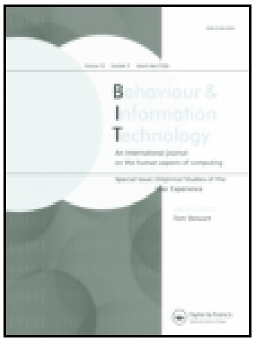

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Adaptive training interfaces for less-experienced, elderly users of electronic devices

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A great number of complex electronic devices are now part of our everyday lives. While many of us learn to handle these products by trial and error; others, especially older users with little experience in using electronic devices, need support. In order to allow the user maximum flexibility in terms of learning time and location, a training programme is presented which is implemented as part of the software embedded in the product itself. Particular focus is placed on the effect of adaptive training on learning. In this study, the training versions differed in their ability to adjust their complexity to the user's experience (adaptive user interface complexity) and their capability to support the learner by prompting them during the learning process (adaptive training advice). The results show that the adjustment of complexity had a positive effect on users' experience: elderly users who trained with an adaptive interface were more successful in learning to use a mobile phone. Adaptive training advice, however, was found to have no significant effects on learners' success and reduced their self-efficacy. This work offers guidelines on how to design integrated training applications for electronic devices that successfully help elderly users with little prior experience.

Keywords: training; electronic devices; elderly users; adaptive; e-learning

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1. Introduction

Lifelong learning is becoming more and more important. Developments in communication technologies are an integral part of everyone's life. Technology is not static; people must continually learn to use new electronic devices. Current electronic devices demand continuous development of a user's skills and knowledge. While many of us learn to handle these products by trial and error, others, especially older users, with little experience in using electronic devices, need support. With an ageing population, there is a growing recognition of the need to consider elderly users when designing products. Negroponte (1995) pointed out: 'Some people worry about the social divide between the information-rich and the information-poor, the haves and the have-nots, the First and the Third World. But the real cultural divide is going to be generational' (p. 6). Czaja *et al*. (2006) concluded that 'not having access to and being able to use technology will increasingly put older adults at a disadvantage in terms of their ability to live and function independently and successfully …' (p. 1). Information and communication technology offers enormous potential to increase the quality of older people's life (Wandke *et al*. 2012). Unfortunately, there are still barriers that are difficult to overcome and above all naïve assumptions based on folk psychology which negatively affect the public opinion. To counteract these barriers, Wandke *et al*. (2012) suggested that academics and practitioners should be responsible for designing interactive devices, which are easy to learn and use by all age groups (described as inclusive design by Clarkson *et al*. 2003).

A promising approach is to help the elderly learn how to handle current devices by integrating a training application into the product itself. In their review article on the computer usage of older adults, Wagner *et al*. (2010) concluded that providing support and training 'seem[s] to be very important, with good support and training leading to higher levels of self-efficacy, confidence, attitudes, and reduced anxiety' (p. 878). In order to make electronic devices usable for everyone, it is important to understand how to support and train older people to use electronic devices effectively.

1.1. *Addressing the elderly learner*

Differences between younger and older adults in using technical devices can often be traced back to the generation effect (i.e. elderly users have less experience (Poynton 2005)). For example, handling a hierarchical structure relies on knowledge about interaction techniques – such as multiple mapping – that are unfamiliar and confusing to less-experienced users. Baldi (1997) found no relationship between age and training success after adjusting for trainees' knowledge of technical devices.

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Furthermore, elderly users differ from younger ones in terms of their computer-related self-confidence (Marquie *et al*. 2002). Jay and Willis (1992) showed that the age-related lack of computer-related self-confidence can be modified by direct experience with computers. Computer-related self-efficacy (e.g. expectation of training success) mediates the relation between age and skill acquisition (Baldi 1997, Reed *et al*. 2005). Therefore, any training application should keep the initial barrier low, so as to ensure that the majority of users can succeed easily in executing the initial tasks and develop confidence for further more advanced tasks.

Fisk *et al*. (2004) gave some recommendations about how training for elderly users should be designed. The subject matter should be divided into short lessons that motivate through immediate success. There was a favourable effect if the programme alternated between lessons and exercises (Fisk *et al*. 2004). In contrast to young people who like exploration-based learning, the elderly prefer explicit training (Poynton 2005). Govaere *et al*. (2012) examined the effects of guided and unguided lessons for a software package on younger and older adults. They found that guided training results in superior performance.

Further tips for designing training for the elderly were derived from an interview study (Bruder *et al*. 2006). In order to address the needs of inexperienced users, it is necessary to provide an easy introduction to basic functions and a complete step-by-step explanation of required actions. A training study (Bruder *et al*. 2007a) and a follow-up study (Bruder *et al*. 2007b) provided evidence that a training as integrated part of an electronic device which follows this recommendation is indeed very appropriate for effectively teaching older users and improving the transfer of knowledge from training to everyday use. Trainees needed less than one keystroke per task more than was actually required and rated their self-efficacy as good. Six weeks after training, participants who were trained were more successful in using their own mobile phones than people without training and used more functions of their own mobile phone after training than before.

Baltes and Baltes (1990) postulated that older users optimise their performance through extensive practise. There is strong consensus that older adults are able and willing to learn how to use technology (Baldi 1997, Fisk *et al*. 2004, Mitzner *et al*. 2010). However, comparing younger and older novice adults, the elderly take longer to train, do not perform as well after training, and need more help (Kelley and Charness 1995, Baldi 1997, Charness *et al*. 2001, Fisk *et al*. 2004). This decreased performance is correlated with the complexity of the technical device (Ziefle and Bay 2005).

How can a complex device be taught while still keeping the initial barrier low and making it easy enough for the majority of people to learn successfully? Given the fact that older people vary substantially in their experience and their individual learning requirements (Fisk *et al*. 2004, Czaja *et al*. 2006), adapting the training to the learner's experience with electronic devices is a promising approach.

1.2. Studies about adaptive training

Adaptivity is defined as a system's ability to automatically adjust its properties to the user and the user situation. The idea of an adaptive interface is straightforward. It means that the interface should adjust to the user, rather than the user having to adapt to the system. There is some evidence that users maintain inefficient procedures for interactive tasks even when more efficient procedures exist (Carroll and Rosson 1987, Fu and Gray 2004). Giving an adaptive interface to the user is a possible solution to this problem and may help users learn more efficient ways of interacting with the system. With adaptive electronic devices, the individual requirements of a wide variety of users can be addressed (Stephanidis 2001). Norcio and Standley (1989) emphasised the potential of adaptive design, especially for less-experienced users. Oppermann (1994) compared adaptive and non-adaptive design, and found that users of non-adaptive electronic devices continued to operate systems inefficiently. However, many aspects of adaptive user interfaces were also criticised, e.g. loss of control, lack of transparency of system behaviour, and unnecessary interruptions which could all reduce self-efficacy.

In the context of training systems, adaptivity can be used to adjust the training system to trainees' individual differences, e.g. prior knowledge, experience using electronic devices or learning process. Various aspects of training systems can be adapted, e.g. repetition of lessons or the complexity of training content. McGrenere (2002) pointed out that 'users prefer to feel like an expert in a functionality subset rather than a novice in the total functionality' (p. 17). Nilsen *et al*. (1993) concluded that people try to master one task before taking on a more complex task. Especially for older users, the adjustment of content complexity to learners' experience or prior knowledge seems to be an appropriate principle, and should be taken into account when designing electronic devices and training applications. As mentioned above, how much lower older users' performance is, depends on the complexity of the electronic device and has a negative effect on their computer-related self-confidence. Carroll and Carrithers (1984) and later McGrenere (2002) and Bannert (2000) developed training-wheel systems, in which functionality grew stepwise with the users' experience using the device. The trainee started with an interface which only offered basic functions. The functionality increased gradually up to full functionality. In comparison with the full version of electronic device, which offered all functionality from the outset, younger users with less experience mastered tasks faster and with fewer mistakes (Carroll and Carrithers 1984, McGrenere and Moore 2000) and had a better mental representation of the functionality (Carroll and Carrithers 1984, McGrenere and Moore 2000). That is why adaptive complexity seems

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to be a promising principle for supporting older learners with less prior experience.

Additionally, older learners should benefit from advice on learning success and recommendations for repeating certain lessons. Mack *et al*. (1983) researched how novice users learned to use a text editor, and found that novice users went through a long period in which they encountered many problems using the system. Reasons for those difficulties included a lack of knowledge, false interpretations, and inaccurate generalisations. When designing adaptive training systems for elderly users, one has to take into account that older learners have a greater need for a well-structured learning process (Bruder *et al*. 2006) and benefit from repeated practice (Arning and Ziefle 2010). A promising principle is to offer adaptive training advice for less-experienced trainees (Tennyson 1981, McGrenere 2002,), e.g. giving feedback on their learning progress and offer suitable exercises. When people learn something new, their cognitive resources are often strongly focused on the acquisition of this new knowledge. This reduces their capacity to assess their need for further learning. Thus, a training application which diagnoses the learners' level of experience and supports them adequately is beneficial (Park and Lee 2003). Lee and Lee (1991) as well as Ross and Rakow (1981) found that learners with little previous knowledge benefit more from adaptive advice on their training success than learners who already have deeper knowledge about the content. In contrast to learner control (Vandewaetere and Clarebout 2011), in which the learner makes the key decisions about the learning process, adaptive advice is more appropriate for learners with less prior knowledge and less meta-cognitive skills (Tennyson 1981, Lee and Lee 1991). As a restriction, adaptive advice involves the risk of reducing learner's feeling of being responsible and in control (McGrenere 2002).

In summary, providing adaptive complexity of user interface and adaptive training advice is a promising method for training the elderly to use electronic devices. The challenge is avoiding frustration and preventing a reduction in the learner's perceived control. What makes the current study different from previous research is its focus on the effect of adaptive training on elderly users. Additionally, the preferred principles of 'adaptive complexity of user interface' and 'adaptive advice in training' are combined to investigate the interaction effects of both design and training principles on elderly users. In doing so, this study particularly emphasises the impact of 'training just in time' in contrast to institutional training. In this paper adaptive training with older users was focussed in order to answer the following questions:

(1) How is training success affected when the complexity of a training application is adapted according to the learner's experience?
(2) How does adaptive advice for repeating training tasks affect training success?
(3) Which principle is better for elderly, less-experienced learners: adaptive user interface complexity, adaptive training advice or a combination of both?

2. Method

The study presented and discussed in this publication focuses on an adaptive training application and investigates two distinct principles: adaptive user interface complexity and adaptive training advice. A training study with older, less-experienced mobile phone users was conducted. During two separate training days, participants learned to use 27 functions of a mobile phone. The study involved an experiment to compare the effects of the different versions of the training on older, less-experienced users.

2.1. Participants

The participants consisted of 48 individuals between ages 54 and 77 years. Participants owned a mobile phone, but had little to no experience using it. They were recruited through an advertisement for free mobile phone training in a local newspaper.

2.2. Training application

The training application described in this paper is based upon the preliminary study (Bruder *et al*. 2007a) and follow-up study (Bruder *et al*. 2007b) mentioned in Section 1.1. A task-oriented training application was designed which taught all the basic functions of a mobile phone in short lessons. The user interface of a mobile phone was simulated using a computer (Figure 1). The simulation was as complex as mobile phones available at the time and provided functions for several components such as phone book, calling lists, and messages. The trainees interacted with the simulated mobile phone via touch screen.

The training application provided the content in 27 lessons (Table 1). Every lesson started from the initial display of the mobile phone. The order of the lessons was based on the complexity of the training tasks. Tasks ranged from easy ones, such as 'dial a number', to more complex ones, such as 'add a new number to your telephone list'. More complex tasks were those which required the user to understand several new rules in order to complete the task successfully.

Every lesson had three parts: (1) An introduction to motivate the trainee and explain the goal of the lesson, (2) A step-by-step guided tour from the first display through the task and back, and (3) exercises to practice the task. The step-by-step guided tour was implemented using spoken instructions, e.g. 'You are in the phone book list. Mark the item … and press the button ….' If the trainees pressed

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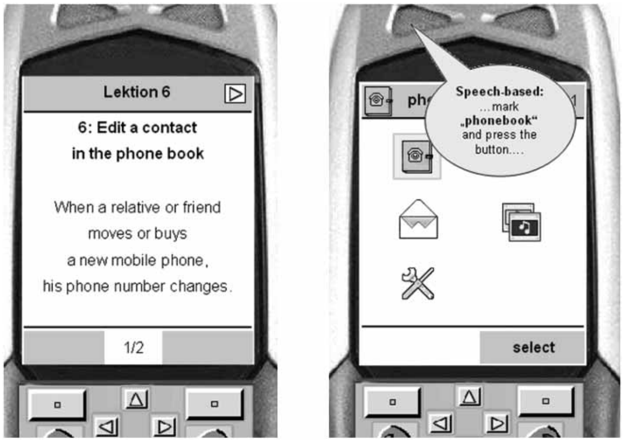

Figure 1. Screenshots of the simulated mobile phone and training application (menu language translated from German): introduction of a lesson (left), main menu display (right).

Table 1. Overview of training lessons and tasks (learning content) for the performance tests (see Section 2.4).

Learning content	Training	Test 1	Test 2	Final Test
Get a call	Lesson 1			
Dial a number	Lesson 2			
Call from phonebook	Lesson 3	Task 1	Task 1	Task 1
Recall	Lesson 4			
Phone book				
Read	Lesson 5	Task 2	Task 2	
Change number	Lesson 6	Task 3	Task 3	
Edit	Lesson 7	Task 4	Task 4	Task 2
Delete	Lesson 8	Task 5	Task 5	
Add a picture				Transfer 1
Calling lists				
Read	Lesson 9	Task 6	Task 6	
Check missed call	Lesson 10			
Call	Lesson 11			Task 3
Save	Lesson 12	Task 7	Task 7	
Delete	Lesson 13	Task 8	Task 8	
Duration of calls	Lesson 14			
Settings				
Adjust volume	Lesson 15			Task 4
Change ringtone	Lesson 16			
Hide number	Lesson 17			
Lock keys	Lesson 18			
Messages				
Read	Lesson 19			
Delete	Lesson 20			
Send	Lesson 21			
Send msg. to missed call				Transfer 2
Save message	Lesson 22			
Send once more	Lesson 23			
Safe number	Lesson 24			
Answer message				Transfer 3
Pictures				
Open	Lesson 25			
Delete	Lesson 26			
Add to message	Lesson 27			
Delete music				Transfer 4

the corresponding button, the next step was activated. Otherwise if the trainees did not press the corresponding button, the spoken instructions were repeated. To give an example, Table 2 shows the step-by-step guided tour of lesson 3 'call from phonebook'.

2.3. *Study design*

A 2 × 2 factorial independent groups' experimental design was used. All groups were comparable in terms of the participants' age and their experience with mobile phones and other technical devices. Prior to taking part in the study semi-standardised interviews were conducted to determine the participants' prior knowledge of and experience with mobile phones and other electronic devices. These data were converted into a scale: the more knowledge and experience, the higher the value. The scale ran from one (no experience with mobile phones and other devices) to 15 (very experienced). These data were used to calculate a prior knowledge score (Table 3). Based on this score and age, participants were distributed over four equivalent groups.

Two independent variables were included (Table 4). The first independent variable was 'adaptive user interface complexity' consisting of two conditions: the 'complete user interface' of the electronic device and a 'growing user interface'. The 'growing interface group' started with a training version which presented only the basic functions of the mobile phone. Active functions were highlighted in colour; disabled options were greyed out. At the beginning of the adaptive training, all functions were disabled and greyed out. Functionality grew stepwise with the learners' experience in using the device. With each lesson, an additional function was activated and presented in colour. The control group trained with a simulated mobile phone which provided a complete user interface right from the start.

The second independent variable was 'adaptive training advice' with the two conditions: with and without 'adaptive prompting'. The 'adaptive prompting group' received feedback on their training success. The training application suggested certain exercises if the trainees' performance indicated that the lesson was not adequately understood. The control group was trained without adaptive training advice.

Adaptive advice was implemented using the 'Wizard-of-Oz' approach. The decisions of the 'wizard' were based on observations from the preliminary study (Bruder *et al.* 2007a). In short, if the learner finished a lesson successfully without making major mistakes, the wizard suggested commencing the next lesson. However, if the learner made mistakes, was unsure, or needed help during the lesson, the wizard suggested exercises to repeat in the lesson. To calculate inter-rater reliability, two instructors observed the trainees for a subset of samples and rated the need to repeat the lesson or their readiness to switch to next lesson. A high degree of inter-rater reliability (89.6%; $\kappa = .64$) was observed which was considered to be more than sufficient.

Table 2. Step-by-step guided tour of the training application using the example of lesson 3 ‘call from phonebook’.

Speech-based instruction	Corresponding action	Incorrect action
1. You are now presenting with the ‘initial screen’ Switch to the main menu! To do so, press the button directly below the label ‘menu’	By pressing the button below the label ‘menu’, the trainee switches to the main menu. The first menu item ‘phone book pre-selected’	By pressing any other key or doing nothing, the speech-based instruction is repeated
2. You are now presenting with the ‘main menu’ The yellow label indicates the menu item that you have just selected. In your case, the menu item ‘phone book’ is selected Press the corresponding button below the label ‘enter’!	By pressing the button below the label ‘phone book’, the trainee switches to the phone book (first menu item pre-selected)	
3. You are now presenting with the ‘phone book’ The yellow label indicates the menu that you have just selected. In your case, the menu item ‘open phone book’ is selected To move to this menu item, press the corresponding button below the label ‘enter’!	By pressing the button below the label ‘enter’, the trainee opens the contact list (first menu item pre-selected)	
4. You are now presenting with the ‘contact list of your mobile phone’. Move the yellow label to the contact, you want to call. To do so, use the arrow buttons of your mobile phone Select the contact ‘Stefan’ by pressing the down arrow button! Finally, press the call key to dial ‘Stefan’!	By selecting the contact ‘Stefan’ and pressing the call button, the trainee dials ‘Stefan’	
5. The mobile phone is just establishing the connection to ‘Stefan’. The name of the person being called, in this case ‘Stefan’ is shown	At first the trainee is listen a dial tone. Finally the contact’s voice speaks a welcome text	No incorrect action possible

Table 3. Calculation of prior knowledge score.

Category	Items	Points
Mobile phone usage	Owns a mobile phone, has used several phones in his life, read the manual, uses several components of his mobile phone	0–8
Fixed line phone	Uses answering machine, uses phone book	0–2
Electronic devices	Uses PC, digital camera, music player, DVD player, vending, and ticket machines	0–5
Prior knowledge score	Sum	0–15

2.4. Dependent variables and control variables

In order to compare the training versions, both training effort and training success were measured. Training effort included several factors necessary for successful learning, i.e. perceived effort during and after training and the time needed to do the training. Training success was defined by the benefits of training to the learner, i.e. performance after training and knowledge about training content. Subjective ratings of learners’ self-efficacy and subjective acceptance of training were also measured. Table 5 gives an overview of the variables and parameters measured to represent training success and training effort.

Training effort: In general, because the training was voluntary, the training effort should be low to reduce the risk that the learner stops training. Perceived effort was measured before, during, and at the end of the training (Scale for Validating the Recording of Subjectively Experienced Effort (SEA-scale), Eilers *et al*. 1986). Objective parameters of training effort consisted of: training time, numbers of exercises voluntarily done, and number of keystrokes needed to complete the training.

Training success: For performance measurement, subjects completed performance tests (Tables 1 and 4) between training sessions (stage performance tests 1 and 5) and after the training (final test). Tests consist of operational tasks which varied in difficulty. Indicators of performance were duration (in seconds), number of keystrokes, and the amount of support. The participant had the opportunity to ask for support. The amount of support they received was calculated by counting the number of requests for support per task. Four of the eight task of the final test were designed

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Table 4. Independent variables used.

		Adaptive user interface complexity	
		Complete user interface from start (control group)	User interface increasing in complexity
Adaptive training advice	No prompting (control group)	Group 1	Group 2
	Adaptive prompting (when participant made mistakes, took too much time, was unsure what to do)	Group 3	Group 4

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Table 5. Dependent variables and methods.

Dependent variable	Method
Training effort	
Perceived effort during training	SEA scale rating (Eilers *et al.* 1986)
Training time	Time and keystrokes needed to complete training lessons
Learning workload	Number of exercises voluntarily done
Training success	
Test performance during training	Stage test performance in test 1 and test 2 (duration, number of keystrokes and support per task)
Test performance after training	Final test performance (duration, number of keystrokes, and support per task)
Explicit knowledge	Cloze-test performance (frequency correct answers)
Procedural knowledge	Card-sorting (correct action sequences)
Mental representation	Card-sorting (correct hierarchical structure)
Subjective rating	
Self-efficacy	Rating of domain specific self-efficacy
Acceptance of training	Rating of training appropriateness

to measure 'transfer' (Table 1), which means taking knowledge learned in a given setting and applying it to closely related settings. In order to measure 'transfer', subjects had to perform new tasks (e.g. 'add a picture to a contact in your phone book') which consisted of a combination of rules, some previously learned and some new.

For knowledge assessment, a cloze test was conducted to measure participants' explicit knowledge of the mobile phone (item examples: 'To end the call, press the ___ button' and 'Use the ___button to lock all buttons of the phone.'). Mental representation of action sequences and hierarchical structure were assessed using a card-sorting technique (comparable to Groeben and Scheele 1984). This was done to measure the correctness of participants' mental models of the mobile phone. Mental models affect people's understanding-of and interactions-with artefacts (Kieras and Bovair 1984, Ziefle and Bay 2005, Ziefle and Arning 2009). Using the closed version of card-sorting, participants were provided with a predetermined set of cards. Every card contained a picture of mobile phone display. First, participants were required to order the display pictures into action sequences. Second, participants were asked to sort pictures of different states of the interface into tree formats which represented their mental representation of the mobile phone function structure. A score ranging from zero (lack of representation) to four (elaborated representation) was calculated based on how many pictures were sorted correctly and incorrectly.

Subjective rating: Participants completed a questionnaire measuring domain-specific self-efficacy (following Compeau and Higgins 1995) and training acceptance. The five questions concerning self-efficacy focused on: feeling of control while training, self-assessment of training success, and satisfaction with learning progress. The scale 'training appropriateness' consisted of six items which captured participants' ratings of the training design, enjoyment of the training, and an overall rating. All items were rated using a 5-level Likert-scale (1 = does not apply; 5 = applies completely). See the appendix to this paper for a complete list of items in the questionnaires.

Control variables: The following demographic characteristics were collected: age, gender, education, (former) profession, and participants' experience with mobile phones and other technical devices.

2.5. Procedure

The experiment took place on two training days, with a four- to seven-day gap (Figure 2). Each participant was trained individually. Each training unit lasted between 90 and 150 min. Before training, the participants were interviewed about their experience with mobile phones and completed a questionnaire about their experience with and attitude towards technical devices. The perceived effort before training was used as a baseline.

The first training unit involved 14 lessons, the second 13 lessons. Their performance was tested and their perceived effort rated at three intervals: at the end of the first training

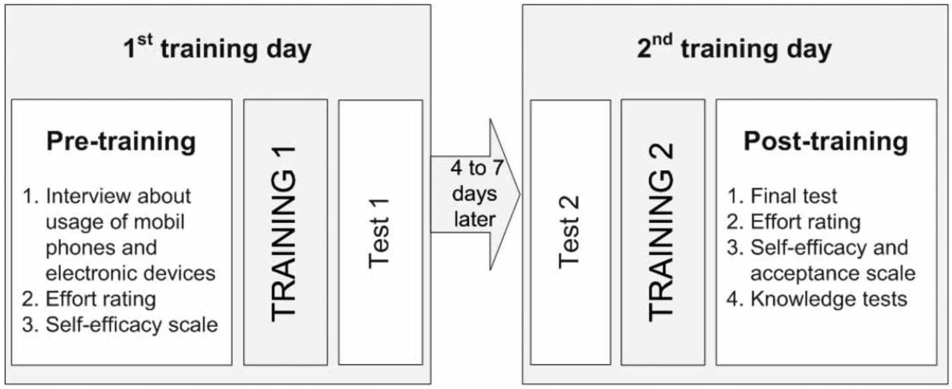

Figure 2. Procedure.

unit (test 1), at the beginning of the second unit (test 2), and end of this second unit (final test). Each performance test consisted of eight tasks differing in the degree of transfer needed to solve the task (Table 1). After the second training unit, participants completed tests concerning their explicit knowledge and mental representation of the mobile phone. At the end of the training, subjects also completed a questionnaire about their self-efficacy and acceptance of training.

3. Results

Data were analysed using two-way ANOVAs. Training success parameter 'support per task' is not normally distributed and was analysed using a Mann–Whitney U-test. A significance level of $p \leq .05$ was set a priori.

3.1. Sample characteristics

The sample consisted of 48 adults, 17 men, and 31 women. Their age ranged from 54 to 77 years with a mean age of 66 (SD = 5). Their prior knowledge score (from one to 15 points) varied from 1 to 13 points, with a mean of 7 points (SD = 3).

3.2. Training effort

Concerning the training time, the group with the growing user interface was trained in 91.20 (SD = 36.94) min, in comparison with 102.96 (SD = 38.64) min for the control group. No significant effects were found for adaptive user interface complexity ($F(1, 44) = 1.23$; n.s.). The group with adaptive prompting needed 102.17 (SD = 44.41) min to finish the training, the control group without adaptive prompting only 91.50 (SD = 29.88) min; again the differences were not significant ($F(1, 44) = 1.03$; n.s.). Regarding the number of keystrokes, significant effect was found for adaptive training advice ($F(1, 43) = 6.05$; $p < .05$). Learners with adaptive prompting ($M = 381.00$; SD = 118.53) needed significantly more keystrokes to finish the first training unit than learners in the control group ($M = 303.04$; SD = 99.90).

Adaptive training advice also had a significant effect on the number of exercises voluntarily done after each lesson ($F(1, 42) = 6.18$; $p < .05$). Learners with adaptive prompting ($M = 2.00$; SD = 2.02) did significantly fewer exercises on the second training unit than learners without adaptive prompting ($M = 4.25$; SD = 5.40). There were no significant effect of adaptive user interface complexity ($F(1, 42) = 0.30$; n.s.) and no interactions ($F(1, 42) = 0.00$; n.s.).

Table 6. Perceived effort before, during, and after training sessions (SEA scale from 0–220, $N = 48$).

	Adaptive user interface complexity				Adaptive training advice			
	Complete user interface		Growing user interface		No prompting		Adaptive prompting	
	M	SD	M	SD	M	SD	M	SD
Baseline	21.68	13.55	21.30	15.45	19.92	14.64	23.07	14.36
Training 1	58.43	43.44	65.07	30.77	49.67	33.65	73.82	40.55
Test 1	61.83	43.84	73.90	38.56	61.05	43.86	74.68	38.54
Test 2	57.44	51.32	53.79	31.04	48.96	41.55	62.27	40.81
Training 2	45.44	35.64	55.76	32.35	47.09	33.42	54.11	34.57
Final test	45.83	38.77	35.13	26.93	45.07	40.92	35.88	24.78
Knowledge tests	94.92	35.44	115.76	47.23	105.16	47.57	105.52	35.10

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Table 7. Cross tabulation of data summarising the relationship between the wizard's suggestions and trainee's decisions ($n = 24$).

		Trainees' decisions		
		Repeat lesson	Switch to next lesson	Sum
Wizard's advice	Repeat lesson	140	17	157
	Switch to next lesson	14	383	397
	Sum	154	400	554

Subjective perceived effort was measured before, during, and after training. On the whole, learners rated the perceived effort from low to medium (Table 6). For the first training unit, adaptive training advice was found to have a significant effect on the perceived effort ($F(1,44) = 4.91$, $p < .05$). Learners with adaptive prompting needed significantly more effort than learners without adaptive prompting.

Table 7 gives an overview of the wizard's suggestions and the trainees' decision whether or not to repeat the lesson. Summing up the results, 28% of the wizard's suggestions were to repeat lessons and 72% to switch to next lesson. In nearly 95%, the trainee followed the wizard's suggestions.

3.3. *Training success*

To measure the subjects' performance using the simulated mobile phone, the duration per task, number of keystrokes per task, and required support per task were compared during test 1 (after the first training unit on the first day); test 2 (before the second training unit on the second day); and final test (Table 8).

In comparison with previous tests, all training groups completed the tasks on the final test significantly faster ($F(2,42) = 21.44$, $p < .001$), using fewer keystrokes ($F(2,42) = 4.91$, $p < .05$), and requiring less help ($F(2,41) = 9.95$, $p < .005$). Concerning the number of keystrokes, significant effects were found for adaptive user interface complexity in test 1 ($F(1,44) = 7.33$, $p < .01$) and test 2 ($F(1,44) = 5.84$, $p < .05$). Comparing with the complete interface group, the growing interface group needed fewer keystrokes.

The number of unnecessary keystrokes was calculated by taking the difference between necessary and actual keystrokes. The same effect was found for the keystrokes variable: Adaptive user interface complexity had a significant effect in test 1 ($F(1,44) = 5.04$, $p < .05$) and test 2 ($F(1,44) = 5.17$, $p < .05$). This indicates that adaptive user interface complexity leads to a reduction of unnecessary keystrokes in comparison with training with the complete interface.

In an additional step trained tasks and transfer tasks of the final tests (test 3) were analysed separately (Table 9). Taking only the trained tasks of the final test into account, participants needed about three more keystrokes than were actually required. Regarding the transfer tasks, adaptive user interface complexity was found to have a significant effect on the amount of required support per task ($F(1,43) = 4.39$, $p < .05$); i.e. the growing user interface group performed the transfer task with less support than the control group who practiced with the full interface version. There were no significant effect of adaptive training advice ($F(1,43) = 1.55$; n.s.) and no interactions ($F(1,43) = 0.08$; n.s.).

The participants' knowledge about the operation of the simulated mobile phone was investigated. As previously mentioned, the difference between cloze-text performance before and after training was analysed. Adaptive user interface complexity had a significant effect on cloze-text performance ($F(1,42) = 3.36$, $p < .10$) i.e. training with a growing user interface ($M = 0.79$; SD $= 2.21$) results in better conceptual and functional knowledge about the simulated mobile phone than training with a complete user interface ($M = 0.64$; SD $= 3.15$). There were no significant

Table 8. Performance data from test 1, test 2, and the final test ($n = 47$).

	Adaptive user interface complexity				Adaptive training advice			
	Complete user interface		Growing user interface		No prompting		Adaptive prompting	
Time per task (s)	*M*	SD	*M*	SD	*M*	SD	*M*	SD
Test 1	118.73	58.94	100.43	45.86	114.17	61.70	104.99	43.10
Test 2	145.33	69.24	132.37	77.89	143.66	80.12	134.03	67.02
Final Test	88.03	35.96	77.61	33.65	80.97	25.66	84.68	43.95
Keystrokes per task (*n*)	*M*	SD	*M*	SD	*M*	SD	*M*	SD
Test 1	26.09	4.66	22.17	5.18	25.48	5.26	22.78	4.58
Test 2	29.54	7.76	24.46	5.57	27.68	7.52	26.32	5.81
Final Test	23.68	6.06	21.58	2.50	23.74	4.82	21.52	3.74
Required support (*n*)	Median		Median		Median		Median	
Test 1	0.75		0.38		0.56		0.75	
Test 2	0.38		0.44		0.31		0.75	
Final test	0.25		0.13		0.25		0.13	

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Table 9. Transfer tasks and simple tasks of final test ($n = 47$).

	Adaptive user interface complexity			
	Complete user interface		Growing user interface	
Keystrokes per task (n)	M	SD	M	SD
Simple tasks	26.09	4.66	22.17	5.18
Transfer tasks	29.54	7.76	24.46	5.57
Overall	23.68	6.06	21.58	2.50
Required support (n)	Median		Median	
Simple tasks	0.00		0.00	
Transfer tasks	0.50		0.13	
Overall	0.25		0.13	

effects of adaptive training advice ($F(1,42) = 0.04$; n.s.) and no interactions ($F(1,42) = 1.16$; n.s.).

To measure learner's procedural knowledge, the participants had to recognise action sequences required to use the mobile phone successfully. Adaptive user interface complexity was found to have a significant effect on the number of correctly recognised action sequences ($F(1,42) = 4.24$, $p < .05$), i.e. the growing user interface ($M = 5.50$; SD $= 1.38$) improved procedural knowledge more than training with a complete user interface ($M = 4.77$; SD $= 0.92$). There were no significant effects of adaptive training advice ($F(1,42) = 0.37$; n.s.) and no interactions ($F(1,42) = 3.30$; n.s.).

Finally, the learner's mental representation of the functional structure of the simulated mobile phone was analysed. The number of hierarchical levels and correctness of representation were calculated. A score between zero points (no representation) and four (elaborated representation) was calculated. Adaptive user interface complexity was found to have a significant effect on the quality of mental representation ($F(1,42) = 6,23, p < .05$), i.e. learners in the growing user interface group ($M = 2.58$; SD $= 0.58$) had a better mental representation of the hierarchical structure than the control group with the complete user interface ($M = 2.0$; SD $= 0.98$). There were no significant effects of adaptive training advice ($F(1,42) = 1.19$; n.s.) and no interactions ($F(1,42) = 0.10$; n.s.).

3.4. *Subjective ratings*

The reliability estimate for the measure of domain-specific self-efficacy was Cronbach's $\alpha = 0.79$ and, for training appropriateness, $\alpha = 0.71$. The reliability estimates were good for each scale.

The ratings suggest that the training provided was appropriate for learning to use the mobile phone (Table 10). Concerning the main factor 'adaptive training advice', significant effects were found for 'self-efficacy' ($F(1,44) = 6.10$, $p < .05$), i.e. learners with adaptive prompting rated 'self-efficacy' of the training lower than the learners in the control group. There were no significant effects of adaptive user interface complexity on 'self-efficacy' ($F(1,44) = 0.29$; n.s.) and no interactions ($F(1,44) = 0.29$; n.s.).

4. Discussion

The results show that adaptive training has substantial beneficial effects on training success and training effort. Comparing 'adaptive user interface complexity' and 'adaptive training advice', adaptive user interface complexity was better suited for supporting older, less-experienced users to learn how to handle electronic devices. The adaptive training principles that were investigated in this study were found to affect training success and training effort almost independently. Interestingly, adaptive complexity was found to mainly influence training success, adaptive advice was found to mainly influence training effort. In the following, both results will be discussed separately (summarised in Table 11).

Adaptive training advice primarily affects training effort and learner's self-efficacy, but in an unexpectedly negative way. Based on feedback from many of the participants, it can be concluded that they perceived the suggestions from the adaptive training advice system as being negative feedback. Thus, adaptive training advice has the potential of giving learners the impression of criticism, which reduces their self-confidence. As mentioned earlier, Baldi (1997) and Reed *et al.* (2005) found that computer-related self-efficacy (e.g. expectation of training success) mediates the relation between age and skill acquisition. This could be the reason why adaptive training advice increases the number of keystrokes and the perceived effort for the first half of the

Table 10. Appropriateness and self-efficacy after training ($n = 47$), rated on a 5-point Likert-scale (1 = does not apply; 5 = applies completely).

	Adaptive user interface complexity				Adaptive training advice			
	Complete user interface		Growing user interface		No prompting		Adaptive prompting	
	M	SD	M	SD	M	SD	M	SD
Appropriateness	4.09	0.47	4.12	0.43	4.27	0.47	3.93	0.43
Self-efficacy	3.78	0.70	3.65	0.66	3.91	0.72	3.52	0.64

Table 11. Significant effects of adaptive training principles.

		Adaptive user interface complexity		Adaptive training advice
Subjective evaluation		No significant effects	–	Reduced self-efficacy
Training effort		No significant effects	–	Higher subjective effort
			–	More keystrokes needed
			+	Fewer exercises needed
Training success	+	Better test performance		No significant effects
	+	Better transfer of knowledge		
	+	Better procedural knowledge		
	+	Better structural knowledge		

Note: '–' negative effects, '+' positive effects.

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training, when elderly learners needed felt insecure about their training success.

Concerning training effort, SEA values in the training and test sessions indicated an acceptable level of effort. A benchmark was provided by Wandke and Nachtwei (2008), who studied a rather challenging supervisory task, which resulted in SEA-means between 40 and 54. In comparison with SEA values found by Wandke and Nachtwei (2008), the perceived effort was within a reasonable range.

Focussing on exercises done voluntarily after each lesson, 95% of the participants followed the suggestions of the adaptive training advice because they interpreted the adaptive feedback not as recommendations but as binding instructions. Furthermore, self-efficacy was reduced after training with adaptive training advice. McGrenere (2002) concluded that programme control involves the danger of reducing the learner's feeling of being in control. This could be a reason for the reduced self-efficacy. Self-efficacy is an essential condition for successful learning and transfer, and therefore must be taken into account.

In order to support less-experienced learners by using adaptive training advice and taking the increasing need for learner control into account, a combination of programme control and learner control may be useful. Initially, inexperienced trainees would start with a programme-controlled training; during the course of the training, they would increasingly take over control of the learning process.

In contrast to adaptive training advice, adaptive user interface complexity improves the training success without negatively affecting training effort or self-efficacy, i.e. growing complexity as an integrated part of the mobile phone is an appropriate way to train older learners how to use electronic devices. This positive effect supports the assumption made by Nilsen *et al*. (1993) that people try to learn to handle an easy task well, before they attempt a more complex task. Learners who trained with a growing user interface performed better after training, showed a better ability to transfer knowledge to unknown tasks, and had a better mental representation of the mobile phone.

Adaptive user interface complexity was not found to have any negative effects on training effort and self-efficacy. It is advantageous for the training application to keep the initial barrier low, so that inexperienced users can complete the tasks successfully. This is in line with Ziefle and Bay (2005), who found that older adults' decreased performance was correlated with the complexity of the electronic device and, conversely, the less complex an electronic device, the smaller the performance gap between older and younger users.

The principle of growing complexity shows consistent and robust positive effects on training success. These positive effects replicate the findings of Carroll and Carrithers (1984), as well as McGrenere (2002) and Bannert (2000), with training-wheel systems. Compared with training with the complete user interface of an electronic device which provides full functionality from the outset, inexperienced users master tasks faster and with fewer mistakes. Furthermore, adaptive user interface complexity has positive effects on learners' knowledge transfer to unfamiliar tasks, as well as their knowledge about the electronic device. This is why the users need fewer steps to complete their tasks. Adjusting the complexity of the interface according to the learner's experience reduces the error rate.

Adaptive user interface complexity also offers substantial benefits if the user has to deal with new tasks. Dealing with unfamiliar tasks involves mental representation and requires the transfer of knowledge from familiar to unfamiliar tasks. This is in line with the strong effects that adaptive user interface complexity had on the subject's procedural knowledge and their mental representation of the electronic device's functions. These findings support the results of McGrenere and Moore (2000), as well as Carroll and Carrithers (1984), who found that inexperienced users who have trained with adaptive user interface complexity have a better mental representation of the functionality. Therefore, adaptive user interface complexity offers a promising approach to supporting older learners.

5. Conclusion

Integrating adaptive training programmes into a product is a solution to bridge the gap and support less-experienced users, helping them live independently and utilise the technology effectively. The work presented provides valuable information about the design of training applications for elderly users which allow them to learn 'just in time'.

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Perhaps the most important lessons for practitioners are that elderly users are willing and able to learn the use of an electronic device. This is particularly important with regard to common myths in the field of 'human–computer interaction and elderly people' (as summarised by Wandke *et al*. 2012).

Several recommendations can be made for practitioners. Elderly users benefit significantly from a training application:

- which provides complete instructions per task,
- which interactively teaches the use of the electronic device step-by-step, and
- which adapts their complexity to the user's experience.

Adaptive user interface complexity is an effective principle for supporting less-experienced, older users. This study provides strong evidence of the positive effects of implementing adaptive training as part of the product itself. When the complexity of the training application was adapted according to the learner's experience, learners performed better, were able to undertake new tasks with less help, and had better knowledge about the electronic device. Training applications with adaptive complexity of the user interface can be useful for many other electronic devices, not only for mobile phones. For example, ticket vending machines (Struve and Wandke 2009) and car infotainment systems reveal similar barriers for less-experienced users.

Comparing both adaptive principles, adaptive user interface complexity is better suited for training older adults in the use of electronic devices. Concerning adaptive training advice, no effects were found on learners training success. In part, adaptive training advice as implemented in this study affected training effort and self-efficacy in a negative way. Further research is needed to identify the reason for largely negative effect of adaptive advice as implemented. Is it the way in which the feedback was phrased, its content, its frequency or something else?

In a theoretical perspective, a more detailed understanding of how adaptive training applications affect elderly users' information processing is still necessary, e.g. to ascertain the reasons why adaptive user interface complexity has such a strong positive effect. Is it the highlighting of the active options and greying out disabled options, thus guiding the learner's visual attention to the relevant new aspects? Or is it the result of actually reducing the number of possible actions, since certain options and thus a range of errors automatically prevented. Preliminary results of a follow-up study indicate that the benefit of adaptive user interface complexity is mainly caused by blocking options.

Despite all the questions that are still open, the presented work brings us closer to our goal to provide seamless transitions between learning and using information and communication technology which is also appropriate for elderly users.

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Appendix. Listed items of subjective scales

Domain-specific self-efficacy (translated from German)
I am satisfied with my training success.
When working through the lessons, I could apply my knowledge.
I saw through the training easily.
I learned easily how to use the simulated mobile phone.
Due to the training, I could draw upon my prior knowledge.

Training appropriateness (translated from German)
The training was difficult.
The training was appropriate to learn the use of the simulated mobile phone.
The lessons were a bit long in their explanations.
I have enjoyed learning how to use the simulated mobile phone.
Due to the training, I am able to use my mobile phone better than before.
The training offers enough opportunities for practicing.