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USER EVALUATION OF SYMBOLS FOR CORE BUSINESS PROCESS MODELING CONCEPTS

Research paper

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Abstract

Process modeling notations are visual languages that use symbols to represent their main concepts. This study investigates the quality of such symbols from users' perspective. The design of a symbol influences whether it is easy to spot in a model and is correctly associated with the concept it represents. In an empirical study with 188 participants, the normative ratings of process model symbols (for the basic concepts of start, end, task, AND, XOR) were gathered on the dimensions of perceptual pop-out, semantic transparency, perceptual discriminability, and aesthetics. Overall, the results are consistent with our predictions based on the theoretical analyses of the designs of the symbols. Prior familiarity with process modeling notations led to more clear-cut evaluations of routing symbols (AND, XOR) and a reduced tendency to prefer middle rating options, but it did not affect the evaluations of the other symbols. Standardization organizations and academic developers of notations can use insights from the study to enhance the usability of process modeling notations.

Keywords: Business Process Modeling, Comprehension, Symbols, Notational Design.

1 Introduction

Symbols surround us. Langer (2009, p. 20) even goes as far as claiming that “it is the power of using symbols ... that makes [humans] lords of the earth.” Business process modeling notations use the power of symbols to provide a visual language that specifies the sequence of activities in business processes. The symbols used in this context represent the common elements of a process, such as tasks/activities, events (e.g., start and end of a process), routing symbols/gateways (describing temporal and logical dependencies among tasks), and the sequence flow between tasks.

To be successful, the process models used in business process initiatives must fulfill their purpose to “create shared meaning and a common understanding across all stakeholders involved in business processes” (vom Brocke et al., 2014, p. 537). A critical factor in enabling shared meaning and communication by means of a modeling language is ensuring that its users can understand the symbols the language uses to represent concepts. However, the choice of symbols for process modeling notations often neglects theoretical considerations, and their authors sometimes document no reasons or design rationale for choosing particular symbols (Hitchman, 2002). Wand and Weber (2002) describe how lack of theory led to the proliferation of modeling approaches in the 1980s. Without theory, researchers created new conceptual modeling techniques and selected symbols based on personal experience or exploratory case studies, rather than on scientific procedures (Olle, Sol and MacDonald, 1991). This problem has not yet been overcome; van der Linden and Hadar (2015, p. 10) comment on researchers' ongoing reliance on theoretical analyses and prescriptive self-made proposals for new symbols to improve the cognitive effectiveness of notations, rather than empirical research and user involvement: “[R]esearchers understand the need to adapt a notation to its users, but by not grounding them in empirical evidence, they end up stipulating things they assume to be universally understood (or appreciated).”

The variety of process modeling notations show ontological overlap. A global study of 130 Forbes Global 2000-listed companies (Patig and Casanova-Brito, 2011) finds that the most commonly used diagrammatic technique for process documentation were Business Process Model and Notation

(BPMN) (Object Management Group, 2011) (21.3% usage), followed by Unified Modeling Language (UML) Activity Diagrams (Object Management Group, 2013) (15.0%), and Event-driven Process Chains (EPCs) (Keller, Nüttgens and Scheer, 1992) (12.6%). Another notation rooted in the academic community is Yet Another Workflow Language (YAWL) (van der Aalst and ter Hofstede, 2005). These are the notations we consider in the context of this paper.

To address the relevance of notational design in the context of the development of process modeling notations, research has investigated whether notational deficiencies impair the ability to understand process models (Figl, Mendling and Strembeck, 2013; Figl, Recker and Mendling, 2013); research has likewise analyzed process modeling notations (Figl, Mendling and Strembeck, 2009; Figl et al., 2010; Genon, Heymans and Amyot, 2010) and conducted comprehension studies that compare modeling notations (Weitlaner, Guettinger and Kohlbacher, 2013; Jošt et al., 2016; Wiebring and Sandkuhl, 2015; Recker and Dreiling, 2011; Sarshar and Loos, 2005). The “physics of notations” framework (Moody, 2009), one of the first efforts to address the lack of scientific guidelines, provided designers with cognitively effective design principles for modeling notations. Various researchers have already applied this framework to the process modeling field (Figl, Mendling and Strembeck, 2009; Figl et al., 2010; Genon, Heymans and Amyot, 2010).

However, no current work offers comparative symbol evaluations, as existing comparisons are centered primarily on the level of notation, not on individual symbols or subsets of symbols. An exception is the work of Figl, Recker and Mendling (2013), in which routing symbols are examined in isolation and user evaluations of process-routing symbols are collected. Although they neither present nor discuss concrete evaluations of symbols, they analyze how user evaluations relate to model comprehensibility. As research has not clarified which symbols are preferred to represent process modeling concepts, the present paper addresses this research gap. One goal of this study is to assess the relative strengths and weaknesses of the symbols of EPCs, UML, YAWL, and BPMN for basic process modeling concepts on the basis of a user evaluation study. How do users evaluate existing process modeling symbols according to notational design criteria, such as perceptual discriminability and semantic transparency? Are some symbols more easily perceived and processed by the human mind? This study provides normative symbol ratings for the process modeling domain that researchers can use as reference values to discuss changes in existing notations or to compare symbol evaluations of other notations with. The article complements research streams that have published symbol norms for other domains (e.g. Prada et al., 2015).

Users’ perceptions of a modeling notation and its symbols are an important factor in perceived usefulness, and these perceptions may affect the adoption of a notation in practice (Figl and Derntl, 2011). The relevance of user ratings of notational symbols is also demonstrated by the fact that the perceived perceptual discriminability and pop-out of symbols improve comprehension, whereas the perceived semantic transparency and aesthetic design lower users’ perception of difficulty in comprehension (Figl, Recker and Mendling, 2013). Therefore, determining users’ perceptions empirically enables improvement in the usability of a notation, leading to higher comprehensibility of the models and adoption in practice.

2 Theoretical Background

Generally, a visual modeling notation offers “a set of graphical symbols (visual vocabulary), a set of compositional rules (visual grammar), and definitions of the meaning of each symbol (visual semantics)” (Moody, 2009, p. 756) to form valid expressions, i.e., diagrams. While a variety of frameworks, such as the revised SEQUAL framework (Krogstie, Sindre and Jørgensen, 2006) and the “cognitive dimensions” framework (Green, Blandford and Church, 2006), are related to notation quality, the “physics of notations” framework (Moody, 2009) deals most closely with the quality of chosen symbols. However, some of the principles of this framework are helpful in assessing notations only, not subsets of symbols, which are the focus of this paper. The following principles should be considered at the symbol and symbol-set levels (Figl, Mendling and Strembeck, 2013): semiotic clarity, visual ex-

pressiveness, perceptual discriminability, and semantic transparency. Semiotic clarity is outside the scope of this paper because we compare the visual designs of symbols that might be used to represent the same underlying semantic construct.

Semantic transparency refers to the extent to which users intuitively associate the meaning of a symbol with its visual appearance (Moody, 2009). Semantic transparency runs on a continuum from semantic perversity (where users infer an opposite or different meaning from a visual symbol, such as when they interpret an AND symbol as an XOR symbol or vice versa) to semantic immediacy (where users immediately understand the meaning of a visual symbol) (Moody, 2009). Most symbols used in modeling notations are neither semantically immediate, nor do they provide cues on their meaning; instead, their meaning must be explained. In contrast to icons, which visually resemble their referent real-world concepts and are usually easily associated with them, modeling symbols consist of abstract shapes. Semantic transparency is especially important for users learning a notation and for readers of the models who have not yet learned the meaning of the symbols. Caire et al. (2013) characterize semantic transparency as “one of the most powerful tools” to improve comprehension by novices.

When designing a symbol set to represent concepts in a visual model, designers must ensure that “these symbols [are] as distinct as possible” (Ware, 2004, p. 149). **Discriminability of symbols** is the “number of visual variables on which they differ and the size of these differences” (Moody, 2009, p. 762). The graphic symbols used for process modeling typically utilize the visual variables shape and brightness, but no other visual variables, thereby limiting the potential for distinctness.

An important design goal is that symbols should “**pop-out**” from their surrounding without the users’ conscious effort; that means they are processed pre-attentively. Pre-attentive processing “determines what visual objects are offered up to our attention” (Ware, 2004, p. 149). Two main influence factors enable pre-attentive processing: the degree to which the target differs from non-targets and the degree to which non-targets differ from one another (Ware, 2004). In other words, it is easier to spot a circle among rectangles than a small rectangle among medium-sized rectangles. If symbols are unique in a visual variable, such as shape, they stand out pre-attentively. Such effects are backed up by feature integration theory (Treisman and Gelade, 1980).

Aesthetics is also relevant when considering symbol characteristics because “up to some point, the design and appreciation of a symbol remains subject to subjective evaluation” (Figl, Recker and Mendling, 2013, p. 1106). Furthermore, research in the area of icons has reported that appeal ratings also reflect users’ unconscious awareness of the ease of cognitive information processing of the visual stimuli (McDougall et al., 2016). On the other hand, the aesthetic appeal of visual stimuli may also positively influence task performance in search-and-localization tasks (Reppa and McDougall, 2015).

3 Research Method

A fully randomized experimental approach was chosen for symbol evaluation. Four experimental groups received all experimental materials with symbols taken from either one of four process modeling notations (EPCs, UML, BPMN, or YAWL). The choice of a between-subjects experimental design (one symbol set per experimental group) gave sufficient time for the participants to be familiar with the symbols and evaluate them. Using a within-subjects design and letting the participants evaluate and rank all basic symbols considered might have led to the major disadvantage of carry-over-effects, in which one evaluation influences other evaluations of symbols representing the same concept.

The paper-based questionnaire first asked the participants for their demographic data, process modeling experience, and familiarity with process modeling notations. Eight items were adapted from Mendling, Strembeck and Recker (2012) to measure the participants’ knowledge of process modeling. The experimental study design was based on two phases: In the “symbol acquaintance phase,” the participants were provided with a tutorial on the meaning of the modeling symbols, and they spent some time working with the notation, completing 24 comprehension tasks on two process models, and identifying differences between a textual process description and a process model (Figl, Mendling and

Strembeck, 2013). We used three models from the domains of study planning, e-mail election processes, and product planning. This phase ensured that all the participants knew the symbols and how they were used so that confrontation with process models as stimuli was adequately long to facilitate the rating of symbol quality. Next, in the “symbol evaluation phase,” the participants answered the symbol evaluation questionnaire.

We focused on five main symbols: start, end, activity, XOR, and AND. Event symbols in EPCs were included in the symbol evaluation but were not considered in the analysis; the comparison of event symbols with the other modeling languages’ start and end symbols becomes difficult because of semiotic issues. The event symbols of EPCs represent not only start and end events but also intermediate events (e.g., decision points for divergent exclusive process paths or loops) during a process, but this study focuses on visual differences, not on semiotic differences. When a symbol represents more than one concept the anomaly of symbol overload occurs (Moody, 2009). Figl, Mendling and Strembeck (2013) have reported that such a deficiency in semiotic clarity may increase cognitive load and decrease comprehension.

3.1 Symbol Evaluation Questionnaire

A shortened version of the scales developed in Figl, Recker and Mendling (2013) was used for the symbol evaluation. The instrument, theoretically grounded in Moody’s (2009) framework of the desirable properties of effective visual notations, evaluates individuals’ judgments about symbols with the use of 15 items. The final instrument was developed by generating an item pool, pre-testing the wording, and conducting a “card-sorting” test to check content validity. It uses scales for perceptual pop-out, semantic transparency, aesthetics, and perceptual discriminability with three or four items per scale.

As we evaluated five symbols (start, end, activity, XOR, and AND), we reduced the number of items per scale to avoid a long questionnaire, and used only two items per dimension. The selection of the final two items included items that received the highest content validity scores in the pretest, and excluded item combinations with the same word or word stem. The final selection of the scales with two items each can be found in the Appendix.

Depending on the semantics in a model, not only distinguishing symbols but also recognizing the symbols/elements that belong to each other is important (e.g., two corresponding AND or XOR symbols (split and join)). Therefore, we added two more items on perceptual connectedness (e.g., “Recognizing in a model which XOR-split belongs to which corresponding XOR-join in a model is easy.”).

For an overall assessment of symbol quality, we calculated the mean score of the three scales perceptual pop-out, semantic transparency, and aesthetics. This symbol quality index reached adequate reliability indices (Cronbach’s $\alpha > 0.8$) for all symbols evaluated. Perceptual discriminability and connectedness were not included in the overall symbol quality index, as they do not evaluate an individual symbol but refer to two symbols.

3.2 Sample

The participants were recruited from five information systems and business curricula classes. Approximately half were recruited from introductory courses, so the students had no experience with modeling notations, and another half were recruited from modeling courses. This was necessary to assess the potential moderating effect of familiarity with process modeling notations on symbol evaluation.

A total of 189 students participated in this study. We performed an outlier-detection analysis leading to a final sample size of 188.

Table 1 provides the age and gender breakdown of the participants and their familiarity with the four process modeling notations. The participants averaged 22 years of age, and gender was distributed equally. Almost half of the participants knew UML (37%–47%); EPC was the second most familiar

notation, followed by BPMN, and then YAWL. Further data on modeling training and experience with the four process modeling notations showed differences between notations. Experience with YAWL was especially low. This imbalance is due to the prevalence and diffusion of languages and their inclusion in academic curricula. The participants' relatively low familiarity with the standard BPMN might be due to their university's use of the modeling tool ARIS and the teaching of EPCs in modeling courses for beginners.

On the basis of distribution of familiarity, clustering the participants of each experimental group into two groups of approximately equal size was possible: those without any experience or familiarity with a particular process modeling notation and those who were familiar with such (20–26 participants per group).

	UML (n=50)		BPMN (n=46)		YAWL (n=45)		EPC (n=47)	
	Mean/#	SD/%	Mean/#	SD/%	Mean/#	SD/%	Mean/#	SD/%
Age	22.08	2.72	22.02	4.02	22.13	3.34	21.62	2.71
Gender								
Male	23	46%	24	52%	25	56%	28	60%
Female	27	54%	22	48%	20	44%	19	40%
Familiarity with specific process modeling notations								
UML	21	42%	17	37%	19	42%	22	47%
BPMN	7	14%	7	15%	8	18%	6	13%
YAWL	1	2%	1	2%	3	7%	2	4.3%
EPC	12	24%	11	24%	11	24%	15	32%
Familiarity with any process modeling notation								
Yes	24	48%	20	43%	24	53%	23	49%
No	26	52%	26	57%	21	47%	24	51%

Table 1. Participants' Demographic Data and Familiarity with Process Modeling Notations

3.3 Analyses

For the evaluation of each symbol (for the overall score, as well as for all subscales), we conducted ANOVAs with “notation” [UML, BPMN, YAWL, EPC] and “familiarity with process modeling notations” [with/without] as independent factors.

4 Start and End Symbols

Start symbols, which are used for the initial node in a process model, have one or more outgoing process paths, whereas end symbols, representing the final node, have one or more incoming process paths. Research has discussed the quality of the start and end symbols of UML, YAWL, and BPMN (Figl, Mendling and Strembeck, 2013, 2009). In general, these three notations propose circles (partly filled, with thin and thick lines) to represent start and end symbols. With the exception of YAWL, which uses the “audio player metaphor” and therefore provides a higher semantic transparency, all circles tend to be abstract. Figl, Mendling and Strembeck (2013) identify the low discriminability of start and end symbols in UML and BPMN as a notational deficiency, although they rate it as “minor” because “most process models have one start and one end element, and they can easily be identified based on the overall visual layout of a model” (Figl, Mendling and Strembeck, 2013, p. 319). Other hints in a process model enable users to distinguish start symbols from end symbols: for example, the flow direction (direction of edges) of the model usually makes it clear where the model starts and ends. Only when such cues are missing (e.g., if the model's flow direction switches, as in zigzag models) must the designer ensure that the start and end symbols are visually distinct.

Based on observations of prior analyses (Figl, Mendling and Strembeck, 2013, 2009), H1 is as follows:

- H1. Users rate the symbol quality of YAWL's start (H1a) and end (H1b) symbols higher than they do BPMN's and UML's start/end symbols.

4.1 Results

Overall, the ANOVA results indicate that the factor notation significantly influences user evaluation of start symbols ($F=24.31$, $p \leq 0.001$, $\eta_p^2=0.26$) and end symbols ($F=24.33$, $p \leq 0.001$, $\eta_p^2=0.28$), whereas the users' familiarity with process modeling notations has no effect on the evaluation. We performed post-hoc analyses (Fisher's LSD tests) to determine which symbols significantly differ from one another, and found that the YAWL start symbol was rated significantly better than the UML start symbol (mean difference=0.89, $SD=0.14$, $p=0.04$) and the BPMN start symbol (mean difference=0.43, $SD=0.14$, $p=0.003$). On the level of subscales (pop-out, semantic transparency, aesthetics), the results were similar, and the same reported effects reached significance. Thus, H1a was supported. Concerning end symbols, the YAWL end symbol was rated significantly better than the UML end symbol (mean difference=0.63, $SD=0.13$, $p \leq 0.001$) and the BPMN end symbol (mean difference=0.92, $SD=0.13$, $p \leq 0.001$). In addition, the average rating of the UML end symbol was higher than that of the BPMN end symbol (mean difference=0.29, $SD=0.13$, $p=0.03$). The same results showed for the subscale aesthetics and trendwise for pop-out, but not for semantic transparency. Overall, H1b was supported, as well. **Fig. 1** shows the mean evaluations of the start and end symbols of the three process modeling notations.

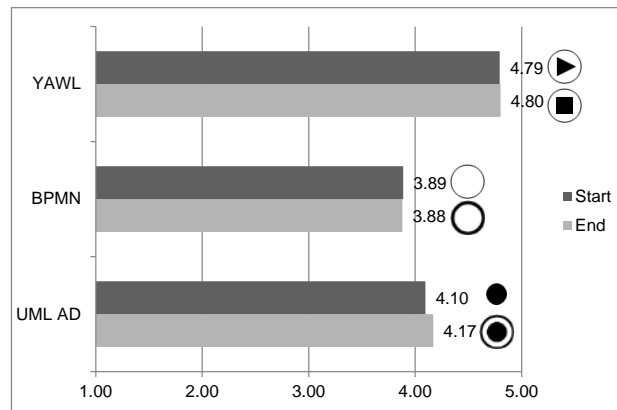


Fig. 1. User Evaluation of Start and End Symbols (1=Low Symbol Quality, 5=High Symbol Quality)

5 AND and XOR Symbols

Routing symbols (also called gateways) are key elements in process models, as they indicate when a process flow diverges or converges according to certain conditions. Routing symbols are used to model optional, alternative, reoccurring, or parallel process paths. We consider the AND and XOR routing concepts the most relevant to practice. These symbols are typically used in sets in a model—in a “split” and a corresponding “merge”—because many modelers adhere to the rule of “block-structuredness” (Dumas et al., 2012). An XOR (exclusive choice) indicates a choice among several branches (van der Aalst et al., 2003, p. 11), so there is usually one incoming and more than one outgoing edge for an XOR symbol. The conditions of the decision are typically added as textual labels visually close to the outgoing arcs/arrows of the XOR routing symbol. An AND symbol, which is used as a parallel split, represents “a point in the ... process where a single thread of control splits into multiple threads of control which can be executed in parallel, thus allowing activities to be executed simultaneously or in any order” (van der Aalst et al., 2003, p. 10). An AND symbol used in a “merge” situation indicates that “the process continues in the same way for all routes possible at a previous split point” (Soffer, Wand and Kaner, 2015, p. 346).

EPCs use circle shapes with logical markers (\wedge for AND and \times for XOR). UML clearly discriminates between AND and XOR with significantly different symbols (a narrow bar and a diamond). On the other hand, using differing shapes makes users encounter difficulty in recognizing, at first glance, that both AND and XOR symbols in a model represent routing behavior. YAWL uses rectangles with left- and right-sided triangles inside for AND and XOR, but the similarity of the symbols can cause problems with perceptual discriminability. The routing symbols of BPMN have a diamond shape, but that for AND has a + inside. Figl et al. (2010) have presented the first analysis of routing symbols according to cognitive effectiveness criteria based on the three authors' assessments, and rated the semantic transparency low for all symbols and the perceptual discriminability between XOR and AND as good for UML, but weak for the symbols of the three other notations. Figl, Mendling and Strembeck (2013) have shown that the perceptual discriminability problems of YAWL reduce model comprehension, as the participants took more time to answer comprehension tasks. Figl, Recker and Mendling (2013) have constructed process models that differ only in routing symbols, and demonstrated in an experiment that perceived perceptual discriminability and pop-out of routing symbols improve comprehension accuracy, whereas perceived semantic transparency and aesthetic design reduce perceived comprehension difficulty. In light of these arguments, we advance the following hypotheses:

- H2a-b. Users rate the quality of YAWL's AND (H2a) and XOR (H2b) symbols lower than the quality of other symbols.
- H2c-d. Users rate the quality of UML's AND and XOR (H2b) symbols higher than the quality of other symbols.

5.1 Results

Fig. 2 presents evaluations of the AND and XOR symbols. In line with our expectations, the notation was a significant influence factor for AND symbol evaluations ($F_{3,171}=19.45$, $p \leq 0.001$, $\eta_p^2=0.25$), whereas familiarity with process modeling notations was not significant on a general level.

The AND symbol of YAWL was rated worse than the other three symbols (mean difference > 0.98 , $SD=0.18$, $p \leq 0.001$), supporting H2a. In addition, the AND symbol of BPMN tended to be rated better than the AND symbol of UML (mean difference $= 0.34$, $SD=0.18$, $p=0.06$). This effect was significant for the pop-out subscale, but not for the other subscales (mean difference $= 0.48$, $SD=0.19$, $p=0.01$). Therefore, H2c was not supported.

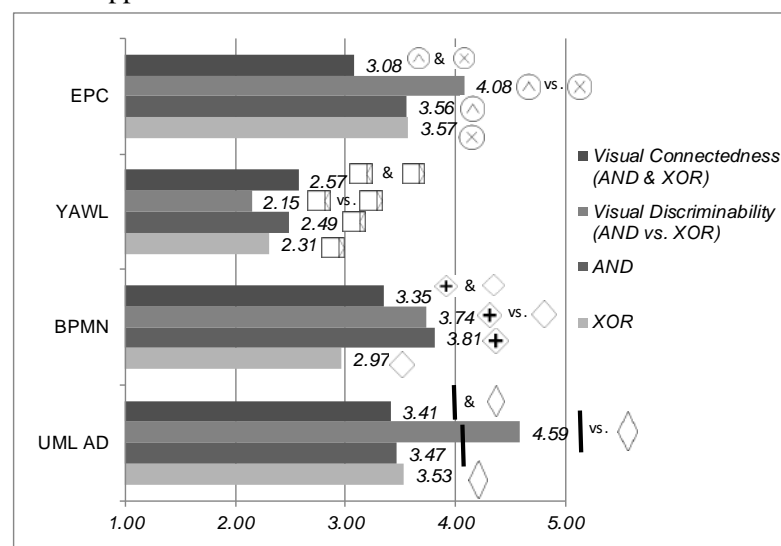


Fig. 2. User Evaluation of AND and XOR Symbols (1=Low Symbol Quality, 5=High Symbol Quality)

Concerning familiarity with process modeling notations, we found a significant effect of familiarity on AND symbol ratings on the semantic transparency scale ($F_{3,171}=5.29$, $p=0.02$, $\eta_p^2=0.03$), as well as a significant and a trendwise interaction effect of notation and familiarity with process modeling notations on symbol quality ratings (pop-out scale, $F_{3,171}=2.22$, $p=0.05$, $\eta_p^2=0.05$, semantic transparency scale, $F_{3,170}=2.56$, $p=0.06$, $\eta_p^2=0.04$). Regarding the pop-out subscale, the interaction effect shows that users who are familiar with process modeling notations rated the AND symbols of UML and BPMN higher than unfamiliar users did, whereas unfamiliar users rated the AND symbols of YAWL and EPCs higher than familiar users did. On average, familiar users rated the semantic transparency of AND symbols higher than unfamiliar users did. More specifically, they rated the AND symbols of UML much higher, the AND symbols of BPMN higher, and the AND symbols of EPCs slightly higher, but the AND symbols of YAWL lower than did the unfamiliar users.

Regarding users' evaluations of XOR symbols, notation had a significant influence ($F_{3,168}=21.73$, $p\leq 0.001$, $\eta_p^2=0.28$) on symbol evaluation, whereas notation and familiarity with process modeling notations had a significant interaction effect ($F_{3,168}=3.30$, $p=0.02$, $\eta_p^2=0.06$). The effect of notation was significant for all subscales. The interaction effect was significant at $p<0.5$ for semantic transparency, but it reached significance only at $p<0.1$ for pop-out and aesthetics. The XOR symbol of YAWL was rated the worst of the four XOR symbols (mean difference <0.66 , $SD<0.18$, $p\leq 0.001$); this comparison also reached significance for all three subscales, lending support to H2b. In addition, the XOR symbol of BPMN was rated worse than the XOR symbols of UML or EPCs (mean difference <0.57 , $SD<0.17$, $p=0.001$), also for all subscales. Thus, only partial support for H2d was obtained. Familiar users rated the XOR symbols of YAWL worse and the XOR symbols of UML better than unfamiliar users did.

Evaluations of the combination of the perceptual discriminability of XOR and AND symbols ($F_{3,170}=63.18$, $p\leq 0.001$, $\eta_p^2=0.53$) and perceptual connectedness ($F_{3,171}=6.70$, $p\leq 0.001$, $\eta_p^2=0.11$) differed depending on the notation. The discriminability of XOR versus AND symbols was rated higher for UML (mean difference >0.51 , $SD<0.79$, $p<0.005$) and lower for YAWL (mean difference >1.59 , $SD<0.18$, $p\leq 0.001$) than it was for the other notations. Furthermore, connectedness was rated lower for the symbols of YAWL than it was for the other notations (mean difference >0.51 , $SD<0.20$, $p<0.01$).

6 Task Symbols

Most process modeling notations visualize task symbols as rectangles, so semantic transparency and visual expressiveness are comparable. However, the placement of the label differs; UML, EPC, and BPMN symbols typically place the label inside the rectangle, whereas YAWL places it beside the rectangle. Gestalt theory can offer insights into how such a difference may affect cognitive effectiveness and Gestalt laws explain how humans organize elements in groups and recognize patterns or structures (Wertheimer, 1938). The law of proximity states that when an individual perceives an assortment of objects, he or she perceives objects that are close to one another as forming a group. Closeness of labels and symbols affects not only perception but also memory and learning, as the "spatial contiguity effect" (Mayer and Moreno, 2003) shows that humans remember learning material better if text and corresponding graphic elements are placed physically close together. Therefore, a label should be placed close to the task symbol, which is the case for both UML and BPMN, which typically place the task label inside the rectangle, and YAWL, which places it beside the rectangle.

Another Gestalt law related to label design is the law of common region, which posits "the tendency for elements that lie within the same bounded area to be grouped together" (Palmer, Brooks and Nelson, 2003, p. 312). Basing on this law, Moody (2012) suggests placing labels inside symbols, so readers can recognize without conscious effort to which symbol a label belongs. Koschmider, Figl and Schoknecht (2015) introduce this recommendation to the process modeling field. The following hypothesis is thus generated:

- H3. Users rate the quality of UML's, EPC's and BPMN's task symbols higher than they do YAWL's task symbols.

6.1 Results

The results show significant differences between the mean values (see also **Fig. 3**) of the evaluation of the task symbols ($F_{3,166}=5.13$, $p=0.002$, $\eta^2=0.09$), but familiarity with process modeling notations had no effect on the evaluation. Contrary to the hypothesis, however, the task symbols of YAWL were not rated lower than the rest of the symbols; instead, the symbols of EPCs were (mean difference <0.62 , $SD<0.18$, $p\leq 0.007$). The effect was similar for all three subscales (pop-out, semantic transparency, aesthetics).

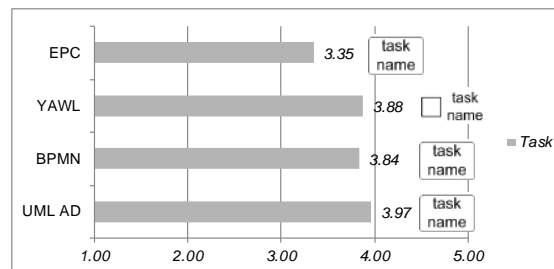


Fig. 3. User Evaluation of Task Symbols (1=Low Symbol Quality, 5=High Symbol Quality)

7 Discussion

This study sought to assess the quality of process modeling symbols from users' perspective. Users rate the start and end symbols of YAWL the best among the notations, but they rate the AND and XOR symbols of YAWL lower than the routing symbols that the other notations use. The task symbols of EPCs were rated lower than other task symbols, although the same symbol is used as in UML and BPMN.

The anticipated result of the positive assessment of the start and end symbols of YAWL likely occurred because these symbols have a higher semantic transparency than others. Users also rate the end symbols of UML higher than those of BPMN, perhaps because the former remind users of a dartboard, which is easy to associate with a goal. However, as the semantic transparency of the UML end symbol was not rated higher than that of the BPMN symbol, an alternative interpretation that this symbol exhibits a higher complexity level may be more fitting. A higher complexity might be more aesthetically pleasing and easier to spot than an ordinary single circle with a thick line (McDougall et al., 2016).

Concerning the evaluation of AND and XOR symbols, YAWL symbols were rated lowest in pop-out, semantic transparency, and aesthetics, as well as in the additional scale of perceptual discriminability. This result relates to a common problem of modeling notations—poor discriminability—as they use similar shapes (Moody, 2009, p. 762). The obtained result is largely consistent with that of Figl et al. (2013; 2013), who discuss low discriminability and its effect on model comprehension. Still, the present user evaluation reveals nuances on how users experience different symbols.

The results on task symbols were unexpected. While the literature suggests placing labels inside task symbols, the users did not give higher ratings to such versions. A study on memory of process modeling symbols (UML, BPMN, YAWL) makes a similar observation in that users performed differently on memory tasks related to routing symbols, but not on memory tasks related to task symbols (Figl, 2012). Perhaps placing a label beside a symbol is sufficient for perceiving symbol and text as a unit (as the Gestalt law of proximity suggests), and following the Gestalt law of common region is unnecessary. The worse rating of users on the task symbols of EPCs than the task symbols of BPMN and UML, although the symbols were identical, was surprising. One possible reason may be that EPCs use hexagons for events, in which labels of conditions are also placed inside. By contrast, in the UML, BPMN, YAWL models in the study, conditions were written next to respective process paths without a surrounding symbol. Thus, the combination of visually similar task and event symbols in an EPC model may lead to the less favorable evaluation of the task symbols.

Familiarity with process modeling notations had no effect on the evaluation of start and end symbols or on the evaluation of task symbols, but it did influence users' evaluations of routing symbols. A likely explanation is that routing symbols have a higher effect on the ability to comprehend the process flow correctly. The relative importance of those symbols is also reflected in the variety of studies that discuss routing symbols (e.g. Figl et al., 2010; Figl, Recker and Mendling, 2013), whereas there are none on start and end symbols.

Users who are familiar with process modeling tend to give more extreme evaluations in both directions: they were both more critical toward symbols (e.g., YAWL's AND and XOR) and more positive toward symbols (e.g., UML's AND and XOR symbols) than unfamiliar users were. A possible interpretation of this finding is that familiar users are more confident in their judgments. Therefore, the "central tendency bias," the tendency to avoid extreme response categories, is low or nonexistent for familiar users.

While users who were familiar with notations tended to know UML and EPC, fewer knew BPMN, and almost none knew YAWL, no bias favoring the symbols of specific notations showed up in the users' evaluations. For example, familiarity did not influence the evaluation of YAWL's start, or end symbols, which were judged as the best symbol options.

8 Limitations

The current research was limited in several ways. Because of the high number of symbols and symbol versions used in various tools, we could evaluate only the most common symbols. (For example, the BPMN standard offers alternative XOR symbols with an \times marker inside and a variety of event symbols beyond the simple start and end symbols). For practical reasons, assessing how users evaluate symbols from different notations in combination was also not possible. Regarding perceptual discriminability, we used realistic symbol combinations of XOR and AND symbols, but the results might differ when the symbols of notations are mixed and combined.

Examining the effect of colors on symbol preference was beyond the scope of this study, although the use of color could have a stronger impact than the shape of the symbol because color is perceived pre-attentively. For instance, colors can help users distinguish between symbols whose forms demonstrate low discriminability.

Future research could use symbol evaluation strategies other than the questionnaire-based method used in this study—for example, asking users whether they can think of better symbols to use in place of the standard ones to reflect particular semantics or evaluating the semantic transparency of symbols with the "card sorting" method, where participants sort symbols into semantic categories.

9 Implications

From a practical perspective, knowledge gained from the present study should inform decisions about symbol choice in the development of process modeling notations. The findings can inform future standardization efforts in process modeling notations (particularly BPMN) and assist modeling notation developers in their design efforts. For instance, the results could inspire notation developers to exchange or revise the start and end symbols of BPMN or the XOR and AND symbols of YAWL. However, the benefit of introducing more usable symbol designs in a standard, such as BPMN, must be weighed against the additional learning and adaption effort required from users who are already familiar with the current symbols. Nevertheless, hints indicate that exchanging symbols might offer more advantages than disadvantages in the long run. For example, Recker and Dreiling (2007) show that the transfer of understanding of models in a specific process modeling notation to that of models in another notation is relatively easy. Moreover, adapting and refining symbols might be a good possibility to slightly improve the desirable properties of the symbols without disrupting the comprehensibility of users already familiar with the notation. For instance, one possible refinement for BPMN

might be to place a “start” (triangle) and a “stop” (rectangle) sign within the untyped “start” and “end” events to increase the semantic transparency of these two symbols by using the audio player metaphor and traffic light colors (green for start and red for end). This suggestion was first put forward by Genon, Heymans and Amyot (2010) and is supported by the empirical data presented in this study. BPMN provides a high number of symbols for variations of 13 event types. An end symbol, such as the symbol of the UML, is already in use as a “terminate” end symbol, so changing the meaning of this symbol for use as a regular untyped end is impractical.

YAWL routing symbols were rated lower than neutral and lower than other routing symbols. Moreover, familiar users even judged them harsher than unfamiliar users did. Therefore, users would likely welcome a change in the visual appearance of the symbols, despite the fact that users need to get used to a new version. Thus, we suggest adapting the symbols, e.g., by adding + markers, as in BPMN, to existing AND symbols.

Concerning the task symbol of EPC, in practice, the tool ARIS (often used to model EPCs) uses different colors for events and tasks, which would probably increase the symbol evaluation score we obtained. Another option to improve the perceptual discriminability of these two symbols would be to make the activity symbols in EPCs per default larger than the event symbols.

However, these are only suggestions. Caire et al. (2013) have reported that larger numbers of novices outperform small groups of experts when designing visual notations. Thus, future research can implement and use crowdsourcing approaches (Caire et al., 2013) and online databases for visual elements (van der Linden, Hadar and Zamansky, 2016) to improve the quality of existing process modeling notations.

The evaluation of symbols in this study demonstrates the usefulness of operationalization and measurement principles in effective visual notational design, as proposed in Figl, Recker and Mendling (2013), and extends them through a measurement scale for the perceptual connectedness of symbols that future studies can use. In addition, the present study shows how “physics of notations” principles (Moody, 2009) can be applied to evaluate the strengths and weaknesses of notational symbols. The results demonstrate that user evaluations provide valuable insights that can refine and complement analytic discussions of symbols based on experts’ opinion.

10 Conclusion

This empirical study provides user evaluations of symbols for the process modeling domain. Returning to the hypotheses posed at the beginning of this study, one can state that the quality of symbols that exhibit a higher semantic transparency (as identified in prior expert evaluations) is rated higher than the quality of symbols that do not, that symbols that are difficult to discriminate from one another receive lower quality ratings, and that no clear support exists for the hypothesized benefit of placing labels inside a symbol instead of next to it. Overall, this research adds strength to a growing body of empirical work in the context of the cognitively effective design of process model notations and visual languages, in general.

References

- Caire, P., N. Genon, P. Heymans and D.L. Moody (2013). “Visual notation design 2.0: Towards user comprehensible requirements engineering notations.” In *Proceedings of the 21st IEEE International Conference on Requirements Engineering*, p. 115-124.
- Dumas, M. et al. (2012). Understanding Business Process Models: The Costs and Benefits of Structuredness. In Ralyté, J. et al. (eds.) *Advanced Information Systems Engineering*. Springer, Berlin, Heidelberg.

- Figl, K. (2012). "Symbol choice and memory of visual models." In *Proceedings of the IEEE Symposium on Visual Languages and Human-Centric Computing*, p. 97-100, Innsbruck, Austria.
- Figl, K. and M. Derntl (2011). "The impact of perceived cognitive effectiveness on perceived usefulness of visual conceptual modeling languages." In *Proceedings of the International Conference on Conceptual Modeling (ER)*, p. 78-91, Brussels, Belgium.
- Figl, K., J. Mendling and M. Strembeck (2009). "Towards a usability assessment of process modeling languages." In *Proceedings of the GI-Workshop EPK: Geschäftsprozessmanagement mit Ereignisgesteuerten Prozessketten*, p. 138-156, Berlin, Germany.
- Figl, K., J. Mendling and M. Strembeck (2013). "The influence of notational deficiencies on process model comprehension." *Journal of the Association for Information Systems*, 14 (6), 312-338.
- Figl, K., J. Mendling, M. Strembeck and J. Recker (2010). "On the cognitive effectiveness of routing symbols in process modeling languages." In *Proceedings of the International Conference on Business Information Systems (BIS)*, Berlin, Germany.
- Figl, K., J. Recker and J. Mendling (2013). "A study on the effects of routing symbol design on process model comprehension." *Decision Support Systems*, 54 (2), 1104-1118.
- Genon, N., P. Heymans and D. Amyot (2010). "Analysing the cognitive effectiveness of the BPMN 2.0 visual syntax." In *Proceedings of the International Conference on Software Language Engineering* p. 377-396.
- Green, T.R.G., A.E. Blandford and L. Church (2006). "Cognitive dimensions: Achievements, new directions, and open questions." *Journal of Visual Languages & Computing*, 17 (4), 328-365.
- Hitchman, S. (2002). "The details of conceptual modelling notations are important - a comparison of relationship normative language." *Communications of the Association for Information Systems*, 9 (10).
- Jošt, G., J. Huber, M. Heričko and G. Polančič (2016). "An empirical investigation of intuitive understandability of process diagrams." *Computer Standards & Interfaces*, 48, 90-111.
- Keller, G., M. Nüttgens and A.W. Scheer (1992). *Semantische Prozessmodellierung auf der Grundlage Ereignisgesteuerter Prozessketten (EPK)*. Institute of Information Systems, Saarbrücken.
- Koschmider, A., K. Figl and A. Schoknecht (2015). "A comprehensive overview of visual design of process model element labels." In *Proceedings of the Business Process Management Workshops*, p. 571-582, Innsbruck, Austria.
- Krogstie, J., G. Sindre and H.D. Jørgensen (2006). "Process models representing knowledge for action: a revised quality framework." *European Journal of Information Systems*, 15 (1), 91-102.
- Langer, S.K. (2009). *Philosophy in a New Key: A Study in the Symbolism of Reason, Rite, and Art*. Harvard University Press.
- Mayer, R.E. and R. Moreno (2003). "Nine ways to reduce cognitive load in multimedia learning." *Educational Psychologist*, 38 (1), 43-52.
- McDougall, S., I. Reppa, J. Kulik and A. Taylor (2016). "What makes icons appealing? the role of processing fluency in predicting icon appeal in different task contexts." *Applied Ergonomics*, 55, 156-172.
- Mendling, J., M. Strembeck and J. Recker (2012). "Factors of process model comprehension—Findings from a series of experiments." *Decision Support Systems*, 53 (1), 195-206.
- Moody, D.L. (2009). "The "physics" of notations: towards a scientific basis for constructing visual notations in software engineering." *IEEE Transactions on Software Engineering*, 35 (5), 756-779.
- Moody, D.L. (2012). "The art (and science) of diagramming: communicating effectively using diagrams (tutorial)." In *Proceedings of the IEEE Symposium on Visual Languages and Human-Centric Computing*, Innsbruck, Austria.
- Object Management Group (2011). *Business Process Model and Notation (BPMN)*.

- Object Management Group (2013). *Unified Modeling Language (UML)*.
- Olle, T.W., H.G. Sol and I.G. MacDonald (1991). *Information Systems Methodologies; A Framework for Understanding*. Addison-Wesley Longman Publishing Co., Inc.
- Palmer, S.E., J.L. Brooks and R. Nelson (2003). "When does grouping happen?" *Acta Psychologica*, 114 (3), 311-330.
- Patig, S. and V. Casanova-Brito (2011). "Requirements of process modeling languages - results from an empirical investigation." In *Proceedings of the Wirtschaftsinformatik*, p. 39.
- Prada, M., D. Rodrigues, R.R. Silva and M.V. Garrido (2015). "Lisbon Symbol Database (LSD): Subjective norms for 600 symbols." *Behavior research methods*, 1-13.
- Recker, J. and A. Dreiling (2007). "Does it matter which process modelling language we teach or use? an experimental study on understanding process modelling languages without formal education." In *Proceedings of the Australasian Conference on Information Systems*, p. 356-366, Toowoomba, Australia.
- Recker, J. and A. Dreiling (2011). "The effects of content presentation format and user characteristics on novice developers' understanding of process models." *Communications of the Association for Information Systems*, 22 (15).
- Reppa, I. and S. McDougall (2015). "When the going gets tough the beautiful get going: aesthetic appeal facilitates task performance." *Psychonomic Bulletin & Review*, 22 (5), 1243-1254.
- Sarshar, K. and P. Loos (2005). "Comparing the control-flow of EPC and petri net from the end-user perspective." In *Proceedings of the 3rd International Conference on Business Process Management*, p. 434-439.
- Soffer, P., Y. Wand and M. Kaner (2015). "Conceptualizing routing decisions in business processes: theoretical analysis and empirical testing." *Journal of the Association for Information Systems*, 16 (5), 2.
- Treisman, A. and G. Gelade (1980). "A feature-integration theory of attention." *Cognitive Psychology*, 12 (1), 97-136.
- van der Aalst, W.M.P. and A.H.M. ter Hofstede (2005). "YAWL: Yet Another Workflow Language." *Information Systems*, 30 (4).
- van der Aalst, W.M.P., A.H.M. ter Hofstede, B. Kiepuszewski and A.P. Barros (2003). "Workflow patterns." *Distrib. Parallel Databases*, 14 (1), 5-51.
- van der Linden, D. and I. Hadar (2015). "Cognitive effectiveness of conceptual modeling languages: Examining professional modelers." In *Proceedings of the Fifth IEEE International Workshop on Empirical Requirements Engineering (EmpiRE)*, p. 9-12.
- van der Linden, D., I. Hadar and A. Zamansky (2016). "Towards a marketplace of visual elements for notation design." In *Proceedings of the 24th IEEE International Requirements Engineering Conference (RE)*, p. 353-358.
- vom Brocke, J. et al. (2014). "Ten principles of good business process management." *Business Process Management Journal*, 20 (4), 2-2.
- Wand, Y. and R. Weber (2002). "Research commentary: information systems and conceptual modeling—a research agenda." *Information Systems Research*, 13 (4), 363-376.
- Ware, C. (2004). *Information Visualization*. Elsevier. Morgan Kaufmann, San Francisco.
- Weitlaner, D., A. Guettinger and M. Kohlbacher (2013). Intuitive Comprehensibility of Process Models. In Fischer, H. and Schneeberger, J. (eds.) *S-BPM ONE - Running Processes*. Springer, Berlin, Heidelberg.
- Wertheimer, M. (1938). Laws of Organization in Perceptual Forms. In Ellis, W.D. (ed.) *A sourcebook of Gestalt psychology*. Routledge and Kegan Paul, London, UK.
- Wiebring, J. and K. Sandkuhl (2015). Selecting the "Right" Notation for Business Process Modeling: Experiences from an Industrial Case. In Matulevičius, R. and Dumas, M. (eds.) *Perspectives in Business Informatics Research*. Springer International Publishing.

Appendix

Symbol Evaluation Scales (a shortened version of that in Figl, Recker and Mendling (2013))

- **Perceptual Pop-out**
 - Start/End/Task/XOR/AND symbols can be found quickly in a model.
 - Recognizing Start/End/Task/XOR/AND symbols in a model is easy.
- **Semantic Transparency**
 - Start/End/Task/XOR/AND symbols are intuitively understandable in a model.
 - Even without explanation, what a Start/End/Task/XOR/AND symbol represents is clear.
- **Aesthetics**
 - The Start/End/Task/XOR/AND symbol is optically pleasing.
 - The Start/End/Task/XOR/AND symbol is well designed.
- **Perceptual discriminability**
 - AND und XOR Symbols are
 - ...difficult to distinguish in a model.
 - ...easy to confuse in a model.
- **Perceptual connectedness**
 - Recognizing in a model which AND-split belongs to which corresponding AND-join in a model is easy.
 - Recognizing in a model which XOR-split belongs to which corresponding XOR-join in a model is easy.