, in: 24th IEEE Requirements Engi-neering Conference - RE, Beijing – China, pp. 206-215, (2016).
23. Kitchenham, B.; Charters, S.: Guidelines for performing Systematic Literature Reviews in Software Engineering, in: Technical Report EBSE 2007-001, Keele University and Durham University Joint Report, (2007).
24. Budgen, D.; Turner, M.; Brereton, P.; Kitchenham, B.: Using mapping studies in software engi-neering, in: Proceedings of PPIG 2008, Lancaster University, pp. 195–204. (2008).
25. Kitchenham, B.; Brereton P.; Budgen D.: Using mapping studies as the basis for further research – A participant-observercase study, Information & Software Technology Volume 53, Issue 6, pp. 638-651, (2011).
26. OMG BPMN2, Business Process Model and Notation (BPMN) v2.0, Object Management Group (2011).
27. Da Silva, F. Q., Suassuna, M., França, A. C. C., Grubb, A. M., Gouveia, T. B., Monteiro, C. V., dos Santos, I. E.: Replication of empirical studies in software engineering research: a systematic mapping study. Empirical Software Engineering, vol. 19(3), pp. 501-557, (2014).
28. Jamshidi, P., Ghafari, M., Ahmad, A., Pahl, C.: A Protocol for Systematic Literature Review on Architecture-Centric Software Evolution Research, Technical Report, Lero-TheIrish Software Engineering Research Centre, Dublin City University, Oct. 2012.
29. Brito, V., Duarte, R., Lopes, C. S., Silveira, D. S.: Understanding Process Models Using the Eye-Tracking: A Systematic Mapping. In International Conference on the Quality of Information and Communications Technology. Springer, Cham. p. 89-104 (2019).
30. ­­Andaloussi, A. A., Burattin, A., Slaats, T., Petersen, A. C. M., Hildebrandt, T. T., & Weber, B.: Exploring the understandability of a hybrid process design artifact based on DCR graphs. In Enterprise, Business-Process and Information Systems Modeling (pp. 69-84). Springer, Cham, (2019).
31. Tallon, M., Winter, M., Pryss, R., Rakoczy, K., Reichert, M., Greenlee, M. W., & Frick, U.: Comprehension of business process models: Insight into cognitive strategies via eye tracking. Expert Systems with Applications, 136, p. 145-158, (2019).
32. Bera, P., Soffer, P., & Parsons, J. Using Eye Tracking to Expose Cognitive Processes in Understanding Conceptual Models. MIS Quarterly, 43(4), 1105-1126, (2019).
33. Wang, W.: The Effect of Rule Linking on Business Process Model Understanding. In: Integrating Business Process Models and Rules. Springer, Cham. p. 42-59 (2019).
34. AbbadAndaloussi, A.; Slaats, T.; Burattin, A.; Hildebrandt, T.: Evaluating the Understandability of Hybrid Process Model Representations Using Eye Tracking: First Insights. In: International Conference on Business Process Management, Springer, Cham, pp. 475-481 (2019).
35. Boutin, K.; Léger, P.; Davis, C.; Hevner, A.; Labonté-LeMoyne, É.: Attentional Characteristics of Anomaly Detection.In: Conceptual Modeling. Information Systems and Neuroscience. Springer, Cham, pp. 57-63 (2019).
36. Zimoch, M.; Pryss, R.; Layher, G.; Neumann, H.; Probst, T.; Schlee, W.; Reichert, M.: Utilizing the Capabilities Offered by Eye-Tracking to Foster Novices’ Comprehension of Business Process Models. In: ICCC - International Conference on Cognitive Computing. Lecture Notes in Computer Science, vol. 10971, pp. 155-163, Springer, Cham (2018).
37. Vermeulen, S.: Real-Time Business Process Model Tailoring: The Effect of Domain Knowledge on Reading Strategy. In: Debruyne C. et al. (eds) On the Move to Meaningful Internet Systems. OTM 2017 Workshops, vol: 10697, pp. 280-286, Springer (2018).
38. Zimoch, M.; Mohring, T.; Pryss, R.; Probst, T.; Schlee, W.; Reichert, M.: Using Insights from Cognitive Neuroscience to Investigate the Effects of Event-Driven Process Chains on ­­Process Model Comprehension. In: Business Process Management Workshops. Vol: 308, pp. 446-459, Springer, Cham (2018).
39. Pavlicek, J.; Hronza, R.; Pavlickova, P.; Jelinkova, K.: The Business Process Model Quality Metrics. In: Enterprise andOrganizationalModelingandSimulation. pp. 134-148 (2017).
40. Weber, B.; Neurauter, M.; Burattin, A.; Pinggera, J.; Davis, C.: Measuring and Explaining Cognitive Load During Design Activities: A Fine-Grained Approach. In: Information Systems and Neuroscience. Lecture Notes in Information Systems and Organisation 2017, vol 25, pp. 47-53. Springer, Cham (2018).
41. Petrusel, R.; Mendling, J.; Reijers, H. A.: How visual cognition influences process model comprehension. DecisionSupport Systems, vol 96, pp. 1-16. Elsevier (2017).
42. Burattin, A.; Kaiser, M.; Neurauter, M.; Weber, B.: Eye Tracking Meets the Process of Process Modeling: A Visual Analytic Approach. In: Dumas M., Fantinato M. (eds) Business Process Management Workshops 2016. BPM. vol 281, pp. 461-473. Springer, Cham (2017).
43. Zimoch, M.; Pryss, R.; Schobel, J.; Reichert, M.: Eye Tracking Experiments on Process Model Comprehension: Lessons Learned. In: Reinhartz-Berger I., Gulden J., Nurcan S., Guédria W., Bera P. (eds) Enterprise, Business-Process and Information Systems Modeling. BPMDS 2017, EMMSAD. vol 287, pp. 153-168. Springer, Cham (2017).
44. Zimoch, M.; Pryss, R.; Probst, T.; Schlee, W.; Reichert, M.: Cognitive Insights into Business Process Model Comprehension: Preliminary Results for Experienced and Inexperienced Individuals. In: Reinhartz-Berger I., Gulden J., Nurcan S., Guédria W., Bera P. (eds) BPMDS 2017, vol 287, pp. 137-152. Springer, Cham (2017).
45. Petrusel, R.; Mendling, J.; Reijers, H. A.: Task-specific visual cues for improving process model understanding. Informationand Software Technology, 79, pp. 63-78 (2016).
46. Weber, B.; Neurauter, M.; Pinggera, J.; Zugal, S.; Furtner, M.; Martini, M.; Sachse, P.: Measuring cognitive load during process model creation. In: Information Systems andNeuroscience, pp. 129-136. Springer, Cham (2015).
47. Petrusel, R.; Mendling, J.: Eye-tracking the factors of process model comprehension tasks. In: International Conference on Advanced Information Systems Engineering, pp. 224-239. Springer, Berlin, Heidelberg (2013).
48. Pinggera, J.; Furtner, M.; Martini, M.; Sachse, P.; Reiter, K.; Zugal, S.; Weber, B.: Investigating the process of process modeling with eye movement analysis. In: International Conference on Business Process Management. pp. 438-450. Springer, Berlin, (2012).
49. Molina, A. I.; Redondo, M. A.; Ortega, M.; Lacave, C.: Evaluating a graphical notation for modeling collaborative learning activities: A family of experiments.In: Science of Computer Programming, v. 88, pp. 54-81, (2014).
50. Burattin, A.; Kaiser, M.; Neurauter, M.; Weber, B.: Learning process modeling phases from modeling interactions and eye tracking data. In: Data & Knowledge Engineering, (2019).
51. Chen, T.; Wang, W.; Indulska, M.; Sadiq, S.: Business Process and Rule Integration Ap-proaches- An Empirical Analysis. In: International Conference on Business Process Man-agement. Springer, Cham, pp. 37-52 (2018).
52. Santos, M. C. D. F.: Avaliação da Eficácia Cognitiva de Modelos de Requisitos Orientados a Objetivos. Masters Dissertation, Faculdade de Ciência e Tecnologia Universidade nova de Lisboa, (2016).
53. Sharafi, Z.; Soh Z.; Guéhéneuc, Y. G.: A systematic literature review on the usage of eye-tracking in software engineering. In: Information and Software Technology 67, pp. 79–107 (2015).
54. Scheer, A. W.; Nüttgens, M.: ARIS Architecture and Reference Models for Business Process Management, In: Proceedings of the Business Process Management, Models, Techniques, and Empirical Studies, Springer-Verlag, pp 376–389 (2000).
55. Petri, C. A.: Kommunikation mit Automaten. PhD thesis, Institut fur InstrumentelleMathematik, (1962).
56. Sommer, M.: ZeitlicheDarstellung und Modellierung von Prozessenmithilfe von Gantt-Diagrammen. Bachelors Thesis, Ulm University (2012).
57. Lacaze, Xavier, and Philippe Palanque. "Comprehensive handling of temporal issues in tasks models: What is needed and how to support it. Workshop ‘The Temporal Aspects of Work for HCI (CHI 2004)’. Vienna, Austria. (2004).
58. Paternò, Fabio. ConcurTaskTrees: an engineered notation for task models. The handbook of task analysis for human-computer interaction, p. 483-503. (2004).
59. Dikici, A.; Turetken, O.; Demirors, O.: Factors influencing the understandability of process models: A systematic literature review. Informationand Software Technology, vol. 93, pp. 112-129 (2018).
60. FIGL, K.: Comprehension of procedural visual business process models. In: Business &Information Systems Engineering, vol. 59, n. 1, pp. 41-67 (2017).

1. The process built using BPMN (Business Process Modeling Notation) [26]. [↑](#footnote-ref-1)
2. <https://scholar.google.com.br/> [↑](#footnote-ref-2)