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

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**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 provides evidence on the contributions of eye-trackers to new empirical studies in this area.

**Design/methodology/approach –** To achieve this goal, we performed a Systematic Literature Review (SLR) fol-lowing the good practices from the Evidence-Based Software Engineering (EBSE) field.

**Findings -** This study resulted in XX primary studies selected for analysis and data extraction, from the 1,477 initially retrieved. So, our major findings indicate that [COMPLETAR].

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

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

**Paper type -** Literature review.

1. Introduction

Establishing efficient processes is the goal that all companies must pursue (Vaknin and Filipowska, 2017). Business processes are a set of activities, well determined, coordinated in time and space to achieve goals and organizational objectives (Alotaibi and Liu, 2016). 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 and Seese, 2008). 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 (Unterkalmsteiner *et al.*, 2011). Studies show that the growth of the models both increases the quality of the information systems produced and the productivity of this development (Gibson *et al.*, 2006; Mohd *et al.*, 2008; Hani, 209).

Recent and more innovative researches analyze how these models are explained and perceived by their stakeholders (Mendoza *et al.*, 2018; Rodrigues *et al.*, 2015). Hereupon, users understand models differently, resulting in different abstractions (Figl and Recker, 2014). 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. 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 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, we decided to perform an SLR process due to the possibility to have a more rigorous and controlled process, including a protocol definition and validation, and also because we are 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 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 (Ko, 2009). The aim of business process modeling is to build Business Process Diagrams (BPD), which are technical drawings that translate abstract representations of processes (Wahl and 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. The next section presents some concepts about understanding.

* 1. Understanding

Understanding is a criterion that helps to measure whether the information contained in a model can be understood by all stakeholders (Laue and Gadatsch, 2010). 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.

* 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 (Sharafi *et al.,* 2015), 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 (Moody, 2009). 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 (Santos *et al.*, 2016). Researchers try to understand which cognitive processes underlie the various activities of a business designer, for example.

* 1. Systematic Literature Reviews (SLR)

An SLR aims to establish the state of evidence and identification of best practices based on empirical evidence. The typical SLR process illustre in Figure 1 is composed of three main phases with the objectives to plan the SLR, conduct the search and report the results. In phase (A) “Plan the SLR” the objectives are to identify the need of the review, commission the review, specify research questions and review the protocol. In phase (B) “Search Studies” the objectives are to collect the studies, select primary studies, apply quality assessment, and extract and synthetize data. In phase (C) “Analyze Studies” the objective is to format and communicate results.

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**Figure 1** Typical Systematic Literature Reviews Processes[[1]](#footnote-1)*.*

In general, the complexity and rigor required to conduct an SLR is higher than in a systematic mapping study. 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.
* 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.

Our current research aims at building catalogues for a set of the existing studies to derive the selection of equipment types, the participants’ selection, and the study variables for the purpose of classifying them with respect to their context, benefits, content, and validation, in order to offer a comprehensive overview, as well as advices to overcome or limit threats to the validity of eye-tracking studies.

1. SLR Process

This section describes the SLR process to performing our study. Our initial intention was to simply apply the method proposed in Kitchenham and Charters (2007). However, as the application of the process evolved, the difficulties to establish and maintain a clear SLR strategy, manage the amount of data, deal with a set of non-structured search databases, deal with non-standardized papers metadata, manage changes during the process, ensure a minimum level of quality of the papers, and consolidate and classify data, led us to: define 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 our SLR discussing in detail how the subprocesses, which make up each of the three phases, were performed.

* 1. Plan the SLR

This sub process is composed of one other subprocess and four activities (see Figure 2). Two of those activities ((A.4) Review Protocol and (A.5) Define Templates and Rules) and more one subprocess ((A.1) Define Protocol) are assigned to the team of Researchers responsible and two ((A.2) Analyze Protocol and (A.3) Provide Feedbacks) are assigned to the Reviewers for the execution of the study.

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**Figure 2.** Subprocess (A) Plan the SLR.

In the expanded (A.1) Define Protocol subprocess illustrated in Figure 3 the research protocol is formed by the composition of the following dataobjects: 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 from Figures 2 and 3, showing how they were performed in our SLR.

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**Figure 3.** Subprocess define protocol.

* + 1. Define Research Questions (A.1.1)

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 and Charters (2007), it is useful to consider the PICOC method, first proposed in the medical area Petticrew and Roberts (2005). The results of applying PICOC to our research questions are presented in Table 1. This helps us focusing on what matters for the study in hand, guiding also the extraction phase of the process.

**Table 1.** PICOC when applied to our SLR.

|  |  |
| --- | --- |
| Viewpoint | Description |
| P (population) | Works that use eye-tracking to analyze the understanding of process models |
| I (Intervention) | The use of eye-tracking in understanding analysis |
| C (comparison) | It doesn’t apply, as we won’t compare the analysis or the use of eye-tracking, we’ll just collect as much information as possible to build a catalog that contains a thorough analysis of approaches that use eye tracking with the intuition of measuring how much a model of business process is understandable. |
| O (outcome) | relate factors of interest to professionals, eg, 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 (context) | Works that highlight the scope of using eye-tracking to analyze the understanding of process models. |

In summary, our goal is to identify quality attributes and factors that XXXXXX. The results obtained should help business designers during the activities of the XXXXX. Hence, the research questions defined to 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?
* 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: What is the profile of the subjects who used the eye tracking device to evaluate understanding in process models?
  + 1. Define Search Sources (A.1.2)

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, and we did no different. The digital libraries sources selected for this study were:

* Web of Science;
* ACM Digital library;
* IEEE Explore;
* Science Direct (Elsevier);
* Scopus;
* Springer Link;
* Engineering Village.

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

No restriction of date period was applied during the search in the specified sources, as we did not want to risk ignoring useful information that would limit the value of our findings.

* + 1. Define Search Queries (A.1.3)

The objective of this activity is to define keywords and Boolean expressions to perform automatic searches in digital libraries. First step to define the search queries was the identification of keywords. The list of keywords was based on a preliminary ad-hoc search, so to guarantee that relevant terms would not be omitted from the very beginning. Table 2 shows the keywords used in the final queries, already grouped with Boolean operators.

**Table 2.**. Search queries.

|  |  |
| --- | --- |
| Digital Libraries | Query |
| 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: ]] OR [Abstract: [eye-tracking]] OR [[Abstract: "eye tracking"] OR [Abstract: Restricted Focus Viewer] ]] AND [[Abstract: [bpm]] OR [[Abstract: "business process model"] OR [Abstract: ]] OR [[Abstract: "business process"] OR [Abstract: ]] OR [[Abstract: "process model"] OR [Abstract: ]]] 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":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") ) |

* + 1. Define Inclusion and Exclusion Criteria (A.1.4)

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. Table 3 shows our inclusion and exclusion criteria.

**Table 3**. Inclusion and Exclusion Criteria.

|  |  |
| --- | --- |
| Criteria | Detail |
| I1 (inclusion) | We included peer-reviewed papers from journals, conferences and workshops that present use of eye-tracking technology in the analysis of the understanding of process models. |
| I2 (inclusion) | Relevant studies cited by authors of the papers we read during the conduction process obtained by forward snowball search. |
| E1 (exclusion) | Papers with unavailable access. |
| E2 (exclusion) | Papers with only abstract available; extended abstracts or short paper (less than six pages). |
| E3 (exclusion) | Duplicated papers. |
| E4 (exclusion) | Papers that did not apply to research questions. |
| E5 (exclusion) | Papers written in other than the English language. |
| E6 (exclusion) | Papers not meeting some quality criteria (regarding quality criteria, more details are given in the section 3.1.6). |

Given that not all the criteria are mutually exclusive and the execution order matters, we suggest an analysis of the criteria to define one equation to prioritize exclusion criteria and another for inclusion criteria. These equations ensure that exclusion and inclusion criteria are applied in the same sequence during each paper analysis. An example is given in Figure 4. This was particularly important in our case with four people executing the SLR.

**if** *paper* **http://www.somatematica.com.br/figuras/simbolos/contido.gif** (E1 | E2 | E3 | E4 | E5) **then** exclude (*paper*);

**if** *paper* **http://www.somatematica.com.br/figuras/simbolos/contido.gif** (!(E1 | E2 | E3 | E4 | E5) & (I1 | I2)) **then** include (*paper*) **else** exclude (*paper*)

**Figure 4. Equation defining order of execution.**

* + 1. Define Data Extraction Strategy (A.1.5)

The objective of this activity is to define a strategy to extract data from selected primary studies. In our case we define a template 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 are 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 the contributions 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 so because not all the papers answer all the research questions.

* + 1. Define Quality Assessment (A.1.6)

The objective of this activity is to define the criteria to measure the quality of each primary study. However, there isn't agreed definition of what a high-level quality study is; there is a common agreement that the quality of the selected primary studies is fundamental to obtain more reliable results (Kitchenham and Charters, 2007).

Thus, we defined four quality assessment criteria (QA1 – QA4) 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 4. The result is a numerical quantification to rank the selected studies.

|  |  |
| --- | --- |
|  | (1) |

**Table 4**. Quality Assessment Checklist.

|  |  |
| --- | --- |
| General Items (G) = 25% | Specific Items (S) = 75% |
| G1: Is there a problem definition and motivation?   * (1.0) Explicit Definition * (0.5) General Definition * (0.0) No Definition.   G2: 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.   G2: Has research methodology been defined?   * (1.0) - There is a methodology * (0.5) There is only one generalized analysis. * (0.0) Doesn’t have.   G3: Contributions of the study refer to the study results:   * (1.0) explicitly presents contributions / results. * (0.5) presents its results in general. * (0.0) There isn’t description of the results.   G4: There are limitations and future implications for 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. | S1: 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.   S2: 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.   S3: 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.   S4: 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. |

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 is more important than the general contributions (G). Papers with an overall score >= 3 were considered “high” quality studies; papers with a score >= 1.5 and < 3 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 we do not evaluate the quality of the paper itself with this criterion, but only its contributions’ alignment with our purpose.

The second quality assessment criteria (QA2) rates papers according to the forums where they were published. It considers “high” for papers published in forums rated A, and “medium” for papers published in forums rated B, according CORE[[2]](#footnote-2) for conferences, and SJR[[3]](#footnote-3) for journals.

The third quality assessment criteria (QA3) rates papers according to their citations. Where, 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 low score for articles without citations. We will use Google Scholar to verify citations.

However, the QA3 will be unfair to recent work for having fewer citations. For these cases, the fourth quality assessment criteria (QA4) analyze, 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. Analyze Protocol (A.2), Provide Feedback (A.3) and Review Protocol (A.4)

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, we prepared a 30-minute presentation with the objective of the study, the process followed, and the outcomes. After presentation, we had session to discuss and collect reviewer comments based on the presentation and a checklist was provided to the Reviewers for feedback. This checklist was composed of 10 questions, each evaluated in a range 1 to 5, where 1 meant full disagreement and 5 meant full agreement with the statement. In general, the feedback received was very good, as the quality assessment results ranged from 75% (average 4) to 100% (average 5).

1. Search Studies

This subprocess is composed of four activities (see Figure 5). From these activities, three are assigned to the Researchers responsible for the study and one is assigned to the Reviewers. The Researchers are responsible for the activities Perform Search in the Sources (B.1), Analyze Search Results (B.2)and Apply Quality Assessment (B.3); and the Reviewers is responsible for the activity Review Primary Studies (B.4). Each activity will be detailed in next sections.

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Figure 5. Subprocess (B) Search Studies.

* + 1. Perform Search in the Sources (B.1)

The objective of this activity is to execute the searches in digital libraries. Thus, some specific configurations were considered during the search in each database: advanced search with command line was selected in all databases as it demonstrated to be more accurate than a simple advanced search; papers metadata was used to perform the searches; and the following specificities were considered per database:

* Web of Science: ;
* ACM Digital library:;
* IEEE Explore:;
* Science Direct (Elsevier):;
* Scopus:;
* Springer Link:;
* Engineering Village:.

Figure ?? shows the results of the search queries in Table 2 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. 3.** Studies found distributed by digital libraries.

* + 1. Analyze Search Results (B.2) and Apply Quality Assessment (B.3)

The objective of theses activities is to analyze papers 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 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.

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Figure 6. An Overview of the Primary Studies 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, that occurs in the Apply Quality Assessment activity, 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 ??? papers selected in the previous phase, ??? were rejected by the exclusion criteria (E1 to E5) after reading the entire text.

About o E6 criteria, ??? papers (Ref) with a score <1.5 were excluded from the analysis.

**Fig. 4.** Studies found distributed by digital libraries.

Review Primary Studies (B.4) The objective of this activity is to reviews list 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. Thus, any inconsistency of the researchers 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.

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

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Ref** | **Year** | **GCQ1** | **GCQ2** | **GCQ3** | **GCQ4** | **GCQ5** | **GCQ6** | **EQC1** | **EQC2** | **EQC3** | **EQC4** | **QC1 score** | **QC1** | **Qty ref** | **QC3** | **CQ4** | **Status** |
|  | 2019 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2019 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ? | 2019 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 3.25 | High | 1 | Medium | High | Accepted |
| 29 | 2019 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.50 | 1.00 | 1.00 | 1.00 | 0.00 | 3.17 | High | 1 | Medium | High | Accepted |
| 30 | 2019 | 1.00 | 1.00 | 1.00 | 0.50 | 0.50 | 0.50 | 1.00 | 1.00 | 1.00 | 0.00 | 3.00 | High | 5 | Medium | High | Accepted |
| 31 | 2019 | 1.00 | 1.00 | 1.00 | 0.50 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 3.17 | High | 2 | Medium | High | Accepted |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 33 | 2018 | 1.00 | 1.00 | 0.50 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 1.00 | 0.00 | 1.92 | Medium | 1 | Medium | High | Accepted |
| 46 | 2019 | 1.00 | 1.00 | 1.00 | 0.50 | 1.00 | 0.50 | 1.00 | 1.00 | 1.00 | 0.00 | 3.08 | High | 4 | Medium | High | Accepted |
| 47 | 2018 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 3.25 | High | 3.00 | Medium | High | Accepted |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2018 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2018 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2017 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2017 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2017 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2017 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2017 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2017 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2016 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2015 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2014 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2013 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2013 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

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 [34, 39, 45] use the eye tracking device to evaluate different business process modeling notations to determine which is best understood. Studies [34, 41, 47] 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 | Studies |
| In the comparison between notations | [34, 39, 45] |
| In addition of new artifacts | [29, 41, 47] |
| In the evaluation of the models | [30, 31, 32, 33, 35, 36, 37, 38, 40, 42, 43, 44, 46] |

* 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 [48], 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 [48]. Meanwhile, the *duration* represents the time the participant takes to complete a task [49] 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.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Eye Fixation | Saccade | Scan Path | Duration | Pupillometry | Comprehension Questions | Not  Specified |
| [29, 30, 31, 32, 33, 28, 36, 37, 38, 39, 40, 44, 45, 46] | [29, 32, 33, 34, 38, 39] | [32, 33, 28, 37, 39, 40, 45] | [31, 32, 33, 37, 40, 44, 45] | [36, 42] | [28, 40, 44, 45, 47] | [35] |

* 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 [34] compares the understanding between models in BPMN [29] and EPC [44]. Likewise, the work A11 performs the comparison between the understanding of the models in the notations BPMN [26], EPC [50], Petri Net [51] and eGantt [52]. As well as the study A17 that makes a comparison between the languages CIAN [53] and CIT [54]. Finally, study [30] uses the DCR notation to evaluate the understanding of business process models; and studies [38, 40] 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 |
| [29, 31, 32, 33, 34, 35, 36, 37, 39, 40, 42, 43, 44, 46, 47] | [29] | [31, 39] | [39] | [39] | [45] | [45] | [38, 40] |

* 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.

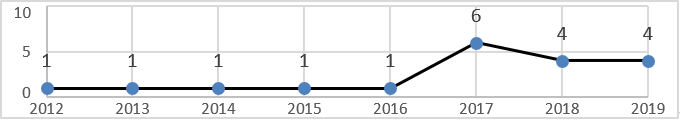
**Table 6.** Studies Contributions.

|  |  |
| --- | --- |
| Reference | Contributions |
| [29] | The process models with linked rules are associated with a lower cognitive load, shorter comprehension time and higher accuracy comprehension. |
| [30] | The evaluation of the data allowed the study to classify three distinct reading profiles (Graph, Simulation, and Law text) of process models. |
| [31] | The results suggest that successful error diagnoses are linked to shorter total viewing time and shorter fixation duration, with a significant difference between semantic and syntactic errors. |
| [32] | He identified that both samples of participants, beginners, and experts, have similar strategies to understand a process model in the first iteration. However, they argue that specialists understand process models more efficiently; that is, exploration paths reflect fewer fixations and balances. |
| [33] | 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. |
| [34] | 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. |
| [35] | The understanding of the model decreases with the increasing number of nesting and with the size of the model. They point out that the enthusiasm of the reader of the process model disappears with the rising complexity of the model. |
| [36] | It is a work in progress, presenting only a description of the experiment that investigates how designers experience challenges by measuring the cognitive load. The authors did not describe anything in terms of outcome. |
| [37] | 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. |
| [38] | The authors pointed out that participants took longer to understand parts of the gateway models, especially XOR and loops. |
| [39] | Participants faced difficulties in understanding the models as complexity increased, even with the participant knowing the model scenario. Among the modeling languages, only the eGantts notation obtained a higher level of accuracy as the level of difficulty of the models increased. Regardless of the experience a subject has with process modeling, generally, in the first iteration of understanding all follow the same analysis of the model. During the experiments, they found that process models with an explicit start and a final symbol make it easier to understand the process model. |
| [40] | The results indicate that intermediate readers tend to be more effective in terms of understanding the process model compared to beginners. As the level of difficulty increases, the time is taken to understand the process model increases as well. Concerning the less complicated process model, it seems that the newcomers show a weaker performance compared to the intermediaries. In turn, the performance of novices is approaching the same level as that of the intermediaries with an increased level of difficulty. In general, they seem that the BPMN process models can be intuitively understood. |
| [41] | 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. |
| [42] | For a modeler, an increase in the cognitive load was observed whenever it is necessary to name activities of the process model from the text information. |
| [43] | 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. |
| [44] | 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. |
| [45] | In regard to cognitive processing measures, it can be concluded that the layout of the CIAN diagrams generates less efficient searches due to having the highest total number of fixations when the model is explored. Determining the cognitive load during the comprehension task is less in the case of CIAN, which indicates that the participants need more time to understand the individual objects.We can conclude that the use of icons to represent roles facilitates the finding of the answer in the case of CIAN, although the subject needed more time to be sure before responding (they need to visualize more elements). In case of CTT, the location of the response is not so straightforward, but when the subject has located the solution of the comprehension task, he / she is sure of the answer more quickly. |
| [46] | 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. |
| [47] | 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 [34, 39, 40] emphasize that the size and complexity of the model influence its understanding. On the other hand, studies [35, 38] affirm that complex structures like loops and nestings diminish the understanding of process models. It was also observed in studies [34, 39] 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 [29, 41], the addition of complementary elements in the models facilitated the understanding of the participants. Only studies [36, 42] 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 [43] 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.

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**Fig. 5.**Distribution of studies per year.

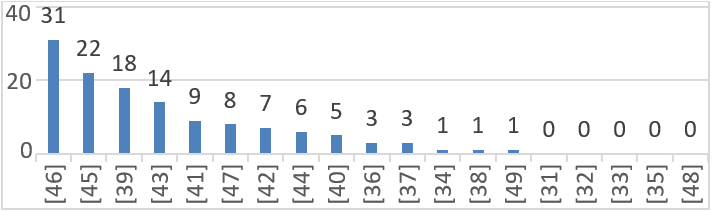
As can it be seen in Fig. 4, the Springer Link research database returned most (78.95%) of the selected studies. Only studies [37, 41] have as source the basis of research Science Direct. No reviews were chosen on the bases: ACM, Engineering Village, IEEE, Scopus and Web of Science.

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 [30, 38, 43], Information Systems and Neuroscience also with three mapped studies [31, 36, 42] and Enterprise, Business Process and Information Systems Modeling has 2 mapped reviews [38, 39]. Also, we outlined 4 (21.06%) studies which published papers in journals and only one study [29] (5.26%) was released as a chapter of the book Integrating Business Process Models and Rules.

****

**Fig. 6.** 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. 7.** Number of citations per study.

Papers [**43**, 42, 37, 41] are the most popular accounting for 65.89% of citations. The paper [**43**] has 31 citations, and this may be due to the pioneering nature of this study, being published in 2012. The works [29, 30, 31] and [33] 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 [32, 41] have the most significant number of authors written by the same seven authors. All the authors of the study [32] 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 [55, 56] 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 [49] 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 [49] 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 [36, 41] 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 [29, 32, 33, 34].

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.

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