TV Applications for the Elderly: Assessing the Acceptance of Adaptation and Multimodality

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***Abstract*— Current TV applications present uncountable challenges to an elderly user and these are prone to increase, working as a vehicle of exclusion. The GUIDE project aims at improving the elderly experience with present TV applications by deploying interfaces adapted to their abilities and preferences. We do so by building the interface based on a user model and providing new ways to interact with the TV (multimodality), and tailoring the UI to the users' abilities, needs and preferences. In this paper, we assess concepts of the GUIDE framework with particular focus to the User Initialization Application (UIA), an interactive application able to build the aforementioned user model. We report an evaluation with 40 older users from two countries (UK and Spain). Results show that the UIA is able to create adequate profiles and that the users are able to positively observe the adaptations. Further, novel ways of interacting with the TV were also successfully evaluated as the users tended to experiment and rate positively most alternatives, particularly Speech and Tablet interaction.**

Keywords-accessible applications, elderly, multimodal, simulation, GUIDE

I. INTRODUCTION

The rapid increase of new TV-based systems and applications excludes users with certain impairments or different levels of technology awareness and expertise from accessing the same information as others do. By 2050 elderly people will represent 26% of the developed countries' population. Living in this constantly evolving world is getting harder, leaving them no time to adapt to modern technology from which, sooner or later, their well-being and social inclusion will dramatically depend. Having this type of technology adapt to each user without requiring too much learning and giving them similar opportunities as everybody else is the only way to prevent this. However, solutions being studied focus more on the use of assistive devices to help or guide the interaction than on the design of inclusive systems. We can offer valuable contributions for making this type of systems and applications more accessible by focusing on modern research in multimodal interactive systems, leading to less effort from elderly users, and offering them more natural ways of interaction.

This paper focuses on how the GUIDE project concentrates on the integration of several natural modalities and devices towards the inclusive use of TV-based applications in the user's home. Special attention will be given to the understanding of how elderly people can interact naturally with this type of technology. With this in mind, and after presenting related work, we will show how the GUIDE framework is built around keeping relevant user information stored and accessible in a User Model component. This allows adapting UIs, based on the specific user characteristics and preferences as well as on a context model. We will then focus on how a novel approach called User Initialization Application (UIA) was implemented. This process allows discovering each user's relevant characteristics for the system to adapt in the most appropriate and understandable way. At the same time, the UIA instructs the user on how to make use of the most suitable interaction possibilities available. We complement and attest these approaches with the description and results of a user study consisting of a technical trial with both the UIA and a TV based realistic Electronic Program Guide (EPG) application. We present results of the evaluation of the UIA capability to discover user characteristics and assign user profiles. With the EPG application we assessed users' modality preferences and evaluated the adaptation capabilities of the framework. The paper main contributions are the results of user studies conducted in two different countries (Spain and UK) with 40 participants, and the evaluation of novel approaches on adaptability and multimodal interaction of TV-based systems supported by the UIA application and GUIDE's multimodal and adaptive capabilities.

II. RELATED WORK

Elderly users are getting detached from technology and consequently from the modern world characterized by innovation in interaction and communication standards. In a society where people live longer, it's common to see elderly people living alone and struggling to adapt to all the technological advances [13]. Although older people are not generally considered to have disabilities, the natural ageing process carries some degenerative ability changes, which can include diminished vision, varying degrees of hearing loss, psychomotor impairments, as well as reduced attention, memory and learning abilities [20]. However, problems learning to use and engage with interactive technology are not confined to physical and cognitive factors [11]. In recent investigation, it is clear that even if computer based systems are a positive influence on the lives of older people [12], they tend to reject standard technologies [8] or technologies too

 ISBN: 978-1-61208-250-9

difficult to use, that look bad, make them appear older, or that do not appear to have net gain effect for them [7].

For these reasons, Information and Communication Technology (ICT) must be adjusted to ensure that elderly users are not disadvantaged when using it [7, 8]. This accommodation can only be done by realizing the consequences associated with ageing and offering natural and efficient ways of interacting with both new and well-known technical systems.

Multimodal interfaces aim to provide a more natural and transparent interaction to users. They have been able to enhance human-computer interaction (HCI) in many ways, including: User satisfaction: studies revealed that people favor multiple-action modalities for virtual object manipulation tasks [18], and that about 95% of users prefer multimodal interaction over unimodal interaction [18]; Robustness and Accuracy: "using a number of modes can increase the vocabulary of symbols available to the user" leading to an increased accessibility [16]. Oviatt stated also that multiple inputs have a great potential to improve information and systems accessibility, because by complementing each other, they can yield a "highly synergistic blend in which the strengths of each mode are capitalized upon and used to overcome weaknesses in the other" [19]; Efficiency and Reliability: Multimodal interfaces are more efficient than unimodal interfaces, because they can in fact speed up tasks completion by 10% and improve error handling and reliability [17]; and Adaptivity: Multimodal interfaces offer an increase in flexibility and adaptivity in interaction because of the ability to switch among different modes of input, to whichever is more convenient or accessible to a user [16]. For all these reasons, multimodal interfaces have the potential to increase ICT applications' accessibility for elderly users. Introducing elderly users to multimodal solutions makes possible a familiar and natural step through the accommodation necessary to ensure that older users are not disadvantaged when using new technologies like the ones based on TV and STBs [13, 21].

Interface personalization is mainly explored in the domain of content personalization and developing intelligent information filtering or recommendation systems based on user profiles. In most of those systems, content is represented in a graph like structure and filtering or recommendation is generated by storing and analyzing users' interaction patterns. Little research has been done beyond content personalization. A few significant projects on interface personalization are the SUPPLE project[10], the Lumiere Project [14] and the AVANTI project [22] for people with disabilities. The SUPPLE project personalizes interfaces by changing layout and font size for people with visual and motor impairment and ubiquitous devices. However, the user models do not consider visual and motor impairment in detail and thus work for only loss of visual acuity and a few types of motor impairment. The Lumiere project uses an influence diagram in modeling users. This records the relationships among users' needs, goals, background etc. The AVANTI project provides a multimedia Web browser for people with light or severe motor disabilities, and for blind people. It distinguishes personalization into two classes: static adaptation which is personalization based on user profile and dynamic adaptation that is personalization following the interaction pattern with the system. However, the Lumiere project does not generalize their personalization mechanisms for other applications and the AVANTI project only addresses a small segment of disabilities for a particular application. The lack of a generalized framework for personalization of users with a wide range of abilities affects the scalability of products.

III. THE GUIDE PROJECT

As a multimodal adaptive system, GUIDE offers several modalities of interaction coordinated by the system core, through fusion and fission modules that function based on a User Model [4], which represents the user, and a Context Model, which represents the context (environment, devices, etc.) the user is in. Input modalities are based in natural ways of communication for humans: speech and pointing (and gestures). Complementary to these modalities and being based in a TV environment, the system also supports the usage of remote controls (both traditional and endowed with gyroscopic capabilities) and other devices capable of providing haptic input or feedback. GUIDE incorporates four main types of UI components: visual sensing and gesture interpretation; audio; remote control; haptic interfaces and a multi-touch tablet. In what concerns the output modalities, the framework integrates the following: video rendering equipment (TV); audio rendering equipment (speakers); tablet supporting a subset of video and audio rendering; and remote control supporting a subset of audio rendering and vibration feedback. The tablet, used as a secondary display, may be used to clone the TV screen or complement information displayed on the TV. In addition to the application's interface, the framework is capable of rendering a 3D avatar. This is expected to play a major role for elderly acceptance and adoption of the GUIDE system, being able to perform non-verbal expressions like facial expressions and gestures and giving the system a more human like communication ability. Both input and output modalities can be used in a combined manner to enrich interaction and reach all user types. In order for the UI to be adapted to the user's preferences and abilities, the interface elements are highly configurable and scalable (vector-based). Graphical properties like size, font, location and color are some attributes needed to ensure adaptability. Other modalities' properties, like sound volume, are also configurable. The GUIDE User Model, responsible for the dynamic adaptation of the system, will be described in a later section.

A previous study was conducted last year [5] with the goal of identifying the most relevant UI component configurations and user impairments for elderly users. This was particularly important for deriving a list of relevant topics and metrics to be considered in the development of accessible applications for these users. Closely connected to the new study are the conclusions related with the way elderly prefer and perform multimodal interaction in TV-based systems. However, in the previous study the application used was not a realistic TV-application. Thus, a more contextualized evaluation can be done. Additionally, the process of user characterization and clustering is now focused.

IV. THE USER MODEL

The GUIDE user model maps users' functional parameters to interface parameters. It was developed using a simulator [4] and calibrated through the user study [5] discussed in the previous section. The simulator consists of detailed models of visual and auditory perception, cognition and motor action. The simulator can show the effects of a particular disease on visual functions and hand strength metrics and in turn their effect on interaction. Using information from more than 100 users from three different countries (Spain, UK and Germany), collected with an extensive survey focusing a wide array of characteristics, we have selected a set of variables that are relevant to the user model and statistically significantly different among clusters ($p<0.01$). We separately clustered these data for visual, cognitive and motor abilities of users using k-means clustering. Table 1 shows the cluster centers.

Table 1: Cluster Centers

Visual[1]	A	B	C
CS1 (Contrast Sensitivity on Pelli Robson Chart n. 1)	0.15	1.75	1.46
CS2 (Contrast Sensitivity on Pelli Robson Chart n. 2)	0.15	1.84	1.56
CS3 (Contrast Sensitivity on Pelli Robson Chart n. 3)	0	1.79	1.37
Cognitive	A	B	
TMTSEC (Time to complete Trial Making Test in sec)	45.97	115.3	
DIGIT_SY (Result on Digit Symbol Test)	45.93	23.71	
Motor	A	B	C
GS (Grip Strength in Kg)	16.22	25.02	58.68
ROMW (Active Range of Motion of Wrist)	71.28	51.58	65.67

Following this, we ran the GUIDE simulator [4], taking the parameters of each cluster centre for configuration, and generated recommendations for each cluster. Individual users were assigned to the recommendations based on their cluster memberships. For the present set of users we identified the following three profiles: Profile A: No adaptation required; Profile B: Increase button spacing (Mobility Impaired); Profile C: Increase button spacing + change Color Contrast (Mobility Impaired + Color Blind).

The GUIDE User Model predicts three sets of parameters: UI parameters for the Multimodal Fission Module, Adaptation Code for the Input Adaptation Module and Modality Preference for the Multimodal Fusion Module. The rules relating the users' range of abilities with interface parameters were developed by running the simulator [3, 4] in Monte Carlo simulation.

We began by selecting a set of variables to define a Web based interface. These parameters include: Button spacing: Minimum distance between two buttons to avoid missed selection; Button Color: foreground and background color of a button; Button Size: The size of a button; Text Size: Font size for any text rendered in the interface; Cursor Type: The shape and color of the cursor.

The user model predicts the minimum button spacing required, from the users' motor capabilities and screen size. The simulation predicts that users having less than 10 kg of grip strength or 80º of Active Range of motion of wrist or significant tremor in hand produce a lot of random movement while they try to stop pointer movement to select. The area of this random movement is also calculated from the simulator. Based on this result, we calculated the radius of the region of the random movement and the minimum button spacing is predicted in such a way so that this random movement does not produce a wrong target selection. Regarding the other parameters, the UIA takes user preferences for color, text size and cursor type. The user model stores these preferences. However if a user has color blindness it recommends an appropriated foreground and background color. The adaptation code aims to help users while they use a pointer to interact with the screen through the visual human sensing capabilities or the gyroscopic remote. So if the user has any motor impairment, the adaptation will remove jitters in movement through exponential average and then attract the pointer towards a target when it is near by using the gravity well mechanism [3]. Otherwise, the adaptation will only work to remove minor jitters in movement. The modality prediction system predicts the best modality of interaction for users. Though users are free to use any modality irrespective of the prediction, the fusion module uses this prediction to disambiguate input streams when there is more than one.

V. USER INITIALIZATION APPLICATION

The UIA is an introductory application that runs the first time a user initializes the system. When a new user is recognized, the UIA presents a step-by-step introduction of the system, acting as a tutorial on how to use the system and how to interact using the different modalities available. Another purpose of the UIA, as important as the one described before, is to expedite the user profiling procedure. It would not be feasible to ask each user of a mass market product to complete an extensive survey before using it. The UIA presents a much reduced set of questions and tasks to the user in order to allow the User Model to assign the user to one of the previously created profiles. Even though this does not allow for a profile perfectly fitted to the user, it is a good starting point for adaptation purposes, because the profiles described in the previous section were created from a large pool of representative users. Additional information collected during system usage is used to refine the user profile (run-time adaptation).

The tasks and metrics chosen for the UIA are the ones for which the resulting data is the most capable to assign the more appropriate profile to the user profile. They were selected from an analysis of the extensive survey data, taking into account the feasibility of gathering the data. For those instances where it was not feasible to gather the data in a living room environment, alternative sources were selected

[1] Each of these clusters is further divided based on presence of color blindness

and combined to estimate the required data. A description of these variables is listed below: Color Blindness: Plates 16 and 17 of Ishihara Test [6] as it may classify among Protanopia, Deuteranopia and any other type of color blindness; Dexterity: We estimated Grip Strength and Active Range of Motion of wrist from age, sex and height of users following earlier Ergonomics research [2]; Tremor: We conducted earlier a test involving a Tablet device in horizontal position, and estimated tremor from the average number of times users need to touch the screen to select small buttons. Details of the study can be found in a separate paper [4]. Additionally, other tasks were chosen with the purpose of allowing users to personalize the system, while being a hands-on tutorial regarding new modality interaction and feedback configuration. The most relevant ones are the following: Modality Introduction: Self-explanatory videos of how to interact with each modality, followed by "do-it-yourself" tasks; Button and Menu Configuration: Button size, and font and background color configuration; Cursor Configuration: Cursor size, shape and color configuration; Audio Perception: Hearing capabilities and preferences.

The UIA has a simple user interface, with a different screen for every task and metric identified above. Few buttons are presented per screen (preventing user confusion). Every screen preserves the same navigation model - an area with "next", "previous" and "repeat" buttons, and another visually distinct area for presenting information and requests. For every metric to be measured, tests are presented as simple questions about preferences. Also, for every modality available in the system, a video introducing its use is presented, followed by the possibility for the user to try it out. A virtual character accompanies the user through this process, offering explanations and assisting the user in the personalization. As the user goes through each task and preference setting, the UIA adapts itself to the preferences already manifested. For example, if user manifests preference for big, blue buttons with yellow text, all buttons will be presented with those settings from that moment onwards. It is worth pointing out that the results of our previous study are reflected in the UIA's design: high contrast colors, big, centered and well-spaced buttons, etc.

VI. STUDY DESCRIPTION

The study's main goal is to assess the acceptance of adaptation and multimodality by elderly users when interacting with TV based applications. We do this by addressing several questions related with the UIA, multimodal interaction and adaptation, and GUIDE in general. Regarding the UIA: first we want to measure the efficacy of this application in discovering the relevant characteristics of users and assigning user profiles; secondly, we want to evaluate how understandable the UIA is in terms of its goals and the instructions it provides; and finally, how easy it is for elderly to interact with this application, or if they would do it if it was part of their daily lives. Regarding multimodal interaction, we want to assess which modalities are the most used by elderly in a realistic TV interaction scenario. In what relates to adaptation, the goal of this study is to understand if users perceive it and if they are more satisfied using UIs adapted to their characteristics than non-adapted versions of the same applications. Lastly, regarding GUIDE in general, we want to measure its acceptability and if elderly users perceive improvements in their quality of life just by using this system.

A. Development of a Realistic EPG

Similarly to the UIA, we used the knowledge gained in the first study to develop an Electronic Program Guide (EPG) application and focused on the engagement between users and a realistic TV interaction scenario. By developing this application we wanted to validate previously developed notions about elderly users interaction. For instance, do users favor alternative and multimodal ways of interaction with the TV or when they are in the presence of a realistic application they prefer the traditional interaction devices, like a remote control?

The development of this application started with mockup designs, which were then reviewed and approved by experts in the development of TV and STB applications. Later all elements were implemented using HTML, JQuery, CSS and JS languages. The EPG had real information about channels and respective schedules and shows, to confer more realism to the application. Adapted versions were developed to fit each user profile. Output modalities, including the Virtual character, were made available and selected according to the user profile.

B. Participants (Pre-Survey)

We recruited 40 elderly people (24 female and 16 male) with different age-related disabilities. Users were recruited in two countries, with 21 participants (14 female and 7 male) being recruited in Spain and 19 participants (10 female and 9 male) in the UK. The average age was 70.9 years old and the different user profiles were assigned to the participants in the following manner: 14 users with profile A, 22 users with profile B, and 4 users with profile C. As the non-adapted version of the EPG was developed already addressing accessibility issues, each of the profiles reflected few adaptations. All users participated voluntarily and all activities involved in this study were safeguarded from the ethical point of view.

C. Apparatus

The study was conducted in two locations (Spain and UK). Efforts were directed to create similar environment and technical conditions in both labs. Trials were conducted by usability experts. Users were given freedom to interact (the trial conductor would only intervene when really needed, or user asked for help). In what concerns the technical setup and specification, different modalities of interaction were configured: pointing resorted to the use of a Microsoft Kinect; for speech recognition we used the Loquendo SR engine; a simplified remote control, with less buttons than traditional ones and capable of controlling pointer coordinates using a gyroscopic sensor was made available; an iPad was used for tablet interaction; and a full 1080p HDMI TV with integrated speakers and a 32'' screen was used for visual and audio output. User interactions and answers were video recorded.

D. Design and Analysis

We used a within-subjects design where all users ran the UIA and were evaluated in both adapted and non-adapted settings. The order in which they performed both versions of the EPG was randomized to counteract learning effects. Qualitative analysis was retrieved from the pre, intermediate and post-questionnaires. Quantitative data was retrieved from the UIA (user profile and interface preferences). Herein, we discarded quantitative measures like trial errors and time as the trials followed a semi-supervised methodology: the participants were motivated to perform the tasks on their own but they were free to ask questions when they felt lost. Wilcoxon Signed rank tests were used in comparisons to subjective measures between both versions of the EPG. Whereas to binomial measures, Mcnemar's was performed. Cohen's Kappa was used to assess the inter-reliability of the profile ratings.

VII. RESULTS

The goal of this study was to make a preliminary assessment of our adaptation approach for interacting with the TV. We focused our attention on how well we are able to interactively retrieve information about the user and generate adaptations accordingly. We start by analyzing how well our UIA is able to profile the users along with an assessment of the initialization interface itself. Then, we analyze how the users interacted with the different modalities and their acceptance of the multimodal concept. To end, we evaluate subjective acceptance towards adaptation and GUIDE in the overall.

A. Discovering Elderly Profiles with UIA

Our take for adaptation relies on a User Model fed by the UIA. All participants in our study performed both the pre-survey and the UIA. Twenty-nine out of forty profile assessments were performed similarly by the two methods (74%). The interrater reliability between the profiles assigned with the pre-survey and the UIA was found to be Kappa = 0.58 ($p < .0.001$), revealing a moderate agreement [15]. It is relevant to notice that the UIA enables the user to input preference values, something that goes beyond ability profile. This is likely to explain part of the mismatch (e.g., a user with no visual impairments is likely to prefer a higher contrast button when he is confronted with such an hypothesis). Another source of uncertainty may be the under-statements by part of the users in the pre-survey. Indeed, in a questionnaire it is likely that part of the users fail to acknowledge some limitations while they clearly state them when confronted with an interface with options to surpass it. A deeper understanding of the mismatches that are not created by these observed flaws can only be retrieved in a more extensive evaluation by analyzing how both methodologies enable the users to improve performance.

B. UIA evaluation by the Elderly

As mentioned before, we have reproduced a realistic EPG and have focused our attention on improving its overall accessibility. Conversely, we have included the UIA, a component the users are not used to. It is important to assess how the users see this component and if they are willing to use such a thing to improve their performance.

The participants took between 12 and 37 minutes to complete the UIA (M=22.8, SD=5.9). Once again, although they were discouraged to engage in long dialogues the participants were free to express their opinions and doubts during the UIA which increased the time to finalize the process. The UIA classified 16 people as profile A, 20 as profile B, and 4 as profile C. Table 2 presents the subjective ratings given by all the participants to the questions posed. Regarding the understanding of the purpose of the UIA (Question 1), 9 out of 40 (22%) did not understand the purpose of the UIA. This indicates that such a process should be better motivated or else it will be likely ignored by the users. In line with this, 11 out of 40 (28%) stated they would skip the process if they had the system at home (Q2). Five participants stated to find the process too long while four other were neutral about it (Q3) All the remaining thought it was neither too long nor tiring. Most users (35) thought the UIA was easy to follow and understand (Q4). Regarding the adaptations felt during the UIA (Q5), 26 participants stated to have noticed them. This is easily explained as 16 participants were classified as profile A which means they had little or no adaptations done during the UIA. In sum, the users seem positive towards the UIA (Table 2) although it is clear that it should be well motivated and accompanied.

Table 2: Subjective ratings of the UIA

Question about the UIA	Median	IQR
Have you understood why we do the UIA? [1 - Yes ; 2 - No]	1	0
If you have had the system at home, would you go through it or skip it? [1 - Would do it ; 2 - Would skip it]	1	1
Do you think the UIA is too long? [1- Yes;2 - Neutral;3 - No]	3	0
Were the instructions easy enough to understand? [1 - Yes; 2 - No]	1	0
Did you notice any changes in the application while you were using it? [1 - Yes ; 2 - No]	1	1

C. Evaluating Multimodal Interaction

One of GUIDE's main concepts relies on offering a set of modalities to the elderly population to fit their different profiles and abilities. In this study, in the Adapted setting we allowed the participants to perform the tasks with any of the previously described modalities. After each task, the users were asked about their preferred modality. Figure 1 presents their preference count after each task. Overall, it shows that both Speech as Tablet interaction were seen as positive improvements for interacting with the EPG. Conversely, the standard remote is seen by a part of the users as a safe option which they are not willing to trade easily. The gyroscopic remote was mildly used while pointing at the screen was the least preferred unimodal option. The users were also able to use Pointing and Speech together but this option was not revealed as interesting. This may be due to the complexity of using more than one modality and the reduced timespan of training. Further, the simplicity of the tasks is likely to be fitted with simpler selection approaches while a multimodal option is directed at more complex tasks. Nonetheless, given the population and the overall goal of simplifying processes and the aforementioned trends, it seems reasonable to suggest that a variety of unimodal interfaces seems to be adequate to fit the users' needs and preferences. Interestingly enough, when explained the modalities available in the adapted version, most users stated that they would stick with standard remote. Conversely, during the trials they showed interest in using other modalities.

Looking at the order of the trials, those that ran the adapted version first seem to be eager to try out different modalities, particularly the gyroscopic remote, tablet and speech, while those that performed the tasks previously with the Non-Adapted version, use a more conservative approach in the Adapted setting, giving preference to Speech followed by the standard remote and the tablet and ignoring the remaining.

In both scenarios, about half the users shifted their preference during the Adapted trial while the other half sticked with their initial preference (first task). Preferences also diverge between users from different profiles. Participants from Profile A (no adaptation) showed a predilection for both the standard remote and speech and a mild preference for using the tablet. All the other modalities were ignored. As to Profile B (medium adaptation level), participants showed a less consistent selection. The tablet was the most preferred modality but all the other unimodal approaches were seen as useful by part of the users. As to Profile C (high adaptation level), consistency was once again revealed with preferences going for both remotes, pointing and speech

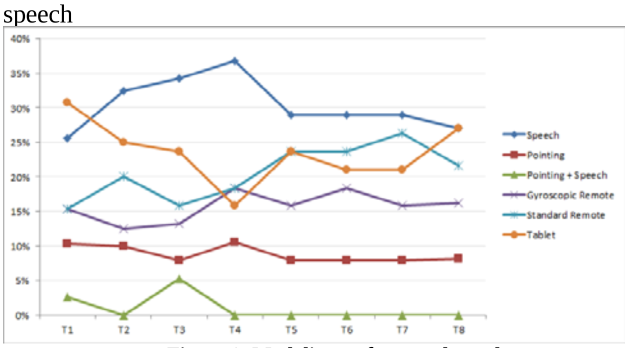

Figure 1: Modality preferences by task

This first analysis on how older people resort to non-conventional modalities reveals acceptance of the underlying multimodal concepts: results suggested that the population does not reject the usage of other control interfaces if these are adapted to their profiles and the task in hand. Further, Age did not show a significant correlation with acceptance nor any observable tendency on the set of preferred modalities, suggesting that this overall acceptance is pervasive to the age groups in our sample.

D. *Evaluating Adaptation*

Subjective acceptance to EPG adapted and non-adapted versions was evaluated through a statement to classify using a five-point Likert scale (1-the system has not supported me at all; 2-the system has supported me only in some parts of the task; 3-undecided; 4- the system has supported me in almost all the tasks; 5-the system has supported me at every moment). A Wilcoxon Signed Rank Test revealed a statistically significant minor difference between the EPG adapted (Mode=4, IQR = 1) and non-adapted versions (Mode=3, IQR=2), $z=-1.665$, $p<.1$, with a medium effect size ($r=0.37$). Although not significant statistically, subjective acceptance of adaptation showed to be slightly higher by participants in profile C, suggesting that the adaptations (more noticeable) improved the relation between the participants and the interface. In-detail acceptance comparisons of icon and text properties (evaluated as a dichotomous response to the suitability of the property) in both adapted and non-adapted settings revealed no significant differences. Apart from the large number of users with no adaptation, the baseline EPG was already designed as an accessible version. This may be the reason for the participants to rate the non-adapted EPG as adapted to their needs as well.

E. *Evaluating GUIDE concepts*

The adaptation and multimodality concepts pervade the GUIDE project. These preliminary trials seeked to assess how older people would react to such an adaptable and flexible system. While the aforementioned behaviors suggested that both adaptation and a wide coverage of control interfaces were positively seen and felt by the participants, we questioned them directly about their opinions on GUIDE. To this end, we performed a self-rating post-questionnaire to assess their overall opinion about the system (5-point Likert scale) and their Behavioral Intention to Use the System (7-point Likert scale).

Table 3: Subjective ratings to GUIDE, Median[IQR}

Overall opinion about the system	Rating [1-5]
Overall, I am satisfied with how easy it is to use	4 [2]
I am able to efficiently complete the tasks using the system	4 [2]
I feel comfortable using the system	5 [1]
It was easy to learn to use it	4 [1]
Whenever I make a mistake, I recover easily and quickly	4 [2]
it is easy to find the information I needed	4 [1]
The interface of the system is pleasant	5 [1]
Overall, I am satisfied with the system	5 [1]
Behavioural Intention to Use the System (BI)	**Rating [1-7]**
Intend to use GUIDE in the next semesters if I have access to it.	6 [2.5]

Overall, all items were highly positively rated by most users (table 3). Regarding the opinion about the system, the overall satisfaction with it, the comfort and pleasure it guarantees were consistently highly rated as shown by the median and low dispersion. The ratings with slightly larger dispersions were about the easiness, efficiency and

 ISBN: 978-1-61208-250-9

recovering of errors of the system, although still on the positive end of the rating scale (Median 5, IQR = 2). This can be explained by technical errors with a small part of the users regarding both the speech recognizer and the tablet device (temporarily unavailable wireless access). These users were unable to complete the tasks as they desired which translated in the mentioned lower ratings. This, although it can be explained by a technical glitch, is a relevant lesson learned as an unexpected, even localized, flaw, particularly in an adoption phase, is prone to damage the user's relationship with the system as a whole.

When asked about their Behavioral intention, users were also very positive which can be observed by an overall median value of 6 in 7 regarding intention of use. Here, the dispersion is a little larger. Five participants, although enjoying and understanding the benefits of GUIDE, argued to be happy with their systems at home, and therefore were neutral about a change. Only two participants showed to be unwilling to adopt GUIDE: one of the users showed preference to use the tablet for all tasks and experienced the aforementioned technical glitches which can explain his position; the other user did not have a TV at home, did not show an interest in having one, and presented an overall attitude towards technology ("I do not like technology"). Interestingly enough, he did not resort to conventional interaction modalities.

VIII. Discussion

Upon analyzing the UIA process and its impact on adaptation along with the usage of the GUIDE system and its underlying concepts, we answer our research topics as follows:

A. *Deriving a suitable user adaptation profile through the UIA.*

The UIA aims at creating a user profile by performing a simple set of questions and interactive tests. Results showed that the UIA is able to match profiles obtained with an extensive survey in 74% of the cases. Further, the UIA showed to be more realistic than its paper-based counterpart as data is likely to be more accurate when the users are faced with their limitations rather than just being questioned about them. Moreover, the UIA gives space for preference and subjectiveness. In sum, we consider that adapted TV applications based on simple initialization profiling are feasible and likely to improve over traditional methodologies.

B. *Acceptance of the UIA.*

The UIA took over 12 minutes, averaging around 23 minutes. This amount of time can be discouraging for an elderly user if the benefits are not clear. Taking in consideration that it is supposed to be ran only once, the participants showed to be very positive about it. This is supported by the almost general understanding of the purpose of the UIA: they understood the benefits of such an application and perceived the adaptations during the process. Most participants (35) considered the application easy to follow which indicates that although the concepts underlying the creation of the user model are complex, the interface to generate it is not.

C. *On perceived adaptation.*

Our analysis on adaptation is restricted to the subjective understanding and acceptance of the created profiles and consequent adaptation. Results showed that participants perceived the adaptation both during the UIA and the adapted EPG tasks. Also, those that were subject to adaptations rated the adaptive version as an improvement over the non-adapted one. The baseline EPG was already an improved accessibility-wise version over traditional EPGs, a fact that may have reduced the impact of the adaptations in such a short term evaluation. The impact of these adaptations needs further longitudinal evaluations supported by quantitative measurements to be further assessed. Nonetheless, the participants showed to be positive about the adaptations, which is relevant as a requirement for adoption, particularly in an elderly population.

D. *On Multimodality.*

It is commonplace to underlook the elderly population as one that is attached to traditional methods and unwilling to adopt new technologies. We acknowledge that the adoption of new technologies by the elderly is not straightforward and needs to be supported and accompanied. In this study, the participants showed to be eager to try new methodologies and experience their benefits over traditional counterparts. Speech recognition and interacting with the Tablet were tried during the tasks by most users and together achieve over 50% of the participants' preference. On the other hand, more conservative users, although resorting to other modalities when they saw fit, selected the standard remote as their main control interface. Providing an enriched set of modalities showed to fit the different user profiles. In that sense, multimodality seems to provide the flexibility argued in our motivation. Conversely, the unique multimodal option provided (Pointing + Speech) failed to prove the combination of modalities as useful for the target population. This may be due to the difficulty (easy) of the tasks in hand.

E. *Overall acceptance of GUIDE.*

Participants showed an overall positive acceptance towards GUIDE. Some participants stated that their EPGs were difficult and would desire a simpler system. They saw it in GUIDE. The avatar in the UIA was seen as a friendly helper and the overall usage of the EPG was considered simple and comfortable. Moderate opinions were given only in extreme cases of technology rejection (1 user) and technical glitches that disabled the users from completing the tasks as desired (inability to use their preferred interfaces). Participants stated to be interested in using GUIDE if it would be made available

IX. Conclusions

New interaction paradigms, supported by new modalities and applications, are transforming a classical appliance that is the TV. If not handled properly, this transformation can increase the access barriers to TV content for elderly users.

In this paper, we assessed several of the proposals that the GUIDE project puts forward in order to increase the accessibility of TV applications. GUIDE aims to provide application developers with a multimodal adaptive framework and a set of functionalities that will increase their products' accessibility, without demanding major changes in their development process. The assessment was based on a user trial, with 40 participants from two different countries.

Being an adaptive framework, it relies on knowledge and information about users. We described how the GUIDE User Model was built and how it integrates with the framework. Essential for the integration, is the UIA, a process that streamlines user profile identification, based on short number of tasks and questions. We present an assessment of the efficacy of this process, concluding that it is possible to reliably identify user profiles, while also recognizing ways in which to further improve the process. From the user's point of view, the process motivation was understood, and it was considered easy enough, although also here we were able to find ways to improve it.

Being a multimodal framework, it makes use of several input and output modalities. The paper assessed the usage of these modalities in the context of a realistic EPG application. Conversely to what could be expected, the traditional remote control was not the most favored modality, being surpassed by speech and tablet as preferred modalities. Effects of adaptation on this application, in spite of an already accessible non-adapted version and the limited amount of interaction time with it, achieved a statistically significant minor difference between subjective acceptance of adaptive and non-adaptive versions.

These results, together with the positive acceptance of the GUIDE concepts and their expected impact in the quality of life of its users, validate the approach followed so far and pave the road for the project's future developments, which will be verified in a longitudinal trial for better assessing the effects of adaptation

A. Relation with the Previous Study.

Regarding the use of modalities, speech interaction was singled out as the most attractive modality. In the first study, a Wizard-of-Oz approach was used to replace the speech recognition engine, and we questioned how that might have contributed to the results. In this follow-up study, where a speech recognition engine was used, we can see that speech remains the preferred modality, overcoming any technical issues that might be raised. It seems safe to say that speech plays an important role in promoting the adoption of these systems, and efforts to ensure its adequate operation are justified by the satisfaction it provides users with. Tablets, although not fully integrated with the system in the initial study, collected a positive response from participants, with 92% of them considering interacting with a TV using the Tablet. This tendency was confirmed in this study, with Tablet interaction being the second most used modality to interact with the EPG. Finally, regarding the clustering process, by increasing the number of users available we have updated the profiling process, which resulted in a more accurate representation of the users' characteristics and a more precise identification of the relative importance of each variable. For example, contrast sensitivity is now more relevant than the capability of seeing at distance or at night, and grip strength is now more relevant than any other motor related variable.

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 ISBN: 978-1-61208-250-9