Assessing Process Models with Cognitive Psychology

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Abstract: The importance of a business process model to be understandable to its reader is widely acknowledged. In this vein, several approaches to assess and improve understandability exist, such as theoretical quality frameworks, modeling guidelines and process model metrics. In this paper we propose to investigate the issue of understandability from the angle of cognitive psychology. To this end, we discuss how the cognitive process of inference acts as a central process of problem solving. In particular, we illustrate in how far chunking, computational offloading and external memory might have an impact on the understandability of process models. Our propositions are theory-based so far and will serve as basis for planned empirical investigations, as discussed in the research agenda.

Keywords: Business Process Modeling, Model Understandability, Cognitive Psychology.

1 Introduction

In order to support the analysis and design of, for example, process-aware information systems, service-oriented architectures and web services, *business process models* or *process models* for short, are employed [RM11]. Especially process models used in project phases that are concerned with requirement documentation are needed to be intuitive and easy to understand [WW02]. As consequence, various process modeling languages have been proposed, each one of them claiming superiority, cf. [FMR+09]. To contribute to an objective discussion, we employ *cognitive psychology* as tool for assessing and discussing the understandability of process models. More specifically, we embed the concept of *inference* as central process for problem solving in the context of business process modeling.

The remainder of this paper is structured as follows. Section 2 discusses related work. Then, Section 3 introduces concepts from cognitive psychology and puts them in the context of business process modeling. Finally, Section 4 summarizes the findings and concludes the paper with a research agenda.

2 Related Work

The understandability of process models is approached from various angles. For instance, in [BRU00], a theoretical point of view is chosen. Complementary, several studies report from empirical investigations. Most works thereby employ the concept of

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metrics computed on structural aspects of the process model to assess understandability, e.g., [MRC07, VRvdA08, RM11, Car06, MMRS09]. An overview of metrics from software engineering, adapted to business process models can be found in [CMNR06, GL06]. Another interesting work to be mentioned is [MRvdA10], in which empirically validated guidelines for process modeling with the aim to improve understandability are presented. Common to all these approaches is that the model is in the focus of investigation. In our work, however, we use cognitive psychology to focus on the *interplay of model and human* to examine understandability.

3 Cognitive Concepts for Understanding Process Models

Basically, three different problem-solving *"programs"* or *"processes"* are known from cognitive psychology: search, recognition and inference [LS87]. Search and recognition allow for the identification of information of rather low complexity, i.e., locating an object or the recognition of patterns. Most conceptual models, however, go well beyond complexity that can be handled by search and recognition. Here, the human brain as *"truly generic problem solver"* [Tra79] comes into play. Thereby, cognitive psychology differentiates between *working memory* that contains information that is currently being processed, as well as *long-term memory* in which information can be stored for a long period of time [PTTG03]. Most severe, and thus of high interest and relevance, are the limitations of the working memory. As reported in [Mil56], the working memory can not hold more than 7 ± 2 items at the same time. In addition, information held in the working memory decays after 18–30 seconds if not rehearsed [Tra79]. To illustrate how severe these limitations are, consider the sequence A-G-K-O-M-L-J. The average human mind is just capable of keeping this sequence in working memory, and, after 18–30 seconds the sequence will be forgotten.

The importance of the working memory has been recognized and led to the development and establishment of *Cognitive Load Theory* (CLT), meanwhile widespread and empirically validated in numerous studies [Ban02]. Theories of CLT revolve around the limitations of the working memory and how these limitations can be overcome—especially the second question is of interest for the understandability of process models. Hence, subsequently, we will discuss three strategies for dealing with the working memory's limits. First, we will discuss the chunking of information. Second, we will show how process models can support inference through computational offloading. Third, we will introduce external memory, which allows to free resources in the working memory.

Chunking and Schema Acquisition. Information is believed to be memorized in interconnected *schemata* rather than in isolation [Gra07]. Those schemata, which are stored in long-time memory, can be used to aggregate information and handle it as a "*chunk*" of information in the working memory. Each schemata requires only one slot in working memory when used, hence mental effort is effectively reduced, cf. [New90, CWWW00, Gra07]. The process of aggregating information to a chunk using a schema, in turn, is referred to

as *"chunking"* [Gra07].

To illustrate how chunking actually influences the understandability of business process models, an example is provided in Figure 1. An unexperienced reader may, as shown on the left hand side, use three chunks to store the process fragment: one for each XOR-gateway and one for activity *A*. In contrast, an expert may, as shown on the right hand side, recognize this process fragment as a pattern for making activity *A* optional. In other words, in her long-time memory a schema for optional activities is present, thereby allowing her to store the entire process fragment in *one* slot in the working memory.

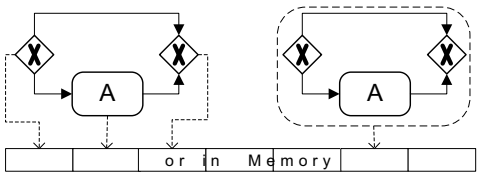

Figure 1: Chunking of an Optional Activity

Computational Offloading. In contrast to chunking, which is highly dependent on the internal representation of information, i.e., how the reader organizes information in his mind, *computational offloading* highly depends on the exact external presentation of the business process model, i.e., visualization of the process model. In particular, computational offloading *"refers the extent to which differential external representations reduce the amount of cognitive effort required to solve information equivalent problems"* [SR96]. In other words, an external representation may provide features that help the reader to extract information. Instead of computing and inferencing respective information in the modeler's mind, information can, as in the process of recognition, more or less be "read-off" [SR96].

To put computational offloading into the context of business process modeling, a simple example illustrating the described phenomenon is shown in Figure 2. The illustrated process models are information equivalent, i.e., the same execution traces can be produced based on both Model A and Model B. However, Model A is modeled in BPMN, whereas for Model B the declarative modeling language ConDec [Pes08] was used (for a detailed explanation of declarative process models we refer to [Pes08, MPvdA$^+$10]). Consider the task of listing *all* execution traces that can be inferred from the process model. A reader familiar with BPMN will probably infer within a few seconds that Model A supports execution traces $<A, B, D>$ and $<A, C, D>$. Such information is easy to extract as BPMN provides an explicit concept for the representation of execution sequences, namely sequence flows. Thus, for identifying all possible execution traces, the reader simply follows the process model's sequence flows—the computation of all execution traces is offloaded to the process model. In contrast, for Model B, *no explicit representation* of sequences is present. Rather, constraints define the interplay of actions and do not necessarily specify sequential behavior. Thus, the reader cannot directly read off execution traces, but has to interpret the constraints in her mind to infer execution traces. In other words, process model B, while information equivalent to Model A, does not provide computational of-

floading for extracting execution traces. Consequently, even for a reader experienced with ConDec, listing all supported traces is far from trivial.

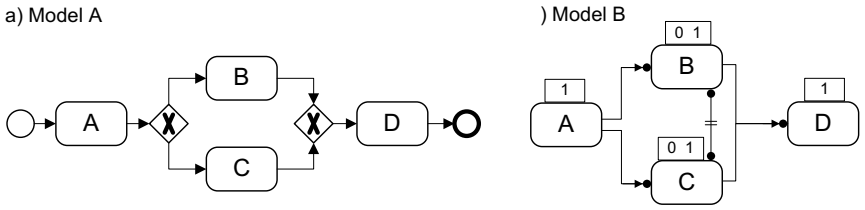

Figure 2: Computational Offloading

External Memory. Finally, we would like to introduce another mechanism that is known for reducing *mental effort*, i.e., the amount of working memory slots in use. In particular, we will discuss the concept of *external memory* in the context of business process models. An external memory is referred to any information storage outside the human cognitive system, e.g., pencil and paper or a black board [Swe88, Tra79, SR96, LS87]. Information that is taken from the working memory and stored in an external memory is then referred to as *cognitive trace*. In the context of a diagram, a cognitive trace would be to, e.g., mark, update and highlight information [SR96]. Likewise, in the context of process modeling, the model itself may serve as external memory. When interpreting a process model, marking an activity as executed while checking whether an execution trace is supported, can be seen as leaving a cognitive trace.

For the illustration of external memory and cognitive traces, consider the process model shown in Figure 3. Assuming the reader wants to verify, whether execution trace $<A, D, E, F, G, H>$ is supported by the process model. So far, as indicated by the bold path and the position of the token, she has "mentally executed" the activities A, D, E, F and G. Without the aid of external memory, she will have to keep in the working memory, which activities have been executed, i.e., sub-trace $<A, D, E, F, G>$, as well as the position of the token within the process instance. By writing down the activities executed so far, i.e., transferring this information from working memory to external memory (e.g., piece of paper), load on working memory is reduced. In addition, the process model even allows to store the "mental token"—either by simply putting a finger on the respective part of the process model or by marking the location of the token, as shown in Figure 3.

4 Summary and Research Agenda

In this paper we discussed the concept of inference from cognitive psychology in the context of business process modeling. In particular, we described how chunking, computational offloading and external memory can lower mental effort and, in turn, support inference and facilitate the understanding of a process model.

We acknowledge that this approach is still work in progress and conclude with identifying

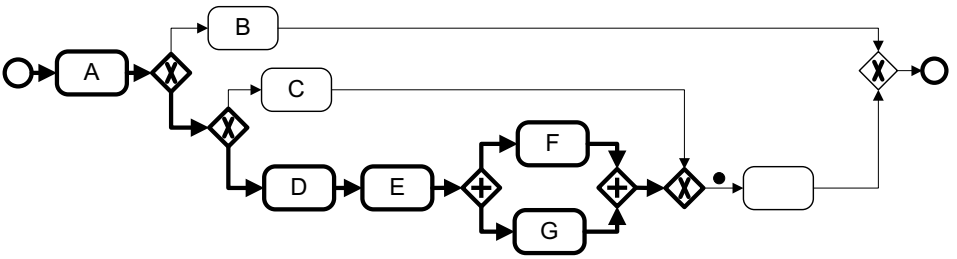

Figure 3: External Memory

a research agenda guiding our future research. First and foremost, we are planning to validate the described concepts for process models, i.e., to verify whether the expected effects can be observed in practice. It is assumed that effects are highly dependent on the exact representation of information, e.g., computational offloading may work differently in BPMN models than in ConDec [Pes08] models. Hence, we will start validation using well-known languages like BPMN and then investigate in how far findings can be generalized to other modeling languages like ConDec. Second, after concepts have been validated, we envision two major directions. On the one hand, as motivated in the discussion, we aim at contributing to an objective discussion about the superiority of process modeling languages. Validated concepts will give us then a *tool* to assess or predict the understandability of a process model. Such insights may be then used to guide the developement and improvement of process modeling languages. On the other hand, we plan to use the introduced concepts to systematically develop software that supports the understandability of process models. More specifically, as soon as the cognitive processes of understanding a process model are well enough understood, they can be used to systematically analyze shortcomings of process modeling languages and to provide appropriate computer-based support for compensating those shortcomings.

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