COMPUTER, LIGHT ON!

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Abstract

The potential benefits of environment automation for older adults and for individuals with physical limitations are becoming well known. At the same time, there is concern that high-tech solutions will not be widely accepted by this target population. In this paper we present the results of a human factors study in which we allow individuals with varied backgrounds and physical limitations to selectively employ voice control of devices in their own homes. Here we summarize the results of the study and highlight issues for further investigation.

1 Introduction

Today in the United States there are 54 million people with disabilities [5]. Many of these individuals require help. The most common source of help are the 25.8 million US family members who provide 17.9 hours/week of unpaid care with a value estimated at $196 billion [2]. This figure looms large compared with national spending of $32 billion for formal home health care and $83 billion for nursing home care [2].

While human care cannot be replaced, intelligent environments can make a difference in the care for people with disabilities. Routine task automation offers the potential of reducing the load on caregivers and at the same time providing more independence and improving the quality of life for individuals with disabilities. Intelligent environment technology has matured to the point where it can provide benefits in everyday settings [3]. However, a primary hindrance to realizing this potential is the ease with which intelligent environment technology can be integrated into the lifestyle of its residents.

We hypothesize that spoken language provides a natural and appropriate method of interacting with a smart environment. To validate our hypothesis, we recruited ten volunteers with a variety of backgrounds and physical limitations to test voice-controlled automation of an electrical device in their homes. Here we summarize the results of the study and highlight areas for future research. This work represents one of the first usability studies for intelligent environment technologies and is an important direction to pursue if we want to transition the technologies from the research environment to everyday usage.

2 Voice Control of Intelligent Environments

For our study we installed a laptop computer in the home of the participant and connected a microphone to the computer. We recognized that the quality of the microphone and of the speech capture and recognition software could play an important role in the acceptance of the technology by our participant group.

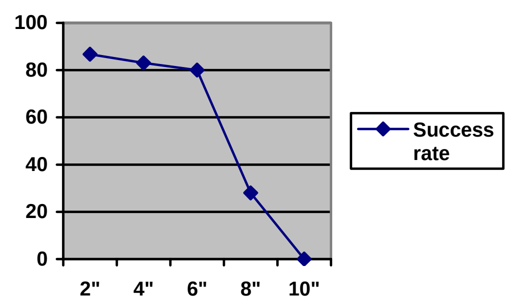

Figure 1: Spoken command performance rate as a function of microphone distance.

For our study we used a low-cost microphone with noise cancellation technology. We determined experimentally that the success rate (measured in number of correctly heard commands) for this microphone drops to zero at distances greater than 10” (see Figure 1). Based on these findings, we moved all ambient noises (e.g., TV, kitchen noises, people talking) at least 10” from the microphone. Our computer controlled two lights using Insteon controllers and issued the corresponding powerline command once it heard the appropriate command through the microphone interface. Our test room was 20’x12’x10’. During the three-hour experiment some of the ambient noises were interpreted as legitimate commands and as a result the lights went on and off by themselves twice.

3 Experiment Design

This goal of this study was to determine if and under what conditions people would use voice interfaces to control their living environments. Our participant group consisted of ten individuals. Five of these individuals had physical disabilities that resulted in mild to severe mobility and agility limitations. The participants were predominantly elderly females: there was only one male participant and the mean age of the group was 63.4 with a median age of 61 and a range from 44 to 87. Three of the participants were employed, the rest were retired. None of the participants had any known cognitive, hearing, speech, or visual disability.

For each participant we set up a voice user interface (VUI) to control a light or appliance in the participant's home. The device was selected by the participant with encouragement to select one that would be used often throughout the day. The selected devices were generally desktop lamps, standing floor lamps, or portable radios. We utilized Perlbox-Voice, an open source application, to execute actions in response to specific spoken commands. The participants' list of spoken commands included "Computer, Light On" and "Computer, Light Off". In addition, we installed ilink on the laptop, which is an open source program that allows a computer to manipulate electrical appliances by sending a command through the powerline. An Insteon powerline controller and the microphone were directly connect to the laptop, as shown in Figure 2. The selected device was connected to the Insteon controller. A standard switch was also connected to the controller, so that participants could use either the voice interface or a standard switch to control the device.

Figure 2: Hardware configuration used for study.

After training the participant in the user of the VUI, we asked them to operate the device in whichever manner (voice interface or manual switch) they preferred over a three-day period. The participant's usage pattern was recorded automatically by the sampling program and later analyzed to determine how often the participant operated the device manually or with the VUI.

In our interactions with some participants we found that the "light on" and "light off" commands were so similar that the computer occasionally experienced difficulty distinguishing between them. We also found that robustness increased if we employed an activation word before the command (in our case, "computer"). This allowed the software to distinguish between the command word "light" and the word "light" used in normal conversation near the microphone. The voice recognition error rate for the ten trials ranged from 0% to 10%, and in most cases did not exceed 5% of the total number of issued commands. The number of commands themselves ranged from 46 to 120 over the three-day trial.

A short survey was conducted before the beginning of the trial with each participant. The survey queried the participant for socio-demographic information, disability status, and pre-study bias and attitudes toward computer-based technologies. An exit interview was also held with each participant on the day after the end of a trial. The one-day delay in conducting the interview was designed to identify the value of the voice automation for the participant and was based on the notion that sometimes the value of something comes only after losing it. During this interview participants were asked how they felt about using the technology and how they felt about no longer having the technology. They were also asked to list the positive and negative aspects of the experiment and to comment on features of the system including the time delay between command and action, the performance of the voice recognition software, and so forth. The qualitative data obtained from the interviews was coded using Grounded theory methods [6].

4 Study Results

To assess user experience with the VUI, we calculated the ratio of the VUI / manual operations. The results are summarized in Table 1. Note that this ratio is never less than one, which normally would indicate strong user preference in favour of VUI control. However, this result should be treated cautiously because of phenomena such as the Hawthorn effect (change in participant behaviour may occur due to knowing they are in a study) and the effects of novelty (any change produces an increment in behaviour) [4]. With a longer trial period the impact of such effects could be minimized.

The VUI / manual operation ratio, though valuable, does not fully reflect user experience during the trial. Therefore we also summarize the following three themes that reoccurred during exit interviews to better summarize the user experience:

1. More devices. Some of the participants indicated that they would like to be able to operate more devices throughout their home. One participant specifically requested control of the hallway light to prevent falls during the frequent times they got up at night.
2. Usefulness of the system. Despite the limitations of the system, including the ability of the system to only operate one device and that from a short distance, several participants found the system to be quite useful. Perhaps not coincidentally, all of

the participants who indicated that the system was useful also had some level of physical disability.

3. Potential usefulness. A number of participants indicated that even though the system is not useful in its present state, it would be useful if the limitations (number of devices controlled, microphone location, and speech recognition problems) were overcome.
4. Fun. Most of the participants, even if they did not find the interface useful, did find the automated control of the device to be appealing.
5. No negative experiences. Even though almost every participant reported at least one problem with the setup, when confronted with the question of whether there were any negative effects from the experiment none indicated that there were any.

In determining a quantitative value for the quality of the user's experience with the VUI, we calculated the total of the VUI/manual ratio and added 1 for each category where the participant responded positively. The category values and overall VUI score are summarized in Tables 1 and 2.

ID	VUI / Manual ratio	More devices	Useful	Potentially useful
1	1.8	0	0	0
2	1.5	0	0	1
3	2.1	1	1	0
4	1.7	0	0	0
5	2.3	1	0	1
6	1.2	1	1	0
7	2.4	1	0	1
8	1.3	0	0	0
9	1.8	1	0	1
10	2.0	1	0	1

Table 1: VUI use score for each participant.

ID	Fun	No negative experience	**Total VUI Use Score**
1	1	1	**3.8**
2	0	1	**3.5**
3	1	1	**6.1**
4	0	1	**2.7**
5	1	1	**6.3**
6	1	1	**5.2**
7	1	1	**6.4**
8	0	1	**2.3**
9	1	1	**5.8**
10	1	1	**6.0**

Table 2: VUI use score for each participant.

Despite the generally positive reaction to the study, at least one of the following three types of problems was reported by every participant:

1. The user had trouble remembering the exact way to say the commands. Sometimes a participant would forget to use the activation word before the command itself. At other times a participant would forget the command itself though remembering the activation word. Some participants wrote down the command and kept it close to the microphone. Given the fact that there were only two commands to remember, it was surprising to observe that 6 of the 10 participants reported this type of problem. Taking into consideration the age of the participants who reported this problem (59+), this indicates an important design issue if such a system is intended for use with elder adults. As the number of automated devices increases, remembering all of the commands will become a challenge even for younger users.

2. The user reported that the "computer did not hear the command", which mean that the command was given in a correct manner but no action followed. In addition, a couple of the participants expressed the desire for the microphone to be more sensitive. These types of problems were anticipated given our experimental analysis of the microphone and speech recognition software.

3. The user complained about the need to come close to the microphone. This problem was most often reported by participants with disabilities (5 out of the 6 complaints of this type were lodged by participants with physical limitations). This points to the particular value a VUI or other type of automated control of devices in an intelligent environment: it allows users to operate devices remotely. The frequency of each type of reported problem is graphed in Figure 3.

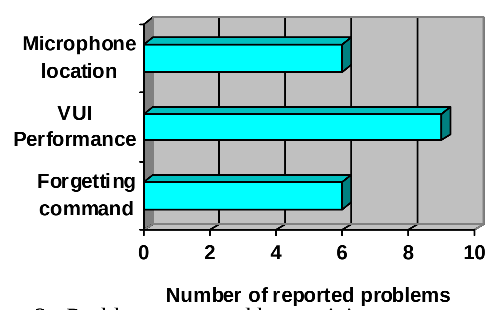

Figure 3: Problems reported by participants.

In order to identify correlations between features of the participants and their experiences with the VUI, we computed a problem score and a disability score. The problem score sums the number of reported problems with the setup and the disability score is 0, 1, 2, or 3, depending upon whether the participant has any disability, uses a wheelchair, and experiences problems with agility. The scores for each participant are shown in Figure 4.

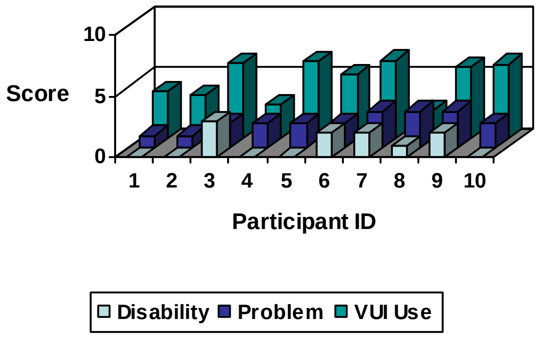

Figure 4: Study results summarized by section.

We notice from these results that participants with higher scores for disability also receive higher VUI use scores. Participants with disabilities were also more likely to express the desire to be able to operate more devices by voice (4 out of 5) and to find the system potentially useful if the reported problems could be overcome.

In contrast, almost none of the participants without disabilities found the system helpful in its current state, with the exception of one participant who enthusiastically indicated that the system would be useful if it could more robustly control all of the devices in the home.

Another unique case is participant 10, who did not report a disability yet found the voice control of a device very useful. However, this participant was the oldest in the sample (87 years old) and thus likely found remote control of a device convenient even if it was not necessary.

Interestingly, the majority of the participants (9 out of 10) believed that computing technologies could improve the quality of their lives. This question was asked before the trial, and none of the participants were familiar with intelligent environment technologies and their potential benefits. At the end of the trial, regardless of the limitations of the tested system, none of the participants changed their positive outlook. The reported problems were not reflected as negative experiences, but rather as temporary issues that could and should be overcome.

An additional observation is that while the participants were aware that the system was operated by an inanimate object (the computer), most of them tended to refer to it as a living being. In fact, two of the participants insisted on using the word “please” as an activation word or as part of the command itself, stating the rationale that “one must be polite when asking for something”.

5 Conclusions and Directions for Future Work

The question we want to address is that, given the fact that 30% of non-institutionalized older Americans (10.6 million people) live alone [1], is it plausible for a VUI or another intelligent conversational agent to provide a natural interface between older adults, with our without physical disabilities, and intelligent environments?

Given the positive assessments of the VUI by our study participants, the initial response to the question appears to be positive. These results, however, should be treated with caution. The short period of the trial and the limited scope of the control did not provide sufficient VUI exposure to generalize the collected findings.

Based on these results, our future work will expand this study to design longer trials with a larger collection and diversity of controlled devices. We will also compare alternative interfaces as well as automated control of devices based on learned patterns. In addition, we would like to target population subgroups from a variety of cultural and socio-economic backgrounds. To address the limitations of the setup used in this study, we will employ a wireless microphone and more robust speech recognition software.

This study provided a much-needed foray into the area of usability studies for intelligent environments. The study results highlighted the need for this technology. The research also pointed to some limitations in the current technology and the need for improvements. In future studies we will make use of higher-quality noise-canceling microphones and expand the number of microphones as well as the number of devices controlled by the computer. Given the likely economic impact and improved quality of life for individuals trying to maintain their independence, we feel that such studies will be instrumental in bringing intelligent environment technologies to the individuals who are ready to embrace them.

Acknowledgements

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References

[1] Administration on Aging. A statistical profile of older Americans aged 65+. http://www.aoa.gov/press/fact/pdf/ss_stat_profile.pdf.

[2] P.S. Arno, C. Levine, and M.M. Memmott. The economic value of informal caregiving. *Health Aff*, 18(2):182-188, 1999.

[3] D. Cook and S. Das. How smart are our environments? An updated look at the state of the art. *Journal of Pervasive and Mobile Computing*, 3(2):53-73, 2007.

[4] R.J. Corsini. The Dictionary of Psychology. Psychology Press, 1999.

[5] Rehabilitation Research and Training Center on Disability Demographics and Statistics. 2006 Disability Status Report, Cornell University, 2007.

[6] E.M. Rogers. Diffusion of Innovations. The Free Press, NY, 1995.