Ask and You Will Receive: Training Novice Adults to Use a PDA in an Active Learning Environment

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ABSTRACT

Even though the effective usage of mobile devices has become a mandatory requirement in many professional and private areas, inexperienced users face especially great difficulties in acquiring computer skills. Based on the assumptions of constructivist learning theories, the effect of asking questions and repeated practice on PDA skill acquisition in adults (n = 36) was examined. Learners had the opportunity to ask questions and receive answers during the learning process. One learner group additionally received a manual with basic PDA-operating-principles; a control group received no instructional support at all. As dependent variables task effectiveness, efficiency, subjective ratings of perceived ease of use as well as number and content of questions were assessed. Findings showed that asking questions and repeated practice considerably enhanced PDA-performance in adult novice learners, but not perceived ease of use. Furthermore, the content-analysis of learner questions gave valuable insights into information needs, cognitive barriers and mental models of adult learners, which can contribute to the design of interfaces and computer-based tutors.

Keywords: *Active Learning, Adults, Mental Model, Novices, PDA, Questioning, Repeated Practice*

1. INTRODUCTION

In the last few years, Information- and Communication Technologies (ICT) have proliferated into most professional and private areas (Shiffler, Smulders, Correia, Hale & Hahn, 2005). Parallel to the increasing diffusion of ICT, the technology itself has changed rapidly. In the 1980s, stationary PCs were predominantly used; the 1990s were characterized by the Internet and a worldwide information access. Nowadays, mobile communication technologies are widely spread, e.g., mobile- and smartphones, communicators and electronic organizers, which show continuously increasing rates of growth each year (Shiffler et al., 2005). Mobile devices and applications offer innovative areas of application and their effective use is not longer restricted to young and technology-prone user groups. Instead, mobile technologies will be used by broader and more heterogeneous groups, such as older or technology-inexperienced users. Also, beyond fun-, entertainment- or office functionalities, current and future mobile technologies will take over essential and vital parts of daily living, as in eHealth- or smart home

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technologies (Arning & Ziefle, 2008a; Arning & Ziefle, 2007a; Heidmann, Hovenschiold & Ringbauer, 2003; Ringbauer, Heidmann & Biesterfeldt, 2003). Future mobile technologies will offer enormous potential especially for users of all ages by maintaining and enhancing social exchange and communication (e.g., email, chats) and mobility (e.g., wayfinding and travelling aids), by providing medical monitoring (e.g., blood sugar or heart rate monitoring) and serving as memory aid (e.g., a digital diary with a reminder for doctors' appointments). Up to now, mobile devices are predominantly designed to suit the demands, knowledge and cognitive abilities of technology-experienced and younger user groups, neglecting the specific demands and characteristics of adult users or those with restricted computer experience (Arning & Ziefle, 2007a, 2007b). Contrary to current stereotypes, technology-inexperienced adults express a great interest to acquire technical competencies and acknowledge the basic potential of technical devices for them (Arning & Ziefle, 2006). However, research concordantly shows that especially inexperienced and older users face greater difficulties in learning to use novel technical devices (e.g., Kelley & Charness, 1995; Freudenthal, 2001; Ziefle & Bay, 2005; Ziefle, 2008).

The structure and design of menus in a technical device is a central issue of human computer interaction research. The problem most often cited in menu navigation is disorientation and distraction from the correct navigational path (e.g., Conklin, 1987). Users get lost in a menu system, without knowing where they are, where to go next and how to get back to previous navigation routes or known parts in the menu. This especially applies to menus implemented in small screen devices. The mobile character of these devices in combination with small displays imposes considerably higher usability demands compared to large display technologies. Limited screen space is extremely problematic for providing optimized information access. Only a few items can be seen at a time and users navigate through a menu, whose complexity, extension and spatial structure is not transparent to them as it is hidden from sight. Users have to memorize the functions' names, their relative location within the menu and have to keep up orientation. Disorientation in handheld devices' menus is a rather frequent problem, especially for adult users and those with restricted computer-related knowledge and experience (Arning & Ziefle, 2006, 2007a,b). Recent studies have focused on menu navigation behaviour in hierarchical menus of small screen devices such as mobile phones (e.g., Omori, Watanabe, Takai, Takada & Miyao, 2002; Ziefle & Bay, 2004; 2005; 2006; Ziefle, Schroeder, Strenk, & Michel, 2007), but contrary to the profound knowledge about menu navigation in mobile phones and computer systems, only restricted knowledge is present regarding menu navigation in PDAs (Dorn, Zelik, Vepadharmalingam, Ghosh & Adams 2004; Goodman, Gray, Khammampad & Brewster, 2004; Arning & Ziefle, 2007a,b; 2009).

The majority of studies concerned with the usability of small screen devices focused on menu navigation issues. However, hardly any studies have investigated computer skill acquisition in small screen devices in an adult learner group so far. Recently, three studies conducted by our working group were concerned with the benefit of navigation aids for small screen devices (Bay & Ziefle, 2008; Ziefle, 2008; Ziefle, 2009, in press a). However, these studies neither considered learning curves over several task trials, nor the specific characteristics of the PDA menu structure, which is different from a completely hierarchically structured mobile phone menu. Also, these studies do not allow the identification of users' specific information needs at a certain time in the learning process. This is the specific aim of the present article. Adult learners of varying computer expertise levels solved different PDA tasks four times consecutively. In the task breaks between the tasks trials some users had the possibility to ask content-related questions with respect to how to accomplish the tasks, which were fully answered by the experimenter. By this, not only were the number and sequence of questions analysed, but also the specific knowledge deficits of the adult learners were examined. The analysis of learner questions can be useful for the design of training environments for adult learners on the one hand and for the development of computer tutors on the other hand.

In the following sections, theoretical background about (1) instructional design and user training will be presented, followed by a characterization (2) of adult learner characteristics in computer skill acquisition and (3) of active learning environments such as the questioning method. The chapter closes with (4) some theoretical and empirical background about learning through repeated practice and (5) the formulation of the research aims.

1.1 Instructional Design and User Training

In order to benefit from technical advancements (e.g., enhanced mobility offered by driving assistance systems or prolonged independent living provided by eHealth applications) older and inexperienced users should be enabled to successfully handle modern mobile devices and applications. This aim is pursued by instructional design activities, which "*refer to the systematic process of translating principles of learning and instruction into plans for instructional materials and activities*" (Smith & Ragan, 1993, p. 23). Instructional design activities therefore strive for developing effective learning environments, which offer learners adequate and effective instructional support or training – i.e., necessary information and operating guidelines to successfully interact with technical devices (Rogers & Fisk, 2003; Kirschner & Gerjets, 2006). In this context, the term "learning/training environment" refers to all kinds of learning settings, in which different pedagogic treatment factors are applied (e.g., learning methods, learning reinforcement, learning procedures, learning styles, etc.).

Although, since the 1980s, many empirical studies investigated the effectiveness of instructional support such as computer skill trainings, comparably few studies focused on the development and evaluation of training for adult and technically inexperienced users. However, considerable age and expertise differences remain in computer performance after receiving instructional support (Kelley & Charness, 1995), independent from learning to use stationary (Morell, Park, Mayhorn & Kelley, 2000) or mobile technical devices (Ziefle, 2008). After being trained, adult novice users still needed more time to accomplish computer tasks, they were less successful in solving computer tasks, they made more operating errors and needed more support while using a technical device. Even worse, contra-productive training effects were found, when adult learners' performance deteriorated after receiving specific instruction formats (Caplan & Schooler, 1990; Chou & Wang, 1999; Kehoe, Bednall, Yin, Olsen, Pitts, Henry & Bailey, 2009). The theoretical framework, which refers to contra-productive training effects for specific learner groups, is called "aptitude-treatment interaction" (ATI) (Cronbach & Snow, 1977). The ATI-concept states that some learning environments or instructional strategies (treatments) are more or less effective for learners depending upon their specific abilities. According to ATI, optimal learning results can be achieved when the learning environment is exactly matched to the abilities and learning characteristics of the user. Therefore, the specific characteristics to be considered in designing learning environments for adult learners will be outlined in the following section.

1.2 Adult Learner Characteristics

Adult users often face greater difficulties in interacting with mobile technical devices and in acquiring computer skills. However, with respect to the nature and the underlying reasons of learning difficulties of adult users, it has to be noted that the consideration of the factor "age" alone does not have much explanatory power. Age is only a "carrier variable" that involves many factors, which change over the life span. Thus, age-related difficulties in learning to use technical devices can be related to several connected factors. Firstly, due to a different upbringing, adult users often have an outdated or inappropriate mental model of how technology works. Mental models are built on-the-fly, from prior knowledge or experience, schema segments, perception, and problem-solving strategies and contain individual assumptions about how a technical system works. Based on their mental models users plan their interaction steps with technical systems, infer about system states and functionalities and evaluate the results of their actions (Gentner & Stevens, 1983; Sasse, 1991). Users who fail to develop an adequate mental model of how a device works are highly likely to experience learning and interaction problems (Edwards & Hardman, 1989), whereas an appropriate mental model supports the successful usage of a technical device (Gray, 1990, Arning & Ziefle, 2009). Secondly, adults often have a lack of interaction experience with modern technical devices which might be connected to the interaction problems they experience (Rodger & Pendharker, 2004; Downing, Moore & Brown, 2005). In contrast to experts in a specific technical domain, novices do not possess highly organized domain-specific knowledge structures. Hence, while learning to use a technical device or solving technical interaction problems, novices cannot draw upon extensive domain-specific knowledge structures, which often leads to a superficial perception of problems and less flexible problem solutions (Chi, Glaser & Farr, 1988). Finally, information processing abilities, which are relevant for successful interaction with technology, are subject to age-related declines and increase interaction problems experienced by adult users of technical devices. This especially refers to age-related declines in spatial abilities, processing speed, reasoning and memory abilities, which were identified as relevant cognitive abilities for a successful interaction with technical devices and the acquisition of computer skills (Czaja & Sharit, 1998; Freudenthal, 2001; Arning & Ziefle, 2009).

Importantly though, older adults are highly motivated to use modern devices but they do not feel that current devices meet their learning and usability demands (Arning & Ziefle, 2007a; Melenhorst et al. 2001; Morrell, Park, Mayhorn & Kelley, 2000).

1.3 Active Learning Through Questioning

Adult learners often face greater difficulties in acquiring computer skills in spite of receiving user training (see section 1.2). Although the computer training differed with regard to learning content (e.g., learning to use different technical devices or specific software packages), the majority of training had something in common: they were based on the assumptions of instructionist learning theories. Learning theories contain assumptions about how the human mind learns and how learning environments or training should be designed and delivered. According to the instructionist learning theory, learning is conceptualized as the acquisition or reorganization of cognitive structures through which humans process and store information. Moreover, it is assumed that human learning involves associations established through contiguity and repetition (Duffy & Jonassen, 1992). However, research has shown that user training which builds on instructionist approaches (e.g., user manuals containing step-by-step instructions) often fail to meet intended learning goals or learners' acceptance (Morrell & Park, 1993; Olfman & Mandviwalla, 1994; Ziefle & Bay, 2004; Arning & Ziefle, 2007b). The main points of criticism regarding instructionist approaches refer to: (1) the concept of the mind as a passive knowledge storage system which neglects active knowledge construction processes of the human mind; (2) the passive role of the learner without control over the learning process and learning contents; (3) the neglect of meta-cognitive learning goals (e.g., development of elaborated problem-solving strategies and knowledge concepts); and finally (4), the ignorance of further factors which affect the learning situation, such as attitudes, learners' emotions and motivation (Duffy & Jonassen, 1992; Tennyson, Schott, Seel, Dijkstra, 1997). Moreover, user training based on instructionist approaches often led to differential effects (aptitude-treatment-interactions, see section 1) – i.e., only subgroups of learners benefitted from instructional support (Caplan & Schooler, 1990; Bay & Ziefle, 2008; Arning & Ziefle, 2007a). In particular, one of the main target groups of user trainings – i.e., adults with restricted computer experience – was not adequately supported by training which was designed according to instructionist learning theories.

In contrast, constructivist learning theories try to overcome the shortcomings of instructionist assumptions. Constructivist theories assume that learning is an active process, where learners actively construct knowledge and mental models (Bonwell & Eison, 1991; Duffy & Jonassen, 1992). In other words, according to constructivism, students will learn best by trying to make sense of learning content on their own with the teacher as a guide or coach to help them along the way. Constructivist approaches strongly support the role of active learning processes. Active learning means that learners do more than reading a manual or listening to instructions, but are engaged in problem solving activities and higher-order thinking tasks such as analysis, synthesis and evaluation (Bonwell & Eison, 1991). As knowledge construction builds on existing knowledge structures, instructional designers of active learning environments have to consider previous knowledge and experiences that learners bring with them to the learning task.

Asking questions during the learning process is one strategy to create an active learning environment – i.e., promote active learning processes and to consider learners' individual knowledge. Referring to the questioning strategy as active learning strategy, it is important to distinguish between teacher questions and learner questions. Up to now, the focus was predominantly laid on teacher questions, which were asked to guide students' attention or to test their knowledge. As constructivist approaches are characterized by a higher learner orientation, the research focus in the present article is laid on the questions asked by learners. Asking questions offers several advantages for learners: (1) asking questions is a method to fill knowledge gaps and match informational needs; (2) it aids in comprehension; (3) it fosters self-regulation; and (4) it guides attention to learning content (Rosenshine, Meister & Chapman, 1996). Therefore, according to constructivist assumptions, active learning by asking questions will lead to a more elaborated processing of knowledge and to a higher learning motivation.

Empirical studies in school and university contexts confirmed the positive effect of asking questions on learning success and motivation (Rosenshine et al., 1996; Waugh, 1996). The more questions were asked by students, the better the test results that were achieved and the higher the motivation scores that were obtained. Waugh (1996) examined the quality of student questions and found, that "good learners are good question askers". However, the ability to ask "good questions" requires a certain level of previous knowledge or a minimal understanding about the learning domain. Miyake and Norman (1979) found a reverse U-shaped relationship between learners' previous knowledge and the ability to ask questions. According to that, novice learners with low levels of previous knowledge asked only few questions, as they did not possess a minimal understanding (basic knowledge structures) to produce meaningful questions. In turn, experts with high levels of previous knowledge also produced few questions, as they drew back on their extensive knowledge structures and derived problem solutions on their own in case of knowledge deficits.

It had been assumed that adult novice learners also benefit from active learning methods (Huang, 2002), but the effect of questioning on learning success in adult novice learners has not been empirically studied yet. However, active learning environments - as provided by the questioning method - should be especially advantageous for adult novices because they offer the possibility to acquire technical interaction knowledge while considering novice users' restricted technical experience and their fear of failure. Apart from an increased learner-orientation and the adaptation to learners' information deficits, the questioning method additionally offers an enormous benefit for software designers of technical devices and systems of technical support, such as help-desks or electronic tutor systems (Sarrafzadeh, Alexander, Dadgostar, Fan & Bigdeli, 2008). The analysis of the kind and nature of learners' questions might help to uncover shortcomings in the technical knowledge of users, which should be considered in the design of human-machine interfaces and support systems. Moreover, the questioning method might uncover mental models and major (cognitive) barriers to a successful system interaction (Walraven, Brand-Gruwel & Boshuizen, 2008). By understanding users' mental models – i.e., what users know about the system and how they reason about system functionalities from the provided interface – it will be possible to predict, support and improve computer skill acquisition and, in turn, to design interfaces that support the acquisition of appropriate mental models.

1.4 Learning Through Repeated Practice

In cognitive research, learning through repeated practice is regarded as an antonym to active and elaborative learning strategies. Newell and Rosenbloom (1981) formulated the "power law of learning" which states that the logarithm of the reaction time for a particular task decreases linearly with the logarithm of the number of practice trials taken. On other words, the law means that practice improves performance. Cognitive psychology has proved that the power law of practice is ubiquitous and applies for perceptual (e.g., visual search), motor (e.g., rolling cigarettes), and cognitive tasks (e.g., mental arithmetic) (Ritter & Schooler, 2001). The universal character of the power law of learning has important implications for computer skill acquisition. According to the law, repeated practice allows the acquisition of *every learning content*, which also refers to the usage of mobile devices such as PDA. Moreover, the power law states that *every learner* is enabled to acquire new skills by repeated practice – i.e., also adult learners with restricted levels of computer expertise. However, the effect of repetition on computer skill acquisition of adult novices has not been empirically studied yet.

1.5 Research Aims

One central aim of the present study was to investigate the effects of asking questions on adults' skill acquisition regarding the use of a PDA in an active learning environment which allows a user-centred, self-paced and adaptive information presentation. A second aim was to uncover adult users' information deficits and shortcomings of their mental models which should be considered in future design activities. Since knowledge acquisition builds up on existing knowledge, a special focus was placed on learners' previous computer experience. A third aim was therefore to investigate the effects of computer expertise in an active learning environment and to analyse the suitability of the questioning method especially for adult *novice* users, who usually show higher difficulties in computer skill acquisition and performance (e.g., Caplan & Schooler, 1990). Moreover, as repetitive training strategies, which are based on the assumptions of the power law of learning (Newell & Rosenbloom, 1981), are regarded as an antonym of elaborative learning strategies, the effect of repeated practice on adults' learning success was also investigated in this study.

2. METHOD

2.1 Pre-Experimental Considerations

In this study, the research focus was placed on the effects of an active learning environment, as provided by the questioning method, on adult novices' PDA skill acquisition. From the perspective of ecological validity, it would have been the most natural experimental setting to let participants work on a real PDA device. However, as we wanted to understand the benefit of the questioning method for menu navigation performance at a more detailed level, we needed to record the individual menu navigation routes of participants. Technically, it was not possible to record actions on the key-stroke level in a real device. Therefore we decided to use a computer simulation of the PDA, even though the work on a simulated device is much easier to accomplish than working on a real device, where participants also have to meet different demands (holding the device with one hand, using a stylus if necessary with the other hand, handling the small buttons as well as meeting visibility and readability demands). Also, we decided to let participants use the mouse as an input device because they were very familiar with it from their daily computer experience. Thus, we recognize that using the simulation on a PC and the computer mouse underestimates the difficulties using a real PDA. However, even though multitasking and psychomotor requirements are important key features of mobile devices, which should be carefully studied in this age group (Armbrüster et al., 2007; Ziefle, Sutter & Oehl, under revision), the present article focuses on the effects of an active learning environment in adult users, which should not be affected by the simulation of the PDA device.

2.2 Sample

A total of 36 participants between 50-69 years (M=61.2, SD=6.7, 18 female) volunteered to take part in the study. We aimed at a comparatively healthy and "young" sample of older adults in order to learn about the learning potential of a user group which is today still an active part of the working force but will become a typical senior group in future decades. They responded to a call for participation in a local newspaper and received a small gift for participation. All participants had at least some computer experience, but all were PDA novices. Participants were healthy and highly interested to participate in the study. They did not report suffering from any severe diseases. To rule out visibility losses, visual acuity of participants was tested (TITMUS Tester™). A sufficient visual acuity (Visus of 1, Snellen) was present in all participants. If necessary, corrective lenses were worn throughout the experiment.

2.3 Design

As independent variables, the factors "*questioning*" (between-subject-factor with three levels) and "*repeated practice*" (within-subject-factor with three levels or measurements) were realized.

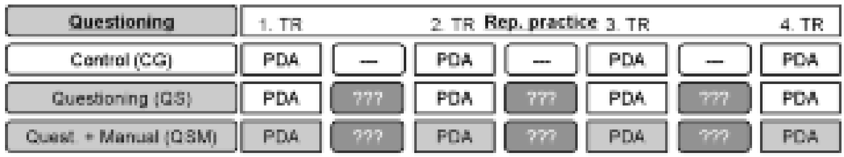
The factor "questioning" had three levels: (1) one group (QS, n=12) had the opportunity to ask questions about how to use the PDA and to execute the experimental PDA tasks; (2) a second group (QSM, n=12) could also ask questions while PDA interaction, but additionally received a written manual containing basic PDA operating guidelines (e.g., "*In order to close an application you have to press the x-button*"); and (3), a control group (CG, n=12) was examined in order to obtain a performance baseline. This group also worked with the PDA but was not allowed to ask questions and did not have access to the manual.

In addition, the factor "repeated practice" was realized, which referred to the number of trials for each PDA task during the training session. Users repeated the PDA tasks four times (TR 1 - 4) in order to understand the effect of repeated practice on learning results. Asking questions was only allowed for the QS-group and the QSM-group in the three breaks between the four task trials (see Figure 1).

As we assumed that the level of computer expertise would affect learning achievements, we categorized adult learners according to their level of computer expertise (quasi-between-factor with two levels). We applied an age-specific computer expertise questionnaire (Arning & Ziefle, 2008b), conducted a median-split on test scores and assigned participants with an individual computer expertise test score above the median to the group of "experts" and participants with a test score below the median to the "novice" group.

In order to investigate effects of questioning behaviour on learning achievements, a further quasi-between-factor was included. A median-

Figure 1. Experimental design



split was conducted based on the number of asked questions and participants were assigned to the group of "frequent" and "nonfrequent" questioners.

As dependent variables, task performance (effectiveness as a proportion of successfully accomplished steps and efficiency as time on task) and subjective ratings of perceived ease of use were assessed according to the ISO Standard for Usability (ISO 9241-11) (EN ISO 9241-11, 1998). Parameters of task performance were derived from logfile-analyses, which were recorded online during PDA-task completion. Moreover, learners' questioning behavior was analyzed quantitatively (number of questions, in total and per trial) and qualitatively (type of questions).

2.4 Procedure

First, demographic variables (age, educational level) and participants' computer expertise were assessed with a computer-based questionnaire. Second, participants were informed about the handling of the PDA and that specific content-related questions regarding PDA interaction and task accomplishment would be directly and fully answered by the experimenter.

The following questioning rules were introduced: (1) questions should be asked during the breaks between the task trials (in order to guarantee an unbiased logging of PDA menu navigation); (2) questions should be formulated as accurately as possible in order to initiate active learning processes – unspecific questions ("*How can I go on?*") would not be answered; and (3), participants were explicitly encouraged to ask questions ("*There are no stupid questions, only stupid answers…*").

In order to conduct a qualitative analysis of questioning behavior, the questions were recorded with a voice recorder. Participants were informed about the recording and gave their consent in the introductory phase of the experiment. In order to standardize the answers which were given by the experimenter, a pre-study was carried out where typical PDA- and task-related questions were collected and standardized answers were developed. Prior to the experiment, the experimenter was intensively trained to answer the questions in a natural, but standardized manner.

2.5 Tasks

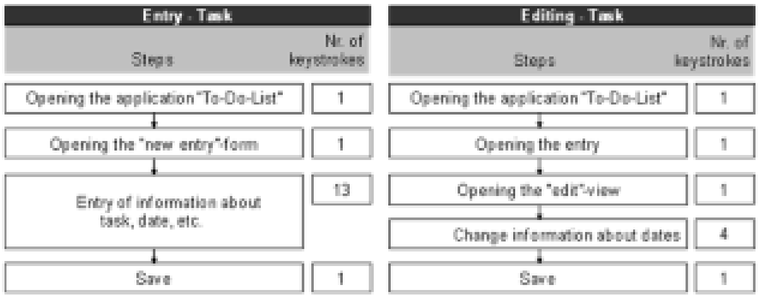
The experimental tasks simulated standard software applications implemented in commercially available PDAs. Participants worked on two different types of PDA tasks (entering a new entry and editing an existing entry in the To-do-list of the PDA) which were both repeated four times, respectively. The entry-task required 16 steps, the editing-task 8 steps. A flowchart of the task procedures for the two task types ("create a new entry" and "change an existing entry") can be seen in Figure 2. Participants had a time limit of five minutes per task. The appropriateness of this time period was taken from earlier studies.

The task instruction for the "New entry" task was (Figure 2, left side):

You want to enter the following task into the digital to-do-list of your PDA.

The single steps to be accomplished were as follows:

Figure 2. Flowchart of the task procedures for the "create a new entry" and "editing" tasks



Task: Request the collection of bulk waste items

- **Priority:** High
- **Status:** Nnot accomplished
- **Due on:** 30.03.2008
- **Frequency:** One time
- **Reminder:** 20.03.2008
- **Confidentiality:** Standard"

The task instruction for the "Editing" task was (Figure 2, right side):

You want to advance the submission of your tax return files. Therefore you want to edit the existing entry in the digital to-do-list of your PDA:
Task: do your taxes

- **Originally due on:** 29.04.2008 → New date: 15.04.2008
- **Old reminder:** 20.03.2008 → New date: 10.04.2008

After accomplishing the PDA tasks, participants rated the perceived ease of use (Davis, 1989) by rating six statements such as "*using the PDA was easy*". An index of "perceived ease of use" was built by aggregating the answers; the maximum to be reached was 30.

2.6 Apparatus

The PDA (iToshiba Pocket PC e740 running Windows CE) was simulated as a software solution and run on a Dell Inspiron 8100 notebook PC that was connected to a TFT-screen (TFT-LCD Iiyama TXA 3841, TN, 15") with a display resolution of 1024 x 768 Pixels. The software prototype exactly corresponded to the real device in size (chassis 80 x 125 mm), display size (3.5"), font size (9 pt for functions, and 11 pt (bold) for category headers), menu structure and operational keys. A logging tool, which was programmed for experimental purposes, guaranteed a precise and non-intrusive measurement of user menu navigation behaviour. Participants' computer expertise was assessed with an age-specific computer-expertise questionnaire for older users with restricted computer expertise (Arning & Ziefle, 2008b). The questionnaire contained 18 items measuring procedural and declarative computer knowledge. The three experimental groups (QS, QSM, CG) did not differ regarding age, education or computer expertise. Hence, performance differences between the three groups can be attributed to the experimental variation of the factor "questioning".

3. RESULTS

3.1 Statistical Analyses

Data were analyzed by bivariate correlations and by analyses of variance. The level of significance was set at α=0.05. Results within the less restrictive significance level of α=0.1 will also be reported due to the higher variability of behavior in adults. Performance in the two PDA task types (entering and editing a task) was comprised as there were no different result patterns and the means for the different factor levels are reported. In order to analyse the effects of learners' computer expertise and the frequency of asked questions on learning results and potential interactions with the experimental factors "questioning" and "repeated practice", quasi-between factors were built by conducting a median-split on the computer-expertise-scores and the number of asked questions.

3.2 Quantitative Analysis of Questioning

Quantitative analyses showed that older learners did use the opportunity to ask questions. In total 317 questions were asked; every participant posed on average 13.2 questions (SD=6.3, range: 5-26 questions). The number of questions significantly decreased for about 85% over the three task breaks ($M_{1st\ break}$=9.8, SD=5.2; $M_{2nd\ break}$=2.0, SD=1.7; $M_{3rd\ break}$=1.5, SD=2.1; $F(2,21)=2,9$; $p<0,01$). Both questioning groups (QS and QSM) did not differ in their total number of asked questions. However, the questioning groups differed regarding the frequency of questions over the learning period. As depicted in Figure 3, the QSM-group asked significantly less questions (-30%) in the first task break (QSM: $M_{1st\ break}$=8.0, SD=3.8; QS: $M_{1st\ break}$=11.5, SD=5.8; $F(2,21)=2,7$; $p<0,01$). Questioners who additionally received the PDA-manual had a lower need for information in the beginning of the learning process. Correlational analyses showed that older participants (r=.6; $p<0.01$) and computer-novices (r=-.7; $p<0.01$) asked questions more frequently. Apparently questioning was used as an information search strategy, which is predominantly adopted by "weaker" users – i.e., older and less experienced participants. Male and female learners did not differ in their questioning behaviour.

3.3 Qualitative Analysis of Questioning

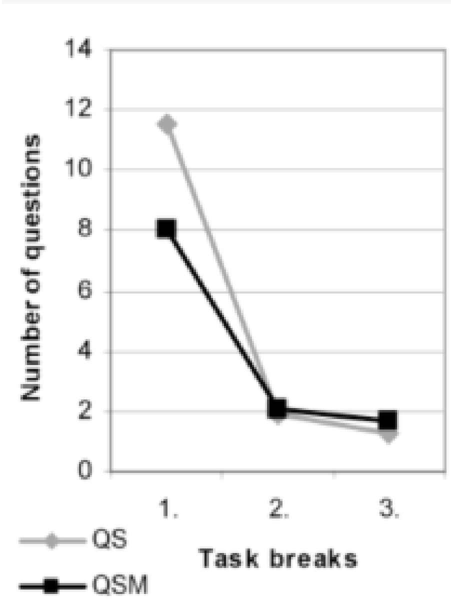
The content of learners' questions was analyzed in a post-hoc categorization analysis in order to get an insight into learners' information deficits, barriers to a successful system interaction and mental models about how the PDA tasks should be accomplished. This analysis was of special importance because we expected the findings would help to improve the design of interfaces and guide the development of instructional support systems. Table 1 shows the results of the content-based categorization of learners' questions in total and for the three task breaks. The column "total" refers to the relative proportion of questions in relation to the total number of questions asked by older learners. The columns "1st – 3rd break" give information about the proportion of questions in the three task breaks and changes in the need of information in older learners. The questions were categorized in five different question types: Three of them (data entry, saving of entries and selecting the correct application) were PDA-task-related, two categories referred to meta-questions concerning the instructions and the questioning procedure. The last category contained questions about the manual in the QSM-group.

Entry of information. The majority of questions—nearly two third (61.5%)—referred to the entry of information or entry mechanisms. Typical learner questions were:

- What happens if I click on the "new" button?
- What is the entry form good for?
- What do the check boxes mean?
- How do I choose "high priority"?

The number of questions referring to PDA-data entry mechanisms and procedures

Figure 3. Number of questions in the three task breaks for the QS- and the QSM-groups



decreased from 49.0% in the first task break to 5.3% in the second task break and increased to 7.2% in the third task break. Remarkably, nearly 50% of all learner questions in the first task break asked for information about data entry mechanisms. This implies that the user interface was not designed in a way that allowed an intuitive usage. Although the proportion of questions decreased in the following task trials, older users still expressed information deficits regarding basic entry mechanisms. However, learners' commentaries and questions were highly insightful in explaining the nature of this information deficit. Although participants in the present study had at least some computer experience, they expressed a high uncertainty about functions and operating principles of data entry mechanisms in the PDA-user-interface.

Table 1. Question categories and proportion of questions in % of total (marked in grey) and for the three task breaks

Question category	Total (in %)	1st break	2nd break	3rd break
Entry of information into the PDA	61.5	49.0	5.3	7.2
Ensuring of task instructions	17.1	11.6	3.4	2.2
Selecting the correct application	11.0	5.7	4.2	1.1
Saving the entries	9.5	7.1	1.9	0.4
Questioning procedure	0.6	0.3	0.2	0.1
Manual (QSM-group)	0.3	0.2	0.1	0.0

We assume that learners are normally urged to learn interaction principles and handling routines in a tedious "trial-and-error"-way. The high information need regarding data entry procedures in older users shows that designers of interfaces and instructional systems should not rely on the (at least assumed) growing computer literacy of users in today's technology-prone societies. Especially older users have immense difficulties to change over to new operating routines and they are highly sensitive to a suboptimal interface design. Hence, interfaces and instructional systems should be developed which do not strive for "uniqueness" in design and operating principles, but allow users to transfer familiar interaction routines across different platforms or systems.

Ensuring understanding of task instructions. The next category of learner questions (17.1%) referred to the task instructions of the practice tasks. The majority of questions in this category was asked in order to re-ensure a correct understanding of PDA task instructions:

- Do I really have to change the date?
- I am supposed to change the date, right?
- Now I have to enter a new entry into the To-do-List?

The number of questions asking for a correct understanding of task instructions decreased from 11.6% in the first task break to 3.4% and 2.2% in the second and third task break, respectively. It has to be noted that learners did not have difficulties in understanding the task instructions and deriving action goals, but wanted to re-ensure a correct understanding of task demands. We assume that this questioning pattern is an indicator of a reduced technology-related self-confidence in older computer users (Arning & Ziefle, 2009). Computer self-efficacy refers to the individual confidence in one's capability to use technical devices. As a high computer self-efficacy is associated with successful computer interaction and with user satisfaction, computer interfaces and instructional systems should clearly communicate defined task procedures, feedback about the processing state of tasks and required user actions during task accomplishment.

Selecting the correct application. A further question category referred to the choice and characteristics of PDA applications. Participants were not sure if they should choose the digital diary or the digital To-do-List or they wanted to know if both applications would exchange data automatically. Typical questions were:

- Do I have to click on the diary- or on the To-do-list-button?
- Which application do I have to choose in order to get into the diary?
- Does the diary automatically write the date into the To-do-list?

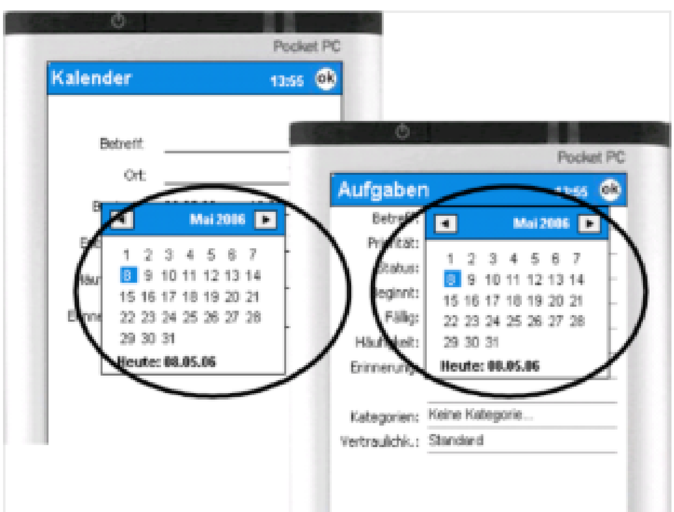
Users had the most questions regarding the selection of applications in the first two trials (5.7% and 4.2%). In the third trial only 1.1% of questions dealt with this issue. Although the tasks only referred to the To-do-list-application of the PDA, the proportion of questions in the first and second task break shows that the information need of learners remained high – even in the second task break. Even though the task instruction contained hints about the correct To-do-list-application to select, participants frequently opened the digital diary in order to enter a new task. We assume that participants were guided by an inappropriate mental model, which stems from semantic similarities of the two applications (Figure 4). Although the diary and the To-do-list were two different applications, the mental model of older learners did not differentiate between the diary- and the To-do-list application. Participants reported that they usually write their To-dos into their diaries. In addition, interface-design features might have contributed to information needs in choosing the right application. Both the To-do-list and the diary contained identically designed date-sheets where date information had to be entered. Users assumed that the date sheets were identical or (in more sophisticated user models) were linked and that information would be automatically transferred and exchanged between the two applications. Hence, users need information about the structure and functionalities of separate applications, which should be picked up by appropriate interface-design features that help to differentiate between different applications and to select the appropriate one.

Saving the entries. Nearly 10% of all user questions asked for information about the saving procedure or the final step in task completion. Participants typically asked:

- Do I have to click on "ok" in order to finish the task?
- Where is the "saving" button?
- Where do I find the "save as"-function?

The information need regarding the "saving"-procedure was the most pronounced in the first task break (7.1%), and decreased to 1.9% and 0.4% in the second and third task break, respectively. This shows that users predominantly asked for the PDA saving procedure in the beginning of the PDA-interaction. Apparently system novices require information about saving procedures in early stages of the knowledge acquisition process. Moreover, interviews showed that users expected to find a saving-button or "saving as"-link as known from desktop computing applications. Instead of that, in the PDA context the entries were saved by closing the entry form, which normally leads to a loss of data in other applications. Accordingly, users expected a system feedback such us "are you sure that you want to close the form without saving", preventing them from loosing data. It can be concluded that users expect a cross-platform-transferability of interaction principles, which should be addressed in interface design. Moreover, it was found that users failed to accomplish a task successfully because they did not save their entries. Users reported that they were sure that the information was saved because they saw it "written" on the PDA-display. Although the knowledge about saving procedures was assumed to be-

Figure 4. Scaled-down screenshots of the date sheets in the digital diary (left) and the to-do-list (right)



long to basic knowledge concepts in computer interaction, it appears that users were guided by an inadequate mental model, derived from traditional paper-based data management. From a cognitive point of view this assumption makes sense: whenever data is written in a conventional paper-based To-do-list, the writing process itself represents the final step of action. Apparently, users where misguided by the conceptual and semantic similarity of the PDA application and a conventional paper-based To-do-list and they transferred their knowledge about paper-based entries to the interaction with the PDA. Design activities are necessary to resolve the mismatch between user models and design characteristics of tasks and applications.

Questioning procedure and QSM-manual. Only a few questions referred to the questioning procedure and rules itself (0.6%) and to the manual in the QSM-group (0.3%). The information demand regarding these issues further decreased over the three task breaks. In the first task break 0.3% of questions were related to the questioning procedure, decreasing to 0.2% in the second task break and 0.3% in the third task break. Typical questions were:

- Am I allowed to ask know?
- I can ask as many questions as I want to, right?

The QSM-group asked in the first task break 0.2% and in the second task break 0.1% questions regarding the manual, which contained basic PDA-operating principles. No questions dealt with the QSM-manual any more after the second task break. Participants had no problems in taking up and following the questioning rules and procedure. The questioning method was accepted and appears as a “barrier free” training-method, which is easily understood and does not impose additional cognitive demand on older learners. The following analyses in the results section will have to prove if the information in the QSM-manual led to a superior PDA-performance.

Summarizing the results of the qualitative analysis of learners’ questions so far, older users were able to identify their knowledge gaps and to generate specific questions. The majority of questions—and therefore the biggest information deficits—referred to the usage of entry mechanisms of the PDA such as buttons, icons, checkboxes, etc. Apparently, the interface design of the PDA does not allow an intuitive usage and therefore brings up many questions among older learners. The majority of learner questions found in the qualitative analysis came from a mismatch between user models and the interface design of the PDA application. Moreover, users expected a cross-platform-compatibility of interaction principles, which was not given in the PDA interface.

3.4 Effects of Asking Questions and Repeated Practice on PDA Interaction

The opportunity to ask questions led to a significantly higher PDA-task performance ($F(2,33)=3.8$; $p<0,05$). In comparison to the control group, both questioning groups reached about 40% higher task effectiveness (CG: M = 33.9%, SD=21.5; QS: M = 73.1%, SD=10.6; QSM: M= 73.1%, SD = 15.3). The same pattern was found for task efficiency, which was about 45% higher in the questioning groups compared to the control group (CG: M = 1574.2 s., SD = 531.4; QS: M = 877.6 s., SD = 188.8; QSM: M = 954.3 s., SD=323.1). The performance of the QS- and the QSM-group did not differ significantly. Remarkably, asking questions did not only exert an enhancing but also a stabilizing effect on performance in adult learners. In the control group, inter-individual variability (SD) was considerably higher than in both questioning groups (QS- and QSM-group).

Regarding participants’ subjective ratings after accomplishing the PDA tasks, the three experimental conditions did not differ significantly, although the perceived ease of use was the lowest in the control group (M = 18.9 out of 30 points, SD = 6.9), followed by the ratings of the QS-group (M = 20.7 points, SD =

5.1). The (numerically) highest perceived ease of use was perceived in the QSM-group (M = 23.3 points, SD = 5.9).

However, repeated practice also had a positive effect on learners' performance outcomes (Table 2).

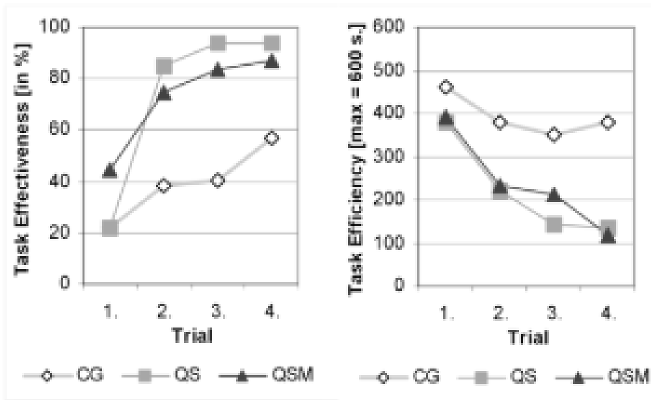
Apart from the positive effect of repeated practice on performance, differential effects in both questioning groups were found. The interaction between repeated practice and questioning shows (Figure 5) that repeated practice was considerably more effective when it was combined with the questioning method: learners in both questioning groups (QS- and QSM-group) benefited the most from task repetition compared to the control group (CG) (effectiveness: $F(6,64)=4.1; p<0,01$; efficiency: $F(6,64)=2.6; p<0,05$). In the control group, task effectiveness increased by about 39% to 57% steps accomplished and efficiency only by about 17% (to 381.1 s.; n.s.) over the four task trials. A significant performance improvement in the control group was not reached until the fourth trial. The QSM-groups' effectiveness rose by about 42% to 86.7% over the four trials and efficiency increased by about 64% to 119.2 seconds needed for task completion. The QS-group benefited the most from task repetition, their effectiveness increased by about 72% to 93.8% and their efficiency improved by about 81% (to 136.3 s.).

The biggest performance leap in both questioning groups (QS and QSM) occurred between the first and the second trial. Moreover, in the first trial the QSM-group reached a higher efficiency in comparison to the control- and the QS-group ($M_{QSM,\ 1st\ trial}=45.5\%$; $M_{CG\ and\ MS,\ 1st\ trial}=22.1\%$; $T(11)= - 2.5$; $p<0.05$). This performance superiority might be explained by the information advantage of the QSM-group, which additionally had access to a manual during task completion, which conveyed a basic understanding of PDA-operating-knowledge. However, the information advantage did not last for a long time: from the second trial onwards, the QS-group out performed the QSM-group ($M_{QS,\ 2nd\ trial}=84.9\%$; M_{QSM}) and the advantage of the manual in the QSM-group (+22% in the first trial) turned to a disadvantage in the following trials (on average -10%) in comparison to the QS-group. No gender effects were found in learning performance.

Table 2. Task effectiveness and efficiency in the four task trials for the whole sample ("total", marked in grey) and the subgroups of the factor "questioning" (CG, QS, QSM)

Trials	**1.**		**2.**		**3.**		**4.**	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Task Effectiveness [% of steps accomplished]								
Total	26.9	25.9	66.0	25.9	72.6	31.5	79.2	23.7
CG	22.1	21.1	38.5	24.4	40.1	29.7	57.0	24.8
QS	22.1	27.9	84.9	20.8	93.8	8.9	93.8	6.4
QSM	44.5	23.4	74.5	21.8	83.9	20.4	86.7	17.4
Task Efficiency [s]								
Total	410.6	136.4	276.4	151.7	236.3	151.1	212.2	160.5
CG	461.7	171.7	378.9	173.4	352.5	157.8	381.1	153.9
QS	379.1	131.6	218.7	99.1	143.6	90.1	136.3	80.0
QSM	391.0	89.5	231.5	126.7	212.7	122.3	119.2	71.0

Figure 5. Interaction of questioning and repeated practice for task effectiveness and efficiency



3.5 Influence of Learners' Computer Expertise on Learning Performance

The influence of computer expertise on the learning process was statistically analyzed by dividing the sample into two groups (computer experts and novices) after median-splitting the computer expertise test scores. This allowed a comparison between computer experts and novices regarding the effects of questioning and repeated practice on learning results. Computer-novices and experts did not significantly differ in their PDA-performance, although experts reached a numerically higher task effectiveness (M_{expert}=66.1%, SD=27.7; M_{novice}=54.0%, SD=25.5) and efficiency (M_{expert}=975.5 s., SD=408.4; M_{novice}=1295.2 s., SD=508.3). A similar pattern was obtained for subjective ratings of perceived ease of use: computer-novices and experts perceived a comparable ease of use while interacting with the PDA (M_{expert}=22.5 points, SD=5.0; M_{novice}=20.9 points, SD=5.8).

Both learning strategies – i.e., asking questions in combination with repeated practice – seem to allow older computer novices to fill their knowledge gaps and to reach the same performance level as computer experts. However, the interaction between computer expertise and repeated practice for task effectiveness reveals that the effect of repeated practice on PDA-performance has a different temporal onset for novices and experts ($F(3,30)=2.3$; $p<0,1$). As Figure 6 (left) shows, both groups were able to improve their effectiveness with increasing practice, but novices needed more repetitive trials to reach the performance level of experts. Apparently, the positive effect of repeated practice is delayed for novices. Focusing on task efficiency, Figure 6 (right) also shows an interacting effect ($F(3,30)=2.3$; $p<0,1$) between repeated practice and computer expertise. Although efficiency between the two groups did not differ in the first trial, computer experts improved their task efficiency to a higher extent (+60%) than novices (+36%). It seems, that experts benefit more from repeated practice regarding the efficiency of PDA-interaction.

3.6 Influence of Amount of Questions on Learning Performance

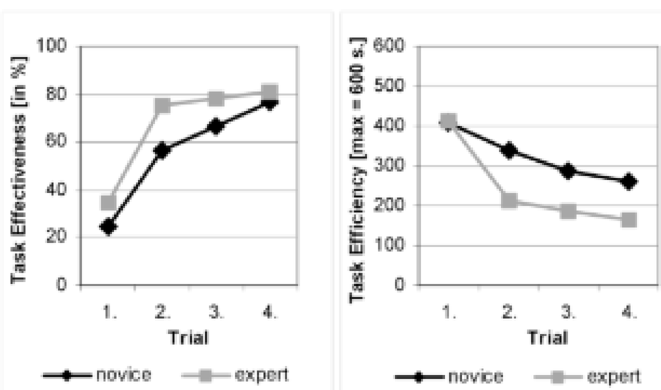
The influence of the amount of questions asked on learning achievements was statistically analyzed by dividing the sample into two groups (frequent and non-frequent questioners) after median-splitting the number of questions asked. Frequent questioners reached about 30% lower task efficiency ($F(1,16)=10.0$; $p<0,05$). They needed M=1081.0 s. (SD=205.6) to accomplish the PDA-tasks, whereas infrequent questioners needed only M=750.9 s. (SD=203.7). Interestingly, both groups did not differ in task effectiveness (M=71% for frequent and non-frequent questioners) or ratings of perceived ease of use.

3.7 Excursus: The Effectiveness of the Manual

The following excursus will deal with the effectiveness of the manual, which was provided to the QSM-group. In order to investigate the effects of a minimal understanding on questioning behaviour and learning results, the QSM-group in this study additionally received a manual, which contained basic PDA operating principles (e.g., "in order to enter a new entry, you have to open the "entry-form" by clicking on the "new"-button", or "in order to edit an existing entry, you have to open the entry by clicking on it and clicking on the "edit"-button"). However, considering the reported results so far, we cannot exclude possible effects of the manual on learning results. In a previous study, we examined the isolated effects of the manual on PDA performance separated from the effects of questioning. In this study, a sample of n = 20 adults between 50-70 years (M = 58.7 years, SD = 6.0) received the manual and, after reading it, had to accomplish six different PDA tasks (entering and editing entries into the digital diary, the to-do-list and the address book of the PDA). The outcomes of the former study are now compared to the findings of the present study. Methodologically it was important that both samples (the manual-group in the previous study (Arning, 2008) and the QSM-group in the present study) were comparable regarding educational background, computer expertise and cognitive variables. Statistical testing revealed no differences between the two samples, therefore it is possible to compare the outcomes across studies. As the tasks were slightly different in both studies, the performance parameters of effectiveness and efficiency[1] were transformed into percent.

A MANOVA analysis with the between-factor "training" (manual-group vs. QSM-group) on the dependent variables effectiveness [%], efficiency [%], and perceived ease of use revealed highly significant differences between both groups ($F(3,28) = 15.7; p < 0.000$). Regarding PDA effectiveness, the manual-group and the QSM-group reached a comparable effectiveness in solving the PDA tasks (manual-group: 72.0% (SD = 17.6); QSM-group: 73.1% (SD = 15.3; n.s.). However, the QSM-group was significantly more efficient in solving the tasks

Figure 6. Interaction of computer-expertise and repeated practice for task effectiveness (left) and efficiency (right)



(M = 60.2%, SD = 13.5; $F(1,30) = 37.5$; $p < 0.000$) and reported a higher perceived ease of use (M = 23.3%, SD = 5.9; $F(1,30) = 13.9$; $p < 0.001$) than the manual-group (efficiency: M = 26.3%, SD = 16.1; perceived ease of use: M = 15.6%, SD = 5.6). This comparison clearly shows that it is not the manual itself which is advantageous for PDA performance, but the combination of asking questions and the manual which benefits the efficiency and satisfaction in using the PDA.

4. DISCUSSION

The results are now discussed with respect to the different main factors: the impact of asking questions, the impact of repeated practice, the influence of computer expertise on learning results, and the lessons learned for the design of active learning environments. Before the desiderata of future research are outlined, we discuss potential limitations of the present study. Finally, potential applications of our findings for the design of computer-based learning environments are presented.

4.1 The Effect of Asking Questions

The results clearly show that active learning by asking questions is an effective training method in supporting adult users in the acquisition of computer skills. Moreover, participants appreciated the opportunity to receive individual knowledge support provided by the questioning method. After they had overcome the initial timidness of uncovering knowledge gaps they enjoyed having "personal assistance" while learning to use the PDA. Also, the questioning method urged the adult learners to primarily focus on the contents and not on emotional aspects of failure and malfunction of technical devices. Accordingly, both questioning groups (QS and QSM) intensively used the opportunity to ask questions. Each learner asked on average 13 questions, quite a high amount of questions given that two rather common data management tasks had to be accomplished. In addition, the qualitative analysis of user questions showed that older learners had no basic difficulties in understanding the questioning instructions. Hence, the questioning method can be regarded as especially suited for adult learners because it does not impose additional cognitive load, which is assumed to hamper the learning process (Chandler & Sweller, 1991). Moreover, the questioning method led to a specific performance benefit (higher effectiveness (+40%) and efficiency (+45%)) compared to the control group, which did not have the opportunity to ask questions. Adult learners were able to identify their knowledge gaps, to derive and specifically formulate questions, and to integrate and directly apply the received information. In addition, the questioning method reduced performance variability – i.e., asking questions did not only lead to a higher, but also to a more stable performance in adult learners over time. The findings of this study show for the first time that adult learners benefit from active learning environments when acquiring computer skills and that this training method is more advantageous than "trial-and-error"-learning strategies. However, on the basis of the present experiment, we do not know if the benefit of the questioning method is indeed age-specific, specifically supporting the adult learner group. Rather, it could be assumed that other age groups (young adults or children) might also profit from this active learning environment to a similar extent. This will have to be investigated in future studies.

Contrary to expectations, the additional information provided by the manual in the QSM-group did not lead to more questions or to a higher PDA-performance. It was assumed that a minimal understanding of PDA operating concepts would enhance both the ability to produce questions and PDA-performance. The analysis of questioning behaviour showed that the QSM-group asked fewer questions (-30%) in the first task break in comparison to the QS-group, which can be explained by the information advantage by the manual in the QSM group. However, this information advantage did not lead to a performance advantage, as the QSM-and the QS-group reached a comparably high performance level. Instead, the higher questioning activity of the QS-group (no additional manual) in the first task break indicates that the QS-learners were able to specifically fill their information deficit in the first task break and to at least reach the QSM-group in the following trials. We assume that the additional information provided by the manual interfered with active knowledge construction processes, which were triggered by questioning activities. Transferring these outcomes to the design of training environments, we conclude that it is not necessary to provide additional information by manuals in active learning environments. However, the role of minimal understanding in active learning processes should be investigated in further research activities.

The effectiveness of the questioning method was not mirrored in learners' subjective ratings of perceived ease of use. Even though learners in the questioning groups (QS, QSM) perceived a numerically but non significant higher perceived ease of use than the control group, learners, when directly asked, did not judge the possibility of asking questions as especially helpful for their performance and the perceived competency to manage the PDA tasks. Apparently, the measurable and factual positive effect was not perceivable by learners. We suggest several reasons to explain this finding. First, in order to avoid learning- and carry-over-effects an independent experimental design was realized. Therefore participants in the three groups were not able to compare between different types of instructional support in this experiment and to perceive the positive effects of questioning. Second, the interaction period with the PDA (ca. 30 min.) might have been too short for learners to perceive a higher ease of use. Third, user ratings might have been affected by usability barriers in the PDA interface and menu design, which interfered with the positive effects of questioning.

4.2 The Effect of Repeated Practice

Repeated practice also exerted a positive influence on PDA-performance in adult learners. In congruence with the assumptions of the power law of learning (Newell & Rosenbloom, 1981), adult learners' performance improved after repeating the PDA tasks. The highest performance leap was reached in the second trial; in the following trials performance still improved, but with lower rates of growth. Up to this point, one could critically argue that adult learners simply have to repeat novel PDA tasks, even if more repetitions are necessary to reach a specific learning aim compared to younger learners. However, this assumption is premature. The analysis of the learning curve of the control group shows that "pure" repeated practice (at least over four trials) is not sufficient for a competent command of PDA-computer skills. After four trials, the repetition led to a task effectiveness of only 59% (accompanied by considerably prolonged processing times). Looking at the learning curve over the four task trials, repeated practice led to an average improvement of 39% in task effectiveness and 17% in efficiency. In contrast, the questioning groups (QS and QSM) benefited much more from repeated practice. Especially the performance of the QS-group improved considerably: their effectiveness increased, on average, by about 72%, their efficiency improved by about 81% and they even reached a task effectiveness of 94% in the fourth trial. This shows clearly that the benefit of repeated practice is strengthened by asking questions and receiving context-sensitive information, which could be successfully processed in further task trials over the learning period. In contrast, the lower performance of repeated practice alone might be attributed to the fact that older adults were not able to learn from mistakes (without appropriate feedback) and, therefore, were not able to integrate new information into their problem solving behaviour. Therefore, when designing learning environments for adult users, repeated practice should only be applied in order to intensify learning effects of previously established effective training strategies.

4.3 The Effect of Computer Expertise

One aim of the present study was to examine learning environments for computer novices in order to reduce the influence of computer expertise on computer skill acquisition and PDA-performance. Findings show that computer novices (nearly) reached the performance level of experts. However, the interaction between repeated practice and computer expertise indicates that the process of knowledge acquisition was still different for computer novices and experts. The positive effect of repeated practice had an earlier onset in experts than in novices as the learning curve of task effectiveness for both expertise groups shows. For novice learners the positive effect of repeated practice has a delayed onset; however, they are able to catch up to the task effectiveness level of computer experts after four trials. Regarding task efficiency, repeated practice leads to a higher performance level for computer experts than novices. This finding can be explained in terms of the ACT-theory (Anderson, 1983), where procedural learning is assumed to proceed in three subsequent stages: (1) declarative phase; (2) automatization; and (3) tuning. According to ACT, computer experts are more advanced in the process of procedural learning – i.e., in the stage of knowledge compilation and in the automatization of operating routines. In these advanced stages of procedural learning cognitive resources are no longer focused on a correct task accomplishment, but on the optimization of operating routines, which leads to a higher task efficiency. Contrary to that, computer novices are still in an earlier stage of the procedural learning process and cognitive resources are directed on avoiding operating errors. Therefore, the efficiency of task accomplishment has a lower cognitive priority in novices. Transferring this finding to the design of support systems and learning environments, it is important to give novices enough opportunity to practice.

Apart from effects of computer expertise the amount of questions asked by learners also affected PDA skill acquisition and performance. Although frequent and non-frequent questioners reached the same task effectiveness, non-frequent questioners showed higher task efficiency. This finding can be interpreted in terms of successful active knowledge construction processes in frequent questioners. The integration and application of novel knowledge required highly demanding cognitive processing activities – and therefore prolonged processing time of PDA tasks. However, the comparably high task effectiveness of frequent questioners indicates, that these cognitive processes were successful in the end.

4. 4 Lessons Learned for the Design of Active Learning Environments

First, questioning represents a successful example of a participative and user-centred approach in designing learning environments. Adult learners were highly interested to participate in the study and expressed a high commitment regarding the development of "senior-friendly" active learning environments. Based on our lab-observations we can state that asking questions was highly demanding for adult learners in the beginning of the learning process. However, performance outcomes in the questioning groups convincingly show that asking questions "forced" adult learners to actively elaborate learning contents – and considerably enhanced computer skill acquisition. Second, the qualitative analysis of user questions provided valuable information for the design of instructional support systems (e.g., computer-based tutors). System novices primarily need information about interaction elements (e.g., the handling of pop-up-menus and -windows, check-boxes, etc.) in the beginning of the learning process. Context-sensitive cues or help-functions are one important design element in order to provide required information and simultaneously maximize learner control regarding the content and sequence of information presentation. Moreover, interaction principles should be designed in a way that facilitates cross-platform-transferability.

Especially inexperienced users reject learning new interaction routines when working with novel devices. Therefore, the challenge for interface design is to ensure that users can change over seamlessly to different platforms and applications without having to learn new interaction principles. Finally, interfaces and task procedures should avoid the activation of inadequate mental models. A high proportion of user questions and interaction problems emanated from a mismatch between the user model and the interface-design model. When interacting with the To-do-list older learners were often misguided by their model about "paper-based" conventional data management. On the one hand, user expectations about system- and interface design were not addressed (e.g., assumption that the diary and the To-do-list would be linked), on the other hand interaction routines required steps which were not represented in the user model (e.g., saving the entries).

Finally, we conclude that the lessons learned from questioning are at least twofold: First, performance outcomes show that learning by questioning is an effective and powerful training method – especially suited for adults learners with restricted computer expertise. Questioning allows maximal individualization and "information dosage" of instructional support, while providing maximum learner control. Second, the content-analysis of questions uncovered information deficits and inadequate mental models, which have to be addressed in instructional support systems and interface design.

4.5 Limitations of the Present Research and Impact for Future Research

Even though the study revealed clear findings and introduced questioning as a fruitful way of identifying specific knowledge gaps in adult learners when interacting with PDAs, there are some limitations in the present research to be considered with respect to the generalizability of the results and for future research.

The Use of a PDA Simulation

Our results are based on laboratory experiments and on interaction with a simulated PDA. This experimental setting was chosen in order to provide maximal experimental control and to rule out confounding effects. However, we acknowledge that the results presented here might represent a solid underestimation of the real situation. In our experiment, the cognitive workload to use the PDA simulation was much lower in comparison to an interaction with mobile devices in real environments, where users have to manage different and complex demands simultaneously. In the laboratory setting a comparably quiet setting was present and users were able to concentrate on the tasks. Also key handling and visibility problems may occur in real contexts, which were controlled in the experiment. Therefore, future studies will have to repeat the study in a more realistic setting. In addition, a basic question remains as to whether the present findings are restricted to the special requirements of small screen devices or if they are more or less the same in a conventional computer interface with a large screen.

The Ageing Impact

Another limitation refers to the selection of the adult learner sample. We investigated a comparably young and healthy group of adults, which also had some experience with the use of technical devices. This selection was based on the fact that this sample might resemble the group of "future seniors". However, we concede that these sample characteristics might not be representative for the whole group of adult or older users. In our study, participants did not report severe age-related performance decreases and functional shortcomings. Especially, neuro-motor impairments are a critical factor that should be considered in future studies (Sanger & Henderson, 2007). However, from aging research it is well known that age is accompanied by a slowing down of functions regarding sensory performance (Kline and Scialfa 1997; Oetjen & Ziefle, 2007), motor performance (Armbrüster, Sutter & Ziefle, 2008; Vercruyssen 1997; Ziefle, Sutter & Oehl, under revision), and cognitive performance (Salthouse, 1992). Therefore, we also need to learn about the performance and the learning potential of older users, which will be pursued in future studies.

The Specificity of the Questioning Method

In the present study, the opportunity of learners to ask questions and to receive appropriate information to fill knowledge gaps proved to be a highly effective learning method. However, so far we cannot claim that this learning environment is especially suited for an adult learner group as we did not investigate the suitability of this method for younger novices. However, we assume that the questioning method provides an effective learning environment for all age groups (including young adults and children, a major target group of technical devices). Future research activities should enlarge the age scope and include users of all ages. In addition, further studies will have to investigate the effects of structured questioning methods, where learners receive meta-questioning training in advance, which supports the identification of knowledge gaps and contradicting knowledge concepts. Although meta-questioning training proved to be successful for younger learners (Rosenshine, Meister & Chapman, 1996) it remains open if adult and older learners will also benefit from this. In order to increase training economy, the effect of questioning in learning groups should also be examined. On the one hand active learning processes might be stimulated in learning groups; on the other hand adult or older learners might be too afraid to openly formulate questions in groups. As learners in the present study had at least some computer experience the effect of questioning should also be investigated in "total" computer novices without any computer experience. Moreover, the effect of active learning should be examined for different technical devices and applications in order to prove a platform-independency of this learning strategy.

The Specificity of the Learning Content

Looking at information needs during the PDA task breaks, where learners were able to ask and receive information, a considerable knowledge gain was found. At first sight, this is good news as users' need for information dropped early in the learning process and showed that people have reasonable learning curves. However, some cautionary notes have to be considered in this context. First, it remains open if the mental models and interaction routines, which are developed while interacting with a specific device (e.g., desk top computer), can be easily transferred to another device (e.g., PDA) or platform. In general, we should be aware that novel technical devices will not always stringently follow user experience, address established mental models and support "familiar interaction routines". However, even if well-established mental models and interaction routines are implemented into interfaces, adult or older novices might be unfamiliar with them due to their limited technical experience. Finally, as technical innovation cycles become faster and faster, new interaction principles will be developed and implemented, which also have to be learned – even by experienced users. In future studies we will have to determine the tradeoffs between the benefit of using established and consistent interaction rules across different devices (seamless migration) and the problems caused by novel or unfamiliar interaction principles. Moreover, usability problems should be investigated in terms of whether they occur universally (i.e., for all user groups in all usage contexts) or specifically (for specific user groups in specific usage contexts).

4.6 Impact for Application Issues

This final section is concerned with potential applications of our findings. Even though it was not the central focus of the study, we found that learning to use current interfaces of mobile ICT is still highly demanding for novice users. Although the PDA tasks used in the experiment represented conventional tasks taken from standard PDA applications, adult users experienced enormous difficulties while learning to use the interface. Therefore, we strongly recommend to focus on the development of age-sensitive learning environments and interface designs.

The questioning method proved to be a highly useful and insightful learning strategy, which is easy to apply and has a high diagnostic power. By using the questioning method, we were able to reveal specific pitfalls and usability barriers which hamper the learning process and successful interaction with the device. Therefore, one application of our findings is to use questioning not only as an active learning strategy, but also as a specific kind of usability testing method, which could be applied during the interface design process as well as a quality control methodology during iterations of the design cycle. Moreover, our findings also could be used to create electronic tutors, either to be implemented into small screen devices or as computer-based training tutors, which assist novice users in the first learning sessions.

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ENDNOTE

[1] A low efficiency in % indicates a long processing time of PDA tasks.

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