Utilizing the Capabilities Offered by Eye-Tracking to Foster Novices' Comprehension of Business Process Models

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Abstract. Business process models constitute fundamental artifacts for enterprise architectures as well as for the engineering of processes and information systems. However, less experienced stakeholders (i.e., novices) face a wide range of issues when trying to read and comprehend these models. In particular, process model comprehension not only requires knowledge on process modeling notations, but also skills to visually and correctly interpret the models. In this context, many unresolved issues concerning the factors hindering process model comprehension exist and, hence, the identification of these factors becomes crucial. Using eye-tracking as an instrument, this paper presents the results obtained of a study, in which we analyzed eye-movements of novices and experts, while comprehending process models expressed in terms of the Business Process Model and Notation (BPMN) 2.0. Further, recorded eye-movements are visualized as scan paths to analyze the applied comprehension strategies. We learned that experts comprehend process models more effectively than novices. In addition, we observed particular patterns for eye-movements (e.g., back-and-forth saccade jumps) as well as different strategies of novices and experts in comprehending process models.

Keywords: Business Process Model Comprehension, Eye-Tracking, Cognition, Eye-Movement Modeling Examples, (Hidden) Markov Model

1 Introduction

Business Process Management (BPM) aims at the creation, improvement, as well as automation of business processes and has become vital for the success of any enterprise [1]. In this context, a *process model* acts as a blueprint comprising tasks, decisions, and actors dedicated to a specific process. Usually, these process models are expressed in terms of textual or graphical artifacts. The latter,

in turn, are utilized to advance the understanding of business processes (i.e., *process model comprehension*) for all involved stakeholders [2].
Generally, process models should be created in a way such that process stakeholders do not face any problems in comprehending them. Still, stakeholders are encountering challenges in the comprehension of process models [3], especially the less experienced ones (i.e., *novices*) [4]. In this context, the use of *eye-tracking* might provide valuable insights into the cognitive processes of comprehending process models [5]. Amongst others, assertions about the *cognitive load* can be made and the *process model comprehension strategies* applied can be identified, e.g., by visualizing the corresponding *scan path*. In detail, the *scan path* reflects the chronological order of *fixations* (i.e., gaze over informative areas of interest) and *saccades* (i.e., quick eye-movements between *fixations*) [6].
This paper presents the results we obtained from a process model comprehension study relying on eye-tracking. In detail, *novices* and *experts* in the domain of process modeling had to study three different process models expressed in terms of the *Business Process Model and Notation (BPMN) 2.0* [7], whilst their *fixation* and *saccade patterns* were recorded by an eye-tracker. The objective of the study is to deliberately disclose the approaches applied by novices and experts to comprehend process models. Further, we want to investigate whether or not there are differences in comprehending process models, e.g., in which way the applied comprehension strategies between the participants differ. The study insights can be used to derive comprehension guidance, especially for novices, and be used to augment tools with features fostering process model comprehension.
The remainder of the paper is structured as follows: Section 2 describes the context and setting of the study. Study results, in turn, are analyzed and discussed in Section 3. Related work is discussed in Section 4. Finally, a summary and an outlook on future work are given in Section 5.

2 Study Context

In general, *comprehension* constitutes a cognitive process that establishes relations between available information on objects and events in the long-term memory, together with information perceived at the moment from the sensory, working, or short term-memory [8]. In this context, *process model comprehension* can be termed as the process for decoding and capturing the information documented in process models [9]. To be more precise, individuals must cope with the complexities involved of parsing the relevant *syntactic*, *semantic*, and *pragmatic information* in a process model. As a consequence, novices are frequently confronted with the challenge to properly read and comprehend process models [10].
To systematically study this challenge, we conducted an eye-tracking study on how to foster the comprehension of process models. For this purpose, we identify the *scan paths* (i.e., chronological order of *fixations* and *saccades*) of both novices and process modeling experts while comprehending process models documented in terms of *BPMN 2.0*. Moreover, it is found in eye-tracking studies that experts comprehending a *stimulus* (e.g., picture) are more likely to reflect a smaller num-

ber of *fixations*, *saccades*, and consequently a shorter *scan path length* compared to novices [11]. Therefore, amongst others, the use of eye-tracking enables us to measure the cognitive load as well as to reveal visual stumbling blocks in a process model, which, in turn, might hinder overall comprehension.

2.1 Study Setting

First of all, we want to identify the strategies for reading and comprehending process models and analyze whether or not there are differences between novices and experts. Therefore, we invite novices ($n = 17$) and experts ($n = 19$) from the field of process modeling to participate in the study. This categorization into two samples (i.e., novices and experts) is accomplished by a median split, i.e., based on the time spent on process modeling so far, as provided through a self-reporting. In the study, participants are asked to read and comprehend **three** different BPMN 2.0 process models. These process models cover three different scenarios, i.e., *fitness training*, the *purchase of an item in an auction*, and the *ordering of a pizza*. Further, the process models reflect three different *levels of complexity*, i.e., *easy*, *medium*, and *hard*. In detail, the *easy process model* only comprises a sequence of basic modeling elements of BPMN 2.0. With increasing *level of complexity*, new BPMN elements are introduced, previously not contained in the process models, and the total number of elements is increased. After comprehending a process model, participants need to answer *four true-or-false comprehension questions*, solely referring on the semantics of the process scenario. The questions are used in order to ensure that participants actually study the process models. Moreover, *relative fixations* and *saccade patterns* are recorded with the SMI iView X Hi-Speed system at a sampling rate of 240 Hz. Demographic data and qualitative feedback, in turn, are gathered based on questionnaires. In addition, participants are given the instruction to complete the study as fast as possible but, on the other, as meticulous as possible.

3 Analysis of Eye-Movements

Table 1 presents *mean* and *standard deviation (SD)* for all values obtained from the two samples, i.e., novices and experts. For each *level of complexity* (i.e., *easy*, *medium*, and *hard*), the process model comprehension *duration (in s)*, the *fixation* and *saccade counts* as well as the length of the *scan path (in px)* are shown. As expected, a clear difference between the single *levels of complexity* is discernible, i.e., an apparent increase in respective factors. Further, juxtaposing the results obtained for novices and experts, novices need more time for process model comprehension. *Fixation* and *saccade counts* reflect a higher number and this results in a longer *scan path* for the comprehension of process models.
Data collected with eye-tracking during the study is analyzed and visualized with SMI BeGaze software, which allows for an extensive analysis of recorded eye-movements. After analyzing of the obtained data, different *scan paths* for comprehending a process model (i.e., *process model comprehension strategies*) are

		Both		Novices		Experts	
	Factor	**Mean**	**(SD)**	**Mean**	**(SD)**	**Mean**	**(SD)**
Easy	**Duration**	35.37	(14.52)	38.53	(16.26)	31.78	(12.29)
	Fixation	121.42	(41.57)	138.76	(39.41)	104.84	(43.39)
	Saccade	120.81	(39.81)	130.47	(36.12)	111.11	(43.84)
	Scan Path	24398.44	(9349.76)	26342.18	(7192.88)	22454.89	(11107.53)
Medium	**Duration**	54.11	(22.05)	63.11	(23.28)	46.05	(16.30)
	Fixation	187.08	(57.98)	209.12	(56.37)	167.47	(57.54)
	Saccade	204.36	(68.50)	220.41	(69.54)	188.32	(68.94)
	Scan Path	42181.03	(29357.56)	47364.35	(38368.67)	37543.32	(17865.93)
Hard	**Duration**	67.14	(29.02)	73.07	(33.04)	62.16	(24.01)
	Fixation	240.94	(79.16)	264.94	(99.88)	216.00	(56.04)
	Saccade	233.69	(83.85)	260.06	(88.90)	207.47	(81.50)
	Scan Path	45217.22	(16077.79)	49534.24	(18576.74)	40900.32	(13962.37)

Table 1: Descriptive Results (i.e., Both, Novices, and Experts)

derived for novices and experts respectively. However, both samples show alike comprehension strategies in the *first iteration*, i.e., after having a first glance on the process models. More precisely, beginning from the start element of a process model, both samples visually consider all elements in a process model through an *element-to-element procedure*. After completing the first iteration, strategies of novices and experts respectively differ during the *second iteration*. Thereby, particular eye-movement patterns become apparent, e.g., *back-and-forth saccade jumps* and *targeted search*. Many novices reconsider the process model once more from the start element, but with a stronger emphasis on single elements and *modeling constructs* (e.g., parallelism, decision points before splitting control flows into alternative paths), indicating strong variabilities in *saccade patterns* as well as *fixation times*. Experts, in turn, focus on decisive *modeling constructs* (e.g., decision points) in the process models and, hence, their attention shifts between these elements. As opposed to experts, the *scan paths* of novices reflect higher *fixation* and *saccade counts*. Further, they require a *greater duration* for comprehending a process model (cf. Table 1). Figs. 1 and 2 illustrate two identified *scan paths*, one from a novice and one from an expert.

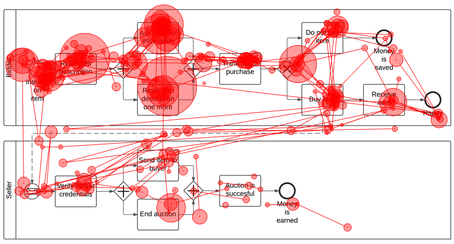

Fig. 1: Scan Path of a Novice

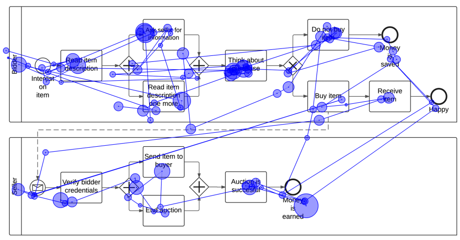

Fig. 2: Scan Path of an Expert

In Fig. 1, the *scan path* of a novice is shown. It consists of *301 fixations*, *254 saccades*, and an overall *comprehension duration of 98.17 seconds*. On the contrary, the experts' *scan path* (cf. Fig 2) comprises *100 fixations* and *99 saccades*. In addition, the *comprehension duration is 27.47 seconds*. Comparing both *scan paths*, it becomes apparent that the novice spent more time studying the elements in the process models, whereas the expert moved quickly over the elements.

3.1 Discussion

An explanation for our study findings might be that process models reflect complex business processes with high information density. Thus, the process of comprehending such models leads to a high cognitive load, especially regarding novices [12]. Process model comprehension not only requires knowledge on process modeling notations, but also the capability to visually interpret these models. Usually, these capabilities evolve over time due to increasing practical experiences [13]. However, existing research revealed that the visual observation capabilities of experts can be efficiently conveyed to novices [14]. To evaluate this, we are currently conducting another exploratory study, in which we explicitly show the novices how experts visually comprehend process models. For this purpose, we are analyzing the *scan paths* of modeling experts more deeply with the goal to derive an *average scan path*. Furthermore, decisive *modeling constructs* (e.g., parallelism) are identified, which are essential regarding the correct comprehension of process models. Consequently, novices can be directed through a process model by selective reading, ensuring a correct process model comprehension.
The material used in the current study is provided in terms of *Eye-Movement Modeling Examples (EMMEs)*, which shall serve as a basis for guiding novices in comprehending process models [15]. *EMMEs* either reflect the *scan paths of experts* or highlight *specific modeling constructs* superimposed onto a process model. In general, the use of *EMMEs* allows us to focus on the various dimensions in a process model. More specifically, any process model contains information related to different dimensions, e.g., *syntactics* or *semantics* [16]. Amongst others, the *syntactic* dimension refers to compliance with modeling rules, whereas *semantics* refer to proper and complete documentation of a scenario in a process model. Therefore, based on the dimension set, the *EMMEs* can reflect different conditions (cf. Figs. 3 and 4). Fig. 3 shows the *Path Display Condition*, which visualizes the derived *experts average scan path* in a process model. The *Path*

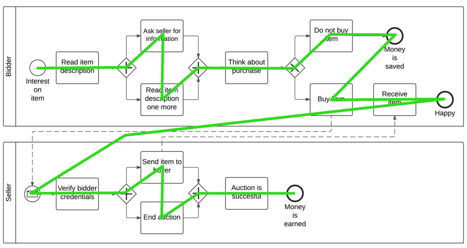

Fig. 3: Path Display Condition

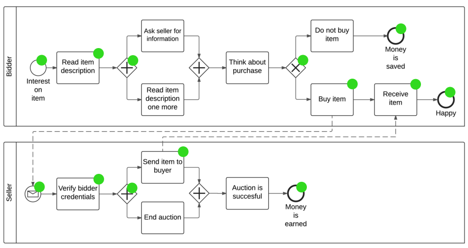

Fig. 4: Dot Display Condition

Display Condition traverses the process model with all relevant elements, ensuring a proper comprehension of the process scenario. The *Dot Display Condition* (cf. Fig. 5), in turn, is used for highlighting specific *modeling constructs* as well as their *function* (e.g., process model behavior) with solid dots that can dynamically change their size (i.e., larger or smaller), according to the *fixation counts*. We believe that the process model comprehension of novices can be increased by exploiting modeling experts' eye-movements in a process model.
After applying the *EMMEs*, we will evaluate the performance of novices in respect to process model comprehension with the results obtained from the first study. Moreover, we will perform a third study, the *scan paths* from the third study will be analyzed and interpreted using a *(Hidden) Markov Model (HMM)* to detect potential latent strategies for model comprehension [17]. Besides the observable states (e.g., *back-and-forth saccade jumps*), there are non-observable states of eye-movements, which can be utilized to foster process model comprehension. In this context, we will introduce a taxonomy to identify latent fixations and saccades in eye-tracking data based on a probabilistic *(Hidden) Markov Model*. Finally, Fig. 5 summarizes the *three-stage study*.

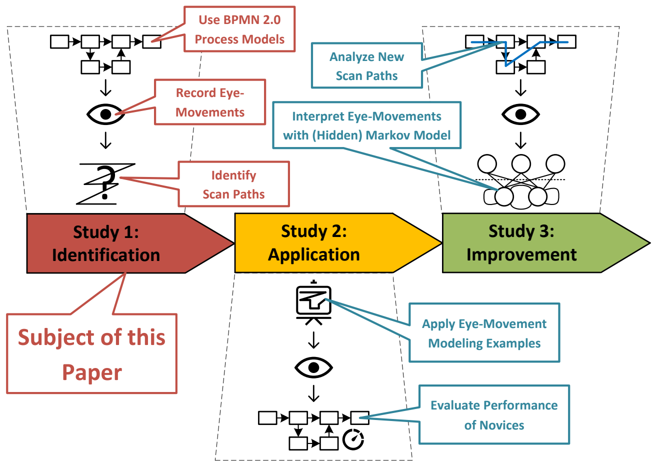

Fig. 5: Three-Stage Study to Foster Process Model Comprehension

4 Related Work

A categorization of empirical works that focus on the influence of both objective and subjective factors on process model comprehension is presented in [18]. This work also involves a discussion of the factors having an impact on model comprehension. A more specific work is presented in [19], which investigates how the characteristics of an individual (e.g., theoretical knowledge) influence the subjective process model comprehensibility, whereas [20] focuses on objective model comprehensibility suggesting guidelines for improving BPMN 2.0 process models. Taking cognitive aspects of process model comprehension into account, [21] shows that cognitive styles as well as theoretical knowledge on process modeling notations are correlated with the performance in comprehending process models. In turn, a cognitive overload impairs model comprehension as demonstrated in [22]. Using eye-tracking in the context of process model comprehension, [23] shows how the performances of individuals vary confronting them with different comprehension tasks. Furthermore, [23] provides insights into the development of strategies for comprehending process models. The study presented in [24], in turn, demonstrates the positive impact of *EMMEs* on learning processes. Further, the improvement of learning styles with derived latent behavior patterns based of a Decision Tree and a (Hidden) Markov Model is reported in [25].

5 Summary and Outlook

We presented results obtained from a process model comprehension study that uses eye-tracking. In detail, the strategies applied by novices and experts in process model comprehension were identified through the analysis of their *fixation* and *saccade counts*, i.e., *scan paths*. While both samples reveal similar strategies for comprehending a process model in the *first iteration* (i.e., after having a first glance on the process model), the strategies applied between novices and experts vary with time passed. Particularly, experts are comprehending process models in a more efficient manner, i.e., *scan paths* reflect less *fixations* and *saccades*. In general, the presented study is part of a *three-stage study* aiming to foster process model comprehension. In detail, all studies utilize the capabilities offered by eye-tracking. As novices obviously experience difficulties in the visual comprehension of process models, support and guidance should be improved to enable proper process model comprehension. Currently, we use the scan paths gathered from experts as *Eye-Movement Modeling Examples (EMMEs)* in another study to teach and convey the applied strategies for process model comprehension to novices. Finally, in a third study, we will use a *(Hidden) Markov Model (HMM)* to unravel latent strategies for process model comprehension. Based on the three-stage study, the objective is to provide guidance and directives, especially for novices, enabling a better comprehension of process models. Moreover, training in model comprehension can be particularly tailored focusing on difficulties to comprehend modeling constructs. Further, the findings can be used to augment tools with features improving the reading and comprehension of process models by providing visual cues about the syntax of process model elements.

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