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ABSTRACT
Traditional television remote control presents frequent challenges to older adults. These challenges arise due to lack of feedback and poor design features such as labeling, size, spatial proximity, physical feel, etc. This paper describes the design of an accessible TV remote control (Potmote) created by employing potentiometers with Arduino to enhance tactile feedback and ease of channel selection with ergonomic controls. An experimental study was conducted with 15 older adults to understand how to design a system that would allow them to change channel numbers and volume levels. The result of experiment have shown positive feedback by the subjects.

ACM Classification Keywords
H.5.2. User Interfaces: Ergonomics; H.5.2 User Interfaces:: Interaction Styles

Author Keywords
TV Remote control; Older adults; Arduino; Potentiometer

INTRODUCTION
The world population is aging. According to a report [12], "An Aging World: 2015" 17 % of the world population comprises of Older Adults (>65 years). This demographic shift necessitates thoughtful design of products to better meet the needs of elderly population. Adults aged over 65 years in Europe spend threefold more waking time watching TV than young adults [6]. Though TV is a most common source of engagement & entertainment, the elderly requirements are not often considered either in the design of remote controls [2]. This leads to dependence on caretakers and hence psychological dissatisfaction among older adults[16].

Remote controls are a ubiquitous part of life. However, the experience of using a remote control is not always pleasurable. The shape of the traditional consumer remote control is a rectangle, reflecting the engineering underpinnings (e.g., the shape of the circuit board). There are too many buttons that are too small, difficult to read, difficult to approach with poor discriminability. Since this is time-based performance, a delay in the button press, loses multiple commands. Also, over pressing to ensure the change also leads to an error due to lack of visual feedback [5]. Despite changing size of either the buttons or overall physical size of the device; the spatial arrangements, legibility is still a challenge to the users [16].

This paper presents Potmote: a remote control that uses potentiometers & arduino. It enhances tactile feedback and ergonomic controls to ease the channel and volume selection. The current prototype is built on framework GUIDE [8] and learning from MYUI project [13]. The prototype is aimed at improving the interaction with TV based systems. The findings can help inform the development of accessible universal remote control for older adults more broadly.

RELATED WORK
Haptic feedback from physical knobs, potentiometers, sliders, etc. has received considerable interest in recent past. Roger et al. [14] evaluated the efficiency of interaction across various controls, showed better performance with rotary encoder than a touch screen or button designed interface. Other designs of remote control for elderly has also been investigated extensively. Bobeth et. al [2] proposed a possible alternative to physical remote control using gesture techniques with older adults. However their system had limitation to recognize longer interactions. RD Vatavu [15] provides guidelines for controlling basic TV operations with mid-air gestures.

There have also been some inventions with respect to Electronic Program Guide (EPG) devices in the recent past [1] [7]. For example, Hara et. al. in 2009 investigated effects of cognitive aging independently from lack of mental models [9]. In their findings, older adults showed problems interacting with the EPG and experienced errors. Of a range of possibilities, that includes exploring different size of buttons and remote control size, one key area of interest is still aimed at improving the interaction with TV based systems for older adults.

POTMOTE: DESIGN PROCESS & EXPERIMENT
To understand the accessibility of TV remote among the older adults, a focus group was conducted. The older adults in the sample comprised of 15 people (8 Male & 7 Female) from India with mean age of 70.5 years. All participants were using traditional TV remote control. We found that selection of buttons is a big challenge for older adults because of its size, cluttered arrangement of buttons and illegible labels. In addition, all of them pointed out the use of rotary buttons on radio as their simplest form of interaction to interact with a device. Based on results of focus group, we decided to adopt rotaries. The process used to design Potmote was highly iterative based on feedback from focus group, however they were

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not included in design process to avoid bias during experiment. From initial conceptualizing, approximately 5 remote concepts were created. From this pool, 1 final design was chosen for further exploration based on GUIDE framework [8].

Potmote consists of 2 blocks (*refer Fig.1*). The lower block consists of 3 rotary switches with detents for changing the channel numbers (as all channel numbers have 3 digits). The spacing between the rotary switches was given by reachable space principle of anthropometry [11]. Each switch can rotate from 0 to 9. For channel change of single digit (e.g. 004) only first rotary from left (see figure 1a) is used, i.e. a channel change from 0 to 4 will require just 4 forward rotations on rotary. For channel change of two digits, first two rotaries will be used. Similar pattern follows for 3 digit channels as well. The remote will wait for 3 seconds before changing the TV channel after the first digit is entered, so as to avoid confusion if more digits need to be input (standard delay between entering multi digit).

The upper part of Potmote consist of volume regulation between 0 - 100. The weight of the current prototype is 105 grams & uses 2 AA batteries. Potmote uses infrared sensors to connect to TV. It also emanates a distinct audible "click" sound that is used as an auditory feedback for channel change.

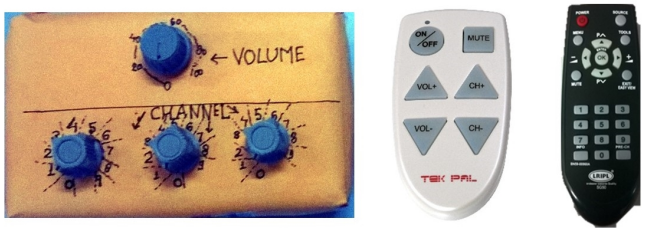

Figure 1. From left, a) Potmote b) Tekpal c) Traditional Remote Control

Experiment

We compared 2 remote controls with Potmote: Tekpal [3] & Traditional Remote Control [4] (Fig. 1) for 2 tasks: volume & channel control, based on frequency and need for use. An experiment was conducted with 15 older adults from focus group with 3 remote controls in random order. All participants were given 15 random channel numbers of equal difficulty for 3 remote controls (rotations on knob for potmote) and were asked to change the channel numbers. Each channel number was informed to participant after every trial. Similarly, for volume control a range of 10 digits was provided eg. 40-50 for every trial. For Traditional Remote Control, channel change for all 1/2/3 digits was performed with buttons labeled as 0-9. Tekpal was used only for 1 digit channel numbers as it needs successive continuous presses for 2/3 digit numbers.

RESULT

Accuracy was compared to change volume/channel for 3 remote controls. As soon as the channel change was done, data was stored in Arduino. It was calculated by number of errors made during the course of 15 trials for all digits channel change and volume. A change to channel number which was different from given was considered as an error. Along with this, evaluation of the experience of the Potmote was done with AttrakDiff model [10].

	Remote Controls			
Channel & Volume	*Potmote*	*Tekpal*	*Traditional Remote*	*p-value**
1-digit	99.17	92.14	98.77	0.026
2-digits	98.44	N/A	90.46	0.032
3-digits	95.32	N/A	84.44	0.043
Volume	90.64	81.46	79.59	–

Table 1. Accuracy results in %. One-way ANOVA results from post hoc tests with Bonferroni correction assuming Normal distribution.

In Table 1, Potmote performed better than other 2 remote controls in terms of channel selection & volume change. Also, the variance of the data for Potmote was less compared to Tekpal & Traditional Remote Control. We performed 1-way ANOVA* to test statistical significance of the results for channel change. The results indicates that the average number of errors in channel change for all digits was significantly lower in potmote (M = 2.4, SD = 1.09) than in the other two remote controls combined (M = 3.62, SD = 5.56), $F(3, 45) = 7.77$, $p = 0.042$.

In addition to this, to understand the UX of potmote with user we collected Word-Pair combinations using AttrakDiff model. Potmote was perceived as simple, clear, structured, cheap, creative, attractive and practical. While most of the word-pairs shows a tendency towards a positive experience, resulted Pragmatic Quality indicates that users are achieving their goals using potmote. One of the user (Male, 73) reported: "*To me, Potmote is just too simple. There is not enough variety. It doesn't give me the opportunity that this one (Traditional Remote) does. For me, the edges on knob and tick-tick sound is very vital as it gives me a clue that channel change is done.*"

CONCLUSION

This paper evaluated use of 3 remote controls in terms of accuracy with channel and volume selection task. In addition to that, for created prototype AttrakDiff evaluation was performed to understand UX of the prototype. The participants frequently mentioned that their decreased ability to learn was the reason why they preferred to use relatively simple forms of technology that do not require additional learning.

Although the prototype was fabricated in the lab, the results observed from participants are encouraging. However the users suggested us to further improve the prototype, considering dedicated ON/OFF, reducing the size of the remote and using better material to design the remote control. We take these suggestions to work upon in near future. Considering that the Potmote was new, the adaptation time as a function of accuracy across all the trials gives the author an opportunity to investigate more robust designs in future.

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