The Effect of Multimodal Feedback Presented via a Touch Screen on the Performance of Older Adults

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Abstract. Many IT devices – such as mobile phones and PDAs – have recently started to incorporate easy-to-use touch screens. There is an associated need for more effective user interfaces for touch screen devices that have a small screen area. One attempt to make such devices more effective and/or easy to use has come through the introduction of multimodal feedback from two or more sensory modalities. Multimodal feedback might provide even larger benefits to older adults who are often unfamiliar with recent developments in electronic devices, and may be suffering from the age-related degeneration of both cognitive and motor processes. Therefore, the beneficial effects associated with the use of multimodal feedback might be expected to be larger for older adults in perceptually and/or cognitively demanding situations. In the present study, we examined the potential benefits associated with the provision of multimodal feedback via a touch screen on older adults' performance in a demanding dual-task situation. We compared unimodal (visual) feedback with various combinations of multimodal (bimodal and trimodal) feedback. We also investigated the subjective difficulty of the task as a function of the type of feedback provided in order to evaluate qualitative usability issues. Overall, the results demonstrate that the presentation of multimodal feedback with auditory signals via a touch screen device results in enhanced performance and subjective benefits for older adults.

Keywords: Multimodal User Interface, Multimodal Feedback, Multimodal Interaction, Older Adults, Touch Screen.

1 Introduction

According to a news item in USA TODAY (June 21, 2007), touch screen phones are poised for rapid growth in the marketplace. In addition to Apple's iPhone®, many international electronics companies have recently launched touch screen phones as new cutting-edge user interfaces. The shipment of touch screens is projected to jump from less than 200,000 units in 2006 to more than 21 million units by 2012, with the bulk of the components going to mobile phones. USA Today quoted a maker of touch

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sensors as saying that: *"This new user interface will be like a tsunami, hitting an entire spectrum of devices"*. Unlike input devices such as the computer mouse that require translation from one plane of movement to another, that require extra space, and can have substantial summative movement time between different parts of the screen, touch screen user interfaces have a one-to-one relationship between the control and display, and often no additional training is necessary for their efficient use. Accordingly, touch screens are now being used extensively in a variety of application domains owing to the intuitiveness and ease of direct manipulation in use. Touch screens will also be beneficial to various user groups, in particular, for older adults (i.e., for those aged 65 and older), who may not be familiar with the recent developments in electronic devices, including complicated functions and structures and also have age-related degeneration in memory, sensory perception, and other aspects of cognitive and motor processing [1]. What is more, as the number of people over the age of 60 is expected to reach 1 billion by 2020, representing 22 percent of the world's population (according to 2006 UN world population prospects), they are likely to become a major group amongst IT consumers.

Meanwhile, previous research has suggested that one of the most important factors determining the usability of touch screen interfaces is the size of menu buttons on the screen. It has been shown that touch screens only provide significant benefits to users when the size of the buttons is made sufficiently large [2, 3]. However, although some applications involving touch screen interfaces, such as information kiosk displays and ATMs, have sufficient space on the screen, others such as mobile phones and PDAs have only limited screen space. Considering that various devices with multiple functions in the IT industry are focused on the miniaturization of portable smart phones including mobile phones and PDAs, the limitation of the screen space represents one of the most important challenges in the field of mobile user interface design. Moreover, this spatial limitation of touch screen devices may constitute a greater constraint for older adults than for younger adults. Consequently, researchers have attempted to integrate information from different sensory modalities in order to overcome the spatial limit of visual information displays. For instance, Gaver (1989) proposed that auditory confirmation might provide a more obvious form of feedback for users than only visual feedback [4], while Akamatsu and Sato (1994) demonstrated that tactile or force feedback can be effectively linked to information provided via a visual display, to give users the advantage of faster response times (RTs) and a more extended effective target area [5].

What is more, certain types of multimodal feedback can enhance performance in direct manipulation tasks consisting of a series of 'drag-and drops' using a mouse, while lowering self-reported mental demand [6]. In this context, the present study was designed to provide empirical evidence regarding the benefits of multimodal (or multisensory) interfaces specifically for older adults. We investigated this issue using a touch screen device, asking whether multimodal feedback can help older adults overcome the constraints of screen space in a dual task situation. RTs, error rates, and subjective ratings of type of feedback were measured.

We conducted an experiment with older adults comparing unimodal (visual), bimodal (auditory + visual, tactile + visual), and trimodal feedback (auditory + tactile + visual) in response to button click events while participants dialed a series of numbers into a touch screen mobile phone. We investigated whether different combinations of modalities of touch screen feedback were differentially effective in facilitating participants' behavioral performance under both single and dual-task conditions. The participants were placed in a dual task situation; they had to perform a visual recognition task (holding a picture in memory) while they carried out the touch screen mobile phone task. In addition to collecting objective measures of performance, we also measured the subjective difficulty of the task as a function of the type of feedback provided. It has been argued that the subjective evaluation of task difficulty may be just as important in terms of measuring (and evaluating) usability as objective behavioral performance measures [7].

2 Experiment

2.1 Methods

2.1.1 Participants

Thirteen older adults (9 female; mean age 73 years, age range 69-75 years) with an average of 6 years mobile phone experience and normal or corrected-to-normal vision and hearing took part in the experiment. All of the participants were right-handed by self-report and all gave their informed consent prior to taking part in the study. All of the participants were naïve as to the purpose of the study which took approximately 50 minutes to complete. They were paid £10 each for their participation.

2.1.2 Apparatus and Stimuli

Each participant was seated in an acoustically-isolated booth. An 8.4 inch LCD touch monitor with vibrotactile feedback (Immersion® TouchSense® Touchscreen Demonstrator; 60 Hz refresh rate) was used to present the mobile phone task (see the right panel of Fig. 1). Auditory feedback was presented from a loudspeaker cone situated directly behind the touch screen. Auditory feedback was synthesized at 16-bit & 44.1

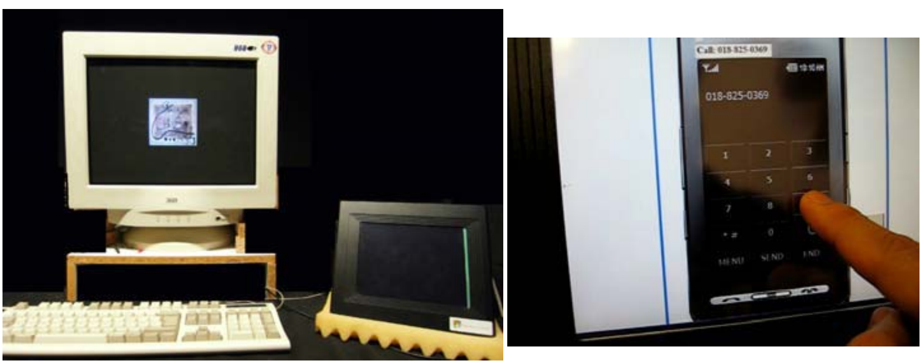

Fig. 1. The left panel shows the experimental set-up involving the secondary task of visual recognition and the primary task of using a mobile phone touch screen; the right panel shows an example of the touch screen device being used during the experimental mobile phone task

kHz and saved in WAV format. The auditory feedback consisted of a bell sound (main frequency: 355 Hz) presented for 150 ms at approximately 70 dB as measured from the participant's ear position. Tactile feedback (consisting of 50 Hz vibration) was presented via the touch screen for 50 ms from four actuators mounted within the touch screen device (index number 14 of the built-in Tactile Effects; for details, see Immersion® TouchSense® SDK Programming Guide, 2006). The tactile feedback was presented at a clearly supra-threshold level. In the dual task condition, the stimuli for the visual recognition task were presented on a 19 inch CRT monitor (75Hz refresh rate) placed 50 cm from the participant (see the left panel of Fig. 1). The picture stimuli were modern art pictures that could not easily be verbally encoded.

2.1.3 Experimental Design

There were two within-participants factors: Type of feedback: Visual only (V), tactile + visual (TV), auditory + visual (AV), or auditory + tactile + visual (ATV); Task: Single (mobile phone task) or dual task (mobile phone task + visual recognition task). For the single and dual task conditions, each participant completed 10 mobile phone task trials (consisting of five four-digit and five eleven-digit telephone numbers) with each type of feedback, with the order of presentation of the four types of feedback counterbalanced across participants. Each participant completed 80 mobile phone trials.

2.1.4 Procedure

In the single task condition, the participants only had to perform the mobile phone task; That is, they had to call a number on the touch screen device. On each trial, the telephone number to be typed was displayed on the touch screen itself. The participants were instructed to respond as rapidly and accurately as possible. If the participants made a mistake on the telephone task, they could delete their last key-press by pressing the 'clear' button on the keypad. In the dual task condition, the participants had to memorize a target picture that was presented in the middle of screen for two seconds. They were then required to hold the picture in memory while they executed the mobile phone task. Next, they had to pick out the target picture from amongst four alternatives. The participants were informed that they should divide their attention so as to perform both tasks as rapidly and accurately as possible. In addition, after the participants had completed 10 single and 10 dual task trials with each type of feedback, they completed a rating concerning the subjective difficulty of the immediately preceding feedback condition.

2.2 Results

Three performance measures were calculated: The mean accuracy of picture recognition, the mean accuracy and RT to complete the touch screen mobile phone task. In the visual recognition task, the number of correct responses did not differ significantly as a function of the type of feedback provided [$F(3,36)<1$, n.s.]. Participants were able to perform the visual recognition task with an average 77.3% correct (range from 75-79%) regardless of the type of feedback presented.

The RT and accuracy data from the touch screen mobile phone task (see Table 1) were combined into a single performance measure – inverse efficiency (IE) – that

Table 1. Mean RT and accuracy (S.D. in brackets) in the single and dual task conditions as a function of the feedback conditions

	Reaction Time (sec)		Accuracy (%)	
Task	Single	Dual	Single	Dual
V	8.9 (3.5)	9.5 (3.5)	83 (10)	86 (13)
TV	8.7 (2.4)	9.3 (2.9)	79 (17)	89 (19)
AV	7.8 (1.6)	8.2 (1.8)	93 (14)	99 (3)
ATV	7.6 (1.6)	7.7 (1.5)	90 (11)	95 (9)

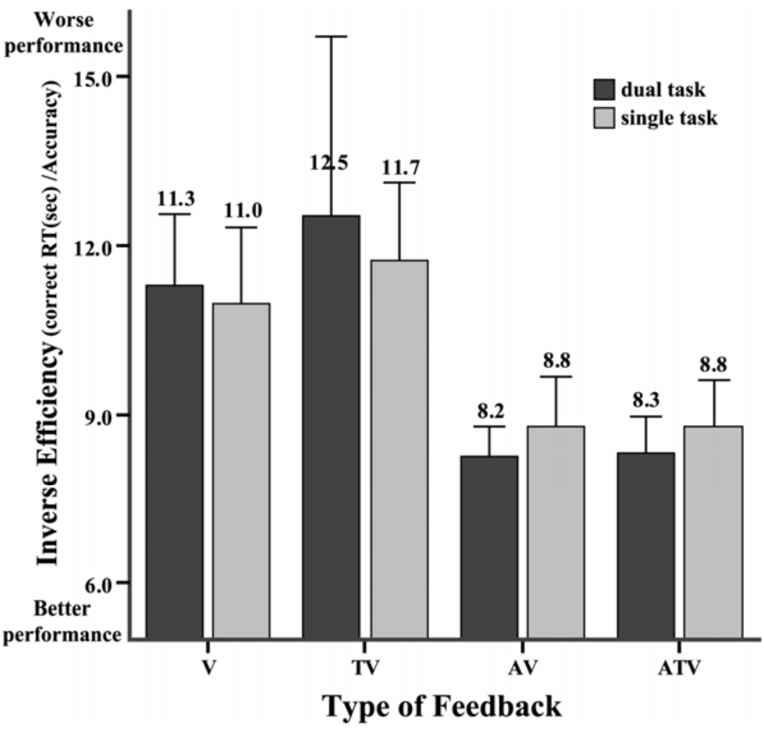

Fig. 2. Inverse efficiency (IE) scores on the mobile phone touch screen task plotted as a function of the type of feedback presented. The error bars show the standard errors of the means.

compensates for any potential speed-accuracy trade-off that may be present in one´s data [8]. IE = RT divided by the proportion of correct responses for a given condition on a participant; with a higher IE score indicating worse performance (see Fig. 2). Analysis of the IE data from the mobile phone task highlighted that the type of feedback affected performance significantly [$F(3,36)=3.10$, $p=.018$]. In particular, bimodal audiovisual and/or trimodal audio-visual-tactile feedback led to more efficient mobile phone performance than either unimodal visual and/or bimodal visuotactile

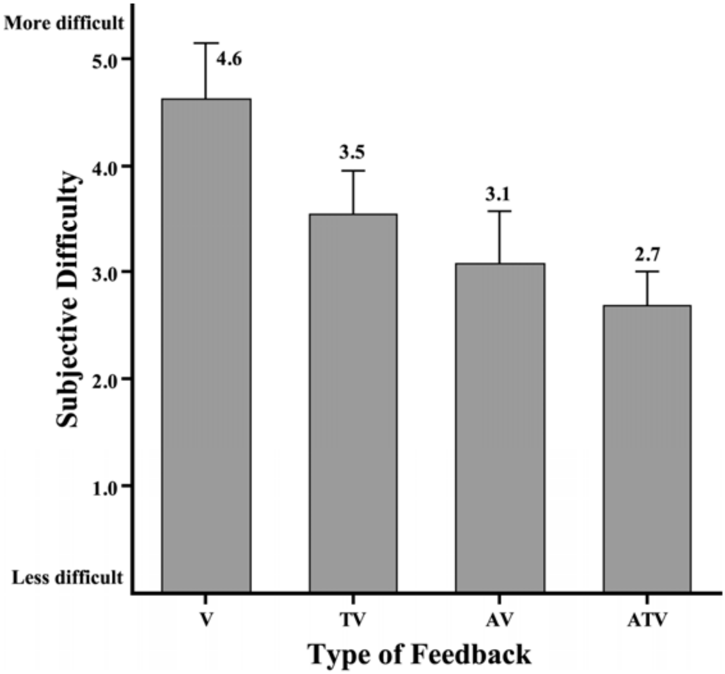

Fig. 3. Average Subjective Difficulty score (ranging from 1 ~ 5) plotted as a function of the type of feedback

feedback (see Fig. 2) [1-tailed Bonferroni comparisons (AV-V, ATV-V): p=.037, p=.045, respectively]. That is to say, crossmodal feedback involving auditory stimuli resulted in the older adults responding more efficiently. These results suggest that crossmodal auditory stimulation has a pronounced effect on participant´s performance of a touch screen task. There was, however, no significant main effect of task type (i.e., single vs. dual task) nor any interaction between the type of feedback and task. The reason that performance in the dual task condition was no worse than in the single condition may be due to the simplicity of the additional secondary visual recognition task that was used (remember that the response was collected after the completion of the mobile phone task). Nevertheless, the participants had to pay more attention (and devote more of their cognitive resources) in the dual task than in the single task trials. The results of the analysis of the behavioral data therefore demonstrate that participants were able to perform the mobile phone task more efficiently when they were given bi- or trimodal sensory feedback including auditory stimulation than when they were provided only with unimodal visual feedback or with bimodal visuotactile feedback.

A similar analysis of the subjective difficulty data revealed that the subjective difficulty of the mobile phone task also varied as a function of the feedback that was provided [$F(3,36)=6.32$, $p<.001$]. The subjective difficulty associated with trimodal feedback was significantly lower than that associated with either the unimodal visual or bimodal visuotactile feedback [1-tailed Bonferroni comparisons, p=.013; p=.044, respectively], while audiovisual bimodal feedback was no different from the other types of feedback (see Fig. 3). These results demonstrate that multimodal feedback (i.e., feedback that includes the stimulation of two or more of an interface operator´s senses) can have a beneficial effect on subjective measures of difficulty, as well as on the more objective measures of participants' behavioural performance.

In summary, these results demonstrate the effectiveness of multimodal feedback presented via a touch screen and the importance of auditory information as a form of crossmodal stimulation in the task that seemingly only involves the visual and tactile modalities, for older adults [9].

3 Conclusions

The experiment reported here investigated the potential beneficial effect of the presentation of multimodal (as opposed to unimodal) sensory feedback on older adults' performance of a mobile phone dialing task, using a commercial touch screen device. Our results clearly show that both objective and subjective measures of older users' performance were enhanced by the presentation of bi- and trimodal (as opposed to unimodal) feedback including auditory stimulation. The experiment reported here tests a larger range of combinations of feedback modality than have been tested in previous research and does so in the practical context of the use of a touch screen mobile phone under both single and dual task conditions. Meanwhile, the absence of a very pronounced effect of vibrotactile feedback when delivered via a touch screen might be due to the increased possibility of slow movement and action/movement error (involving age-related kinematic differences) in the older than in younger adults [10]. However, the subjective ratings of task difficulty suggest that the addition of the tactile feedback had an effect in the trimodal condition, even though it was not picked up in the performance data.

Future research should therefore further investigate age differences, comparing any differential effects of multimodal feedback and cognitive workload on relatively old versus young adults. This is a particularly important issue given the rapid growth of older users of technology. There is some evidence to suggest that older people may find task-irrelevant multisensory stimuli harder to ignore than younger people [11]. On the other hand, it has also been argued that older people may, in fact, benefit more from multisensory (as opposed to unisensory) stimulation than younger people [12]. The relevant feature here then may be how relevant the additional sensory stimuli are to the performance of the participant´s task.

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