The Role of User Factors on the Ease of Using Graphical Notation Systems

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ABSTRACT

In this study, the usability and the learnability of Graphical notation systems in process modeling languages (PMM) are examined. The learnability of PMMs largely depends on the individual PMM knowledge of employees, but also on process-specific knowledge about task elements, process routines and required resources. Differing cognitive abilities might also hamper a correct understanding of process models. Applying a user-centered research approach, a three-step experimental procedure was carried out focusing on the usability of PMM. First, a usability analysis of the graphical notation system of the C3 PMM was conducted, using a naming task (n = 35) and the sign production method (n = 30) in order to check the understandability of the original elements of the C3 - PPM. On the base of the outcomes, elements were reshaped in a second step. Third, the comprehensibility and the learnability of the C3 notation system were assessed (n = 22). In addition, the impact of user factors on learnability and comprehensibility of notation elements was analyzed. The findings show that the efficiency and the effectiveness of graphical notation systems depend on the degree to which user-centered design principles are carefully considered. Usability evaluation methods from the Human-Computer Interaction research were successfully applied to industrial contexts.

Keywords: graphical notation systems, process modeling languages, usability, learnability, user diversity, sign production, Human System Integration

INTRODUCTION

Industrial working environments and production systems require a high amount of knowledge, communication and cooperation between staff members and organizational units. The knowledge about work-flows and processes should be easily communicated across staff members, it should be easily available, should allow depicting even complex interrelations between work components and should provide a high understandability and cognitive transparency at the same time. In order to assess, describe, organize and communicate internal business-specific knowledge, process-modeling methods (PMM) have been developed, which capture and analyze current business processes in so-called process models (Giaglis, 2001, Blackwell & Green, 2003). Business process modeling is highly frequently used in all types of business contexts, and is therefore a central component in many industrial contexts, covering emergent fields of component frameworks, inter-workflow as well as business-to-business interaction (Georgakopoulos et al., 1995). Process models contain information about operating resources, work materials and staff activities. By comparing and contrasting current („as is“) and proposed („to be“) processes, business analysts and managers can identify specific process transformations that could result in quantifiable improvements to their business (Schuh et al., 2007). Hence, process models are an important component for reengineering processes, but serve also for quality management systems and as knowledge or information basis for job descriptions and staff training (Curtis, Kellner & Over, 1992).

The increasing popularity of PMM has led to a rapidly growing number of modeling techniques and tools. While the overall functionality across PPMs is comparable, still, there are different kinds of PPMs in use. Some examples for widely used and well-established PMM are the ARIS-System (Scheer, 1992), the UML-method (Unified Modeling Language; Booch, Rumbaugh & Jacobson, 1998), which is based on BPEL-methods (Business Process Execution Language, (Andrews, Curbera, Dholakia, Goland, Klein, Leymann, Liu, Roller, Smith, Thatte, Trickovic & Weerawarana (2003).

As modern work and production systems are characterized by a high amount of communication and cooperation among staff members, current PMM have to fulfill the requirement to model cooperative, highly interlinked work systems, which are typically weakly structured. Although a huge number of different PMM exists (Gibbons, 2005), no one of these methods completely fulfils the above-named requirements. In 1999, The C3 process-modeling method had been devoped, which fully meets the demands of task modeling for cooperative work (Killich, Luczak, Schlick, Weissenbach, Wiedenmaier & Ziegler, 1999). The C3 method - "coordination", "cooperation" and "communication" - is largely based on the Unified Modeling Language, but was supplemented and enlarged by additional concepts and graphical notation elements for modeling cooperative work processes (Killich et al., 1999).

Though PMMs are widely used in many industrial contexts, still, the main research activities focused the specific process modeling act, structural components, data flow, roles, application interface, temporal constraints or workflow management. Yet, comparably few studies were concerned with the usability of those PMMS and the ease of using and the learnability of its notation systems (Arning & Ziefle, 2009; Arning, Ziefle & Jakobs, 2013). However, the usability and the learnability of PMMs is a crucial prerequisite for effective usage within industrial areas. User-centred evaluation and design methods from Human Computer Interaction (HCI) research represent a potential source of improving the effectiveness of PMMs and the learnability of its elements.

GRAPHICAL NOTATION SYSTEMS, PICTOGRAMS, AND INFORMATION PROCESSING

Process models are depicted in diagrams or work charts by using graphical notation languages (Kindler & Nüttgens, 2005). Graphical notation systems contain a set of graphical elements (pictograms), which can be combined with each other according to a set of rules. Graphical notation systems of process-modeling methods typically consist of objects (such as activities, tools, information) and relations between objects (such as control flows, information flows, decisions). One of the primary reasons to represent work processes in diagrams, is, that graphical representations are assumed to be more effective for further processing steps (Larkin, 1987). The comprehensibility and unambiguousness of a graphical notation system is therefore essential for an effective communication and transfer of relevant knowledge into the work process (Humphrey, 1999). However, the representation of work processes in process models does not automatically guarantee a correct interpretation. Accordingly, one of the biggest problems of process models is their poor communicability to users (Siau & Cao, 2001) and often process models have to be re-translated into textual form for a better understanding (Tasker, 2001). Hence, an error free comprehensibility is not an intrinsic characteristic of diagrams, but requires well-designed notation elements (Moody & van Hillegersberg, 2008). Moreover, the high information density and level of abstraction in process models hold a high potential for misinterpretation by users. These misinterpretations might be caused by characteristics of the graphical notation elements and/or human information processing. Up to now, research activities have almost exclusively focused on semantic issues of process modeling languages not considering the effects of graphical notation systems (e.g. Siau & Cao, 2001).

The increased popularity of pictograms is due to a number of reasons: in comparison to textual information pictograms are regarded as "potentially universal means of communication" (Rogers & Oborne, 1987). Pictograms have a higher information density and therefore need less space for information presentation than textual information (Schröder & Ziefle, 2008 a,b). Also, pictograms are recognized, remembered and learned more easily and they have a higher probability of being correctly interpreted in their meaning (Norman, 1990). However, the usage of pictograms can also be controversial: Not all pictograms show a universal understandability (Schröder & Ziefle, 2008 a,b). In addition, pictograms are culturally sensitive (Pappachan & Ziefle, 2008), and bear the risk of significant confusion by interpreting the inappropriate meaning of a pictogram (e.g. Davies, Haines, Norris, & Wilson, 1998). When arguing from an information processing perspective, bottom-up and top-down-processes are assumed to interact in the identification, classification and interpretation of objects. According to theories of information processing, the identification of an object requires it's processing on several levels and its decomposition into a set of basic and generic shapes (Biederman, 1987, Treisman, 1991). Semantic knowledge and mental representations stored in long-term memory are also involved in the perception of the perceived image into a meaningful and context-sensitive percept. Accordingly, graphical representations such a process models are always perceived and interpreted based on the individual knowledge base of the user. The transfer of visually encoded diagrams (e.g. process models) in verbal or written codes (e.g. for job descriptions) is highly error-prone (Wiedenbeck, 1999; McDougall, Curry, & Bruijn, 2001), as highly abstract visual information in process models have to be correctly interpreted in context, thus needs additional and contextualized information. The latter largely depends on a high domain knowledge, thus knowledge about the specific process-modeling method and its related notation system, as well as process-specific knowledge about task elements, process routines and required resources.

Especially workers with restricted knowledge might not be able to properly interpret process models. Apart from this, further individual variables such as differing mental models, cognitive abilities or sociocultural background might hamper a correct understanding of process models (Arning & Ziefle, 2007; Ziefle & Bay, 2004). Therefore, user diversity and the increasing diversity of skill levels among the workforce is a serious issue that needs to be considered within the usability of PMMs (Ziefle & Jakobs, 2010). As graphical notation elements of PMM can be regarded as pictograms, they can be analyzed by using pictogram design and evaluation guidelines commonly used in the Human Computer Interaction (HCI) community (e.g. ISO 9186, 2001).

In this research we report on a user-centered design cycle applied to PMMs. Due to its unique features regarding the modeling of cooperative and highly interlinked work systems, the C3 process-modeling method was chosen (Killich et al., 1999). In a first step, the elements of the C3 method were examined regarding the pictorial and the semantic transparency of the elements. The results of this first study served as a reengineering process, improving those elements, which had a low usability. In a third step, a specifically tailored training procedure was applied on the base of the reengineering process: Hence, the comprehensibility of the newly designed elements was measured.

FIRST STEP: THE USABILITY OF PMM ELEMENTS

Procedure of the Naming Study

In the naming study it was explored, if the original C3 notation elements are comprehensible for users with differing degrees of PMM-expertise. In a questionnaire, the single pictograms of the C3 notation systemwere presented. Participants had to find the most adequate verbal term for the pictograms of the C3 notation system. Table 1 shows exemplarily some of the C3 notation elements and their meaning. Questionnaires contained 21 pictograms and participants needed on average 30-45 minutes to complete it.

Table 1: C3 elements from the questionnaire in the naming study.

In order to consider effects of PMM experience on naming results, we distinguished the sample according to three expertise levels: (1) The group of novices (users without any knowledge of PMM (2) experts of PMM-experience in general (users with (theoretical/practical knowledge about) PMM-methods and (3) users with C3-experience (users with (theoretical or practical) knowledge of the C3-method. As dependent variable, the proportion of correctly named pictograms was measured. For the analysis of the naming results, we referred to the DIN ISO norm (9186) for icon design, which requests identification rates of at least 66%.

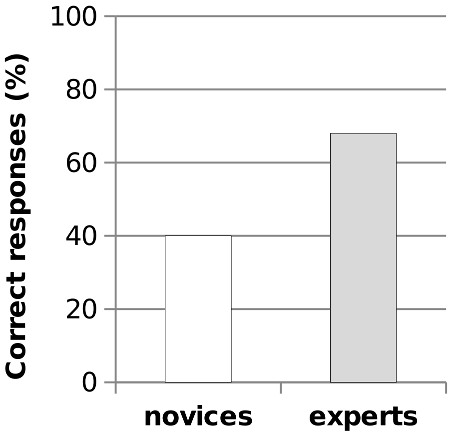
Overall, 35 users (18 - 59 years) took part in the naming study (M = 27.4 years, SD = 7.9, 83% males and 17% females). The sample mainly consisted of students and employees of a technical university, but also engineers, teachers and administrative officers volunteered. The sample consisted of n = 10 PMM-novices (45.7%), n = 12 participants reported to have PMM expertise (34.3%) and n = 7 participants had specific C3-expertise (20.0%).

Results of the Naming Study

Data were analyzed by non-parametric procedures (Kruskal-Wallis-Test). In order to analyze differences in the three PMM-experience groups, ANOVAs with multiple comparisons were carried out. The level of significance was set at 5%; First, total naming performance is described, followed by effects PMM-experience. Then, detailed findings of the comprehensibility of single (central) elements of the C3 notation system will be given.

Overall, participants gave 52.5% correct replies (SD = 26.1), comprising the response rates of all elements. PMM-expertise had a significant effect on naming results (χ (2) = 10.7; $p < 0.05$). Novices gave 39.8% correct replies (SD = 17.5), participants with general PMM experience named 53.8% (SD = 27.0) of pictograms correctly and participants with C3 experience gave 79.2% (SD = 22.1) correct replies (Figure 1). Respecting the detailed analysis of naming results for central C3-elements, identification rates for selected C3 notation elements differed.

The highest rate of correct responses was found for the “swimlane”-element (86%), and the “decision”-element (83%), followed by the identification rate for the “activity-element (71%) and the “information”-element (69%). The rate of correct identification for the “end-condition”-element was 57%, for the “start condition”-element 49%. Still lower performance was found for “synchronal cooperation” (46%), “control flow” (40%), “simultaneous execution” (34%) and “tool” (23%).



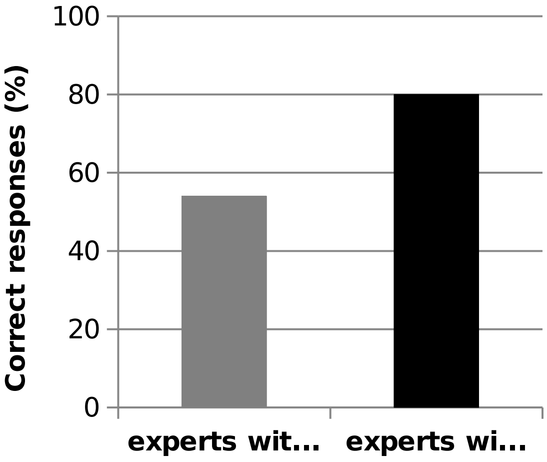


Figure1: Correct responses in % for novices and experts (left) and for PMM-experts and C3-experts (right).

Significant performance differences in C3 identification rates between novices, PMM-experts and C3-experts showed up for “start condition” ($\chi(2) = 6.3$; $p < 0.05$), the “synchronal cooperation”-element ($\chi(2) = 7.2$; $p < 0.05$), the “information flow”-element ($\chi(2) = 9.9$; $p < 0.05$) as well as the “tool”-element ($\chi (2) = 11.4$; $p < 0.05$). In Figure 2, correct responses for single C3 elements are visualized, contrasting the performance of the three expert groups.

Figure 2. Correct responses in % for selected C3 elements for novices, PMM-experts and C3-experts.

SECOND STEP: REDESIGN OF PMM ELEMENTS

In the second study, the sign production method was applied. The sign production method was developed by Howell and Fuchs (1968) and is used for pictorial representations of verbal concepts (Rogers, 1987, Schröder & Ziefle, 2008a, Pappachan & Ziefle, 2008). The sign production method is based on the assumption that respondents develop pictorial representations, which are prototypic for their underlying semantic concept, and therefore reflect basic mental concepts. As users develop the prototypic pictorial representations, it is assumed that representations reflect mental models and the knowledge of users and therefore have a higher probability of being recognized and correctly interpreted. Participants were instructed to produce drawings for single elements of the C3 notation system. They were encouraged to be creative and innovative and to produce as many pictorial representations as possible.

Overall, total of 30 participants aged between 21-46 years took part in the sign production study (M = 27.3 years, SD = 5.9, 64% males, 36% females). The majority of participants in the sign production study were PMM-novices (n = 21, 70%), n = 5 (17%) reported to have general PMM-experience and n = 4 (13%) had specific C3-experience.
Sign production outcomes were analyzed by non-parametric procedures (Kruskal-Wallis-Tests). Participants produced in total 698 drawings (M = 23.3, SD = 4.6) for the C3 concepts. The minimum number of drawings comprised over all C3 concepts was 11, the maximum of ideas was 38. The number of drawings per item and participants ranged between 0.9 and 1.3 (M = 1.2, SD = 0.8). The lowest number of suggestions was made for the

concept “further activities are not relevant” (M = 0.9), followed by “activity”, “aggregated activity” and “optional activity” (all: M = 1.0). The most suggestions were made for the concept “tool” (M = 1.3), “excluded activity” and “weak spot” (for both concepts: M = 1.2). The total number of different ideas per single C3 concept varied between 0 and 4. PMM experience did not affect the number of produced drawings for C3 concepts (n.s.).

Also, a qualitative analysis of participants’ drawing suggestions was carried out. Overall, more abstract than concrete pictogram suggestions were produced (59% abstract vs. 41% concrete pictograms), which might be attributed to the abstract nature of process modeling concepts. The largest number of concrete pictograms was drawn for the element “tool” (97%), the largest number of abstract drawings was produced for the elements “decision” and “weak spot” (both 79%). Interestingly, drawing suggestions for C3 concepts enormously differed from original C3 notation elements. Only for five elements (“activity”, “control flow”, “start condition”, “information”, “decision”), a perfect match between original notation elements and drawing suggestions was revealed. For two C3 elements (“activity” and “control flow”) a higher rate of similarity between drawing suggestions and original C3 notation elements was found. Referring to the “activity”-concept, 6% of drawing suggestions matched the original notation element perfectly and 23% matched it at least closely. The proportion of perfect matches of drawing suggestions for the “control flow” element was 4%, but the proportion of close matches was even 34%. For further C3 concepts the proportion of perfect or close matches was lower and varied between 1 and 11%. These findings indicate, that at least some C3 notation elements correspond to participants’ mental representation of central C3 concepts.

The drawings of participants showed that their pictogram suggestions for C3 concepts were mostly derived from their realm of experience. Concrete activities were depicted (such as a person holding a hammer, a juggling person or persons talking to each other) in order to represent abstract concepts such as “activity”, “simultaneous execution” or “information flow”. In their drawing suggestions with a high degree of stereotypicality not only concrete but also abstract pictograms were found. In these cases, participants referred to well-established pictograms (such as “i” for “information” or a flash-sign for “danger”) or used commonly known abstract pictograms (e.g. “arrow” for the “control flow”-concept or using the letter “Y” for the “decision”-concept). Also, metaphorical drawing suggestions were identified (transfer of the original C3 concept to another context). Metaphors were derived from the sports-context (e.g. “start pistol” or “sprinter at the starting line” for the “start”-element, “finishing line” for the “end”-element). In addition, participants also suggested a combination of visual and verbal elements (e.g. word “start” in a box for the “start”-concept). The findings concordantly show that the evaluation and the design of graphical notation systems of PMM should be harmonized with mental models of PMM-users. On the base of these findings, some of the original C3 elements were redesigned and evaluated in a next step.

THIRD STEP: TRAINING STUDY

In a third step, the learnability and usability of the redesigned C3 notation system was evaluated. A C3-training was delivered and learning effects for the C3 notation system were quantified and related to individual user factors.

Procedure of the Training Study

Before participants received the C3 training, they rated the pictorial and semantic transparency of 25 C3 notation elements (t1: pre-training, interpreted as baseline performance). Following the C3-training, participants were requested to evaluate the semantic transparency of C3 notation elements again (t2: post-training), and ratings of learnability, comprehensibility, ease of use, and usefulness were collected. Since the C3-training focused on the understandability (semantic aspects) of C3 notation elements (as this is the most decisive cognitive process in real world environments), we concentrated on semantic transparency only.

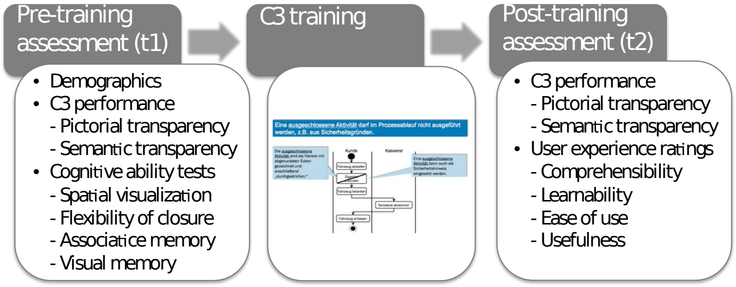


Figure 3. Experimental procedure of the training study

The C3 training was provided in form of a written manual (30 pages), which contained an introduction with a short description of PMM in general and the origins of the C3 method (8 pages), and explanations for the single C3 notation elements (22 pages). For the evaluation of the pictorial transparency, participants had to indicate what each of the C3-elements pictures (clarity of the picture). For the evaluation of the semantic transparency, participants had to indicate the meaning of the C3-element (clarity of the meaning).

Dependent variables were the proportion of correctly described pictogram appearances (pictorial transparency) and pictogram meanings (semantic transparency). For the analysis of results, we referred to the DIN ISO norm (9186) for icon design, which request that for icon revision identification rates for a specific icon are below 66%. Overall, 22 participants aged between 21 and 35 took part in the study (M = 26.7 years, SD = 3.8,). The sample consisted of engineering students and engineers with domain knowledge: The majority (90%) reported to have theoretical and practical knowledge about process modelling languages.

Results of the Pre-Training

The visual quality (pictorial transparency) of the C3 notation system was, on average, 86.2% (SD = 19.31, range 32-100%), which indicates a high pictorial transparency of the C3 method. Looking at the pictorial transparency of single C3 notation elements, the average performance was above the DIN-recommended cut-off of 66%. The highest pictorial transparency was about 100% for the elements “start” and “further activities”, the lowest pictorial transparency was found for the element “synchronization bar” with 70%. Results are given in table 2.

Table 2: C3 elements from the questionnaire in the naming study.

C3 elements	**pictorial transparency (t1)**	**semantic transparency (t1)**
activity	90%	100%
aggregated activity	80%	5%
blob	90%	85%
control flow	95%	100%
decision	90%	85%
end	90%	65%
excluded activity	90%	70%
excluded information	90%	45%
excluded object	75%	100%
further activities	100%	75%
information	90%	50%
information flow	95%	10%
iteration	75%	95%
object	80%	5%
optional activity	85%	75%
optional information	90%	35%
optional object	80%	100%
parallel composite activity	80%	45%
sequential composite activity	80%	40%
start	100%	70%
swimlane	95%	95%
synchronization bar	70%	90%
synchronous cooperation	75%	80%
tool	85%	85%
weak point	85%	55%

Semantic transparency of the C3 notation system was about 58.4% (SD = 11.04, range 40-76%), which indicates a rather low semantic transparency and intuitive comprehensibility. The high level of abstraction of C3 elements and the semantic distance between the pictorial quality of the C3 elements and their semantic meaning might explain this finding. On the single C3 element level, semantic transparency ranged from very low for the elements “aggregated activity” (5%) and “information flow” (10%) up to very high for the elements “activity”, “control flow”, “excluded object”, and “optional object” (all 100%).

Results of the Training: Learnability effect

As effect of the C3 training, semantic transparency performance significantly increased from 58.4% (SD = 11.0) to 87.2% (SD = 9.3; F(1,19) = 132.03, p < 0.000). The knowledge gain reached from 0% for elements, which already possessed a high semantic transparency (e.g. “activity”, “tool”) to above 40% (e.g. “excluded information”, “parallel composite activity”) and even 80-85% (“object”, “aggregated activity”). Contrary to expectations, the C3 training exerted a negative effect for some C3 elements, as the decrease in semantic transparency performance indicates (“control flow”, “excluded object”, “optional object”, “swimlane”, “synchronization bar”). Summarizing the C3 training effectively supports participants in acquiring semantic C3 knowledge.

In Figure 4, the positive learning effect in C3 elements is depicted (comparing pre- and post-training performance). In Figure 5, the negative learning effects are shown., thus those elements, in which no improvement or even a deterioration between the pre- and post-training phase was found.

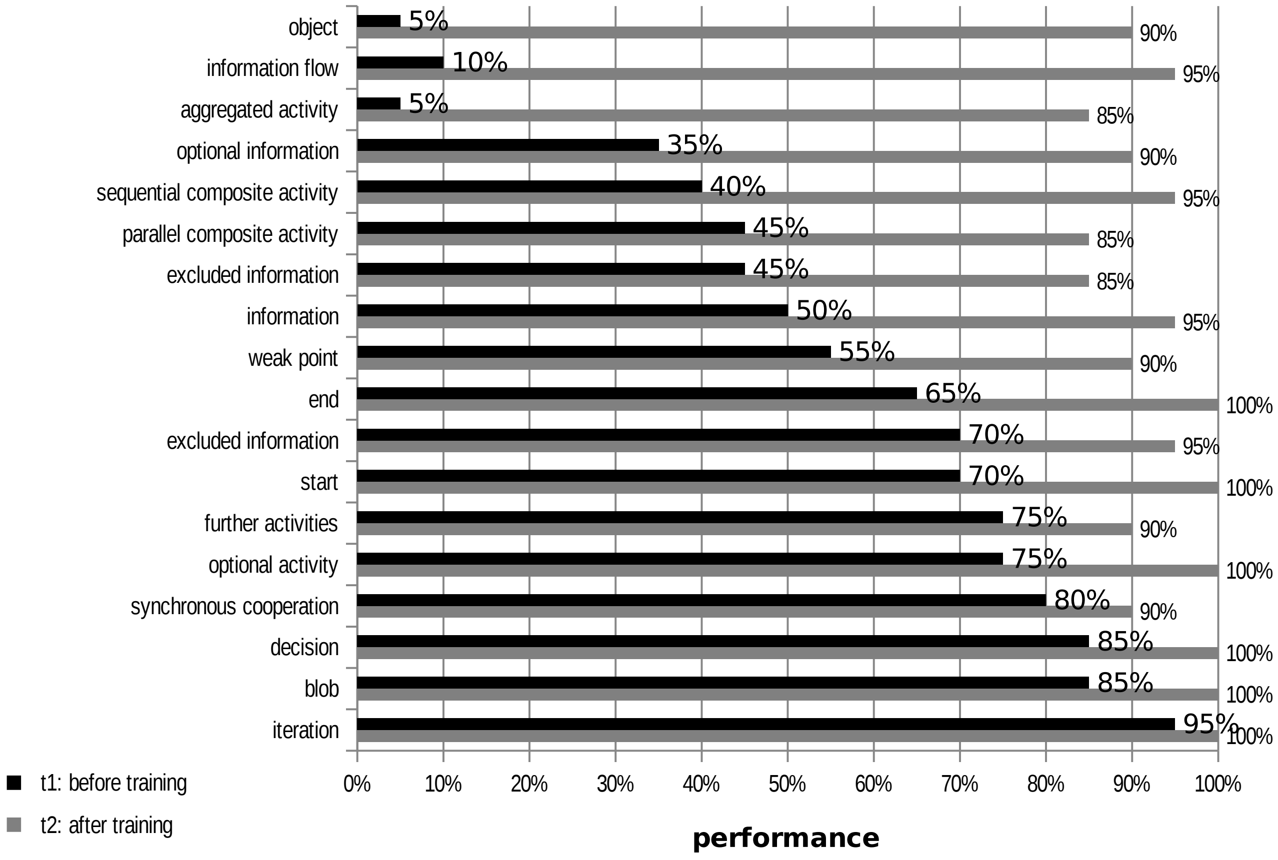


Figure 4. Positive learning effect for C3 elements (Pre-Post-Training)

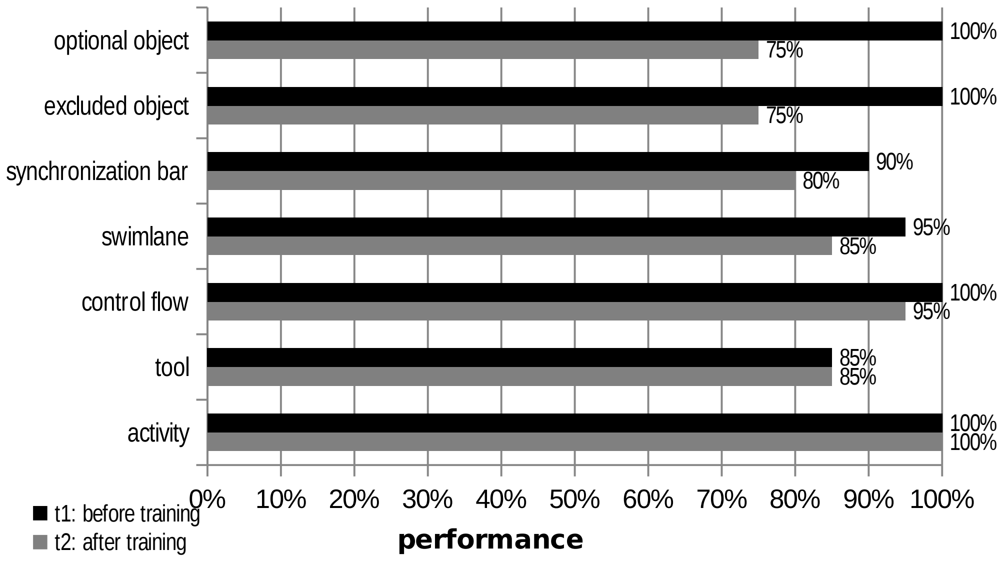


Figure 5. Positive learning effect for C3 elements (Pre-Post-Training)

Finally, participants were asked to rate the comprehensibility of notation elements as well as the learnability, the ease of using the elements and the perceived usefulness of the notation system. As found, comprehensibility and learnability of the C3 notation system after the C3 training was positively evaluated. The comprehensibility was rated on average with M=81.2% out of 100% (SD = 7.6, range 67.3 – 96.0) and learnability with M=90.4% (SD = 5.4, range 78.7 – 96.0). Ease of use was on average M=88.0% (SD = 7.6) and usefulness of the C3 system was on average M=75.3 (SD=13.7).

Another interesting point refers to the question if cognitive abilities of workers do affect the performance with using process modelling methods. As cognitive factors we measured the following abilities: (1) spatial visualization ability, i.e., “the ability to manipulate or transform the image of spatial patterns into other visual arrangements” (paper-folding test, VZ-2), (2) flexibility of closure, i.e., “the ability to ‘hold in mind’ a particular visual percept (configuration) and find it embedded in distracting material” (hidden figures test, CF-1), (3) associative memory, i.e., “upon presentation of one part of previously associated but otherwise unrelated material, ability to recall another part” (associative memory test, MA-1), and (4) visual memory (shape memory test, MV-1). These abilities might be relevant when processing abstract process modelling components. The test procedure are standardized and were taken from psychometric assessment of cognitive abilities, the Kit of Factor-referenced Cognitive Tests was applied (Eckstrom et al., 1978).

Outcomes in the cognitive abilities were related to the performance of comprehensibility. As found, the comprehensibility (measured by pictorial and semantic transparency performance in t1) and learnability (semantic transparency performance in t2) of the C3-notation system was not significantly associated with users’ cognitive abilities, as correlational analyses showed.

DISCUSSION AND CONLCUSIONS

A three-step experimental usability analysis of graphical notation systems was under study, taking the C3 PMM as an example. First, in a naming task, the verbal labeling of notation elements was empirically examined. Then, the sign production method was applied, investigating users’ prototypic pictorial representation of central concepts of the C3-method. On this base, some of the suboptimal elements were redesigned. Third, a C3 training was designed and applied, as well as the learnability of the training assessed.

The evaluation of the graphical notation system of the C3-system revealed both, already well-designed elements, which are basically comprehensible, but also notation elements, which are difficult to understand in their current form and might benefit from redesign. According to HCI icon design guidelines (ISO 9186), an effective and efficient application of the C3 process modeling method is at risk due to a reduced comprehensibility of notation elements. Especially notation elements, which make up the uniqueness of the C3 method, namely those who refer to aspects of task coordination (e.g. simultaneous or sequential execution of tasks) and cooperation (e.g. synchronizing activities) provoked misunderstandings.

Moreover, the verbal terms, that participants proposed to describe the notation elements, were incorporated in the verbal design of the current C3 user guide. As found, participants' intuitive labels of functions do represent valuable alternatives to the descriptions used in the C3 guide. Future revision work of C3 notation elements should therefore not only focus on revisions of graphical notation elements, but also on the verbal labeling of C3 concepts.

Valuable insights about how to revise specific C3 notation elements came from the sign production study. Even though some concepts of the C3-system are highly abstract and refer to a specific (business) context, the agreement in drawing types suggests the existence of population stereotypes. Beside the reported shortcomings regarding some C3 notation elements, some original C3 notation elements corresponded well to users' mental representation of central C3 concepts. The utilization and integration of such stereotypic representations into the design of graphical notation systems has a high potential for a good and universal comprehensibility of graphical notation systems.

The comprehension of the C3 notation elements was considerably affected by individual experience with process modeling methods. Interestingly, general knowledge of PMM is not fully sufficient for a correct understanding of C3 notation elements. Although general domain knowledge about process-modeling methods benefits the recognition of C3 notation elements, it does not lead to identification rates demanded by the ISO standard. Apparently, general PMM-experience cannot be easily transferred to the C3-method.

For a successful identification and application of C3 notation elements, specific C3 experience is necessary. Taken from this, users should either receive a specific C3 training before applying the C3 method, or the C3 graphical notation system should be simplified if a broad understanding by inexperienced users of PMM should be achieved. shown, the C3 training proved to be highly successful as taken from the enormous learnability effects and the positive user perceptions after the training. the impact of cognitive diversity on performance outcomes was comparably low. Thus we can conclude that the C3 notation system is comprehensive, learnable, and applicable for every user – independent from his/her cognitive predispositions ("design for all").

The procedure applied here also contributes valuable insights from a methodological point of view, outcomes show that the evaluation and the design of graphical notation systems of PMM benefit dramatically if user-oriented procedures are applied and the elements are harmonized with the knowledge and the mental model of the target group. This user centered approach is a promising way to develop graphical notations which are "designed for all", i.e. independent from differing levels of experience with process modeling methods. Once more it was found that industrial applications and processes do distinctly profit from a cognitive-ergonomic evaluation based on usability methodologies. By applying these user-centered evaluation and design methodologies, valuable insights regarding C3 element optimization needs could be discovered. Since graphical notation systems of process-modeling methods have never been investigated from a user perspective so far, the naming and the sign production method appear as a promising way to integrate users into the research- and design process of graphical notation systems.

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