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# Symbol Choice and Memory of Visual Models

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***Abstract*—Most business process modeling languages are visual languages. Yet, very little attention has been devoted to the choice of symbols used. This article contributes to the visual languages literature by providing an enriched understanding about how symbol choice affects the ease of memorizing and recalling visual diagrams. Specifically, the experiment reported here was designed to compare the effect of three different symbol sets of visual languages from the business process modeling domain on diagram recall. Quantitative analysis based on data collected from 37 business school students, revealed that symbol choice significantly influences memory of visual aspects of the diagrams as layout. However, the study did not find a significant effect of symbol choice on recognition accuracy of the semantic content of the diagrams. Overall, the findings underscore the relevance of symbol choice for visual language design.**

***Index Terms*—model comprehension; visual notation; symbol choice; business process models, empirical evaluation; human memory**

## I. Introduction

Visual process models support the development, analysis and documentation of information systems. In particular, they improve the requirements engineering process and facilitate common understanding of domains and processes between users and system engineers [1]. In this paper we focus on visual languages for the business process modeling domain. There is a variety of different process modeling languages, which are usable for human description of business processes [2]: e.g. IDEF, Petri Nets, Event Process Chains (EPC), Unified Modeling Language (UML) Activity Diagrams, Role Activity Diagrams and Resource-Event-Agent (REA). A recent review on the use of process modeling languages in practice in the banking sector revealed that Business Process Model and Notation (BPMN), UML Activity Diagrams and EPCs are used most often in practice [3]. In addition, there are many more languages in use. 30% of respondents had used other languages including in-house developed languages and many had used a combination of modeling languages. Due to the large number of existing modeling languages, evaluation becomes important to improve existing approaches or to select competing alternatives. More recently, researchers have developed interest in evaluating and comparing process modeling notations empirically [4, 5]. However, existing studies have not explicitly addressed the issue of symbol choice. Most process modeling languages use their own set of notational symbols for the visual representation of processes. In this context, [6] note "a lack of scientific justification for choosing and applying specific types of notational symbols" for business process modeling languages. The research to date has already discussed the quality of symbols based on a theoretical basis. For instance, Figl et al. [7, 8] and Genon et al. [9] have analyzed symbol design of process modeling notations based on the 'physics of notations' framework by Moody [10]. This framework defines desirable properties of notational elements from a cognitive perspective. The motivation of this paper is to complement this stream of work and empirically examine how symbol choice affects the users' domain understanding and memory.

## II. Background

### *A. Basics of Human Memory*

First, we turn to basic cognitive processes involved when reading and learning from and by a visual model. When users try to memorize a model, three steps of cognitive processing take place: encoding of sensory input in mental representations that can be stored in memory, storage of information and retrieving stored information. Atkinson and Shiffrin [11] were the first who suggested distinguishing between three types of memory stores: sensory memory, short-term memory and long-term memory. The first two stores can store a limited amount of information for a brief time period, while long-term memory can store a large amount of information for a long time, perhaps indefinitely. The concept of visual sensory memory – the 'iconic store' was first studied experimentally by Sperling [12]. The iconic store can hold about 12 visual items, but information decays rapidly already in the first second after information presentation and is erased as soon as other information is presented. Short-term-memory allows recall for a period of about 30 seconds without rehearsal. In short-term memory encoding of information is primarily acoustic, although secondary semantic encoding as well as visual encoding is possible as well [12]. The capacity is approximately 7 plus/minus two acoustically storable items (text) or four visual objects [12]. The traditional three-store view of memory has been challenged in recent decades by alternative perspectives. Perhaps the most influential and widely accepted theory is the working memory theory by Baddeley [13]. Working memory is a temporary storage holding recently activated information from long-term memory and fleeting short-term memory [12]. Working memory is composed of four elements: a central executive, which coordinates attention and information flow to the other elements, episodic buffer (binding information from the different systems) a phonological loop (inner rehearsal of verbal information) and a visuospatial sketchpad for visual and spatial information.

### B. Modeling Notations and Memory

Models from different modeling languages are likely to differ according to the effort required to interpret them. [14] has for instance demonstrated that the choice of notation influences data model comprehension. An important basis for learning and memorizing model content is an appropriate translation from the visual model to a cognitive model of the viewer. Problems causing deviations between the actual visual representation (the intended meaning) and the resulting cognitive model can be provoked by ambiguity of a modeling language as confusable visual symbols. Relevant criteria to analyze the quality of symbols from a cognitive perspective are semantic transparency, visual expressiveness and perceptual discriminability [10].

### C. Research Questions and Hypotheses

We hypothesize that the choice of a particular symbol set influences users' memory of process models. Due to the limits of human memory system, deficiencies in the symbol design may place extra burden in the form of additional cognitive load on users, when interacting with a process model. Notational weaknesses make it more difficult for users to understand and memorize the process models itself. As human working memory stores visual and verbal information separately, we formulate hypotheses separately for visual and verbal model content. Since control flow of process models is expressed primarily visually in the models via symbols, we expect a direct effect of notational weaknesses of symbols on visual memory. The choice of symbols will influence the users' memory on how a specific diagram looked like – its layout and amount of symbols used (**H1**: The symbol set of a process modeling language influences memory of visual content of models). Some information in the models is independent of symbol choice - the textual labels for the tasks. But still, the symbols are relevant to understand and remember verbal information of a process. That's why we speculate there will also be an indirect effect of symbol choice on memory of verbal diagram content (**H2**: The symbol set of a process modeling language influences memory of verbal content of models).

## III. Experimental Design

### A. Design and Measures

Our design featured one between-subject factor - symbol set, which had three levels. To manipulate the factor symbol set, we used realistic symbols derived from existing notations of currently available process modeling grammars in-use viz., UML Activity Diagrams ($S_{UML}$) [15], Yet Another Workflow Language ($S_{YAWL}$) [16], and BPMN ($S_{BPMN}$) [17]. Figure 1 depicts symbols that are used in the experiment.

We want to point out that we did not intend to compare the modeling languages per se and therefore, did not follow specific syntactic restrictions, but only exchanged the symbols. In the experiment three different process models were used. The process models were selected from uncommon domains to avoid interfering of prior domain knowledge: an emergency process plan for drinking water pollution, an e-mail election process and a registration of a business process. We randomly assigned the order of the models and the sub items of the tasks to control for learning effects. This was important, because prior research has identified specific primacy and recency effects for memory tasks: items in the beginning and at the end of a list are easier to recall than items in the middle [18].

We used a paper questionnaire in the experiment and briefed four students to supervise groups of 1-2 participants taking part in the experiment. These 'test supervisors' had to take care of the time restrictions and had to control that subjects answered memory tests without looking at the respective process models. As we wanted to participants to solve the tasks from memory, models were taken away from participants. The question whether participants should have models available when answering model comprehension questions has been a controversially discussed subject within the field of conceptual model evaluation. Burton-Jones et al. [19, p. 512] argue that "for studies focusing on pragmatics and connotational semantics…it may be useful to remove scripts from participants".

All learning parts in the experiment were time restricted. Participants got 4 minutes to memorize each process model, respectively. Afterwards, models were taken away and participants were confronted with visual and verbal memory tasks. In the *verbal test part* we posited 8 declarative-knowledge tasks on each model, which participants had to answer from memory. Examples of items were similarly constructed as in [20]. The true-false tasks were addressing several aspects of the control flow as concurrency, exclusiveness, order and repetition. The number of correct answers was used as a measure of verbal memory accuracy. Additionally, we measured perceived difficulty of each task with a 7-point item (anchored between 'very difficult' and 'very easy') as proposed by [21]. In the *visual test part*, tasks were performed on a visual model or directly related to the symbols used in the models. First, participants received modified versions of the process models in which they had to mark differences to the original models. We included three types of model changes (see Fig. 2 for an example): *Layout changes* did not change the semantics of the model, but only its layout. For instance, single activities, connecting edges or larger subparts of a model (including more than one symbol or connector) were moved from left to right or vice versa or visually interchanged. In contrast to layout changes, in which smaller or larger parts of the model were moved, *semantic content changes* subsumed additions or deletions of model parts. For *control flow changes* we changed the control flow, but no addition or deletion of activities took place. For instance, we exchanged XOR with AND routing symbols. Second, we asked participants to estimate the amount of symbols that had been used in the process diagrams. They should fill in numbers for the amount of activities and the amount of AND and XOR routing symbols of the three models. The deviation of the participants' estimates from the original amount of symbols served as a measure for visual symbol recall accuracy.

In addition the questionnaire included a section on demographics and 8 multiple choice items on process modeling knowledge.

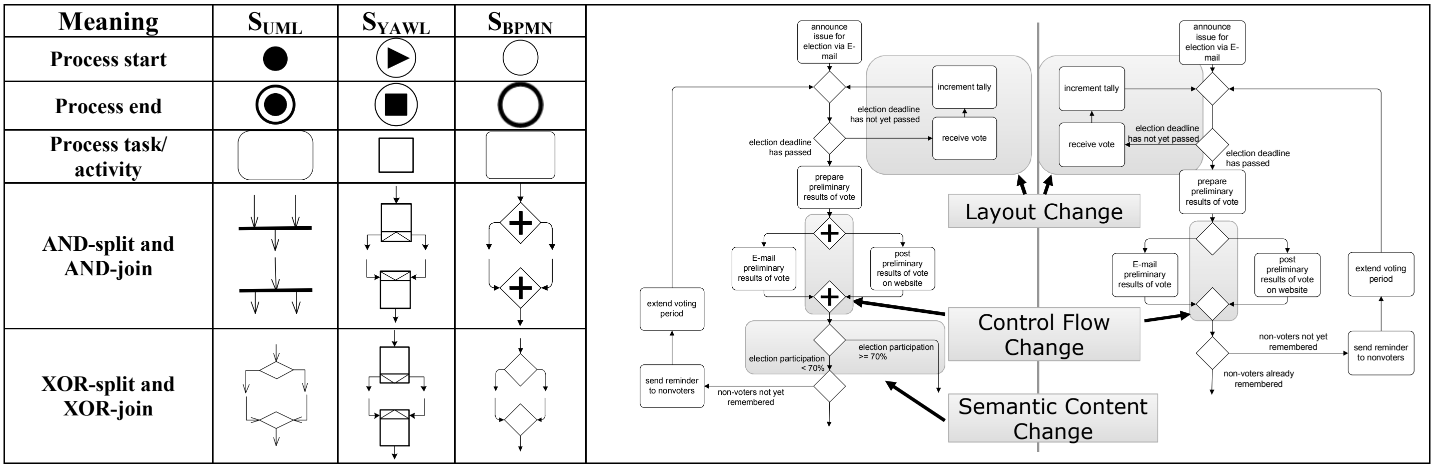


Fig. 1. Symbols used in the experimental groups (on the left) and types of model changes used in the visual memory test (on the right)

*B. Participants*

Subjects were information systems and business students from a European university. 37 students participated and 2 incomplete questionnaires were excluded, resulting in 11-12 subjects per study group. In terms of modeling experience, 46% of participants had received prior training in modeling with a median of 30 hours.

## IV. RESULTS

To analyze the differences between the groups univariate analyses of variance (ANOVAs) were performed. We used the symbol sets as independent factor (with three levels), the verbal and visual memory measures as dependent variables and process modeling knowledge as covariate. Table 1 gives all descriptive results as well as statistical test results. Following the ANOVAs we performed post-hoc Fisher's Least Significant Difference (LSD) tests to determine significant differences between group means.

From the test results in Table 2, it is apparent that the factor symbol choice did only influence dependent measures in the visual test part, but not in the verbal test part. In the verbal memory test part participants were subjected to questions on the semantic content of the models in textual form. It is somewhat surprising, that the symbols chosen did not affect any of the dependent measures in this test part. Thus, hypothesis H2 is not supported. The most striking result to emerge from the data is that groups differed in all tasks related to routing symbols. Participants more often misjudged the original amount of ANDs in the experimental conditions $S_{UML}$ (Mean diff.=3.13, p=0.03) and $S_{Yawl}$ (Mean diff.=3.05, p=0.03) than in the experimental condition $S_{BPMN}$. Concerning the estimation of the XOR routing symbols, participants of the group $S_{Yawl}$ performed worse than in the group $S_{BPMN}$ (Mean diff.=2.03, p=0.02). However, participants of the different groups scored equally well when estimating the amount of activities. Another task related to routing symbols yielded significant results: subjects recognized more control flow changes in the conditions $S_{UML}$ (Mean diff.=0.33, p=0.03) and $S_{Yawl}$ (Mean diff.=0.48, p=0.00) than in the experimental condition $S_{BPMN}$. Additionally, less layout changes were recognized in $S_{Yawl}$ (Mean diff.=0.48, p=0.00) than in $S_{BPMN}$. In summary, we believe there is sufficient evidence to accept H1, which expected the symbol set to influence memory of visual model content. Relative to time taken for answering visual and verbal memory tasks, there were also no differences among the three experimental groups. A possible explanation for this result might be that time does not directly reflect cognitive difficulty, but working style of participants. If participants perceive a task to be difficult, they could either try to work harder and spend more time on the task to solve it correctly or they could lower their effort and spend less time on the task.

TABLE I. RESULTS (DEGREES OF FREEDOM=2, 32)

| | $S_{UML}$ | $S_{BPMN}$ | $S_{Yawl}$ | Stat. Test: F |
|---|---|---|---|---|
| **Verbal Recall** | | | | |
| Total verbal recall score | 64% | 66% | 58% | 1.32, p=0.28 |
| Perceived cognitive load | 4.01 | 3.79 | 4.25 | 1.08, p=0.35 |
| Time taken (minutes: seconds) | 3:21 | 2:32 | 3:51 | 2.91, p=0.07 |
| **Visual Recall: Estimating Symbol Amount** | | | | |
| Estimating amount of activities | 8.69 | 7.94 | 7.72 | 0.15, p=0.86 |
| Estimating amount of ANDs | 5.25 | 2.12 | 5.17 | **3.76, p=0.04** |
| Estimating amount of XORs | 3.03 | 2.45 | 5.06 | **6.93, p=0.00** |
| Time taken (minutes: seconds) | 3:56 | 2:58 | 3:06 | 2.30, p=0.12 |
| **Visual Recall: Recognizing Model Changes** | | | | |
| Recognizing control flow changes | 42% | 75% | 27% | **6.05, p=0.01** |
| Recognizing content changes | 63% | 70% | 46% | 2.20, p=0.13 |
| Recognizing layout changes | 56% | 45% | 25% | **4.69, p=0.02** |
| Time taken (minutes: seconds) | 2:50 | 1:43 | 2:49 | 2.51, p=0.10 |

## V. DISCUSSION

The present study was designed to determine the effect of symbol choice on memory of visual and verbal content of process models. And indeed, the results indicate that symbols choice influences visual memory of models as recognizing control flow and layout changes as well as remembering the amount of specific symbols. Our results suggest that the design of routing symbols is especially relevant for memory of business process models. Routing symbols of BPMN demonstrated especially good performance. This result is in agreement with the discussion of Figl et al. [7] on routing symbols in process modeling languages.

However, this study has been unable to demonstrate that the choice of symbol set would also influence how well participants remember the semantic content of process models. Symbol choice seemed to be no relevant predictor of domain understanding generated from the process models. We want to discuss one possible explanation for the different results for the visual and verbal test. For the verbal tasks, participants first had to encode the visual information of the model in an internal mental representation of the process and then answer textual questions based on this mental representation. Hence, for the verbal test users had to process the information on a semantic level, while processing at a physical level was sufficient for most of the visual tasks.

Several opportunities for future research emerge from our study. For instance, further studies could address in detail how process models are stored in memory. According to prior research in human information processing, in general, words are stored in memory in reading direction, while symbols are stored in their visio-spatial arrangement [22]. Since process models represent a combination of text and symbols, it remains unclear whether user primarily encode and store semantic content of the models or whether they also remember the exact layout of the models. In principle, both, semantic and visual encoding is possible in human memory systems, but it is unclear in which situations and contexts we use one type of storage or the other [12]. In our data the recognition percentage was higher for label changes in the models, than for layout and control flow changes. These differences in recognizing different types of model changes might hint at a possible reorganization of process models in users' memory in so far that content is remembered longer than layout of models. However, it was beyond the scope of this study to examine this issue in detail. This paper, therefore, encourages the storage of process models in memory in further studies. Recall and recognition tests as identifying changes in visual models would be a promising way to address this research question.

## VI. Conclusion

This study has found that differences in symbol sets influence visual memory of models. The current findings add to our understanding of visual language design and are especially relevant for educational contexts in which the emphasis is on learning with and by visual models.

In addition, the research results provide guidance for modeling language developers as they show that even minor design differences may lead to differences in memory. Symbol design is a neglected aspect in visual language development. We recommend that modeling language developers should first take a look on existing symbols. If well-known symbols already exist, it might be better option to use them than to reinvent new symbols. If new symbols are proposed, it is important for inventors to pay attention to criteria as semantic transparency, perceptual discriminability and visual expressiveness. There is not only one best symbol, but a variety of symbols may be effective to promote user understanding and memory of models. Additionally, even small-scale usability tests might enhance quality of symbol choice.

## References


[1] D. L. Moody, "Theoretical and practical issues in evaluating the quality of conceptual models: Current state and future directions," Data and Knowledge Engineering, vol. 15, pp. 243-276, 2005.

[2] H. Mili, G. Tremblay, G. B. Jaoude, E. Lefebvre, L. Elabed, and G. E. Boussaidi, "Business process modeling languages: Sorting through the alphabet soup," ACM Comput. Surv., vol. 43, pp. 1-56, 2010.

[3] J. Becker, D. Breuker, B. Weiß, and A. Winkelmann, "Exploring the status quo of business process modelling languages in the banking sector – an empirical insight into the usage of methods in banks," in 21st Australasian Conference on Information Systems, 2010.

[4] A. Danesh and N. Kock, "An experimental study of process representation approaches and their impact on perceived modeling quality and redesign success," Business Process Management Journal, vol. 11, pp. 724 - 735, 2005.

[5] J. Recker and A. Dreiling, "The effects of content presentation format and user characteristics on novice developers' understanding of process models," Communications of the Association for Information Systems, vol. 22, 2011.

[6] A. D. Jaffar and H. Shah, "Semiotic notation principles for business process modelling," in 14th European Conference on Information Systems, 2006, pp. 1949-1961.

[7] K. Figl, J. Mendling, M. Strembeck, and J. Recker, "On the cognitive effectiveness of routing symbols in process modeling languages," in Business Information Systems (BIS), Berlin, 2010.

[8] K. Figl, J. Mendling, and M. Strembeck, "Towards a usability assessment of process modeling languages," in 8. GI-Workshop EPK 2009: Geschäftsprozessmanagement mit Ereignisgesteuerten Prozessketten, Berlin, 2009.

[9] N. Genon, P. Heymans, and D. Amyot, "Analysing the cognitive effectiveness of the bpmn 2.0 visual syntax," in Software Language Engineering, 2010, pp. 377-396.

[10] D. L. Moody, "The "physics" of notations: Towards a scientific basis for constructing visual notations in software engineering," IEEE Transactions on Software Engineering, vol. 35, pp. 756-779, 2009.

[11] R. C. Atkinson and R. M. Shiffrin, "Human memory: A proposed system and its control processes," in The psychology of learning and motivation. vol. 2, K. W. Spence and J. T. Spence, Eds., ed New York: Academic Press, 1968, pp. 89–195.

[12] R. J. Sternberg, Cognitive psychology, 5 ed. Belmont: Wadsworth, Cengage Learning, 2009.

[13] A. D. Baddeley, Human memory: Theory and practice, 2 ed. Needham Heights, MA: Allyn & Bacon, 1990.

[14] J. C. Nordbotten and M. E. Crosby, "The effect of graphic style on data model interpretation," Information Systems Journal, vol. 9, pp. 139-155, 1999.

[15] Object Management Group. (2010, Unified modeling language™ (uml®) 2.3. Available: http://www.omg.org/spec/UML/2.2/

[16] W. M. P. van der Aalst and A. H. M. ter Hofstede, "Yawl: Yet another workflow language," Information Systems, vol. 30, 2005.

[17] Object Management Group, "Business process model and notation (bpmn) version 2.0," ed, 2011.

[18] N. Cowan, J. S. Saults, E. M. Elliott, and M. V. Moreno, "Deconfounding serial recall," Journal of Memory and Language, vol. 46, pp. 153-177, 2002.

[19] A. Burton-Jones, Y. Wand, and R. Weber, "Guidelines for empirical evaluations of conceptual modeling grammars," Journal of the Association for Information Systems, vol. 10, pp. 495-532, 2009.

[20] K. Figl and R. Laue, "Cognitive complexity in business process modeling," in Advanced information systems engineering. vol. 6741, H. Mouratidis and C. Rolland, Eds., ed: Springer Berlin / Heidelberg, 2011, pp. 452-466.

[21] N. Marcus, M. Cooper, and J. Sweller, "Understanding instructions," Journal of Educational Psychology, vol. 88, pp. 49-63, 1996.

[22] J. L. Santa, "Spatial transformations of words and pictures," Journal of Experimental Psychology: Human Learning and Memory, vol. 3, pp. 418-427, 1977.