Designing studies for the requirements and modelling of users for an accessible set-top box

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ABSTRACT

This paper describes work carried out to address the human centred design process behind the generation of requirements and user data for the prototyping of a user-model intended as part of a TV set-top box intended for use by mild to moderately impaired users. The aim is to develop both the technology and user modelling required within one STB system that will enable individuals with sensory, cognitive and physical impairments to interact with a number of reference applications. In order to do this it will be necessary for the system to categorise users on the basis of their input and interaction performance with a variety of input devices and assign them to a pre-assigned profile in the systems internal user-model. We address the issue of whether a human centred design process can be developed that is in principle capable of adequately generating the required data and specifications. We report the development of an inclusive design approach which subsumes both accessibility and usability. The ultimate aim will be to create a foundation for actual research and development work by identification of requirements from users as well as application and framework developers. We report the requirements analysis of this development and some preliminary results from user focus groups, chosen using an inclusive survey of capability, and interacting with early prototypes of interaction interfaces.

1. INTRODUCTION

This paper describes work carried out to address the human centred design process behind the generation of requirements and user data for the prototyping of a user-model intended as part of a TV set-top box intended for use by mild to moderately impaired users (Pirkl, 1993, Keates, 2004).

The design and prototyping of this approach is the remit of the EU FP7 project: Gentle User Interfaces for Disabled and Elderly Citizens (GUIDE DoW, 2009). The aim is to develop both the technology and user modelling required within one STB system that will enable individuals with sensory, cognitive and physical impairments to interact with a number of reference applications. In order to do this it will be necessary for the system to categorise users on the basis of their interaction performance with a variety of input devices and assign them to a pre-assigned profile in the system's internal user-model. This model will then adjust the output modalities and interaction elements to present the interaction most suited to the user's capabilities within the broad envelope of mild to moderate impairment. The system will be capable of presenting sound, speech, visual, haptic displays, (Langdon, Hwang, Keates, Clarkson and Robinson, 2002) and will be controllable using pointing devices, gyroscopic inputs, gestural and voice commands as well as hand-held controllers and touch screens. The GUIDE displays will utilise multimodal interfaces exploiting multimodal advantages, avatars and accessible displays in order to cater for the range of impairments and their co-occurrence (Duarte and Carrico, 2006).

1.1 Research Question

Although the GUIDE description of work specifies the work-packages, deliverables and time table, it does not address the necessary design process and required data collection and interaction testing required to

achieve the GUIDE user model and technology specifications.

We address the issue of whether a human centred design process can be developed that is in principle capable of adequately generating the required data and specifications. Once user data has been collected it will be analysed and presented by way of empirical verification of the design process and concept. The use of a design based approach to technology development for inclusive design will be thereby tested. Final validation will test the effectiveness of the GUIDE system in user trials.

The fundamental basis of the GUIDE user-centred design is inclusive (Langdon, Clarkson and Robinson, 2008). Furthermore the project can be characterised as a design exercise that configures the necessary technology and research that will be required to deliver working prototypes of hardware and software, a hand-book or manual for its use and for development of software that will run on the system. Hence the process may be characterised as based on Inclusive Design (Clarkson, Coleman, Keats, Lebbon, 2003).

GUIDE will adopt an inclusive design approach which subsumes both accessibility and usability. It proscribes a holistic approach to the entire population age range for accessibility as well as for the disabled. It further addresses usability for the disabled and the ageing by specifically requiring usability to be addressed as an interaction between actual product features and user capability ranges (Waller, Langdon and Clarkson, 2008):

"The design of mainstream products and/or services that are accessible to, and usable by, people with the widest range of abilities within the widest range of situations without the need for special adaptation or design"- British Standards Institute (BS 7000-6:2005).

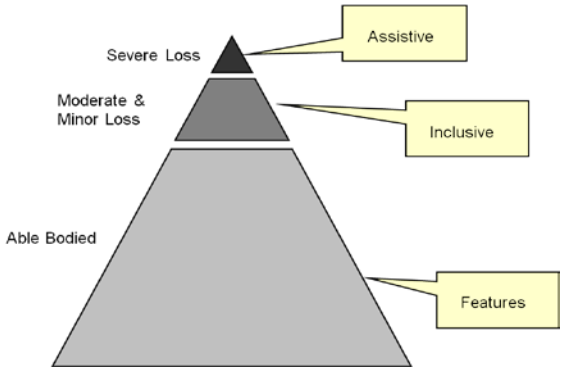

Figure 1. *The Inclusive Design Pyramid.*

1.2 Aims and Goals

Although the project will require many activities and deliverables, a working design and plan was required to enable the human factors and gerontologists and other technological partners to operate together in an integrated way to deliver the right data, models and activities in a well-coordinated way. The ultimate aim will be to create a foundation for actual research and development work by identification of requirements from users as well as application and framework developers. The design goal will be the elements and components of the Guide User Model (GUM) in the form of clustered personas and profiles along with an algorithm and data structure that can support its use in the GUIDE technology system. The GUIDE human-centred design process is based on three concentric iterations of requirements implementation and trials that will be carried out over the duration of the entire project with increasing levels of technologic fidelity and readiness of the human interface.

The research programme may be described as both an investigation and a design process. Figure 2 is concerned with describing the key issues and planning and design for the initial user studies, specifically what activities, methods, data and analysis will be required to deliver the GUIDE user model and prototypes of the GUIDE framework. This corresponds to the inner ring of the human centred design process and is intended to deliver data and early prototypes within the space of one year.

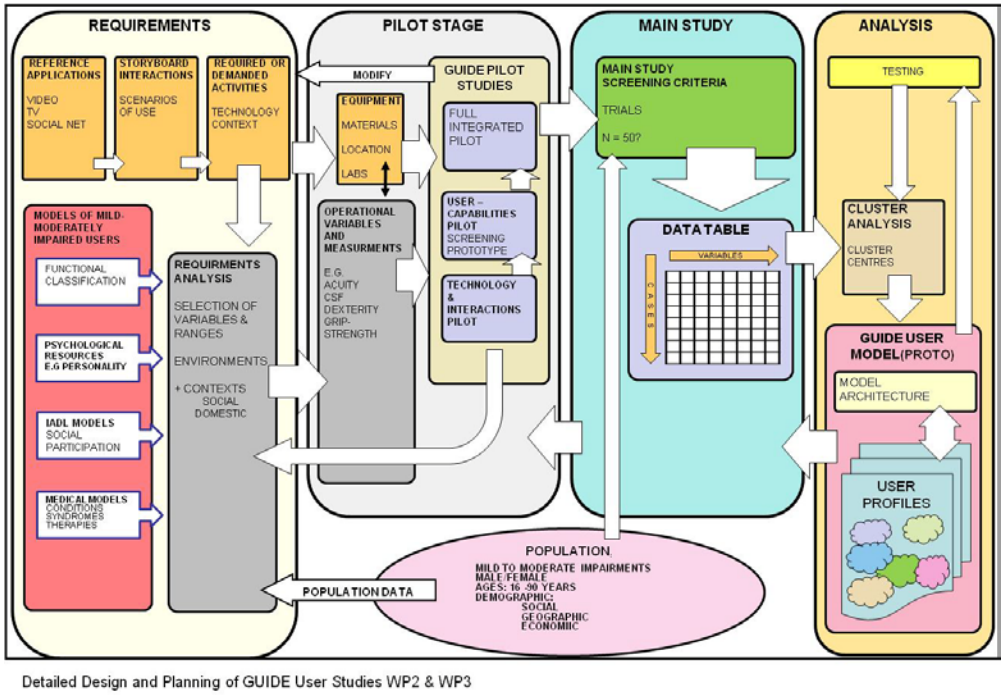

Figure 2. *The GUIDE human Centred Design process.*

2. PROPOSED DESIGN AND PLANNING OVERVIEW OF USER STUDIES

Referring to Figure 2, the designed process will be divided into 4 main stages:

- *Requirements*
- *Pilot Stage*
- *Main Study*
- *Analysis and Model Specification*

Each of these will be described separately and each section refers to a section of the schematic.

2.1 Requirements Stage

The requirements analysis will take as its starting point three main sources of information. These will firstly be the technical interface specifications for the reference applications, incusing their technologies and contexts and secondly the requirements sources from adopted models of mild-moderately impaired users. The third source of information will be the population data taken from existing sources.

2.2 Requirements analysis

The analysis stage will take as input the basic interactions, storyboards and scenarios of the reference applications and technology contexts and combine them with the chosen variables of importance from the various models of impaired users that guide adopts in the contexts of use that are anticipated. These requirements will be used as input to the next pilot studies stage.

2.3 Technical interfaces

The reference applications consist of a set of applications with a simplified set of essential basic Interactions and constraints (ISO 13407, 1999). The applications were chosen to exploit fully interactive TV capability and to provide opportunities for multimodality. An initialisation “application” designed to allocate a user new to the GUIDE system was necessary. This has the main function of performing a first pass through some tests of visual, hearing and movement capability to form a preliminary classification of the user to GUIDE profiles in a manner sensitive to on-technical or technology fearing users.

- *Initialisation of new users.* Assigns a new user to a GUIDE profile in user-friendly way.
- *TVNow.* An electronic programme guide
- *Telelearning*
- *Home Automation*

- *Videoconferencing*

It was necessary to define the activity requirements of the reference applications without considerations of capability. These case definitions will then be used to develop the usage cases and scenarios of use based on expected application contexts. Finally, it will be necessary to Specify I/O devices, modes and ranges of flexibility that will be specific to each reference application. This information will feed into the Requirements analysis.

2.4 Models of the User

GUIDE has adopted requirements from several models of the user. These include:

- *Data from functional classification* systems for human capability classified according to mild-to moderate impairment. Functional capability models and data (Persad, Langdon and Clarkson, 2007). For example: 1) cognitive capabilities such as memory, reasoning, attention, working memory, speed of processing; 2) Qualitative and Quantitative ranges of data; 3) Ranges: age, gender, perceptual, cognitive and physical-motion, (Schaie, 1988; Rabbitt, 1993);
- *Data relating to human psychological resources* as derived from gerontological principles such as personality type and indices of self-efficacy etc. Quality of life; models of Needs, Wants, Pleasures and Joys, (Fisk *et al*. 2004);
- *Data from Instrumental Activities of Daily Living* as researched in Gerontology, for example cooking, communication, mobility and social participation etc. e.g. Specific ADL and IADL difficulties (Lawton and Brody, (1969);
- *Data from medical, practitioner and social models of disability*, including conditions, symptoms, syndromes, therapies rehabilitation requirements and carer relationships and requirements. E.g.: 1) Social class, geography and affiliations; 2) Social context groups (home vs. independent living vs. care).
- *The requirements of the algorithmic GUIDE User Model* and its architecture (data quantity, algorithms and format);
- *Population Data.* It should be noted that the ultimate source of such data will be the population data regarding impairment, disability and handicap. The models will specify the type of data to be included in the requirements.

2.5 Population Data

Statistical and survey data regarding human capability have been used to formulate requirements. This will include variation with respect to gender, age and demography, where demography should include geographical location, social context and specifications, economic information and other sources of data such as models of ageing from medical statistics (Waller, Langdon and Clarkson, 2008).

2.6 The Pilot Stage

The approach here has been to define a simple design space with simplified interaction for proof-of-concept tests that define the activity requirements of the reference applications. The outputs of the requirements analysis are general variables and objective measurements of theoretical and practical utility. This has been completed in the form of a survey of user participants that will form the pool of users for the main GUIDE user study. More than 100 survey items, based on theoretical models, have been used to collect self-report and subjective data in conjunction with objective measurements of vision, hearing and cognitive and physical capability.

On the basis of this operationalised set of variables, a number of pilot studies were carried out in order to specify the final set of measurements and variables that will be collected in the main GUIDE user study. The aim has been to carry out a fully integrated pilot study with a small number of representative users (n = 5-15). These pilot studies have been carried out at the most suitable sites given the distribution of equipment and materials and access to suitable participants. An important part of the pilot trials is continuous feedback and modification of technology, capability and context and scenario information to the requirements stage, allowing optimisation of practical considerations and reduction of management risk (failure to obtain a useful or complete user model for the next stages of the GUIDE project). It has allowed further initial insights on the viability of the multimodal user interfaces for particular impairments, by way of early prototypes and initial user studies. It is also necessary that the results of these pilot studies will assist the specification of the architecture and processes for the usable framework that the ICT developer will interact with.

2.7 Main Study

The main study will consist of trials with around 50-100 participants chosen on the basis of the full integrated

pilot and using the operational variables and measurements from the requirements analysis. These will enable screening of trial participants to give a sample that is controlled and stratified to reflect the anticipated user groups from the main population. The main study will require all the available technology expected for use in GUIDE along with usage scenarios of use and personas from the models of users. Running 50-100 users should yield sufficient data for an accurate cluster analysis but it should be noted that if the number of variables is large that the number of participants (cases) may need to be greater for statistical reasons. These trials should take around 12-16 weeks.

2.8 Analysis and Model Specification for the Prototype User Model

As part of separate work, it has been necessary to research and design the structure of the GUIDE User Model. This includes its underlying principles, algorithms and implementation. Important considerations will be the scope of the model, representations, processes and data structures and modes of adaption (Biswas and Robinson, 2008). Adaption between profiles will use advanced statistical state-space estimation techniques; (Godsill, Doucet and West, 2004) and advanced user modelling. However, for the purposes of this part of the GUIDE programme it will only be necessary to specify the guide user profiles as the end-point of the entire requirements specification and user study process. At minimum it is expected that there will be

- A clustered set of user profiles;
- A model architecture to reference and access the profiles;
- The results of a testing and validation process.

Further validation of the model will then take place in further continued user-centred design processes in GUIDE. In particular it will be necessary to show that the user model can predict and accommodate users who use the prototypes and that the match of random users' capabilities to the framework performance is close and appropriate. Only limited feedback to the results of the main study will be possible at this stage.

2.9 User Adaption

The user initiates interacting with the system after properly configuring it. The configuration stage selects the appropriate modality of interaction. After configuration the user keeps on interacting with the system and the system dynamically adapts its responses. Finally after the interaction, the system updates the user profile based on the history of the interaction. The detail of the configuration stage is given in the following activity and sequence diagrams. It consists of evaluating the range of ability of the user through a battery of tests and uses that information to select the appropriate modality of interaction based on a user model. We have assumed in these figures that our user can use his vision and speech to some extent, can hear sound and can also move body parts. After the user finishes interacting with the system, the system analyzes the history of interaction and updates the user profile to give better adaptation next time. The interaction stage can be explained with the help of Norman's model of seven stages of action (Norman, 1988). The user initially perceives the present state of the system. Based on their intention, the user then decides to perform an action and converts it into a device operation. When the system gets an input from the user, it adapts its response based on the user model to reduce the gulfs between execution and evaluation. Finally the system changes its state and the user perceives this new state and continues to interact.

There will be mainly two forms of adaptation:

- Static adaptation which is personalisation before the user starts interaction;
- Dynamic adaptation that is personalisation following the interaction pattern, such as calculating error rate, user idle time from the usage log, with the system.

The adaptation mechanism will be based on the GUIDE user models. A user model is a representation of the knowledge and preferences of users (Benyon and Murray, 1993). Three main types of user model are in widespread use:

- The GOMS family of models, which were developed only for human computer interaction (HCI);
- Models involving cognitive architectures, which take a detailed view of human cognition;
- Application specific models.

The GOMS (Goal, Operator, Model, Selection) family of HCI models (e.g. KLM, CMN-GOMS,CPM-GOMS) is mainly suitable for modelling the optimal (skilled) behaviour of users. On the other hand, models developed using cognitive architectures consider the uncertainty of human behaviour in detail but have not been widely adopted for simulating HCI as their use demands a detailed knowledge of psychology. Application specific models are developed by keeping only a single application in mind and so they are hardly usable to model human performance in general. There is also not much reported work on systematic modelling of assistive interfaces. A more detailed discussion on user modelling can be found at reference

[Biswas, 2010]. The GUIDE user model will try to solve the problems of existing user modelling techniques. It will work based on the following four stages:

- Data collection: Initially we collect data from a lot of users with different range of abilities to develop the initial user profile;
- Cluster analysis: The data will be clustered to summarize users' impairments and disabilities into groups;
- Mapping interface parameters to user profiles: The interface parameters for different scenarios of interactions will be related to the levels of abilities of users;
- Interface personalization: Finally the interfaces will be personalized according to the relationships established at the previous stage.

3. PRELIMINARY FOCUS GROUPS

A set of preliminary focus groups have been carried out using six participants with a range of capabilities from low to sever impairment in specific functional capability areas.

P1	F Age 41	Visual impairment 10% capability, technology literate - special glasses for TV.
P2	M age 75	Visual impairment 10% capability,y technology literate
P3	F age 70	Mobility impaired leg and elbow (ROM problem), not technology literate (used vid conf with son) . No glasses.
P4	F age75	Memory problems (age related) not technology literate. No glasses.
P5	F age 74	Mobility and hearing impairment, not technology literate. No glasses.
P6	F age 80 -	Objective memory problem (measured) with visual and verbal memory. Glasses

Table 1. *Participants of early user Focus groups*

3.1. Results of Focus Groups

The focus groups were carried out using successive presentation of a scripted sequence of simulation slides followed by questions for stimulating discussion. Tests started with presentation of the speaking GUIDE avatar and an introduction to the system. Subsequent tests examined the response of participants to automated changing of text size, pointing to select items, speech control and combinations of pointing and speech control.

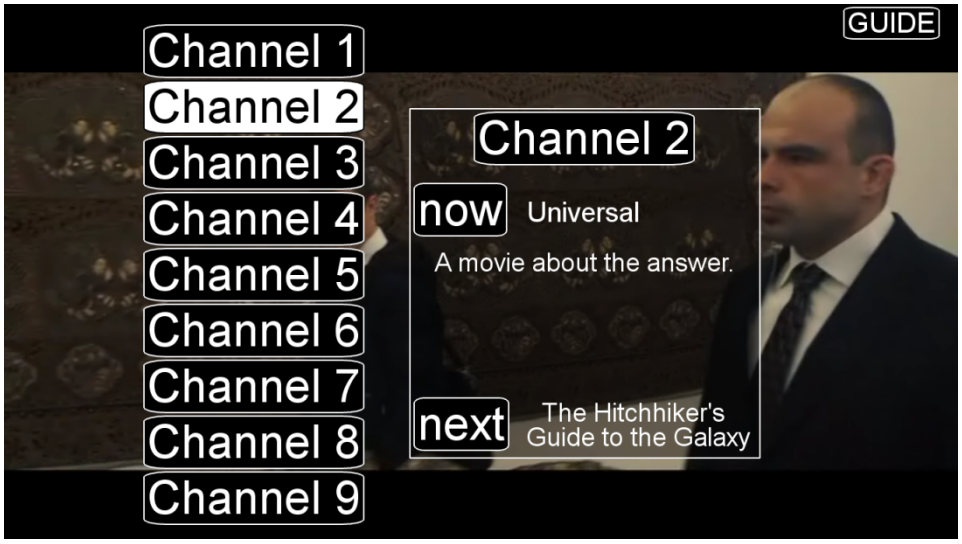

Figure 3. *The working mock-up of the Programme Guide*

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3.1.1. Initialization Scenario

- *Do you know what an Avatar is? Do you have another name for it? Do you prefer to see only the head or whole body?*

  No participant knew what an avatar was so they could not say what they thought about it or if they prefer it with body or just a head. Two preferred the avatar with body (AAMI and Mobility disability) and also they would like it to be really expressive. All commented they would like a different avatar. Both of the avatars were not appealing for them but they did not give a reason why. They want them to be more attractive and realistic.

- *Do you feel comfortable if the system decides to test what is the appropriate letter size or would you prefer that you leave her alone?* Would you like to do the test after you ask if the letter is correct and so you say so?

  Everybody wanted that the system selects them the appropriate letter size. All of them considered appropriate to test the avatar to suit the user and they believe it is necessary that the avatar ask a second time to confirm this, if it is more appropriate.

- *Do you like the idea of selecting something by pointing and saying at the same time? Would you like to use one of two ways?*

  Everyone felt the need to use multiple modalities when deciding to choose an item. They preferred to select it and say it at once. All of them thought this was better than the TV remote control. They thought it could be difficult to succeed with gestures so they preferred verbal mode, specially those with visual and mobility disability.

- *If you had noticed it, would you like to see an arrow to point to what you are confirmed?*

  Yes, they felt it was necessary to use an arrow and illuminate what was selected.

- *Do you find it helpful to change the channel with a gesture?*

  All considered that it could be confusing to select what you want to see using only a gesture. People with visual disability raised the issue of whether it was possible to choose (for several days) the mode you want to use to select a channel. The modalities that they preferred were: verbal, pointing and gestures (in that order).

- *Do you like the possibility of seeing the same content using different forms?*

  Yes, they find it very nice to see the same content presented using different modalities. One person with mobility disability did not like the idea of changing the form of what you are seeing according another the criteria of another person who was present. She felt it could cause family problems.

3.1.2. Home automation

- *What does it mean for you to have a "home automation and modern infrastructure"?*

  This was interpreted as meaning that you do not have to do the such as housework). The use of shutters that rise and fall according to the light were seen as a positive example once this was established.

- *What kind of assistive technologies do you know of?*

  A number of applications were mentioned, including tele-alarm; cooking pots going off when they reach a temperature; ceramic hobs that turn off when spillage occurs, robots that cook and clean.

- *What do you think about what technology support in the various activities of daily living? Considering your capabilities, do you think such a device can help you? How do you think a system like this can help?*

  Nobody had support technologies. They believed that although they have some kind of technology, people are always going to depend on others. They preferred to have a person at home with a new device because they are often different problems that the technology cannot resolve. Some of them commented (AAMI, Mobility) that people who use technology at home would spend all of their time indoors and this could be a problem. Two of them (AAMI) thought that having the system would make them more dependent of it and then be more lazy.

- *Depending on your capabilities, how do you think the system should show reminders and notices?*

  All participants preferred to hear a noise (for example an auditory alarm when they leave the oven on) instead of a note in the TV. They thought this was a bad idea, because most people would have the TV off or they would not read the note if they are looking elsewhere.

- *What is your opinion on the automation system at home? What are the possible problems of this device?*

  One of the main problems expressed was that if the system did not work then you could not get outside your home. Those with visual disability thought that it would be better if the system had a robbery alarm system.

- *Can you imagine having this device at home? How could you increase your sense of security?*

  All users agreed that they would have this at home and that it could increase their sense of security through remote control.

3.1.3. Video conferencing

[No specific questions were recorded for the following applications]

- They did not have experience with computers or video-conferencing and chat systems. Only one person had used the internet before but only through being assisted by her family.
- They preferred to use their voice to make a phone call or to hang up the phone, but they did not want to use hands to make gestures.
- They liked that the avatar but only in the context of education. They especially liked the idea of seeing their relatives on the screen simultaneously. They thought this was charming and improved relationship by making people seem closer.
- Two modalities (speech and gyroscopic pointing) were always preferred together, instead of alone, particularly when difficulties were experienced with the volume.
- In general, they found it a useful, entertaining and different system when compared to the telephone. They like the possibility of talking to several people at the same time. They wanted to know if the other contacts of their list must have also the device.

3.1.4. TV Now

- The participants do not think this application is useful for people who have memory problems. Also they think the avatar is annoying and it would be tiring for the person. It would not help the user and they argued it could even be more difficult for AAMI people.
- They do not think this application is for these kind of people maybe only with elderly people with slight memory problems. So they think that it would be better if the instructions are easy and clearer.

3.1.5. Tele-learning

- The tablet was greatly enjoyed because it was comfortable and can move it with you. One person with Age Associated memory Impairment (AAMI) thought this could be a problem because you may forget where it is.
- Two participants with visual disability thought that it was good to have it in the hands so you can place it closer during use.
- The idea of making a circular touch gesture to ask for help was generally considered difficult so they preferred speech input.
- The instructions for use were adequate. The signs to proceed or return to the menu were good but two participants proposed to make it clearer with text captions (back, pause).
- Different opinions were expressed with this application. One of them with a visual disability wanted to see less cluttered information in the class preferring to see the relevant information of the slides and the text content. Two participants with (AAMI) wanted to see the lecturer in a primary display and the content of the slides in a secondary area. One participant with auditory impairment preferred to see the text content as the main presentation and the lecturer in a second area.

4. SUMMARY AND CONCLUSIONS

We have described the proposed design process for the requirements and technology specification of an accessible set-top box usable by the mild to moderately impaired users. The proposed design approach combines human-centred design philosophy with principles of Inclusive Design and Engineering Design methods.

The process will be verified and tested by:

- An analysis of the effectiveness of the requirements developed from the pilot process;
- An analysis of the effectiveness of the user profiles arrived at for the pilot studies prior to collection of

data from a larger group for 50 – 100 users;

- The adequacy of the data collected during the technology interaction prototyping pilot studies.

The criteria for success will be the extent to which the combined interactions and adaptive model accommodates the range of impairments and capabilities that users can deploy during the interactions required to use the reference applications. Preliminary Focus groups and experimental trials with low-fidelity prototypes and mock-ups have already yielded insights into the users' preferences and likings for specific multimodal interaction styles. Each future participant undergoes a survey of their subjective, self-report preferences, background and objective measures of capability including, vision, hearing, movement and cognitive capability. These two sources of data, survey and experimental pilot trials are being used together to identify key areas of multi-modal interaction that interact with specific capability variation in order to to define priorities for interface development.

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