Process-oriented versus product-oriented worked examples for training older adults to use interactive systems

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***Abstract*—the presented study tried to investigate how older adults can be supported in knowledge acquisition for using interactive systems. More precisely, this study focused on the instructional method worked examples and how they should be designed for older adults. Therefore, 40 subjects between 60 and 74 years (20 male and 20 female; M=66.95, SD=3.65) participated in an experiment where process-oriented worked examples were compared with product-oriented worked examples. Results could show that older adults can be assisted by using worked examples as training method in technical device instruction. However, the experiment could not demonstrate a superior support by process-oriented worked examples as expected. Both versions supported more or less equal older adults in knowledge acquisition. It is suggested that the additional 'how' and 'why' information provided in process-oriented worked examples were also implicitly contained in product-oriented worked examples.**

I. Introduction

Older adults are increasingly confronted with the use of interactive systems in their daily life. One prominent example is the substitution of ticket counters or selling points by complex automatic vending machines. As older adults grew up in a time where computers were not existent or played only a subordinate role, most of them are inexperienced in using modern technologies. Hence, they often meet difficulties while trying to interact with these complex technologies that often lead to a reduced usage and acceptance [1].

Given that the use of technology is in most parts of daily life obligatory (e.g. the use of ATM), a critical issue now is how we can counterbalance the problem of older, inexperienced users to integrate new technologies in their life in a safe and efficient way. One approach to bridge the gap between the older user and technical devices is the design of special age-based products. Here, we often find technical devices that assist the elderly from a cognitive and perceptional perspective with reduced complexity (only basic functions are provided) and huge displays with large buttons. Especially older adults that belong to the generation of the young old may not accept these devices, as they seem to be accommodated and oriented to negative stereotypes of aging. Another approach is to train the elderly in using technology. This approach is more oriented on resources and potentials of the elderly and strengthens the idea of lifelong learning. Furthermore, studies suggest that older adults can learn new computer skills just as young adults [2] [3]. With training, technical knowledge can be provided and a safe and competent use of technology may further enhance self-confidence [4].

To sum up, this research project aims to support the elderly in knowledge acquisition for using technical devices. But how should instructional design conceptualized to support older novices in initial skill acquisition for technology interaction? The following study addresses support formats, precisely worked examples as instructional tools that take into account the learners cognitive resources and how they can be used more effectively in learning processes.

II. Cognitive Load Theory and the Use of Product versus Process-Oriented Worked Examples

Following the Cognitive Load Theory (CLT), instructions should be designed in consideration of the limited capacity of working memory [5] [6] [7]. This is notably important, as capacities of working memory decline with age and will be even more limited in comparison to young adults [8]. Moreover, CLT assumes that instructional material can demand cognitive capacities by intrinsic, germane and extraneous cognitive load that they impose. Intrinsic cognitive load is imposed by the difficulty of the instructional task and their complexity (e.g. number of interactive elements). Hence, intrinsic cognitive load is also dependent on the learner's prior knowledge and schema that were already constructed in the past. Although CLT considers that intrinsic cognitive load is bound to the content to be learned, as it is innate to the task, new research results show that it can be manipulated by presenting interactive elements separately [9]. In general, interacting with technology can be a quite complex task when different information has to be kept in working memory and need to be processed. Therefore instructional ways should be found to reduce that complexity at the beginning of knowledge acquisition. Extraneous cognitive load is imposed by the design of learning material and should be kept as small as possible. At least germane cognitive load is also imposed by the instructional design, but should support the learner in knowledge acquisition. Thus, instructional material, especially for older novices should reduce extraneous, ineffective load, which is imposed by the design of the learning environment itself and should enhance effective, germane load.

One principle in designing instructions to enhance learning for novices is the application of worked examples

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[10], where usually a problem formulation, solution steps and the solution itself is provided to the learner [11]. Novices have usually a lack of prior knowledge and schema how an interactive system works. Therefore they need all their cognitive capacities to construct an appropriate mental representation. Additional extensive searching for the right solution steps in a problem solving task may limit cognitive resources and therefore produce unnecessary extraneous load for learners. Several studies give evidence that knowledge acquisition is much easier, if solutions are shown instead of using conventional problem solving tasks and Sweller [12] assumes that this effect, also known as the worked-example-effect, is already justified. Moreover, for novices it is not only important to know procedural steps for problem-solving tasks, but rather understand when to employ them and why they work. There are two different kinds of worked examples discussed in current literature: product and process-oriented worked examples [13] [14]. In product-oriented worked examples, solution steps are provided, but the rational for taking each step is not. In these worked examples germane cognitive load should stimulate learning by self explaining the given solution. In process-oriented worked examples, additional explanations of principled 'how' (strategic knowledge used by an expert in selecting operators) and 'why' (rationale behind the selection and application of operators) information is provided by an expert. This may help especially novices to understand the solution steps provided, as they have only a limited computer literacy [15]. Furthermore, self explanations may bind again working memory capacities. Hence it is suggested; that instructional design which is based on process-oriented worked examples may enhance learning for older adults to use interactive systems, because it provides an additional help to understand interactive processes and structures.

As mentioned above, several studies found evidence that worked examples in general are better for knowledge acquisition then none worked out solutions. Furthermore, is suggested, that additional 'how' and 'why' explanation will enhance learning for novices, because learners don't have to self-explain the rationale behind solution steps shown in the worked example and when they have to apply them. However, a study of van Gog and colleagues [16] could not find benefits for the additional process information provided in a troubleshooting experiment conducted with young adults. They assumed that working memory load was probably too high in their experiment, because extraneous load, which emerged from graphics with text, called for limited working memory capacities. Therefore the following experiment used instructional videos. This reduces extraneous load, because of the modality principle [17]. Another suggestion of the authors was to present process information not only during task execution for novice learners, but rather before and/or after the worked example. A study of Kester, Kirschner & Merriënboer [18] could show that it is superior to present declarative information and procedural information piece by piece instead of simultaneously. This may free up as well working memory capacity, because less information need to be processed at once. Hence, the instructional design tried to present most of declarative information before procedural information to secure free working memory capacities for knowledge acquisition.

III. DEVELOPMENT OF A TRAINING PROGRAM FOR OLDER ADULTS TO USE A TICKET VENDING MACHINE

As training content a ticket vending machine (TVM) was used as representative of an interactive system. This had several reasons. Firstly, as service points get closed, the usage of a TVM gets essential and is important for many older adults' mobility. Secondly, several studies were already conducted to the usage and acceptance of TVM [19] [20] [21]. And thirdly, the selected system is well-structured and contains enough complexity to build up a demanding training program.

The main goal in designing the instructional material was to reduce the amount of extraneous load to a minimum and to give space for germane load by "how" and "why" information that is suggested to be important for developing schema representation. According to the modality principle, video instructions were used to support dual encoding. Furthermore, content of the training program (ticket types and how to buy them with a TVM) was structured on the basis of an instructional task analysis with GOMS [22]. Here, goals, operators, selectors and selection rules were defined for every task. Then, all tasks were categorized in order to their complexity. Afterwards the learning content was structured from easy to complex tasks in six lessons. Training wheels were used [23] to reduce complexity on screen by inactivating functions that were not learned already and irrelevant for the actual task.

Each lesson consisted of three different parts: an introduction, learning tasks for knowledge acquisition and transfer tasks where gathered knowledge had to be applied to new problem tasks. The introduction gave an overview, what kind of tickets will be trained in each lesson. In knowledge acquisition phase a video model gave at first information about the ticket and explained afterwards step by step how to proceed when buying the ticket with the TVM (see figure 1).

Fig. 1 Video model explaining the use of the ticket vending machine in the training program.

For socio-motivational support during learning it was important to use an older adult as video model. Additionally, condition specific video instructions for the two types of worked examples were produced. Videos based on product-oriented worked examples showed only the steps for buying the ticket. In contrast, videos based on process-oriented worked examples provided additional ‘how’ and ‘why’ information to the learner. Table 1 shows a comparative example of given information for the task “reduced single ticket” of lesson one. It should be noted, that both training methods were not totally product versus process-oriented. Product-oriented worked examples contain also ‘how’ information by showing the learner procedural steps of buying a specified ticket. Therefore the concept should rather described by the main emphasis on additional process-oriented information or simple product-oriented information.

Table 1 Vocal explanations for knowledge acquisition task ‘reduced single ticket’ for product versus process-oriented worked example (italic: additional how-information, bold: additional why-information).

Product-oriented Worked example
At first I select the ticket, e.g. a reduced single ticket for Berlin ABC. Therefore I press the key “single ticket”. Now I press the key “reduced fare” and finally, I press the key “pay”.
Process-oriented Worked example
At first I select a ticket, e.g. a reduced single ticket for Berlin ABC. Therefore I press the key “single ticket” *beside the label “Berlin ABC”*. On the next page I can pay the ticket. Here, I can find on the right hand side the 2 keys “normal fare” and “reduced fare”. **The key “normal fare” is green, hence it is selected**. **Now I need to press the appropriate button to select the reduced fare and this button gets green**. *At the end I check on the left* **if I selected the right ticket** und then I press the key “pay”.

It is suggested that the additional information of process-oriented worked examples may help to understand the functionality of the TVM and explicitly points out computer literacy aspects through the vocal explanations of the expert model.

After video instruction, participants had to reproduce the solution steps that were shown by the model. If they used functions that did not belong to the solution, an immediate feedback was provided. Moreover, in the knowledge acquisition phase a video help was available. At the end of the lesson, participants had to complete three knowledge transfer tasks where no additional help for problem solving was available. Here, the gathered knowledge of a lesson had to be applied on new, but in complexity and content similar tasks. This test was therefore not measuring far transfer but rather knowledge application to analog tasks that were practiced before. Feedback was given only after the task completion.

IV. Method

A. Participants

40 older adults between 60-74 years participated in the study (20 female, 20 male, mean age 66.95 years, SD=3.65). They were recruited through visits in senior clubs, displays of flyer and through referrals from other participants. The newspaper advertisement and flyer asked for people interested in participating in a “training program for using a ticket vending machine”. As compensation, subjects were rewarded with 15 Euro. Most of the participants used ticket vending machines never or less than monthly (65%). All subjects were evenly matched to both training groups regarding participant’s age, gender and prior experience with ticket vending machines.

B. Dependent variables and measures

Training performance was measured in several ways. In knowledge acquisition phase, reproduction performance was measured by time and error rate. In knowledge application tasks, time, error rate and additional keystrokes were recorded.

To measure learning success for declarative knowledge a multiple choice test with eight items was used before and after the training. Additionally, two other tests were used to assess information about the change in mental representation, namely in structure and functionality of the TVM. Here, at first three test items with respectively two printouts of screens were shown. One of the printouts contained erroneous features or a misconception of the ticket vending functionality. In this test, participants had to a) find out which printout contained an error and b) state what exactly is incorrect (see fig. 2 for an example). Subject received for each subtask one point; hence a maximum of two points could be reached for each task.

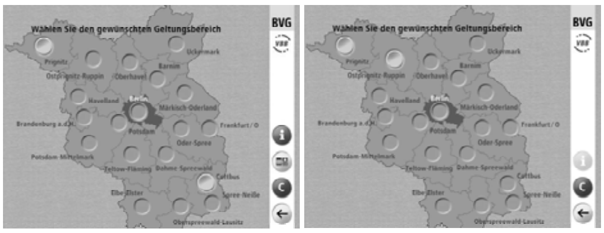

Fig. 2 Screen comparison task for the selection of rural districts: Participants had recognize, that only adjacent districts can be selected for a ticket (right screen = correct answer).

In a second test three printed screens were presented, in which important functions had to be placed on the correct position (e.g. back or cancel button). At first, buttons with additional distractors and the printout with deleted functions were shown to the participants. Then subjects had to choose the appropriate buttons and to place them on the correct position in the printout. One point was given, when the subject selected the right button and one for the correct position. At all, a maximum of 12 points could be reached in this test. Both tests for measuring mental representation were conducted before and after the training.

Perceived Cognitive load was assessed with an 11-point-rating scale after each lesson by the modified NASA-Task Load Index that was used already in other studies [24]

[25]. It distinguishes between the different aspects of cognitive load and asked for ‘task demand’ (how much mental and physical activity was required to accomplish the lesson, e.g. thinking, deciding, searching, remembering, looking etc.), ‘effort’ (how difficult was it to understand the training content of the lesson?) and ‘navigational demands’ (how much effort was invested to work with the training program, e.g. to decide which information a person wanted to see and to orientate his/herself?) According to CLT a mapping is assumed, whereas ‘task demand’ is measuring intrinsic load, ‘effort’ germane cognitive load and ‘navigational demand’ extraneous cognitive load [26]. All Items had to be rated on an 11-point-scale ranging from not at all demanding (1) to extremely demanding (11).

C. Procedure

The experiment was conducted in a lab of the Department of Psychology at Humboldt University Berlin as well as in two senior clubs. All participants were tested in individual sessions. On average, the experiment took three hours and was structured in three parts. In the first phase, participants were informed about the experiment and data protection. In a following interview demographic data were gathered as well as subject’s prior experience with ticket vending machines. Moreover, subjects had to fill in a survey about self efficacy beliefs and a test to pre-measure declarative knowledge about the TVM. Also mental representation of the TVM was assessed before the training. Participants had to complete at first three structural tasks afterwards three test items with screen comparisons.

In the second phase, the training with the interactive training program was conducted, using a touch screen. Participants were told that the experimenter will remain in the room, but that they should work on the instructional material on their own as much as possible. After each lesson subjects filled in the survey for measuring cognitive load. Following the training a short break of 5-10 minutes was provided.

In the last phase participants were post-tested with a multiple choice test for measuring declarative knowledge and they completed again the structural test items as well as the screen comparison test.

V. RESULTS

A. Performance in reproduction tasks

On average participants of the group with process-oriented worked examples needed less time during task reproduction (M=55.03 minutes, SE=2.17) in comparison to the group with product-oriented worked examples (M=56.35, SE=1.77); differences were not significant, t (38) = .47, *ns,* r=.07. Analysis of number of errors show that the group with process-oriented worked examples made less errors during reproduction tasks (Mdn=2.5) than the group with product-oriented worked examples (Mdn=5), differences were not significant, U=150.5, p=.09, r=-.22.

B. Performance in knowledge transfer tasks

Relating to the time for solving the 18 transfer tasks, no significant differences were found between the process-oriented worked example group (M= 25.7 minutes, SE= 1.63) and product-oriented worked example group (M=22.2 minutes, SE= 1.36), t (38) = -1.17, p=.13, r=.19.

Furthermore, participants of the group process-oriented worked examples (Mdn=2.5) didn’t seem to differ in number of errors in transfer tasks from participants of the product-oriented worked example group (Mdn=2); U=195, *ns,* r=-.28). Additionally, the number of steps that were irrelevant for solving problem tasks was calculated as a measure of efficiency in training. Here, no differences were found between the group of process-oriented worked examples (Mdn=3) in comparison with the group of product-oriented worked examples (Mdn=3.5), U= 162, p=.15, r=-.17.

C. Declarative knowledge test & test for mental representation

To measure learning success, pre-post-tests were analyzed with a mixed design ANOVA. For declarative knowledge, a significant main effect was found for the training in general, F(1, 37) = 56.99. p<.001, r=.78, but not for the training version F(1, 37) = .937, *ns,* r=.16. Furthermore, a significant interaction was found, F(1, 37) = 5.152, p<.05, r=.35. This indicates that learning success for declarative knowledge differed in the two versions. Figure 3 shows the recovered effect. Moreover, learners improved significantly from pre to post test in the screen comparison test. Here a main effect was found for training in general (F(1, 38) = 84.707, p<.001, r=.83, but not for the training version F(1, 38) = .008, *ns,* r=.02. Furthermore, no significant interaction occurred, F(1, 38) = 3,459, p=.071, r=.30. Finally, structural test measures were compared before and after the training. Here again a significant main effect was found for the training in general, (F(1, 38) = 46,288, p<.001, r=.74, but no main effect was found for the training version, F(1, 38) = .003, *ns,* r=.008. No interaction was detected F(1,38) = .02, *ns,* r=.07.

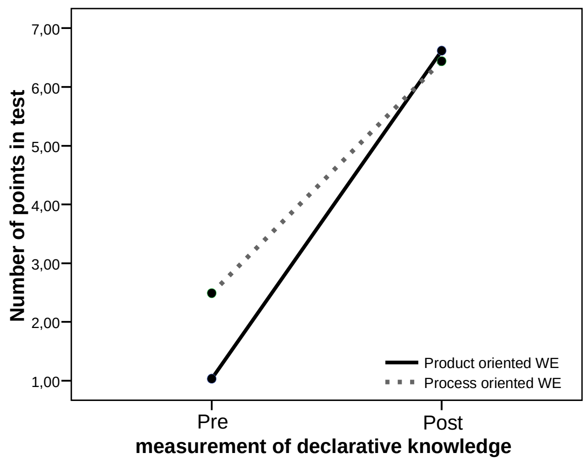

Fig. 2 Interaction graph for declarative knowledge before and after the training for process versus product-oriented worked examples.

D. *Cognitive load*

Finally, subjects in both groups estimated cognitive load after each lesson. At all, no significant differences occurred for measures of intrinsic (t(38) = .687, *ns*), germane (t(38) = .379, *ns*) and extraneous load (t(38) = .739, *ns*). Table 2 shows a comparison of subjective cognitive load for all six lessons.

Table 2: Overview on descriptive data for product versus process-oriented worked examples in intrinsic, germane, and extraneous cognitive load load (CL), measured with the modified NASA-TLX.

	Information presentation format			
	Product-oriented worked examples		Process-oriented worked examples	
	M	*SD*	*M*	*SD*
Intrinsic CL	1.81	.66	1.65	.71
Germane CL	2.06	.81	2.17	.99
Extraneous CL	1.91	.78	2.01	.93

VI. DISCUSSION

Results of the study showed that training programs using worked examples as instructional method can support older adults in using ticket vending machines. The hypotheses that worked examples will support older adults in knowledge acquisition and in building up mental representations were basically confirmed. Additional information provided by process-oriented worked examples may have only limited effects on learning performance and success. Like van Gog et al. [16], this study didn't find evidence that process-oriented worked examples enhance learning more than product-oriented worked examples. Analysis of performance in reproduction tasks could show that the training group using process-oriented worked examples needed on average less time and made less errors. However, no significant differences were found. Comparisons in performance in knowledge transfer tasks yielded to the opposite result. Here, on average participants of the process-oriented worked example group needed more time, but differences were not significant. Furthermore, there seemed to be no differences in error rate and additional steps in problem solving.

Pre-post analysis of declarative knowledge detected a significant interaction for the training version. Here subjects of the product-oriented worked example group achieved fewer points in pre-measures and slightly more points in the post-measures of the multiple choice test in comparison to the group of process-oriented worked examples. This result mostly refers to the differences in prior knowledge. Therefore, further studies should try to assure a balanced prior knowledge in both groups for a better interpretation. Moreover, for mental representation measures, no differences between both groups were detected.

Concerning measurements of different cognitive load during the training, all participants stated a low intrinsic, germane and extraneous load, hence participants didn't experience mental overload. Comparisons of the experimental conditions yielded to no significant differences in all three measures.

At all, no fundamental differences were found between the training methods product-oriented worked examples and process-oriented worked examples. One explanation of this finding is that the additional information provided in process-oriented worked examples might have been implicit shown in the product-oriented worked examples. Given that participants stated low mental effort in all cognitive load measures, subjects of the product-oriented worked examples group may had enough capacities for self-explaining how the TVM works and what are special features they have to take into account while interacting with the machine just by observing the procedural steps shown by the model.

A second possible explanation is that the additional information was a kind of noise for subjects. Although subjects stated little mental effort during the training in cognitive load measures, it might be possible that subjects focused their attention on procedures that were shown in the video instead of additional vocal information provided during interaction.

It should also be noted that the training program in general was already well designed to support older adults in knowledge acquisition (e.g. in using training wheels). As experimental condition only video instructions were changed and compared to each other, namely product-oriented versus process-oriented worked examples. Therefore additional 'how' and 'why' information may have only a little additional effect on knowledge acquisition compared to the other instructional methods that were used in both versions. Consequently, when instructional videos are used for knowledge transfer in training programs, it seems to be promising to use product oriented worked examples, given that additional 'how' and 'why' information is implicitly shown and described during the interaction between the model and the technical device.

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