Effects of Multimodal Feedback on the Usability of Mobile Diet Diary for Older Adults

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Abstract. Globally, overweight is an increasing problem and this especially the case for older adults, facing physical challenges and who need to maintain a healthy diet. eHealth services, such as a digital diet diary could support them. Consequently, we designed a multimodal mobile diet diary supporting interaction through text, graphics and speech. The diary, which gave personalized advice about maintaining a healthy diet based on meals entries, was evaluated with 32 older adults in a Smart Home Lab through use of scenarios. Results indicate that participants' satisfaction was highest when the feedback was provided through text and graphics. We found no effect on the effectiveness and efficiency. Additionally, spatial ability, computer experience and age explained variance in the evaluation of the diary. Our findings show that a multimodal mobile diet diary can support older adults maintaining a healthy diet and give insights on designing usable mobile interfaces for older adults.

Keywords: older adults, multimodal feedback, multimodal interaction, usability, diet diary, diet knowledge, eHealth, self-care, mobile devices, PDA.

1 Introduction

The global growth of people who are overweight is a substantial problem. Illustratively, in the Netherlands, approximately 50% of the population [3] is overweight while the percentage is even higher among the older adults. In addition to the emotional strain, overweight lies at the cause of many chronic diseases, such as diabetes and chronic hart failure.

The difficulty in addressing overweight lies mainly in the fact that people, and especially older adults, due to their decrease in mobility, have problems adhering to a healthy lifestyle. Therefore, it is important to increase health awareness and support self-care activities, such as maintaining a healthy diet.

One proven way to support self-care activities is through eHealth services. Previous eHealth studies focused specifically on a digital assistant in the form of an electronic diary located on the personal computer [1][2]. This study has shown that such a

C. Stephanidis (Ed.): Universal Access in HCI, Part III, HCII 2009, LNCS 5616, pp. 293–302, 2009.
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diary can increase health literacy and stimulate self-care. However, the study has also shown that this innovative technology can be challenging to use.

The challenges are twofold. First, the older adults often experience problems in interface navigation, due to the cognitive and physical limitations that possibly occur as part of the aging process [7]. Second, a diet diary running on a desktop computer is found to be too unwieldy for everyday use, because it constrains user's freedom of use, both in sense of location and time. As result of these constraints, the accuracy of user's entries can be compromised. A mobile version of a diet diary would be a possible solution.

While there are many usability guidelines that can help in design of a usable interface for older adults, there is very little empirical research on usability of software for older adults on mobile devices, such as PDA's. Literature agrees that one way to increase user effectiveness, efficiency and satisfaction with an interface in general is through multimodal interaction [6][7][11]. This could be of special benefit to older adults who may have limitations in interacting through use of one modality and may rely on other.

Following previous the research, we are studying the effect of multimodal feedback on the usability of mobile devices for older adults. First, we design and developed a fully functional multimodal mobile diet diary. Second, we conducted an experiment, in a Smart Home setting, to evaluate the effects of different feedback modality combinations on the use of the mobile diet diary by older adults. The paper concludes with discussing the results and their implications.

2 Application Design

The goal of the diet diary is to make people aware of their diet and give personalized advice in a usable way on how they could improve it. In order to support mobility, we developed the application to run on a PDA. We defined and implemented the following functionality in the diet diary.

Diary – The diary, the most important part of the application, was presented as a calendar and viewable per month, per week or per day. In the monthly and weekly view, the user could see which days contain entries. In the daily view, the user could see entries of meals for that particular day. We allowed the users to enter up to six meals per day, i.e., breakfast, lunch, dinner and three snacks. In the diary, the users could see the nutritional values of the meals they entered and ask for advices.

Food database – The diary relied on a food database that was included with the application. The database contained description of various foods covering name, portion size, calories, fat, proteins, carbohydrates and icons and images of the food. The actual values of calories, fat, proteins and carbohydrates per portion came from an existing Dutch web-based diet diary application called DieetInzicht (www.dieetinzicht.nl). All food was sorted in food groups, according to 'Disc of Five'[1].

[1] 'The Disc of Five', or in Dutch 'De Schijf van Vijf', is an arrangement of food into five food groups, sorted in a circle, widely used in the Netherlands.

Advices – As listed in Table 1, we included both general diet-related advices as well as personalized advices that were calculated based on daily consumption and user preferences. The general advice was presented in the style of facts and trivia after entering each meal, while personalized advises was available on request after entering meals.

User preferences – In order to give personalized diet advice, it is required to possess at least basic knowledge about the user. We included the possibility for the user to enter and adjust his weight, height, gender and birth date. This data is used throughout the application to calculate the Body Mass Index (BMI)[2], assess the daily-advised amount of various nutritional components, and give directed advice.

Progress charts – The data collected through diary was drawn in a graph and compared to optimal daily intakes of calories and nutritional components. In this way, the users could see how has their diet progressed over time.

Table 1. Examples of advices provided by the diet diary

General advice	Personalized advice
For a healthy diet, it is suggested to eat two pieces of fruit every day.	You have eaten too much food containing carbohydrates today. Carbohydrates are found in food products such, as bread, potatoes and pasta. In the future, try to eat less food from this group.

Most PDA's can be operated through different ways: hardware buttons, touchscreen, or both. Taking into consideration that few older adults have any experience with PDA's, we chose to limit input modality to on-screen buttons. We avoided drag and drop and sliding bar interface elements because we expected that the target user group could have problems using these as consequence of potentially reduced motor skills [7].

The output of the diet diary interface was through three different modalities: text, speech, and graphics, consisting of icons and images. Textual concepts, such as diary components, food products, and nutritional elements, e.g., carbohydrates, were accompanied by images and icons. In addition, the advice given about food intake was accompanied by illustrations representing the same concepts. The spoken feedback was prerecorded instead of computer generated to make it sound more natural. Moreover, because occasionally older adults have hearing problems in upper frequency range, a male Dutch native speaker with low voice was used [7].

The application was developed within .NET compact framework and written in C#, and ran under Windows Mobile 2005 or later. We chose this environment because most current PDA's operate on Windows Mobile. The food database was stored as a XML file. The diet diary was developed iteratively, i.e., during the implementation, we evaluated and improved the application's functionality and usability in a iterative fashion. In this way, the application was thoroughly tested during the development. In

[2] An indication of body weight in relation to height.

Fig. 1. Examples of diet diary interface. From left to right: subdivision of food into 5 groups (text only), food database (text and graphics), an example of general advice (text and graphics) and a comparison of daily view of diary (text and graphics vs. text only). The screens are translated to English, original interface text is in Dutch.

addition, the application was presented to a large crowd during MobileHCI 2008 Mobile Experience [12], where people could freely use it. The people were able to grade the application after trying it out. Subsequently the mobile diet diary was awarded a silver prize for mobile application innovation by the conference's organization [10].

3 Method

For the study we recruited 32 healthy older adults, 21 male and 11 female, between the age of 55 and 70 (M=62, SD=3.93). All participants were computer literate. The participants received monetary compensation for their participation in the experiment.

The experiment took place in TNO Experience Lab at TNO Defense and Security department in Soesterberg, the Netherlands. This is a smart home lab, i.e., an environment designed to represent a trusted home environment, but at the same time allowing researchers to evaluate various new technologies for enhanced living experience in a controlled but unobtrusive way. Participants were alone in the room and were monitored through cameras and remote desktop software.

During the study, we applied scenario-based approach and a within-subject design. After welcoming the participant, we presented them with a number of questionnaires that surveyed demographic, computer and mobile phone experience, locus of control, vocabulary, short-term memory and spatial ability [5][14][15][16]. After filling in these, the participants were given a short training, which demonstrated concept of the scenarios and helped the users to get basic feeling of the application. The purpose of this was to bring all participants to the same level before letting them work with the application; the purpose of the experiment was not to test whether people can figure out the interface but solely to evaluate effects of multimodal feedback.

Next, the participants completed four different scenarios, each under different condition, which were:

1. Text only (control condition);
2. Text and speech;

3. Text and graphics;
4. Text, speech and graphics.

The distribution of the conditions was counter-balanced among the participants.

In the experiment setting, we included a number of functions in the diet diary application that would help collect measurements and keep the experiment under control. We added logging of all user actions and excluded possibility to turn off or on various feedback modalities during application use; instead this could only be selected at application startup.

After each scenario, the participant filled in two questionnaires, a NASA-TLX workload questionnaire and a diet knowledge questionnaire related to the scenario [9]. The retained diet knowledge of the user was used to measure effectiveness of the diet diary. Upon completion of all four scenarios, participants were required to fill in a final questionnaire by putting their interface preference, perceived quickness of use, perceived ease of use and clarity in an ordered list from, rating four conditions from best to worst. This last questionnaire was used to evaluate user satisfaction with the four different feedback modality combinations. Based on the order in which the participants put the four conditions, we awarded a score to each condition; condition rated as best was scored with 4 and condition rated as worst was scored with 1. Finally, the users were debriefed, and they received an opportunity to ask questions and comment on both application and experiment.

In addition to issuing questionnaires we extracted data from the logs that were made during diet diary use. Logs allowed us to assess the time participants need to compete each scenario, count the number of user actions and count the navigation errors made by users. Errors are defined as user actions that resulted in reaching other part of the diet diary menu structure than intended by the scenario. These three variables were used to measure user efficiency. Table 2 lists the variables that were recorded during the study.

Before the experiment, we conducted a pilot to make an estimation of the time and effort required for the participants to complete the different tasks and assess if the application functioned properly. Following the pilot we assessed that, although the tasks differ, the time necessary in order to complete them and mental effort was similar. In addition, we made one main adjustment to the application, i.e., the ‘Food Pyramid’ that was used in the application initially for food group subdivision was substituted for the ‘Disc of Five’.

To study the effect of multimodal feedback on the usability of mobile devices for older adults, our research questions read: How do different multimodality conditions have a significant effect on effectiveness, efficiency and satisfaction of the users? Moreover, can the users’ characteristics explain the variance in diet diary use and outcomes?

The influence of multimodality conditions on the usability of the diary was evaluated through repeated measurement analysis of variance (ANOVA). Moreover, to compare performances on different scenarios, outcome data was standardized prior to analysis. The influence of user characteristics on the variance in user performance during the experiment was evaluated through multiple regression analysis.

Table 2. List of all variables that were measured during experiment, the range of variables and measurement method

Variable	Range	Measurement method
Age	65-75	questionnaire
Education level	1-8 (low-high)[3]	questionnaire
Gender	M / F	questionnaire
Computer use	1-4 (low-high)	questionnaire
Mobile phone feature use	0-7	questionnaire
Locus of control (LOC)	0-20 (low-high)	test sheet
Vocabulary	0-20 (low-high)	quiz
Short term memory	0-14 (low-high)	test
Spatial ability	0-20 (low-high)	test sheet
Diet knowledge	0-5 (low-high)	test sheet
NASA-TLX	0-100 (low-high)	questionnaire
Scenario time	0m – 15m	log
Number of user actions	> 0	log
Number of errors	0 and up	log
Preference	ordering	questionnaire
Perceived quickness	ordering	questionnaire
Perceived clarity	ordering	questionnaire
Perceived ease of use	ordering	questionnaire

4 Results

4.1 H1: Do Different Multimodality Conditions Have a Significant Effect on Effectiveness, Efficiency and Satisfaction of the Users?

As illustrated in Figure 2 (graph of satisfaction of different modality conditions), results show that participants preferred the combination of text and graphics modalities (*M*=3.33, *SD*=0.74) over only text (*M*=2.11, *SD*=1.14), text and speech (*M*=2.00, *SD*=0.72) and text, speech and graphics (*M*=2.56, *SD*=1.25), F(3, 104)=9.7637, p<0.001.

Similarly, the users also thought that the combination of text and graphics was quickest to work with (*M*=3.26, *SD*=0.77) over only text (*M*=2.81, *SD*=1.16), text and speech (*M*=2.04, SD=0.74) and text, speech and graphics (*M*=1.89, SD=1.00), F(3, 104)=13.313 , p<0.001.

For perceived ease of use, the users once more rated text and graphics the highest (*M*=3.33, *SD*=0.68) over just text (*M*=2.33, *SD*=1.17), text and speech (*M*=2.07, *SD*=0.83) and text, speech an graphics (*M*=2.26, SD=1.21), F(3, 104)=8.2545, p<0.001.

Finally, for perceived interface clarity, users rated the text and graphics the highest again (*M*=3.44, *SD*=0.64), over text (*M*= 2.11, *SD*=1.21), text and speech (*M*=1.93, *SD*=0.57), and text, speech and graphics (*M*=2.63, *SD*=1.23), F(3, 104)=11.72, p<.001.

[3] Education levels ranged from lower education to university education and higher. The levels were based on the Dutch education system.

In relation to effectiveness and efficiency, results show that the feedback modality combinations did not significantly affect users' performance. No significant differences were found in retained diet knowledge, scenario time, number of errors and number of performed actions.

4.2 H2: Can the Users' Characteristics Explain the Variance in Diet Diary Use and Outcomes?

As displayed in Table 3, results show that personal characteristics can explain variance in the evaluation of the diary to a certain degree. Spatial ability had a significant influence on diet knowledge (effectiveness); the users with higher spatial knowledge in general were able to retain more diet knowledge that was presented to them during the experiment. Scenario time (efficiency) was significantly influenced by previous user experience with computers and mobile phone use; this was a negative relation however. The participants who used computers less often and used less mobile phone features tended to finish the scenarios quicker. Finally, number of actions required to finish a scenario (efficiency) was influenced by age and spatial ability. Younger participants were able to finish scenario quicker. The relation with spatial ability is negative in this case, the participants with lower spatial ability tended to finish scenarios quicker. Number of errors made (efficiency) was not significantly affected by user characteristics.

Table 3. Multiple regression analysis results: effects of user characteristics on effectiveness and efficiency. Only significant effects are listed, $p < 0.05$.

Predictive	β	R	ΔR^2
Diet Knowledge			
Spatial Ability	0.423	0.345	0.119
Scenario Time			
Computer Experience	-0.315	0.219	0.048
Number of cell phone features used	-0.317	0.267	0.023
Number of Actions			
Spatial Ability	-0.371	0.214	0.046
Age	-0248	0.296	0.042

4.3 User Comments

During the interview, most participants indicated that the application would be useful for them or that they see how it would be useful in applied sense. Most participants also found that the application is user friendly. Considering feedback modalities, there were particularly different views on speech. Some users found speech useful and helpful, while others said that the speech was irritating. A couple of participants was also concerned about privacy, being worried that speech might give away information about their diet and health if the diet diary is used in public.

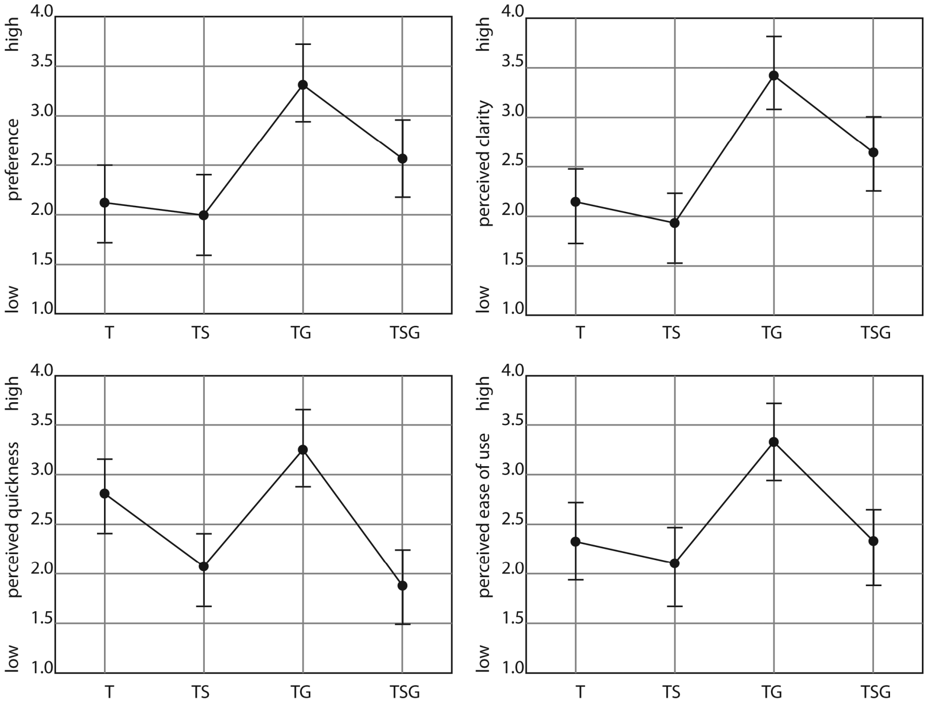

Fig. 2. Satisfaction parameters as rated by the experiment participants. The letters T, S and G stand for Text, Speech and Graphics, respectively. The four conditions are T: text only, TS: text and speech, TG: text and graphics and TSG: text, speech and graphics.

5 Discussion and Conclusion

The motivation for this study came from earlier studies on improvement of older adult self-care through use of digital assistants, specifically, digital diet diaries [1][4]. These studies indicated that many older adults would prefer if their digital diet diaries would be deployed on a mobile device. They also indicated that usability of diet diaries should be improved in relation to interface modality [1][4].

Consequently, we designed and evaluated a multimodal mobile diet diary. We paid special attention to usability during this process. Further, we explored the notion of multimodal feedback increasing usability, how can this be achieved on a mobile device, and whether it has a positive effect on usability for older adults.

To test this, we conducted an experiment. Using within-subject design and scenario based approach we tested four different multimodal feedback conditions with 32 older adults. The study indicated that user satisfaction was by far highest if the feedback in the diet diary was provided through a combination of text and graphics. The effectiveness and efficiency of the users was not influenced by different feedback conditions. This is interesting because the users perceived that they were working quicker and easier with a combination of text and graphics, while in reality there were no significant differences.

However, these results are in line with previous findings. Other studies have also shown similar results when measuring effectiveness and efficiency of application use by older adults under different multimodal interaction conditions [6]. Another reason that we did not find a significant effect of multimodal conditions on user performance could be that the user characteristics variability rises with age and as result, is quite high among older adults [10]. Subsequently, we found a number of cognitive and experience-related user characteristics that had a significant influence on user performance, although the combined effect was not very large. It is interesting to note that the relation between spatial ability and scenario time was negative. This indicates that people with higher spatial ability generally spent more time exploring the interface, while people who have lower spatial ability stuck to the scenario more rigidly, in order not to get lost in the interface. Similarly, the users with lower computer and mobile phone experience tended to complete scenarios with fewer actions. This could be explained in the same way. There are probably additional user characteristics that we did not measure which played a role in user performance variability. If multimodal feedback conditions are correlated with effectiveness and efficiency, the effect might be too small to be statistically significant based on measurements we made with 32 older adults. Reinvestigating the effects of personal characteristics on multimodal mobile devices and increasing the sample size could help answer this question.

On the other hand, effect of multimodal feedback on satisfaction is quite striking. Combination of text and graphics was consistently higher rated than the other conditions. The users generally did not appreciate the spoken feedback that was included in two conditions, although we spent a lot of thought and care into implementing this and based our choices on proven theories [7]. When asked why did they not like speech as feedback, a number of users answered that they would like to keep their diet-related information private if they happened to use a diet diary in a public location, while spoken feedback would obviously give this away to bystanders. This again ties in with the variability of user characteristics and preferences. Users, and older adults in particular, make choices based on a wide and very personal selection of criteria.

Future studies in this area may focus on evaluation on larger scale, to make certain whether multimodal feedback affects user effectiveness and efficiency. Also, since we only focused on feedback in this study, it would be interesting to see the effects of multimodal input, or full multimodal interaction, on the usability of mobile application for older adults and in general.

In conclusion, we created a usable multimodal mobile diet diary. All users were able to successfully complete the scenarios and were uniformly positive towards the application. We did not find an effect of multimodal feedback on effectiveness or efficiency in diet diary use, but we did find a very strong effect on user satisfaction. This finding may help in design of interfaces for older adults in the future. User satisfaction is a very important criterion because a satisfied user will tend to use the product longer and more often. This is especially important in the field of eHealth where medical adherence is crucial [8][13].

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