Cognitive Efforts in Using Integrated Models of Business Processes and Rules

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Abstract. The conceptual and pragmatic overlap between business process models and business rules indicates a need to model the two related aspects together. Yet, in practice, many business rules are modeled separately from the processes models they affect. While a considerable amount of research has developed integration methods for process and business rule modeling, whether such integration improves (or diminishes) the understanding of business processes has not been investigated. This paper explores whether the integration of business process models with business rules improves user cognition of process models. A four-stage cognitive process is proposed in the context of process model understanding followed by a discussion of how each of the process stages is affected by integrated models based on underlying theoretical perspectives from cognitive science.

Keywords: Business Process Management, Business Process Modeling, Integrated Modeling, Cognition Theory, Human Information Processing

1 Introduction

Conceptual models are widely used in organizations by information systems analysts and designers to represent, understand and analyze complex business domains [1]. A good understanding of a domain is a prerequisite to effective communication and design. Thus, how conceptual models improve human cognition of the domain represented is one of the most important research questions, and a considerable amount of work has examined the role of different factors in improving human understanding of conceptual models [2]. Such questions have also been explored in the context of business process models, where, for example, factors that affect the business process model understanding have been examined [3].

Business process models mainly focus on the modeling of business activities of an organization, and, as conceptual models of practice, are regarded as essential tools for the remaining stages of the BPM life cycle such as process (re)design, analysis, simulation, verification, and information system specification. In practice, business rules

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play an indispensable role in the design and implementation of process models. For example, business rules are extracted from laws, policies and procedures, and used to guide the design and specification of business processes.

Business rules can be represented in an integrated manner or in a separated manner. By ‘integrated manner’, we mean graphically in a process model. In such integrated models, business rules can be represented either as text annotations (e.g. BPMN has a text annotation construct for such a purpose), as graphical links to external rules, or diagrammatically using a combination of sequence flows, activities and gateways (see Fig. 1). By ‘separated manner’, we mean the rules constraining process activities are documented in separate documents or rule engines, and the relations and connections of business process models and the rules are not explicitly represented in the process models. Traditionally, business rules, other than control flow, are modeled in a separated manner [4]. Over the past two decades the need to model business rules in an integrated manner with business processes has been argued theoretically as well as validated empirically [5, 6], and a variety of integration methods and several guidelines have been developed [7].

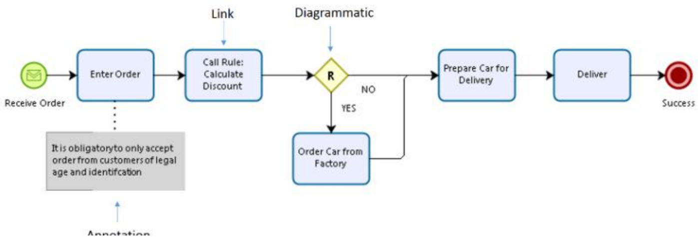

Fig. 1. Illustration of a business process model with rule integration

Despite arguments for such integration and despite the different integration methods developed, whether such integration improves user understanding of the process models has not been investigated. In particular, while researchers have argued that integrated modeling can improve the understanding of business processes, this proposition has neither been theoretically analyzed, nor empirically evaluated. Accordingly, in this paper, we propose a four-stage cognitive process based on a cognitive model in human information searching and processing [8], and explore theoretical foundations that underpin the understanding of process models. We use cognitive load theory, information representation theory, and information integration theory to explore whether the integration of business process models with business rules might improve human understanding of business processes, in each of the four stages. Our work is limited to the context of model understanding. There may be other situations, e.g. process execution, where the separation of rules might be preferable.

2 Theoretical Background

We look to existing theories of cognition, information representation, and information integration to understand the effects of integrating business process models and business rules on user understanding of the models. In the following sections, we outline the related theories.

2.1 Cognitive Load Theory

Cognitive load can be defined as a construct representing the load that performing a particular task imposes on the learner's cognitive system [9, 10]. Three types of cognitive load can be distinguished. Intrinsic cognitive load is determined by an interaction between the nature of the material being learned and the expertise of the learners. Extraneous cognitive load is the extra load beyond the intrinsic cognitive load resulting from mainly poorly designed external representations, whereas germane cognitive load is the load related to processes that contribute to the construction and automation of schemas, which are organized patterns of thought or behavior that organizes categories of information[9]. Due to the limit of working memory capacity and cognitive resources, a heavy cognitive load or cognitive overload typically creates errors, and the rate of error increases with the level of cognitive load [11].

2.2 Information Representation Theory

It has been well argued and evaluated in prior related research that the way information is represented significantly affects both extraneous and germane load [12, 13]. Researchers have argued that "static pictures and diagrams are better than sentential representations" [12] in terms of information comprehension and inferencing. Two key factors distinguish diagrammatical representations from sentential representations in terms of cognition efficiency in human information processing systems- *viz.* information explicitness and search efficiency [13]. In terms of information explicitness, information represented in diagrams is more explicit and needs less computational effort [12]. In contrast, informationally equivalent representation of the same content but in a sentential form typically requires further mental formulation to make it explicit for use, which requires greater computational cognitive effort [12, 13]. In terms of search efficiency, in a diagrammatic representation information is organized by location. Information elements that are relevant are grouped together, and information elements needed for inference are often present at adjacent locations, or connected with associations. Relations between graphical elements map onto the relations of information elements in such a way that they restrict or enforce the kinds of interpretations that can be made [12]. This information grouping and connecting nature of diagrams makes problem solving proceed through a smooth traversal of the diagram, in which little cognitive effort in terms of search computation is required [13]. In a sentential representation, information is often organized as a list of text items. Finding the relevant information item that matches the conditions of inferences requires searching linearly down the list, and the several items needed may be widely dispersed.

2.3 Information Integration Theory

Information presented in an integrated manner is considered to reduce cognitive load, while split-source information can generate a heavy cognitive load in the process of information assimilation [14]. Accordingly, in the context of process and rule modeling, information representation research indicates that integrating business rules into relevant business process models can reduce cognitive load thus to improve the understanding of business processes. The processing of separate and mutually referring information, such as separate business rules and process models, frequently and unnecessarily requires attention to be split and switched between different sources which inevitably consumes part of available working memory capacity and decreases cognitive resources available for learning [15, 16]. Thus, if information is integrated into the external representation, less cognitive efforts are needed to assimilate information [32].

The theories indicate that process models and rules should be represented in a graphical and integrated manner, thus to reduce cognitive effort to achieve a better understanding of process models.

3 Cognitive Load in Integrated Process Models

In this paper, we explore and compare the cognitive effort differences between process and rules that modeled in an integrated manner and a separated manner. To do so, we introduce the cognitive process that takes place when learning or analyzing business process models and business rules. We argue that to fully understand a business process, three components need to be studied: the process model, the business rules, and the impact or implications the rules have on the process activities.While the learning sequence of these components varies due to individual learning habits and preferences, four learning activities are indispensable in such a learning process: one needs to know the existence of rules constraining the process, then identify the rules, study the rules, and finally combine their knowledge of the process and how the business rules constrain it. While these four learning activities are required regardless of whether the business rules are modeled in a separated manner or in an integrated manner, the way the four activities are performed in the two scenarios is significantly different.

We look to the human information searching and processing cognitive model, where information occurs in five stages, *viz. goal formation, category selection, information extraction, integration,* and *recycling* [8]. We adapt this model to the business process and business rule context. *Goal formation* involves identification of the objective in the form of information that is to be found. In the context of business process and rule modeling, this is a *rule awareness* stage, which is the stage at which the user needs to become aware of the rules constraining a business activity. *Category selection* involves locating an appropriate category in which information could be relevant to the task. In our context, the focus is on each rule element/statement instead of a section of information, and we consider this to be a *rule locating* stage. *Extraction of information* related to the extraction of useful information in the identified category so that the goal can be fulfilled. Business rules are more complicated than the information referred to in [8], which can be directly 'decoded'. Accordingly, in our context extraction alone is not sufficient and *rule comprehension* is required. *Integration* is the act of synthesizing information extracted with previously obtained information. In our context, this stage relates to the synthesis of rules with process models. *Recycling* refers to transiting iteratively through the first four stages until the goal is fulfilled. In our context it refers to the understanding of each business activity and the rules constraining it, thus the understanding of the overall business process with all relevant constraints. This stage is an iteration stage which is crucial but is outside the scope of this paper as we consider it to bot differ significantly based on the type of information provided. Our process thus includes the stages of *rule awareness*, *rule locating*, *rule comprehension*, and *information integration*. In the following sub-sections, we explore each stage of the process and the effect of integrated models vs. separated representation.

3.1 Rule Awareness

To ensure a complete understanding of a business process, a stakeholder must be aware of the existence of rules that the business activities are required to be in compliance with. The lack of awareness of business rules can lead to noncompliant process execution, and can also result in longer times and costs in information system development. In a situation where the modeling is done in a separated manner, i.e. with a separate document listing business rules, there is a risk that the stakeholder's understanding of the underlying process model will be incomplete and problematic. Therefore, the execution of business activities by this stakeholder could breach policies or regulations, and generate exceptions that are not allowed by the rules. Further, such modeling might create problems at the requirement engineering phase of systems development projects. If there are rules that cannot be clearly identified or there is a lack of awareness of the rules then these will be missed at the design and implementation stages, and thus could cost significant resources and time for remediation in later stages.

Researchers have found that it is a basic human cognition feature to be aware of information if indications of relevance are explicitly provided [18], and diagrams, by their very nature, can explicitly connect relevant elements together [13]. Thus, we argue that awareness of business rules can be improved by integrating the rules into relevant process model diagrams through any of the already existing integration approaches. In particular, for very large and complex process models, we argue that integration methods such as hyperlinks of rules or collapsible annotations can improve rule awareness without increasing the complexity of the process model.

3.2 Rule Locating

After awareness of relevant rules in existence, the next step is to locate the rules. Depending on whether or how locating indication is provided the cognitive effort in locating information can be significantly different.

In separated models, no indication is provided on where (e.g. location in a rule repository) a relevant business rule is stored. In such a case, a comprehensive search through all of the rules is required to find the relevant rule. Semantic interpretation and matching of each rule to the relevant activity in the process model for the purpose of identifying its relevance is required, which is time-consuming and error-prone. The time needed for the search is directly affected by the size of the rule list, and two types of error can occur. The first type of error is missing relevant rules in the sequential reading of rules (false negatives). The second type of error is focusing on plausible relevant rules that are actually irrelevant (false positives), which results in additional cognitive load and could negatively affect the understanding of the process.

We argue that by integrating business rules into business process models the cognitive effort in searching for relevant rules can be reduced. For example, the use of links [19] to integrate the business rules into the models provides the location of relevant rules to that specific part of the process. Representing business rules in annotations and associating these with relevant activities that the rule constrains, can evidently reduce cognitive effort.

3.3 Rule Comprehension

Rule comprehension refers to the development of understanding of an individual information element. A comprehension process takes place to assimilate the information after it is located. The argument that diagrams are better than sentential representations in terms of cognition efficiency has been well evaluated in research [12, 13]. Diagrammatic representations can explicitly represent information, making information readily available, while sentential descriptions typically are implicit and have to be mentally formulated [12], which requires greater cognitive effort.

Business rules can be represented using business process modeling languages as well as business rule modeling languages [6], or simply natural language. Business process modeling languages generally have simple graphical syntax and semantics, while business rules languages are text-based and often abstract, and have a logical syntax that requires a degree of expertise for interpretation and modeling [20]. Although the representational capacity of process modeling languages may be prohibitive [21], it is evident that business rules that are integrated into business process models, using graphical constructs are easier to comprehend.

3.4 Information Integration

An individual business rule is unintelligible without the business process context. Implications of a business rule can only be correctly and fully interpreted when the context information is integrated. In other words, business activities cannot be fully understood until they are integrated with the constraining business rules. If information elements are not integrated physically in external representation, as is the case with separate business rules and process models, then one has to mentally integrate them which imposes additional cognitive load [22].

The act of mental integration involves dividing attention between the multiple sources of information, cross-referencing each source, mentally manipulating diagrammatic and text elements, and finding relations among elements associated with the diagram and statements.

We observe that physical integration of business rules and process models can enhance process model comprehension and learning. By graphically modeling a rule in the relevant location on the process model, the cognitive load of dividing attention, cross-referencing, and mental information integration of different information sources is removed. Moreover, explicit relations between rules and activities in an integrated graphical representation map onto the relations between the features of the process being modeled in such a way that they restrict or enforce the kinds of interpretations that can be made, which facilitates perceptual inferences [12].

4 Conclusion and Discussion

In this paper, we contribute to business process modeling research by providing a theoretical basis for exploring the effect of integrating business process models and business rules on the understanding of business processes. Our study introduces a 4-stage cognition process in the context of process and rule modeling, viz. *awareness, locating, comprehension* and *integration*, and adopts cognitive theories, including cognitive load theory, information representation theory, and information integration theory to explore each stage. The theoretical analysis indicates that the integration of business process models with business rules can improve awareness of business rules, reduce cognitive effort and reduce errors in the locating of business rules and the mental integration of business process models and business rules. Further, the integration of business rules in diagrammatic form is more explicit for comprehension than sentential representation.

A comprehensive empirical evaluation is required to evaluate this research. We anticipate that besides traditional understanding performance measurements such as time to complete task and number of errors made, which only provide data on the cognition aspect, measurements that capture the process of cognition are essential in the evaluation. In the next step of this research, we will develop an experiment protocol and use eye-tracking devices, which can collect a variety of cognitive behavior data, to explore empirically the four stage process and the effect of integrated and separated modeling of business processes and rules.

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