Understanding Process Models Using the Eye-Tracking: a systematic mapping

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. The objective of this paper is to provide an overview of researches that evaluate the understanding of process models through eye-tracking techniques. A systematic mapping study was developed to achieve this goal, following the best practices in the area of Software Engineering. This study consolidated 19 papers for the analysis and extraction of data from the 1,161 studies initially found in the last ten years.

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 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 methodology, 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 describingthe 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.

2 Background

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].

In [17], 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.

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 [18], 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 [19]. Thus, such technology allows analyzing user's performance in reading and interpreting business process models.

3 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 [20]. 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.
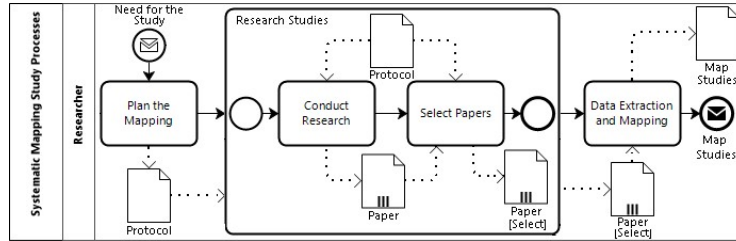

Fig. 1 Typical Systematic Mapping Study Processes[1] adapted from [14].

Other activities of the process, as proposed in [14], were also altered and/or rearranged in this study. As can be observed in Fig. 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.

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[1]The process built using BPMN (Business Process Modeling Notation) [21].

3.1 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).

Table1. Research Questions.

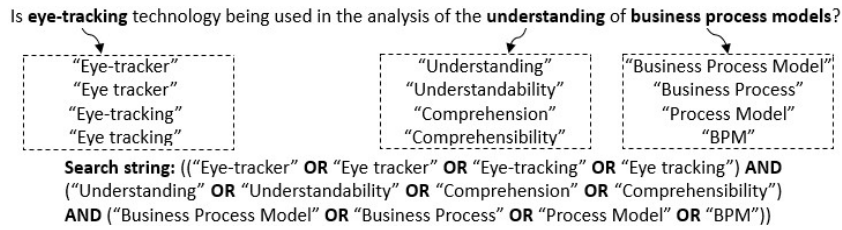| ID	Questions
RQ1 (MAIN)	Is eye-tracking technology being used in the analysis of the understanding of business process models?
RQ2	What metrics are used to measure the visual comprehension of eye-tracking business process models?
RQ3	Which business process model notations are evaluated in the studies?
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?

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

| "Eye-tracker" "Eye tracker" "Eye-tracking" "Eye tracking" | "Understanding" "Understandability" "Comprehension" "Comprehensibility" | "Business Process Model" "Business Process" "Process Model" "BPM" |

Search string: (("Eye-tracker" **OR** "Eye tracker" **OR** "Eye-tracking" **OR** "Eye tracking") **AND** ("Understanding" **OR** "Understandability" **OR** "Comprehension" **OR** "Comprehensibility") **AND** ("Business Process Model" **OR** "Business Process" **OR** "Process Model" **OR** "BPM"))

Fig. 2. Search string construction based on Silva *et. al.* [22].

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.

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).

3.2   Research Studies

This subprocess consists of two activities: *Conduct Research* and *Select Papers*. 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. In total, 1161 studies of the automatic search in the digital libraries were found, in which: 75 studies were retrieved from the ACM Digital Library, 15 came from Engineering Village, 23 were retrieved from the Scopus database, 636 from Springer Link, 8 were found in the Web of Science 404 came from Science Direct and no study was retrieved from the IEEE.

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. In this initial selection, of 1,161, 1057 studies were excluded because the research question was not applied, 41 of which were duplicated, 1 study was not written in the English, 1 article couldn't be accessed, 31 of them were only a summary and did not criteria of inclusion and exclusion. Based on this first selection, only 30 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. This new evaluation resulted in 19 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 thishappened, a third researcher sought a consensus between the two previous ones.

4   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.

4.1   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 [28, 33, 39] use the eye tracking device to evaluate different business process modeling notations to determine which is best understood. Studies [28, 35, 41] 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	[28, 33, 39]
In addition of new artifacts	[23, 35,41]
In the evaluation of the models	[24, 25, 26, 27, 29, 30, 31, 32, 34, 36, 37, 38,40]

4.2   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 [42], 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 [42]. Meanwhile, the *duration* represents the time the participant takes to complete a task [43] 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
[23, 24, 25, 26, 27, 28, 30, 31, 32, 33, 34, 38, 39, 40]	[23, 26, 27, 28, 32, 33]	[26, 27, 28, 31, 33, 34, 39]	[25, 26, 27, 31, 34, 38, 39]	[30, 36]	[28, 34, 38, 39, 41]	[29]

4.3 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 [21]. Study [28] compares the understanding between models in BPMN [23] and EPC [44]. Likewise, the work A11 performs the comparison between the understanding of the models in the notations BPMN [21], EPC [44], Petri Net [45] and eGantt [46]. As well as the study A17 that makes a comparison between the languages CIAN [47] and CIT [48]. Finally, study [24] uses the DCR notation to evaluate the understanding of business process models; and studies [32, 34] 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
[23, 25, 26, 27, 28, 29, 30, 31, 33, 34, 36, 37, 38, 40, 41]	[23]	[25, 33]	[33]	[33]	[39]	[39]	[32, 34]

4.4 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
[23]	The process models with linked rules are associated with a lower cognitive load, shorter comprehension time and higher accuracy comprehension.
[24]	The evaluation of the data allowed the study to classify three distinct reading profiles (Graph, Simulation, and Law text) of process models.
[25]	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.
[26]	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.
[27]	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.
[28]	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.
[29]	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.
[30]	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.
[31]	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.
[32]	The authors pointed out that participants took longer to understand parts of the gateway models, especially XOR and loops.
[33]	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.
[34]	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.
[35]	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.
[36]	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.
[37]	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.
[38]	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.
[39]	Inregards 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.
[40]	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.
[41]	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 [28, 33, 34] emphasize that the size and complexity of the model influence its understanding. On the other hand, studies [29, 32] affirm that complex structures like loops and nestings diminish the understanding of process models. It was also observed in studies [28, 33] 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 [23, 35], the addition of complementary elements in the models facilitated the understanding of the participants. Only studies [30, 36] 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.

4.5 RQ5 - When and where have the studies been published?

Fig. 3 shows the distribution of the studies considering the year of its publication. The first mapped study is [37] 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.
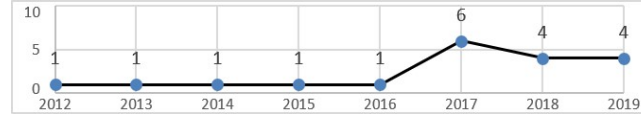
Fig. 3. Distribution of studies per year.

As can it be seen in Fig. 4, the Springer Link research database returned most (78.95%) of the selected studies. Only studies [31,35] 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 [24, 32, 37], Information Systems and Neuroscience also with three mapped studies [25, 30, 36] and Enterprise, Business Process and Information Systems Modeling has 2 mapped reviews [32,33]. Also, we outlined 4 (21.06%) studies which published papers in journals and only one study [23] (5.26%) was released as a chapter of the book Integrating Business Process Models and Rules.
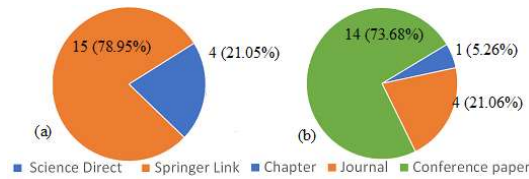

Fig. 4. Studies per database and types.

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.
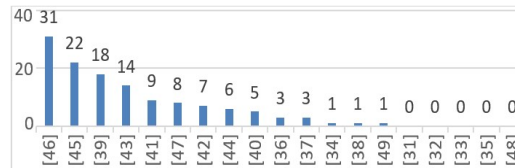

Fig. 5. Number of citations per study.

Papers [37, 36, 31, 35] are the most popular accounting for 65.89% of citations. The paper [37] has 31 citations, and this may be due to the pioneering nature of this study, being published in 2012. The works [23, 24, 25] and [27] have no citation, being less popular perhaps because they were published in more recent years.

4.6 RQ6- How many researchers are using the eye-racking device to evaluate understanding in process models?

In the papers there are 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 [26, 35] have the most significant number of authors written by the same seven authors. All the authors of the study [26] 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.

5 Related Works

The studies [49, 50] 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 [43] 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 [43] 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.

6 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 [30, 35] 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, e.g. for instance, ocular, sacral, sweep path, duration and attempt-pill [23, 26, 27, 28].

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

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