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How can we make IT appliances easy for older adults?: Usability studies of Electronic Program Guide system

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1. Introduction

New information appliances, typically personal computers (PCs), cellular phones or car navigators, have so many functions with great varieties that many elder users have difficulties to use them. Manuals are too thick to read up before starting to use. On the other hand, TV set has been a very common consumer appliance that has been used by most elderly without serious difficulty. In recent years, however, new information technologies are applied to conventional home appliances including TV set, resulting in a lot of problems of usability, especially for elder users. It might cause inequality of chance to access many information resources and resulting in digital divide, one of the most serious social problems.

In order to make IT appliances elder-friendly, so-called “universal design” has been a popular approach. Many appliances equipped with large fonts and large buttons claim a universal design (Hasegawa et al. 2005; Zhao et al. 2007) to ensure easy access to use. Even though the adaptation of these physical designs is important and effective, this approach does not cover all of problems of difficulty in using for elder users, because this approach aims only to compensate declines of sensory- and motor-functions with aging. There are also solid changes of cognitive functioning with aging, based on changes of brains and neural activities and resulting complex phenomena related to lots of social and adaptive factors (Craik & Salthouse, 2008; Harada, in press). Effective support in IT design for these cognitive aging should be considered and investigation of this new approach is important.

Another factor of difficulties in using for elder users is lack or shortage of experience in using IT appliances in general. People living in these days have been making up a generic mental model of IT appliances while they use many kinds of them. Mental model is a kind of knowledge, which offer expectations and indicate assumptions of system behaviour when users try to use (Gentner & Stevens, 1983; Norman, 1988). Users may use general mental model when they try to use a new appliance or service, and then develop more specific mental models for each specific appliance based on their own interactions (Akatsu & Harada, 2008). Many elder users have few experiences on IT appliances resulting in difficulties in using new one because they have only poor mental models for them.

Harada proposed the three-layered model of cognitive aging and usability, consisting of “declines in cognitive functions”, “shortage of knowledge and mental models of objects” and “attitudes and strategies based on meta-cognition and value system”. Three layers are cross-linked to each other, and are affecting interactions between older adults and IT appliances (Harada & Akatsu, 2003).

Reported experimental studies comparing older adults with younger adults in using IT appliances showed effects of aging which were mixture of cognitive aging and shortages of mental models applicable to usages of appliances. For example, Harada et al. analyzed older users’ behaviours of automatic teller machine (ATM), L-mode telephone and other IT-based appliances, and reported some typical features of older adults including difficulties in awareness of changes in an information displayed and error repetitions (Harada et al., 2002; Ogata et al., 2005). Kitajima et al. proposed a test battery for attentional function with aging, and reported that different groups of users whose performance declined in a different subtest showed differential problems in mobility within the train station (Kitajima et al., 2005).

On the basis of these preceding studies, this study had two purposes. One was to investigate effects of cognitive aging and shortages of mental models independently on learning the operation of a new appliance. The other is to explore possibilities of making IT design supportive to learn for elder users, providing errorless environment.

2. Experiment I: Are there really aging effects on using IT appliances or just effects of past experiences of the use of similar appliances?

In experiment I, in order to investigate effects of cognitive aging independently from lack of mental models, the usability testing of EPG system was performed with older and younger adults of different experiences on PCs. (Hara et al., 2005)

2.1 Methods

2.1.1 Participants

Fifteen older adults (8 male and 7 female, mean age: 68.8 years, ranging 65-73) and younger adults (8 male and 7 female, mean age: 20.8, 18-25) participated in the experiment voluntarily and were paid for participation. All participants had no experienced in using EPG system before the test. Half of older participants had substantial experience in using PC, while the remaining half did not have any experiences. Among younger adults, half were PC beginners and the other half were rather experienced PC users. It was impossible to find younger adults without experiences of PC usage. Table 1 shows participants’ experiences in using scheduled recording of VCR and a cellular phone. Two groups in younger adults were not different from each other with these experiences, in contrast with older adults groups. The without-PC experiences group of older adults had little experiences with other equipments also, indicating the larger individual differences of mental models of IT appliances in older adults compared with younger adults.

Age PC experience	Older adults		Younger adults	
	With	Without	Experienced	Beginner
Number of participants	8	7	7	8
Cellular phones	5	0	7	8
Cellular phones mail	1	0	6	8
Scheduled recording of VCR	5	0	5	6

Table 1. Number of participants who had experience of cellular phones and the scheduled recording.

2.1.2. Evaluated system

In this study, we adopted an Electronic Program Guide System, abbreviated as EPG system as the target system of our usability testing. EPG in Japan provides a TV program listing in a format of 2-dimensional matrix of TV-channels and time of the day, which looks similar to the TV program guide in traditional Japanese newspapers (Figure 1). Each program is located at the intersection of the time and the channel. The EPG data including additional information are provided with digital broadcast and displayed on call on the TV screen. The TV set offers many functions e.g. scheduled recording when the program is clicked. There were three reasons why we used the EPG system in this study. At first, the EPG is a quite new system added to TV sets or recorders, which are commonly used daily appliances familiar to everyone including elders. As the second, the user interface of the EPG system is quite different from that of classic TV sets, and similar to the GUI of PCs. Specifically, operation of system depends on information displayed on the screen. Finally, the EPG system is expected to become a widely used standard function of digital TV/ broadcasting system which should be easy to use for all users.

Fig. 1. A TV program listings in Japanese newspaper (a) and in EPG system (b). They aer provided in a format of 2-dimensional matrix of channel and time

In experiment I, a digital high vision TV set (TH-32D30T, Panasonic Corp.) was used for the usability testing for EPG system. Its standard remote controller used in the test is shown in Figure 2. The controller has many buttons, which can be categorized to 4 groups. To use the EPG functions with this controller, users should perform four types of elementary actions associated to different set of buttons, as follows.

- Direct button action: for example [power] and [channel] buttons are directly associated to the system functions. When they are pushed associated actions are immediately invoked.
- Cursor action (move-and-select): the cursor indicates current focus on the items shown on the screen. Users move the cursor with [up][down][left] and [right] buttons and push [execute] button to make choice.
- Colour button action: [blue], [red], [green] and [yellow] buttons are on the EPG remote controller. Each button is directly associated to a system function like direct action buttons, however, the association is not static but dynamically changed depending system state; they are available only when the definition of their functions is displayed on the screen. The colour buttons are defined in the EPG specification and common for all EPG systems.
- Menu selection: because of richness of functions, many complex functions are offered in a multi-layered menu tree structure. Users reach to desired system function in the menu by making step-by-step selections at each layer with cursor action. It is necessary for effective use to understand the menu structure as well as the concept of menu selection.

Fig. 2. Remote controller used in the test

The direct action buttons are simple and equipped on conventional TV sets and were familiar even to older groups. Cursor actions and menu selection are derived from IT systems and cellular phones, and they may have been quite new way of use for older adults who had no experiences on PCs or Cellular phones. Colour buttons are characteristic of digital TV and EPG system, and were new to all of the participants.

Usually, there is some distance between the TV screen and users who operate the remote controller. Users have to move their view focus to and fro between the TV screen and the remote controller, and need to remember information on the screen to operate the remote controller on the basis of information displayed. Both of these costs are to be paid by users for context-dependent button actions, i.e., cursor action, colour button action, and menu selection. It may have been additional problem for older users.

2.1.3 Tasks

A series of tasks are prepared for the usability testing;

1. Turn on the TV set and view a instructed terrestrial channel, and then view a BS channel. Younger participants were asked additional task to view a BS which need to be input by a channel number.
2. Display the electronic program listing of the terrestrial broadcasting, scroll down the screen, and see programs at 19:00 on the same day; do the same task with listing for the BS.

3. See additional information by EPG for a program assigned by instruction.
4. Display the electronic program listing, and see a programs at 12:00 on the day after tomorrow (changing the date).
5. Find a movie program on the same day by EPG (search by category); and then find a sports program on the next day (search by category).
6. Find a program with a given performer (search by performer's name).
7. Setup a scheduled recording of a program found at the task 6.
8. Setup a scheduled weekly watching of a program assigned by instruction; then cancel that scheduling.

Task 1 was pure conventional operation of TV set, but the tasks from 2 to 4 were intended to see the performance of program listing operation. Tasks 5 and 6 were to see the performance of EPG search operation, and tasks 7 and 8 were for reservation operation for recording or viewing. Every task was given with a written document which did not include any words shown on the controller as labels.

2.1.4 Procedures

The experiment was executed with each participant individually. After coming to the lab, participants were told about the experimental objectives and they filled in a questionnaire about personal background and experiences with IT-based systems. Following instruction and demonstration by the experimenter, participants performed a practice session of thinking-aloud method while solving a Tangram puzzle.

After the experimenter explained the EPG system only with conceptual description, the usability test was performed task by task. No system manuals or prior verbal guidance about operations were given. The task was presented by a written card, and participants were requested to read the task aloud at first, and then start the task. Participants were requested to make a guess how to solve the task and try on it, with prompting to think aloud when keeping silent. When a participant seemed to reach to a deadlock, the experimenter asked the participant about his/her problem at that point, then gave them a minimum help to get out of the trouble. After all tasks completed, the experimenter interviewed the participants. The experiment lasted two hours for elder adults, and about one hour for younger participants. Because of the testing time limitation, task 6 was skipped for some older participants.

Utterance of participants was recorded by an IC sound recorder, and three video cameras recorded the operation on the remote controller, information on the TV screen and participant's behaviour as a whole. All button actions on the controller were monitored and recorded at the infra-red receiver.

2.2 Results and implications

All utterance and behaviour of participants were transcribed for analysis. The achievement of each task was coded as 3 categories: succeeded by oneself, succeeded but with experimenter's help, or failed. Statistical significance was determined by one-sided Fisher's exact test unless otherwise indicated. In this paper, results were reported in three kinds of different button actions described earlier.

2.2.1 Troubles with Cursor actions

When pushing [Program Guide] button to display the electronic program listing on the screen, a cursor with yellow frame in the table is shown indicating the current focused program. This focused program can be moved up and down (along with the time axis) and right and left (along with the channel axis) with four cursor buttons. To select the focused program for the extended functions, [Enter] button should be pushed. Participants experienced these cursor actions of EPG in Task 2 at the first time. Younger participants had no difficulty in cursor operations and selection. However, older participants showed some difficulties in understanding the difference between focused and non-focused programs. They needed to become aware that the cursor could be moved and to learn how to move the cursor. Half of the older-PC users and all seven participants in older non-PC user group could not find out the down scroll cursor operations without experimenter’s help. There was no significant difference between PC user and non-PC user groups. As for the side scroll cursor operations, one fourth in the older-PC user group and six of seven in older non-PC user group succeeded after the experimenter’s help ($p<0.05$, older PC user group vs. non-PC user groups).

Understanding the possibility of scroll may have come from knowledge or models of IT appliance operations, or may have been interfered by perceptual constraints which were strong in older adults. In any cases, stretch of the knowledge of paper-based 2-dimensional program listing to EPG system was the key to solve the difficulty in using IT-based display for older adult users.

2.2.2 Troubles with Colour button action

Among the buttons on the controller, the colour buttons have highly context-dependent and quite new for all participants. Colour button actions were expected to be used to change date of the electronic program listing in the tasks 4 and 8. Table 2 shows the number of participants who noticed the display of colour button functions on the screen and used it. Some users completed the tasks without using colour buttons (for example, with a long scrolled down until the next day). Most younger participants noticed the colour button functions by themselves, and no hints were necessary at all. On the contrary, among the older participants, only three in PC user group and one in non-PC user group noticed the colour button functions shown on the screen by themselves.

Age PC experience	Older adults		Younger adults	
	With	Without	Experienced	Beginner
Number of participants	8	7	7	8
By oneself (Task4)	3	1	6	6
With experimenter's help	3	5	0	0
No use	2	1	1	2
By oneself (Task8)	6	1	7	8
With experimenter's help	2	6	0	0

Table 2. Awareness of colour button functions

There observed some errors that colour buttons were pushed while they were disabled. Most of these errors with colour buttons were caused by colour design of the screen. We call

this type of error as “Colour slip”, which was caused by direct but wrong association induced by common colours. Typical examples of utterances while pushing buttons were shown in Table 3. At this time, yellow-coloured area in the electronic program listing indicated the focused program. The participant erroneously associated the yellow colour on the screen with the yellow button, and pushed the yellow button repeatedly. Similar behaviour was seen in several other older participants (Table 4). The PC experiences in older participants seem to have had no effects on these kinds of behaviours.

Participant:	May I push the yellow button? Am I right?
Experimenter:	What do you think is meant by the yellow colour? How do you think why that part is yellow-coloured?
Participant:	I guess I should push the yellow button. Ah, is it wrong? (She pushes the yellow button.) No, it won't work, why? (She pushes the same button again.)

Table 3. Example utterance with colour slip

Age PC experience	Older adults		Younger adults	
	With	Without	Experienced	Beginner
Number of participants	8	7	7	8
None	4	2	5	8
Once	2	3	2	0
Many times	2	2	0	0

Table 4. Number of participants who needlessly pushed 4 color buttons (for all tasks)

Two younger participants also pushed colour buttons by errors. However, their errors did not look like resulting from "colour slip", but from logical searching/testing for a proper operation. The most distinguished differences from older participants was that younger participants never repeated pushing colour buttons; i.e., once they found that the buttons did not related to the expected functions and that the colour of the display had no meaning, they easily abandoned the colour buttons, and tried other buttons without repeating the same errors. Thus was indicated that colour slips seems to have come from poor understanding of the EPG system and/or strong effects of distraction by colours.

2.2.3 Troubles in Structured menu action

From tasks 5 to 8, it is necessary to operate menu-driven functions to achieve the task goal. The multi-layered, tree structured menus is common in PCs but has hardly used in conventional TV sets just to watch TV programs. For the task 5, finding out a movie on the same day, four stages of menu and sub-menu selections were required after invoking menu by pushing [menu] button. The first selection, i.e. the root menu, was to select the action type (search for a program, schedule a recording, etc.), and the second step was the selection of search method (search by category, search-by keyword, etc.). After the “search by category” was selected, program categories (movies, sports, etc.) were displayed and to be selected, then finally, sub-categories for “movie” (domestic movies, foreign movies, etc.) was to be selected.

Table 5 shows the number of participants who could pass each step without experimenter’s help. Some in younger PC beginners group had difficulty with opening the “menu”. (not shown). As for menu selection, all younger participants could perform correct operations, regardless of rich experiences of PC use.

Age PC experience		Older adults		Younger adults	
		With	Without	Experienced	Beginner
Number of participants		8	7	7	8
1. Action	"Searching for"	2	0	7	8
2. Method	"By category"	6	0	7	8
3. Category	"Movie"	6	4	7	8
4. Sub-category	"Japanese Movie"	8	4	7	8

Table 5. Number of participants who passed the each step of task 5

On the other hand, all of older participants showed difficulties at the first stage, regardless of PC experiences. Interestingly enough, these difficulties seems to have been gradually reduced along with going down to the stages for both groups, but the rate of reduction was different with PC experiences. Although most of the older PC user group had little difficulty at the second step, non-PC user group still showed severe difficulties, whose performance were improved at the third and fourth stages. Statistical analysis confirmed that the PC experience did not affect the performance at the first step, but there was a significant difference at the second step ($p<0.01$). On the third stage, the differences did not reach significant, however, on the last fourth stage there was a tendency for the difference ($0.05 < p < 0.1$). Older PC user group showed increase in the number who completed by themselves at the step from the first to the second stage ($p< 0.1$), while the group without PC experience showed increase at the step from second to the third stage ($p<0.05$).

The cause of this observation seems multiple factors. One reason of the increased success rate by older participants might be learning of move-and-select operation in the menu structure. The differences between two groups of older participants should have been related to this learning, because of their prior experiences of using menu interfaces of PC. There seemed to be other reasons related to the characteristics of menu structure. In structured menu operations, the menu items at earlier stages are more distant from the final goal, and with going down the menu structure, the distance become smaller. It was also suggested that the lack of the mental model or system knowledge disturbed the ability to keep their own goal in mind while operating the menu selection and/or understanding external stimuli such as displayed items (De Yong, 2001).

In addition, the feature of item selected at each stage was also different in the structured menu. In the target EPG system, the first stage was the selection of actions which were described by verbs, and second stage was for the selection of methods which were described by adverbs. At the third and fourth stages, menu items were objectives of the action and expressed as nouns, i.e., concrete objects. The action of selection may have easily been connected to nouns, especially concrete objects, with similarity to the selective actions in everyday life. From this view point, selecting an abstract verb may be unfamiliar actions, and needs to be learned.

These characteristics of structured menu systems are coming from the root of PC interfaces or cultures, and the way to avoid of this is not clear. However, the results showed some aspects of possible difficulties for older adults when using PC and IT-based appliances.

2.3 Discussions

The results above showed absolute differences between younger and older adults in using the EPG system at the first time. As long as the final achievement, younger adults had very little problems using EPG system in the usability testing, without regard to experiences of PC usage. On the other hands, older adults, regardless of PC experiences, showed a lot of problems interacting with new systems. There were also effects of experiences observed in older participants groups, even though the significance of effect seems much smaller than aging. With PC experiences participants could take advantages of help by experience, and showed a little bit better performances than older adults with no PC experiences.

Some younger adults could not use the new system and new functions without embarrassments. They made errors at the first time and hesitated to use. However, they were able to overcome and find out the ways to use by themselves while trying to use them. It is implied that for usage of an IT system especially a new one, the key factor affected by aging is learning, with which users acquire some specific mental models of the target system (Harada et al., in press). The knowledge or mental models users already have, has rather small facilitative effects and cannot cover the whole range of aging effects.

Causes for these poverty of learning must be complicated and many factors of cognitive changes are related. Among them, one of the most important issues should be error. Older adults experience more errors, and while recovering from the error, they often make another erroneous operation, which makes older adults difficult to understand the situations. In addition, older adults have tendencies to repeat the same errors in consecutive trials, which is reportedly one of characteristic behaviours for older adults (Harada & Suto, 2008). With these repetitive errors, it is quite difficult to understand the reason of errors and to learn how to use the appliance.

Based on this hypothesis, we planned the following experiment to make IT appliances more easy to use for older adults by making a supportive learning environments by keeping the users away from errors.

3. Experiment II: Can we make IT appliances easy to use by supporting learning?

As mentioned above, it was observed that younger adults could learn how to use the EPG system while they tried to use it, but older adults could not. As a hypothesis, one of the most serious obstacle factors for older adults' learning is experience of errors, especially repetitive errors.

In general, experience of errors provides rich information and it is said that people can learn more from errors than from success. However, for amnesic (memory-impaired) patients, it is difficult to learn from experiences with errors and some successful alternative ways for them to learn, called "errorless learning" were reported (Baddeley & Wilson, 1994; Evans, 2000). The same tendency was observed with healthy older adults (Anderson & Craik, 2006). In addition, older adults do not attend to negative information in general, compared with younger adults (Carstensen et al., 1999).

In the Experiment II, for the purpose of finding the ways to make IT system easy to learn especially for older adults, we examined the effects of environments in which users were supported to be kept away from serious errors with guidance, suggestions, or more conceptual information (Hara et al., 2007). Because of difficulties in making these environments by a system, the experimental settings were supplied by human experimenters with defined rules when/what/how to intervene to users. To ensure that the effects came from the environmental intervention but not the amount of information provided, two groups were set up. To the experimental group named “early-supported” group, helpful information or suggestions were given at the time it was necessary and errors or troubles were anticipated. The same information was given to the other group named “late-supported” group after making errors or end of the daily tasks.

Another purpose of the Experiment II was to see the effects of repeated basic operations. While it is difficult to learn mental modes or some conceptual local rules by older adults, it is known that there are tacit perceptual-motor learning, e.g., inputting a same long line of characters (Harada & Akatsu, 2003), or that it is possible to learn basic operations with supportive cares leading to successive usages (Harada et al., in press). To see the effects of repeated practice on the operations trained, and also observe its effects on operations of other functions, consecutive three-day test was performed on each participant individually. The tasks were organized to ensure repeated trial of basic operations. The repeated basic operations were performed by both early- and late-supported groups.

3.1 Strategies for supported learning

3.1.1 Strategy 1: making environments to avoid experiencing errors

To keep users away from experiencing serious errors, help / guidance / suggestions / explanations were provided by the experimenter during the test at different timing depending on the group. The following two types of information were given:

General concepts: useful general information about the system was given just before starting the related tasks to the early-supported group. To the late-supported group, the same information was given at the end of the day after all tasks had done. The information was provided by the experimenter

- The screen shown by EPG system consists of various different areas including TV program listing, commercial (PR) information and operational instruction areas. The screen image was shown with this message.
- The system has two separate storage areas, which are HDD and DVD.

Context-dependent guidance information: following helpful messages were given as needed. The early-support group was given with these messages immediately when they were applicable. The late-supported group was given after they showed difficulties.

- Invalid operation: e.g. the button you are pushing is invalid at this moment.
- Explanations of current status: e.g. the TV program listing is shown now.
- Suggestions: e.g. please pay attention to the on-screen message.
- Solution: e.g. please push the red button for your purpose.
- Goal reminder: e.g. please confirm the target of your task. This message was given when participants forget the final goal of the task they were tackling during the test.

3.1.2 Strategy 2: Repeated Practice of Basic Operation

In order to ensure that participants were able to learn the skills of basic operations, repetitive practices of basic operation were incorporated in the series of tasks. The basic operations repeated were as follows. They were the fundamental functions of the EPG system. Each basic operation was repeated several times in the series of tasks.

- Examine TV program listing
- Setup scheduled recording
- Review recorded programs

Figure 3 shows the operation schema of EPG system. The relation between basic operations and more complicated operations were described.

Fig.3. The operation schema in the EPG system

3.2 Methods

3.2.1 Participants and condition

Participants were five older (4 male and 1 female, mean age: 69.8 year, ranging 68-73) and 5 middle-aged adults (1 male and 4 female, mean age: 59.6, 51-65), who did not have substantial experiences of PC operation nor cellular phone mail, but had some experiences of using VCR. The familiarity with VCR was tested with easy operation tasks. The participants were stratified by age and VCR familiarity and were randomly assigned to the early-supported group (3 male and 3 female totality 6) and to the late-supported group (2 male and 2 female totality 4).

3.2.2 Tasks

The tasks of the Day1 were as follows:

- 1-1: Turn on the TV set.
- 1-2: Display the Electronic program listing and identify a TV program on the day.
- General concept information about EPG screen layout was given only to the early-supported group. The same information was given to the late-supported group at the end of the day.
- 1-3, 1-4: Display the Electronic program listing and identify TV programs on different days.
- 1-5: Setup scheduled recording for three programs assigned by instruction.
- 1-6: Play recorded programs.
- 1-7, 1-8: Setup scheduled recording for a participant's favourite programs.
- 1-9: See the lists of already scheduled-recording-programs
- 1-10: Cancel a/some specified scheduled-recording-program(s)

Tasks 1-2 to 1-4 were placed for repeated basic cursor operations. The users were expected to become familiar with the information shown on the screen such as context-dependent functions of colour buttons. Task 1-5, 1-7 and 1-8 were placed for repeated scheduled-recording with cursor, enter and colour buttons.

The tasks on the Day2 were as follows:

- 2-1: Turn on the TV set and setup scheduled-recording
- 2-2 to 2-4: Do operations related to playing recorded contents.
- 2-5 to 2-9: Do operations related to scheduled-recording.
- 2-10, 2-11: Do operations related to playing recorded contents.
- 2-12: Search for movie programs assigned by instruction..
- 2-13: Search for programs of favourite genre
- General concept information about storage areas consisting of HDD and DVD were given only to the early-supported group. The same information was given to the late-supported group at the end of the day.
- 2-14: Play the program on the DVD.

The tasks on the Day3 were as follows:

- 3-1: Turn on the TV set and setup the scheduled-recording.
- 3-2, 3-3: Do operations related to playing recorded contents.
- 3-4, 3-5: Do operations related to scheduled-recording.
- 3-6: Play the programs on the DVD.
- 3-7: Dubbing of three recorded programs from HDD to DVD.
- 3-8: Do operations related to scheduled-recording.
- 3-9: Do operations related to scheduled-recording and cancel duplicated reservation.
- 3-10: Start recording current program on air

3.2.3 Evaluated system

In Experiment II, a DVD/HDD recorder (EH-60) with TV monitor (TH-32D30T) was used as the similar EPG system as Experiment I. Button locations of the remote controller, TV program listing layout on the screen, and menu tree structure were almost the same as those of Experiment I.

Some buttons on the remote controller were hidden to minimize confusing factors. For example, a button's label "Chapter" was hidden since many participants in Experiment I

were uncertain about the meaning and the function of the button and showed fears to use it. This button was available only for the edition of a video.

3.2.4 Procedures

The experiment was performed on consecutive three days with each participant individually. Each day had one session lasting less than two hours. A few days before the experimental session, each participant was tested for VCR operation and was interviewed about personal backgrounds and experiences of IT-based system operations.

3.3 Results

The first obstacle for the users was the cursor action in Task 1-2, where the users were requested to display the program listing and identify the TV programs. All users of both experimental groups needed suggestions by the experimenter to complete the task, implying that two groups were equally not familiar with EPG operation at the start of the test. The result was also similar to the Experiment I as compared to the older adults without PC experiences group, suggesting that participants’ performance levels of two experiments were equivalent.

3.3.1 Effects of General concept Information

The second obstacle for the users was the colour button action in Task 1-3, where the colour buttons were assigned to functions to change the date of the TV program table. Only the early-supported group was given with information about general concept of EPG screen layout just before tackling the task. Although the general information was not directly focused on colour buttons, it could be a good suggestion and help for users to become aware of the colour button actions. Table 6 shows the number of participants who completed the task by themselves, i.e. who found the colour button function shown on the screen. Performances were not different in the two experimental groups, suggesting that the general information about screen layout turned out to be ineffective.

Group	Late-supported	Early-supported	Total	Experiment I
Number of participants	4	6	10	7
By oneself (Task1-3)	2	3	5	1
By oneself (Task1-4)	4	4	8	1

Table 6. Awareness of colour button functions

Another general concept information regarding HDD and DVD was given to the early-supported group before Task 2-14, where the users were requested to watch the programs recorded in the DVD. However, the number of users succeeded by oneself in Task 2-14 was two of six in the early-supported and two of four in the late-supported groups, with no significant differences. Again, giving general concept information before the task was not helpful to users.

This result suggested that general information without clear focus on the target operation was not helpful, at least for older adults, even if they were provided before tackling the

related task. It seemed difficult for participants to understand the relationship between general information and an actual operation.

3.3.2 Effects of Repeated Basic Operations with Context-dependent Help

In this experiment, target basic operations were incorporated in different tasks, offering repeated practices of them in various contexts. One of repeated basic operations was scheduled recording, which was incorporated in Tasks 1-5, 1-8, 2-1 and 3-1. The performance of these tasks is shown in Table 7. At the first trial (Task 1-5), the performance was almost the same between two experimental groups. However, the next task performance (1-8) was better in the early-support group than task 1-5 ($p=0.015$). No significant improvement was observed in the late-supported group, suggesting that the context-dependent help information given to the early-supported group facilitated learning of the basic operations. The early-supported group seemed to acquire elementary actions more effectively than the late-supported group. The performance on the day 2 in the early-supported group was a little bit worsened back, however, it improved again on the day 3, suggesting that stable knowledge was acquired. Other task performances also showed improvements by the repetition. For example, the performance in Task 1-4 seemed better than in Task 1-3 (Table 6), even though it was not statistically significant. Similar improvement was observed with other repeated basic operations. It was notable that such improvement was not observed in the experiment I, where help-guidance by the experimenter was not provided before participants voluntarily giving up or falling into deadlock after making repeated errors. Too late help-guidance was not effective nor helpful. These results suggest that older adults can learn by repeated successful practice with timely help-guidance but not by trial-and-errors.

Group	Late-supported			Early-supported		
	Achieved	Suggestion	Solution	Achieved	Suggestion	Solution
Task 1-5	1	1	2	1	1	4
Task 1-8	2	1	1	6	0	0
Task 2-1	2	0	2	3	3	0
Task 3-1	3	1	0	5	1	0

Table 7. Number of participants who achieved "scheduled recording"

3.3.3 Improvement with New and Complicated Tasks

The other obstacle in this experiment was the menu selection action. Task 2-12, TV program search, was quite new to participants as described in the Experiment I. The performance at each stage in four steps of the search menu selection was shown in Table. 8. At the first stage, selecting the action, it is possible to skip of this selection by taking alternative path. Five of ten participants in this experiment found and used this alternative path, which never happened in the Experiment I.

Group		Late-supported	Early-supported	Total	Experiment I
Number of participants		4	6	10	7
1. Action	"Searching for"	2	1	3	0
	Alternative path	(2)	(3)	(5)	-
2. Method	"By category"	3	5	8	0
3. Category	"Movie"	4	6	10	4
4. Sub-category		4	6	10	4
Change of date		3	6	9	-
Scheduled recording		2	4	6	-
No try		2	1	3	-

Table 8. Number of participants who passed each step of menu selection.

Surprisingly enough, the performance of both early- and late-support groups especially at the first and the second steps was better than that in the experiment I ($p<0.01$). The menu selection action itself was new to participants in the present experiment, too. The difference between two experiments was that this task was assigned to the day 2 in this experiment and that participants were able to experience many times more basic operations. So it is suggested that acquisition of basic operations by repetition can facilitate learning of more complicated operations. Actually the screen design of the program listing attained as search result in task 2-12 was quite different from usual TV program listing repeatedly presented to participants. With this “new” screen, participants were asked to change date or to setup scheduled recording. They needed to get the meaning of cursor actions or colour buttons on the new screen. Although it is difficult for older users to get the new meanings of actions by watching the screen in general, most participants had no problems in Task 2-12 in this experiment. They found the proper operation just with the interaction with the system, which was never observed in the Experiment I.

3.4 Discussions

As shown above, it was shown that older adults learn elementary actions with repeated successful basic operations. Timely context-dependent help-guidance information facilitated learning. In addition, the learning of the basic operations facilitates the learning of other new and more complicated operations effectively. In contrast, general and unfocused concept information did not help older participants to use closely related target operations at all.

Another interesting factor observed was the value of personalized purposes. On the task 1-1 to 1-4, TV programs to be handled were pre-assigned by instruction. However after task 1-7, participants were asked to do the similar actions with TV programs which they prefer to see. When they had such chance to select their own favourite programs, the performance was better. It may be attributed to their higher motivation. Unfortunately this result was contaminated with task order and may be affected by repetition or learning. So the effect was not confirmed by comparison. Such motivational aspects by personalized purpose seems to affect learning, too. Some participants told at Task 1-7, “I like to see this program, so I want to make scheduled-recording of it”, and started searching the EPG voluntarily.

Effects of these kind of user's attitudes and/or powers of personalized purposes should be investigated with more systematic methods.

4. General Discussion

As the results of experimental usability testing of the EPG system, Experiment I showed younger adult users can learn how to operate IT appliances while they are trying to use it without reading manuals and any conceptual learning before. It may be achieved with so called "trial-and-error" fashion, or by hypothesis-testing methods. These results gave us a question why older users have difficulty in learning to use IT appliances during trial. What is the differences in the learning between younger and older adults?

In order to learn to use IT appliances by "trial-and-error" fashion or hypothesize-and-test manner, there should be multiple steps to be succeeded, which is similar to the seven stages model of user-computer interaction (Norman 1988): 1) Set a goal, 2) Select an yet untried action, 3) Try the action, 4) Receive the feedback, 5) Compare results to the goal, 6) If failure, step back to 2). To set a goal and to compare results to the goal, the user should keep the goal in his/her working memory, i.e., necessity of a goal maintenance (De Yong, 2001). To select one of yet untried actions, she/he should remember what was already tried, i.e. necessity of output monitoring (Marsh et al., 2007). To receive feedback, the user should be aware of what is shown and how it is changed (sensitivity of display changes; Harada & Akatsu, 2003). Older adults have various obstructive factors for these processes, because of declined memory and/or cognitive control functions (Craik & Salthouse, 2008), which induce the poor learning processes. In addition, many of IT appliances' functions are invoked by a series of interactive actions in nested structures, then the feedback from the system for each action is sometimes far from the final goal. With these structures, users should memorize the cascades of goals, and it makes the stage 5) difficult. Actually, it is not easy to distinguish successful actions from failures clearly in the level of elementary actions (like cursor actions or menu selections) for older adults, especially when they do not have enough knowledge or mental models of the target system.

In addition to these cognitive functional factors, older adults often have attitudes or mental sets to IT systems, and have prejudice-like beliefs that they cannot use or learn IT system (Harada & Akatsu, 2003). These attitudes should be related to the phenomena called "stereotype threat", e.g., older adults showed worse memory performance when they were told or believed that the task was measuring memory than when they think the task was not related to memory (Hasher et al., 1999). Actually, older adults showed different attitudes to IT appliances which look like "very computer-like" from those which seem not-a-computer. These attitudes, computer threat, might get stronger, if they by themselves have experiences of failures to use or learn a new IT systems. With a lot of experiences, they may even get a "learned helplessness" (Seligman & Maier, 1967; Norman, 1988). Such negative attitudes of older adults must make it difficult to learn to use IT appliances. These negative attitudes are often observed in relation to experienced errors. When older adults make many errors, they are easy to lose motivation to learn the target system. This makes them passive to interactions with systems, which makes more errors. This loop can be called "harmful error spiral", which seems a fundamental factor for difficulty in learning operation. Our basic idea was to stop this harmful error spiral and to offer a reverse rotation; leading to success spiral that users experience success, they learn operation by the success, and are motivated,

resulting in less errors. The models of harmful error spiral and success spiral are shown in Figure 4.

Fig. 4. Models of harmful error spiral and success spiral

To get rid of this learning poverty, we tried to provide older adult users with errorless learning environments, in which they would learn from successful experiences. The basis of the errorless learning is: 1) insufficient understanding of the basic operation induces many errors, and 2) consecutive or repetitive errors prevent users from learning the basic and more advanced operations. That is, reduction of errors is expected to facilitate learning.

The results were interesting. Not only basic operations actually repeated but also untrained complex operation was learned better. In addition, the older users started the voluntarily learning. However, general information provided had no effects on learning and improving better performances.

Errorless learning with repetitive basic operations seems to have the following advantages. Older users become aware of basic button layout by repetitive practice. They can operate the remote controller focusing on the video screen but not watching the panel on the controller. Then they will not miss the changes on the screen. They learn basic system behaviour and form mental models. Then they expect what happens with basic operations. Appropriate help-guidance makes users oriented in the context of actions and helps them understand what was wrong. Success experience induces the change of mindset to be positive and motivate them to try more. As a result, the difficulty in the older users is reduced, leading to mode change to the success spiral from harmful error spiral.

The number of practices or repetitions of each basic operation was not so huge in this experiment. A few times of repetitions with fairly long interval between repetitions seems effective enough. However the order and task structures was important for effectiveness: the key of this repetition effect must be the successful experience offered first.

Our results were just observed in a laboratory environment at present. In actual home use, users often have to operate new IT appliances alone. They are sometimes disturbed. They can give up whenever they want without jumping over the first hurdle. How can we implement the repetitive practice and errorless learning environment in the design of utility appliances to break harmful error spiral? Among the help-guidance messages given in this study, "invalid operation" and "current status" messages can be implemented in the system with relative ease. The "suggestion" and "solution" messages should match what the user wants to do, and are difficult to be implemented in the system. Complete feedback of "invalid operation" and "current status" should be helpful because users can learn context of operation. If feedback is inappropriate, users are confused and will not understand system behaviour and learn operation. It seems helpful to incorporate good messages for common situations of errors which are often observed.

Another problem to be solved is how to judge achievement of the learning of the basic operation. In our observation, when an older user proceeded to next operation before establishing good comprehension, he/she got confused by new operation. Specifically, a participant learned the operation of scheduled recording. Thereafter she learned the operation of program review, and then, she forgot what she learned first with scheduled recording.

Our results suggested the importance of breaking harmful error spiral in self-learning environment with repetitive practice in home use. It is still to be investigated how to make environments to support and facilitate the repetitive practice of basic operations and errorless learning in actual daily life. It is also to be discussed whether our method is effective in other new IT appliances. We are convinced that our approach is applicable to not only older users but all who feel difficulty in using new IT appliances.

5. Conclusion

Older adults have difficulties in using unfamiliar IT appliances. In order to investigate effects of cognitive aging and lack of mental models, the usability testing of EPG system was performed with older and younger adults of different experiences on PCs. Experimental results showed PC experiences did not save difficulty of new operations but facilitated learning of operations. Younger adults learn to use IT applications by trial-and-errors or hypothesis-testing method. Older adults especially those without PC experiences, could not learn GUI operation by this trial-and-errors fashion during using. Repetitive errors characteristic to older adults seemed to make it difficult to learn operations, resulting in loss of motivation to use new appliances.

To find a different way for older adults to learn operations effectively, we proposed two methods. Our strategy was to keep users away from serious errors with help-guidance and repeated practice of basic operation. Unfocused general conceptual information was not helpful for learning new operations. Repeated practice of basic operations with timely help-guidance messages facilitated the acquisition of basic operation and system behaviour, resulted in making them easy to learn new and complicated operations. It was suggested that older adults could learn better from successful operations than from trial-and-errors, which may induce harmful error spiral. It is notable that they start to learn operations in trial-and-errors fashion after they got mental models of basic operation. This learning method from success trial seems effective for not only older adults but also all users. It is necessary to investigate how to avoid error spiral in self-learning environment in daily actual life.

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Human-Computer Interaction

Edited by Inaki Maurtua

ISBN 978-953-307-022-3

Hard cover, 560 pages

Publisher InTech

Published online 01, December, 2009

Published in print edition December, 2009

In this book the reader will find a collection of 31 papers presenting different facets of Human Computer Interaction, the result of research projects and experiments as well as new approaches to design user interfaces. The book is organized according to the following main topics in a sequential order: new interaction paradigms, multimodality, usability studies on several interaction mechanisms, human factors, universal design and development methodologies and tools.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Noriyo Hara, Toshiya Naka and Etsuko T. Harada (2009). How Can We Make IT Appliances Easy for Older Adults?: Usability Studies of Electronic Program Guide System, Human-Computer Interaction, Inaki Maurtua (Ed.), ISBN: 978-953-307-022-3, InTech, Available from: <http://www.intechopen.com/books/human-computer-interaction/how-can-we-make-it-appliances-easy-for-older-adults-usability-studies-of-electronic-program-guide-sy>

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