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Improving elderly access to audiovisual and social media, using a multimodal human-computer interface

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Nobody grows old merely by living a number of years. We grow old by deserting our ideals. Years may wrinkle the skin, but to give up enthusiasm wrinkles the soul.

Samuel Ullman

Abstract

With the growth of Internet and especially, the proliferation of social media services, an opportunity has emerged for greater social and technological integration of the elderly. However, the adoption of new technologies by this segment of the population is not always straightforward mainly due to the physical and cognitive difficulties that are typically associated with ageing. Thus, for elderly to take advantage of new technologies and services that can help improve their quality of life, barriers must be broken by designing solutions with those needs in mind from the start.

The aim of this work is to verify whether Multimodal Human-Computer Interaction (MHCI) systems designed with Universal Accessibility principles, taking into account elderly specific requirements, facilitate the adoption and access to popular Social Media Services (SMSs) and Audiovisual Communication Services, thus potentially contributing to the elderly social and technological integration.

A user study was initially conducted in order to learn about the limitations and requirements of elderly people with existing HCI, concerning particularly SMSs and Audiovisual Communication Services, such as Facebook or Windows Live Messenger (WLM). The results of the study, basically a set of new MHCI requirements, were used to inform further development and enhancement of a multimodal prototype previously proposed for mobility-impaired individuals, now targeting the elderly. The prototype allows connecting users with their social networks through a text, audio and video communication service and integrates with SMSs, using natural interaction modalities, like speech, touch and gesture.

After the development stage a usability evaluation study was conducted. The study reveals that such multimodal solution could simplify accessibility to the supported services, through the provision of simpler to use interfaces, by adopting natural interaction modalities and by being more satisfying to use by the elderly population, than most of the current graphical user interfaces for those same services, such as Facebook.

Keywords: **Elderly, multimodal interfaces, usability evaluation, speech, gesture, multi-touch**

Resumo

Com o crescimento da Internet e, especialmente, das redes sociais surge a oportunidade para uma maior integração social e tecnológica dos idosos. No entanto, a adoção de novas tecnologias por essa população nem sempre é simples, principalmente devido às dificuldades físicas e cognitivas que estão associadas com o envelhecimento. Assim, e para que os idosos possam tirar proveito das novas tecnologias e serviços que podem ajudar a melhorar sua qualidade de vida, essas barreiras devem ser ultrapassadas desenhando soluções de raiz com essas necessidades em mente.

O objetivo deste trabalho é verificar se interfaces humano-computador multimodais desenhadas com base em princípios de Acessibilidade Universal, tendo em conta requisitos específicos da população idosa, proporcionam um acesso simplificado a serviços de média social e serviços de comunicação audiovisuais, potencialmente contribuindo para a integração social e tecnológica desta população.

Um estudo com utilizadores foi inicialmente conduzido a fim de apurar as necessidades especiais desses utilizadores com soluções de *software,* mais especificamente serviços de média social e serviços de conferência, como o *Facebook* ou o *Windows Live Messenger*. Os resultados do estudo foram utilizados para planear o desenvolvimento de um protótipo multimodal proposto anteriormente para utilizadores com mobilidade reduzida. Este permite ligar utilizadores às suas redes sociais através de um serviço de conferência por texto, áudio e vídeo, e um serviço integrado de média social, usando modalidades de interação natural, como o toque, fala e gestos.

Após a fase de desenvolvimento foi realizado um estudo de usabilidade. Esse estudo revelou que este tipo de soluções pode simplificar a acessibilidade aos serviços considerados, dado ter interfaces mais simples, por adotar modalidades de interação mais naturais e por ser mais gratificante do que a maioria das interfaces gráficas atuais para os mesmos serviços, como por exemplo o *Facebook*.

Palavras-chave: Idosos, interfaces multimodais, avaliação de usabilidade, fala, gestos, multi-toque

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Vítor Sérgio Duarte Teixeira

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Acronyms

2D	Two-Dimensional
3D	Three Dimensional
AAL	Ambient Assisted Living
API	Application Programming Interface
ASR	Automatic Speech Recognition
CAPTCHA	Completely Automated Public Turing test to tell Computers and Humans Apart
DTMF	Dual-Tone Multi-Frequency
EPG	Electronic program guide
EU	European Union
GPS	Global Positioning System
GUI	Graphical User Interface
HCI	Human-Computer Interaction
HD	High Definition
Hi-Fi	High Fidelity
HTTP	Hypertext Transfer Protocol
HVAC	Heating, Ventilation, Air Conditioning
IASFA	Instituto de Acção Social das Forças Armadas (Social Welfare Institute for the Armed Forces)
ICT	Information and Communications Technology
IIS	Internet Information Services
IM	Instant Messaging
LHC	Living Home Center
LUL	Living Usability Lab
MHCI	Multimodal Human-Computer Interaction
MLDC	Microsoft Language Development Center
MMUI	Multimodal User Interface
MVVM	Model View View Model
OCS	Office Communications Server
OS	Operating System
PC	Personal Computer
PDA	Personal digital assistant
PIN	Personal identification number
PTT	Push-To-Talk
RDS	Radio Data System
REST	Representational State Transfer
SDK	Software Development Kit
SIM	Subscriber Identity Module

SIP	Session Initiation Protocol
SL	Silverlight
SMS	Social Media Service
SQL	Structured Query Language
STAR	Speech Technology and Research
TTS	Text-to-speech
TV	Television
U.S	United States
UCCA	Unified Communications Client API
UCMA	Unified Communications Managed API
UI	User Interface
ULTI	Universidade de Lisboa para a Terceira Idade (Lisbon University for Seniors)
W3C	World Wide Web Consortium
WIMP	Window, Icon, Menu, Pointing device
Win7	Windows 7
WLM	Windows Live Messenger
WLMC	Windows Live Messenger Connect
WM6.5	Windows Mobile 6.5
WP7	Windows Phone 7
WPF	Windows Presentation Foundation
WS	Web Service
WWW	World Wide Web

Chapter 1. Introduction

Nowadays there are over 2 billion Internet users in the world, a number that has grown 480.4% since the year 2000 [1]. Recent studies, such as [2], also highlight that Internet users worldwide spend on average 22% of their time accessing social media services when they are online. Among the most popular services are *Facebook* and *YouTube*.

One of the factors that contributed for such evolution is the emergence and growth of new communication and social sharing services over the Internet, which made the Internet more attractive for everyone. Social media has become an integral part of modern society. There are generic social networks with more users than the population of some countries [3], as well as a variety of social media services, for sharing photos, videos, status updates, meeting new people and to communicating with friends and family. There are social services for just about every need [3].

Mobile technology has also evolved and made it even easier to access the Internet anytime and anywhere. Systems like the Windows Phone 7 (WP7) and the IPhone OS offer support and myriads of applications for accessing the content available on the Internet, on the move [4].

Elderly often face isolation and loneliness because of limited mobility and lack of nearby relatives. Information and Communication Technologies (ICTs) and SMSs offer an excellent opportunity to help overcome these issues. In fact, the study in [5] reveals that elderly people who are connected to the Internet are less likely to become depressed and have greater probability of becoming socially integrated. However, most of the available services, whose HCI design was oriented to the mainstream young and adult population, still present several technological barriers to the elderly and the common interaction modalities are perceived as unnatural and difficult to get used to by these users. Therefore, the need arises to develop solutions that enable elderly to take advantage of the Internet, its' services and contents in a more natural and simpler way.

1.1. Motivation

Audiovisual communication services (or conferencing services) and SMSs frequently have complex user interfaces, use jargon and require the user to have some knowledge and skills in computer use, which most elderly, namely in Europe, still lack. Consequently, it becomes necessary to develop solutions that accommodate these users, who can greatly benefit from the content and services available online. This way, since it is an unexplored possibility, the opportunity arises to verify whether multimodal interfaces can fill these gaps in order to provide a more natural and simple way for these users to access the aforementioned services.

Studies by D'Andrea et al. [6] and Salces et al. [7] have also demonstrated that multimodal solutions can be used to improve the usage experience by a variety of user groups, including the elderly. Therefore, if provided with more natural means of multimodal interaction, elderly can experience improved accessibility to information and an increased ability to integrate socially using services designed for that purpose, such as SMSs [8]. Multimodal User Interfaces (MMUIs) also provide users with the ability to choose and even adapt different input and output HCI modalities depending on usage context, environment conditions or user preference and special needs. The possibility to seamlessly alternate between input modalities is another advantage of MMUIs, helping reducing the probability of hazards due to the overuse of a single modality (see [9] and [10]).

1.2. Problem

There is evidence that the European Union (EU) population is ageing rapidly. The European Commission estimates that by 2050 the elderly population in the EU will be around 29% of the total population [11]. This means that it is hastily becoming necessary to create solutions that allow overcoming the difficulties age brings to people who want to use new technologies in order to remain socially active.

In addition, elderly often have difficulties with motor skills due to health problems such as arthritis [12], so the absence of small and difficult to handle equipment may be presented as an advantage over current solutions.

It is also known that due to ageing, senses like vision become less accurate [13]. Hence, difficulties in the perception of details or important information in conventional graphical interfaces may arise, since current interfaces, most notably in the mobility area, are not designed with these difficulties in mind.

Common interaction modalities are perceived as unnatural and difficult to get used to by those users. Elderly individuals who have developed resistance to conventional forms of human-computer interaction, like the keyboard and mouse of the WIMP paradigm [14], therefore making it necessary to test new natural forms of interaction such as speech, touch and gesture.

However, for the development of appropriate solutions with high accessibility one must also take into account the specificities of universal design [15] as well as user perspectives, thus avoiding the usage of inappropriate content, font or graphical elements size [16].

1.3. Thesis hypothesis and objectives

This thesis proposes the following hypothesis for the elderly citizens: “Multimodal user interaction for accessing audiovisual communication services and SMSs over the Internet, is more adequate than traditional WIMP and keyboard interaction.”

With that statement in mind we defined the following objectives to test our hypothesis:

1. For a sample of the elderly population, understand the limitations of use and gather also a set of Multimodal HCI requirements, focusing especially on interaction modalities (keyboard and mouse, speech, touch, gesture) with Internet services, such as audiovisual, communication and social media services, taking also into account the diversity of hardware choices, via a user study.
2. Adapt and extend the prototype proposed on [17], which was specifically targeted at mobility impaired users, taking into account the MHCI requirements gathered from the elderly in the user study.
3. Test the hypothesis by assessing usability of the extended prototype, with a panel of elderly participants and reach conclusions about the use of Multimodal HCI for improving the access to audiovisual communication services and social media services, in the Internet.

1.4. Scope

This dissertation work was developed in close cooperation with the Microsoft Language Development Center (MLDC), a part of the international Speech @ Microsoft product R&D group, located in the Portuguese subsidiary of Microsoft, in Porto Salvo, Oeiras. The project was co-funded by Microsoft, under QREN Living Usability Lab (LUL) [18], an initiative of the national program of incentives for the Portuguese businesses and industry (in the scope of its R&D incentive program), in the context of the Operational Program for Competitiveness Factors.

1.5. Contributions and Publications

A paper describing the aspects and results of this work was submitted to the 2nd International LUL Workshop on AAL Latest Solutions, Trends and Applications - AAL 2012. 1-4 February 2012.

1.6. Thesis Organization

The remainder of this thesis is structured as follows:

- Chapter 2 reviews relevant work in the field of assistive technology. It also presents the definition and characteristics of multimodal systems as well as provides relevant information about methodologies for designing and evaluating user-centered multimodal systems.
- Chapter 3 presents the initial elderly user requirements study and discusses its results, from which we derive HCI design guidelines and gather knowledge about the elderly requirements concerning the usage of the computer and mobility devices and, especially, social media and audiovisual and conferencing applications.

- Chapter 4 provides an overview of the developed prototype, targeted for the elderly, which is able to provide MHCI access to social media and audiovisual and conferencing services. Architectural and technical aspects of the prototype are also discussed, providing details about the technologies used and the APIs chosen.
- Chapter 5 presents the results of the usability evaluation study of the developed prototype, conducted with a group of elderly people, and discusses the main findings.
- Chapter 6 presents the thesis conclusions and outlines areas for future work.
- Appendix A contains additional data from the Requirements Study sessions, which include interviews transcription, tasks and questionnaires results, as well as observations made during the study sessions.
- Appendix B holds additional data from the Usability Evaluation Study sessions. This includes interviews transcription, tasks and questionnaire results, as well as observations made during the study sessions.

Chapter 2. Background and Related Work

The European Union has launched some initiatives with the objective of allowing elder people and people with disabilities to live independently and be active in society. One of such initiatives is the e-inclusion project [19], which "*aims at reducing gaps in ICT usage and promoting the use of ICT to overcome exclusion, and improve economic performance, employment opportunities, quality of life, social participation and cohesion.*", which proposes a series of measures to promote take-up of digital technologies by potentially disadvantaged groups, such as elderly, less-literate and low-income persons.

In this chapter we will overview the specificities of Accessibility and we will also present the Ambient Assisted Living paradigm, illustrated with some related projects. Subsequently, we will discuss Multimodal HCI systems, their characteristics, possible advantages and provide some examples of existing systems. Finally discuss methodologies for User-Centered Design and Development and Usability evaluation.

2.1. Universal Access to Information Systems

Accessibility plays an important role in a systems' success. Not only does an accessible system opens its doors to an additional 22% of the working-age adults [19] population, it also provides a more natural and user-friendly experience to all other users.

The notion of universal accessibility demands the adaptation of information technology to the user. Above all, elderly and disabled persons in a public environment depend on the accessibility to information technology (e.g. cash dispensers, ticket selling machines, etc.). Due to the technological development and the successive intrusion of information technologies into everyday life, "the range of the population which may gradually be confronted with accessibility problems extends beyond the population of disabled and elderly users." [20].

Being accessible requires that a system is able to adapt to the users' needs, to the task scope and context, and to the technical platform used. An accessible system therefore is a system that is able to optimize its usability depending on the current user, task and system configuration. Universal Accessibility implies that support for users with special needs is not regarded as orthogonal to the application but rather part of the system itself. Users with disabilities are not considered as a distinct class of users, but rather as part of the continuum of human diversity.

Next, we present examples of accessibility tools and an insight on SMSs accessibility.

2.1.1. Accessibility tools

Windows 7 ease of access center provides settings and programs that can make the PC easier to use. It allows quick access to programs such as Magnifier, which allows zooming into the desktop; the full-screen mode allows magnifying the entire desktop, lens mode allows zooming in on particular areas while moving the mouse around, and docked mode which allows the user to have a separate docked window that shows an enlarged version of the area the user is focused on.

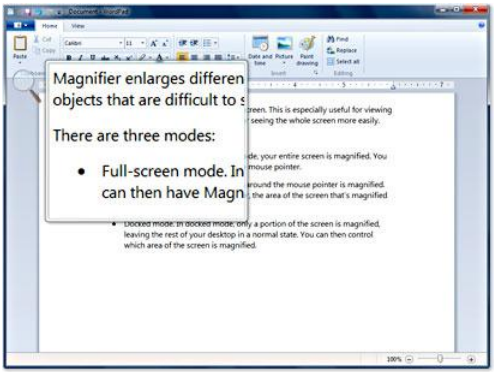

FIGURE 2.1 – WINDOWS 7 MAGNIFIER

FIGURE 2.2 – WINDOWS 7 ON-SCREEN KEYBOARD

Other accessibility tools in Windows 7 include the On-Screen Keyboard which lets users type without a real keyboard, the Narrator, which is able to read on-screen text aloud and Windows Speech Recognition which lets users to use speech to issue commands to the system and dictate text.

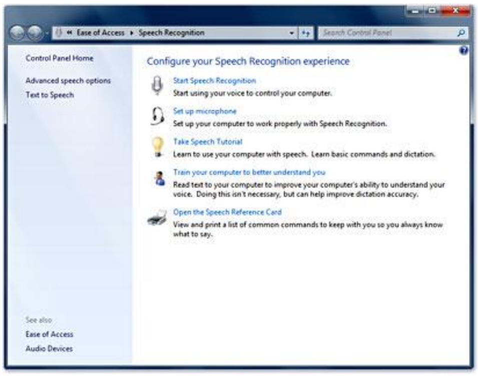

FIGURE 2.3 – WINDOWS 7 SPECH RECOGNITION OPTIONS

FIGURE 2.4 – WINDOWS 7 NARRATOR SETTINGS

Tools like these are likely to enable users with mild or severe difficulties or impairments to use computers, as well as improve their performance and satisfaction while using those systems [21].

2.1.2. Social Media Accessibility

Social media is becoming more and more important in human social interaction. About 22% of the time internet users spend online is accessing social media, as illustrated in Figure 2.5.

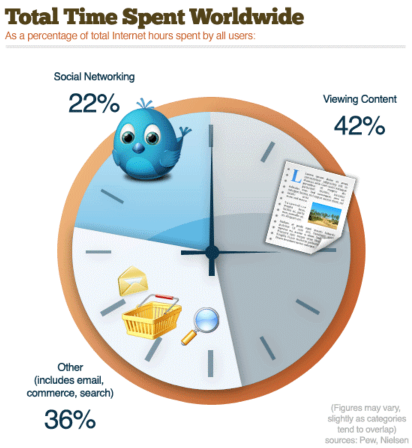

FIGURE 2.5 – TOTAL TIME SPENT ONLINE [2]

Social media can be of many different forms, such as blogs, picture sharing sites, video sharing and podcasts. Such user-generated content becomes instantly accessible by potentially millions of users. Ultimately, the user has the control of who is allowed to see their content.

Some of the most popular social media applications and sites are:

- Windows Live Messenger (WLM): video and voice calling, instant messaging and file sharing. http://explore.live.com/windows-live-messenger
- Facebook: social networking. http://facebook.com
- YouTube: video sharing. http://youtube.com
- Flickr: photograph sharing. http://flickr.com
- Twitter: micro-blogging. http://twitter.com
- MySpace: music sharing and social networking. http://myspace.com

A study that focused on reviewing Social Media accessibility [22] demonstrated that, typically, a site that contains features to ease the access of impaired users is more successful than those who do not. Facebook is one of the most popular SMSs to date, with currently more than 750 million active users [23], and according to [22] is an example of an accessible site with features such as an audio CAPTCHA service, navigational shortcut keys and the possibility to increase font/text sizes (see [24]).. MySpace, in comparison, is in free-fall having lost over 30% of the market in the last 2 years [25]. In the study mentioned above MySpace was considered an inaccessible site, arguing that this contributed to its recent decrease in popularity.

Such considerations lead to the idea that in order to succeed, an SMS must provide ways for all users to easily access its contents, so it may also become a tool for social inclusion for those with special needs, and thus, become popular amongst them.

2.2. Ambient Assisted Living

The main objective of Ambient Assisted Living (AAL) is the development of technologies which enable its users to live independently for a longer period of time, increasing their autonomy and confidence in performing everyday tasks. Age, diseases, disabilities, permanent or transient, are frequent causes of loss of autonomy. Developments made on this area can help individuals improve their quality of life, to stay healthy and continue to develop an active, creative participation in society.

The concept of AAL is often understood as [26]:

- *“An extension of the time that users can live in their preferred environment through improving the autonomy, self-confidence and mobility;*
- *A support for the maintenance of health and functional capacity of older people;*
- *A promotion of a healthier lifestyle for individuals at risk;*
- *Increased security, prevention of social isolation and a support for the maintenance of a multifunctional network around the individual;*
- *A support for caregivers, families and assistance organizations;”*
- *An increase of the efficiency and productivity of resources used in aging societies.*

In fact, also the caregivers can benefit from technologies, to the extent that providing assistance to users with the use of devices will contribute to greater safety for users. Consequently all the stress on caregivers, arising from the care of the elderly will be mitigated, given that they will provide greater autonomy to handle different applied technology devices.

The main stakeholders in AAL have been characterized in several studies [27] [28]. The description that has received the highest consensus is provided by [29]. This work classifies stakeholders into four distinct groups, organized in vertical categories taking into account the primary relationships between them. The following segmentation is proposed:

- *Primary stakeholders: seniors, people with disabilities and caregivers.*
- *Secondary stakeholders: service provider organizations (transport, food, security, etc.);*
- *Tertiary stakeholders: industry and suppliers of goods and services to secondary stakeholders;*
- *Quaternary stakeholders: organizations and institutions working in the economic and legal context of AAL.*

In practical terms, AAL systems help preventing and classifying situations such as falls, physical immobility, monitoring activities of daily living, occupation of space at home, behavior analysis and other possibilities. All improvements in each of these scenarios are an important step in the development of safer and more effective solutions to enable the subsequent development of new mechanisms, products and even services.

2.2.1. AAL Projects

With the creation of initiatives such as, "The Ambient Assisted Living (AAL) Joint Programme" [26], several projects about AAL emerged. Some of the most significant AAL projects include:

- *Assisted Living Laboratory (Fraunhofer IESE)* [30]*, used to train elderly people to handle modern interfaces for Assisted Living and evaluate the usability and suitability of these interfaces in specific situations, e.g., emergency cases;*
- *VirtualECare framework* [31]*, an intelligent multi-agent system able to monitor, interact and serve its customers, which are in need of care services;*
- *SafeHomeHealthCare* [32]*, an interference-free Home and Health-Care Smart Spaces using Search Algorithms and Meta-Reality Reflection;*
- *e-Home* [33]*, assistive home system which can prolong the time of independent living for elderly people.*

More information about Living Labs in Europe can be found at the European Network of Living Labs [34].

Examples of Assisted Living technology used in these projects include:

- Ambient sensors positioned in strategic locations such as switches or power sockets for activity tracking;
- Position tracking trough devices such as, smart floors or carpets, ultrasonic motion sensors in the ceiling, etc.;
- Intelligent household appliances, such as smart refrigerators that keep track of food validation dates, or intelligent electronic scale [35];
- Vital data monitoring through a vital jacket [36] or some similar device that keeps track of pulse, skin temperature and humidity, etc.;
- Biomedical sensors such as, electrocardiogram sensors;
- Visual tracking in order to detect falls or seizures;
- Robot that could provide assistance to emergency situations, handle and manage medicine pills according to prescription or that provides transport;
- Interactive TV with communication system integrated in order to allow connections to relatives or medical staff;
- Computers [37] and software [38] for elderly – with adapted interfaces that allow connecting to social networks or just sending an email to a relative.

2.3. Multimodal Systems

Multimodal interactive systems are described in the work of Bernsen, in [39], as:

[…] systems which use at least two different modalities for input and/or output. Thus, [IM1,OM2], [IM1, IM2, OM1] and [IM1, OM1, OM2] are some minimal examples of multimodal systems, I meaning input, O output, and Mn meaning a specific modality n.

Conversely, a unimodal interactive system is a system which uses the same modality for input and output, i.e., [IMn, OMn] (e.g., an over the phone conversation only uses speech).

Originally started by Richard Bolt's "Put That There" work [40] in the 80's, research on the area of multimodal interfaces has been flourishing in recent years, mainly due to current technological advances, and the pervasiveness of cheaper ICTs. There are examples of works that explore the benefits of multimodal systems to impaired users [41], others that demonstrate the integration possibilities with the latest devices [42], and also relevant works that provide guidelines for the design and development of universal multimodal systems [15] [43].

Some of the motivations for multimodality include:

- Multimodality allows for more natural interaction. Human-Human communication is essentially multimodal; it uses speech, gaze and gesture;
- Multimodal interfaces can rapidly adapt to changes in the environment. E.g., change from speech to GUI, touch input when ambient noise becomes too loud for speech recognition;
- Multimodality allows HCI to extend beyond the conventional computer. A smartphone can use speech and touch for input, increasing the available area of the screen for graphic output.

Ultimately, as has been stated by [44] "*multimodal interfaces have the potential to accommodate a broader range of users than the traditional interfaces*". Thus, multimodality also plays an important role on the improvement of accessibility of information systems [8].

2.3.1. Generic Architecture of Multimodal Systems and Key Components

A representation of a multimodal interaction system architecture introduced by Dumas et al. [45], that is acknowledged in the community, can be seen in Figure 2.6.

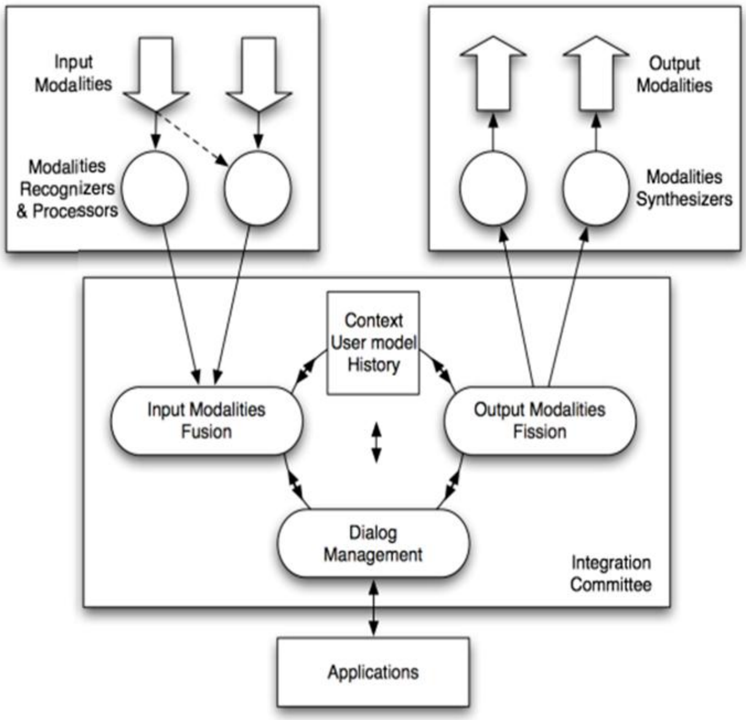

FIGURE 2.6 – ARCHITECTURE OF A MULTIMODAL SYSTEM [45]

According to this representation a multimodal interaction system is composed by input and output modalities, their respective recognizers and synthesizers and a group of integration subcomponents, called an integration committee. The following description of the architecture is from [45] and allows understanding the process that starts with the interpretation of an input and ends with the choice of the adequate output:

As illustrated in the figure, input modalities are first perceived through various recognizers, which output their results to the fusion engine, in charge of giving a common interpretation of the inputs. […] When the fusion engine comes to an interpretation, it communicates it to the dialog manager, in charge of identifying the dialog state, the transition to perform, the action to communicate to a given application, and/or the message to return through the fission component. The fission engine is finally in charge of returning a message to the user through the most adequate modality or combination of modalities, depending on the user profile and context of use. For this reason, the context manager, in charge of tracking the location, context and user profile, closely communicates any changes in the environment to the three other components, so that they can adapt their interpretations.

2.3.2. Modalities

A definition of a Modality is presented in [39]:

A modality or, more explicitly, a modality of information representation is a way of representing information in some physical medium. Thus, a modality is defined by its physical medium and its particular "way" of representation.

To be perceptibly communicated to humans, information must be instantiated in one or more of the following six physical media [39]:

- Light / vision / graphics;
- Sound waves / hearing / acoustics;
- Mechanical touch sensor contact / touch / haptic;
- Molecular smell sensor contact / smell / olfaction;
- Molecular taste sensor contact / taste / gustation; and
- Proprioceptor stimulation. (as when you sense that you are being turned upside down)

The first element of a medium triplet refers to the physical information carrier, the second refers to the perceptual sense needed for perceiving the information, and the third to information presentation in that medium. In this context, the term graphics include not only graphical images, but also ordinary text.

Graphics, acoustics and haptic are currently the all-dominant media used for exchanging information with interactive computer systems [39].

The following table presents a set of possible input and output modalities:

TABLE 2.1 – MODALITIES OF INTERACTION

	Input	Output
Acoustic	Speech recognition	Synthetic speech (TTS, Prompts)
	Tune recognition	Music
Tactile	Pen • Pointing • Handwriting • Gesture (drawings, lines, areas)	Haptic • Force feedback • Braille display
	Touch display • Single-touch / Multi-touch	
	Mouse • Pointing gestures / Drawing	
	Keyboard / Keypad • DTMF / Arrow keys	
	Device orientation (gyroscope	
	Thumb wheel	
	Pressure pads / Foot pedal	
	Hand gesture (glove)	
Visual	Hand gesture (computer vision)	Graphics • Text / Tables • Maps / Diagrams • Animated highlighting • Embodied characters / Visual TTS • Static vs. Dynamic
	Gaze (eye tracking)	
	Body posture / presence • Computer vision	
Other	GPS, Barcode scan	Smelly-vision

2.3.3. Sample Multimodal Applications

In this section we will present some works with multimodal systems. Examples include applications derived from research works, as well as more main-stream applications.

2.3.3.1. Assistive Living

Research has been especially significant in the area of AAL in the last few years, and so, many multimodal systems have emerged. Below we describe two different systems that involve MMUIs.

2.3.3.1.1. i2Home

I2Home is a research project that aims at simplifying the use of home appliances and consumer electronics by persons with cognitive disabilities and elderly, using a multimodal application running on a smartphone [46].

Figure 2.7 shows the GUI of this application. The available modalities of interaction are combinations of click gestures and speech. The current version allows controlling devices such as the TV, HVAC (Heating, Ventilation, Air Conditioning) and a blood sugar meter. It also contains a calendar feature, which reminds the users of their appointments, and an Electronic program guide (EPG), which allows users to access information for current and upcoming programming.

The system is also characterized for being a mediator between the user and the client application. For example, the command “Switch to CNN” suffices to switch the channel, independent from the active graphical menu and. Similarly, the system also uses context information when interpreting speech input. For example, if the active menu is for the air conditioning, the command “Turn on” would activate the air conditioning and not any other appliance.

FIGURE 2.7 – THE I2HOME USER INTERFACE FOR MULTIMODAL INTERACTION ON A SMARTPHONE

2.3.3.1.2. QualiWorld Platform

The QualiWorld platform [47] provides an extensive range of communication, information, control and entertainment applications in a single software solution. It is targeted at individuals with any physical disability and elderly people at home and in retirement home, aiming at simplifying the interaction with computer systems for those individuals.

The software manages several applications, which are included in the following modules:

- **Communication**: Audiovisual conferencing (QualiSpeak), phone calls (QualiPhone), e-mail (Qualimail), SMSs (QualiSMS), written communication (QualiFax, QualiWord);
- **Information and Services**: Public information, Social Media Services (QualiSurf);
- **Environmental Control**: Control electrical devices (i.e. lights, alarms, A/C, television, etc.) (QualiHome);
- **Entertainment**: Internet (QualiSurf), TV (QualiTV), Video/DVD (QualiDVD), Music (QualiPlayer), Radio (QualiRadio), Games (QualiGames), Photos (QualiAlbum).

QualiWorld also provides several different access solutions. Below is a list of some of the possible alternative interaction modalities:

- **Tracking mouse**: The cursor on the screen is controlled by simple body movements detected by a standard USB WebCam;
- **Voice Commands and Dictation**
- **On-screen keyboard** with layout editor and intelligent word prediction

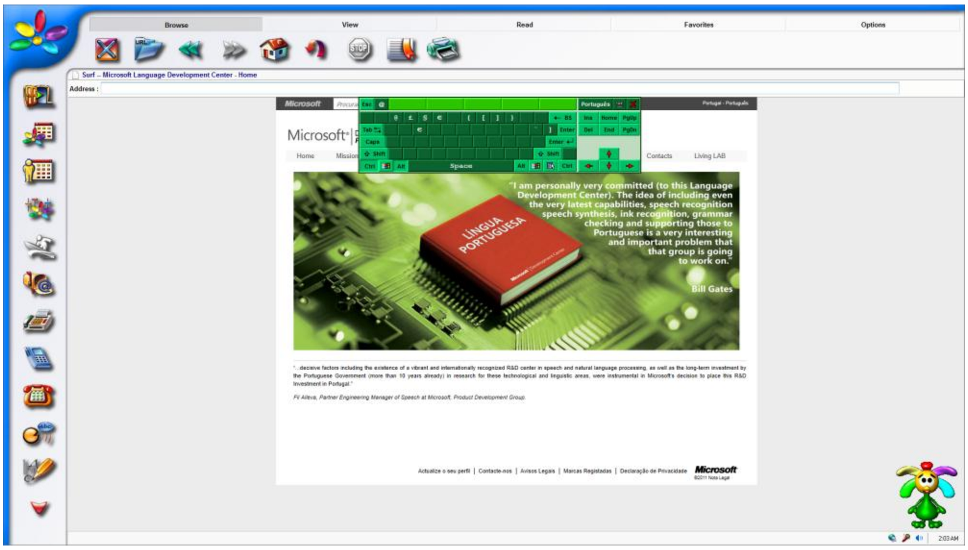

FIGURE 2.8 – QUALISURF INTERACTION EXAMPLE

2.3.3.2. *Mobile (Smartphones, Tablet Computers)*

Multimodality played a big role on the way mobile devices have evolved in the last few years. Thanks to touch, gesture and speech interaction, most devices do not need a physical keyboard any more, thus allowing for bigger touch sensitive screens. Allied to ubiquitous Web access, these devices have become desirable and, consequently, have been the object of many studies with MMUIS.

This section shows some examples of multimodal applications on mobile devices.

2.3.3.2.1. Windows Phone 7.5 (Mango) Speech Features

Windows Phone 7.5 presents some new and interesting features concerning speech interaction [48]. The new version of the OS not only allows the user to setup the phone to synthesize text that appears on-screen to speech, such as reading a received SMS, but also includes a speech recognition engine that allows the user to perform multiple tasks. Below we describe what each possible task is and how it can be achieved:

- **Call:** User can call someone by just saying "Call" and the name or number of the person he/she wants to call;
- **Find:** If user says "Find" and then the topic he/she wants to search, Bing search engine will perform a query using those keywords;
- **Open:** Saying "Open" and then the name of the application, launches any application that is installed on the phone whose name matches the one articulated;
- **Text:** By saying "Text" and then the name of the person the user wants to send a short message to, it is possible to dictate a message and send it using just speech. This works both for SMSs and for Facebook and WLM as well.

Speech recognition on the Windows Phone 7 is activated by pressing and holding the physical start button, while text-to-speech is achieved by just enabling that option on the phone settings.

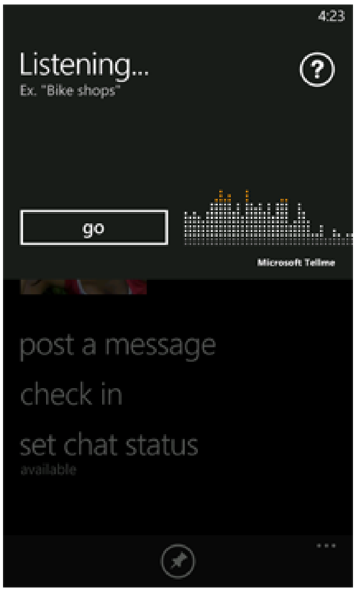

FIGURE 2.9 – WP 7.5 BING VOICE SEARCH INTERACTION [48]

2.3.3.2.2. Siri - Mobile Personal Assistant

Siri [49] is a conversational interface for the iPhone. It allows the user to ask the application to perform a number of tasks, accounting for parameters like context, time of day and location to interpret each request. Some of the tasks allowed by Siri are:

- Sending text messages;
- Placing phone and audiovisual calls;
- Scheduling meetings;
- Setting reminders (Figure 2.10);
- Searching the Web;
- Control music player;
- Read e-mail;
- Etc.

FIGURE 2.10 – SIRI USER INTERFACE [49]

The application was originally developed by SRI Speech Technology and Research (STAR) Laboratory [50], being bought by Apple Inc.in 2011. It relies on a Nuances’ [51] speech recognition engine for interpreting speech commands and dictation.

2.3.3.3. Automotive

With the recent increase and banalization of on-board systems on cars, specifically, driver assistance and infotainment systems, the need has grown for the development of new ways to interact with such systems in an simple and safe way [52]. Thus, the use of speech control for the management of large amounts of audio files, control of GPS systems and integration of mobile phones becomes a desirable feature.

Figure 2.11, illustrates the Audi Multimedia Interface (MMI) which is present in the A8 model. This is an all-in-one system that includes navigation, phone and entertainment features all controlled by touch and/or speech, also using Nuance's speech technology. This type of solution as proven to reduce dangers associated to visual and manual distraction.

FIGURE 2.11 – AUDI A8 MULTIMEDIA UI

2.4. Methodologies for User-Centered Development and Evaluation

2.4.1. AMITUDE

A methodology that we have considered interesting and useful for aiding in the development of the multimodal prototype of this thesis is the AMITUDE model of use, presented in [43], which claims that a multimodal system use can be helpfully modeled as having the following aspects: Application type, Modalities, Interaction, Tasks and other activities, Domain, User, Device and Environment of use. In addition to the notion of usability, AMITUDE is our main conceptual framework because, in order to create a usable system, the above mentioned seven AMITUDE aspects must be analyzed to some satisfactory extent during application specification and design.

We will now see a definition of each of the components of this framework:

Application Type: This is the type of interactive system to be built. Trivial as this may seem, fixing the application type carries advantages for usability development. (E.g.: The application type provides a central clue on how to look for usability information and other information on similar systems).

Modalities: This relates to the choice of modalities to use, and is included in this model since, in general, it makes a difference to usability whether abstract information items are being represented in one or another modality. This methodology proposes that a developer refers to modality properties when doing modality analysis. Essentially, one or both of these questions must be addressed:

- *Is modality M1 useful and usable in the current AMITUDE context?*
- *Is M1 better than alternative modalities M2 ... Mn in the AMITUDE context?*

Interaction: This is associated with the choice of the types of information presentation and exchange the system enables between itself and its human users. Figure 2.12 below presents a model that generalizes interaction and that can be applied to plan the information presentation and exchange involved in most system’s cases.

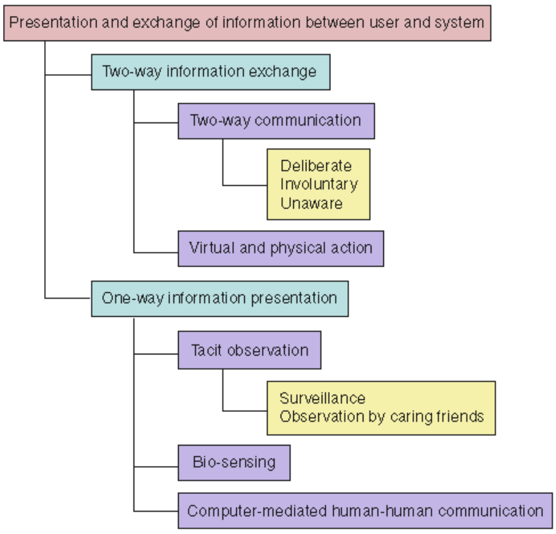

FIGURE 2.12 – VARIETIES OF HUMAN-SYSTEM INFORMATION EXCHANGE [43]

Task: This refers to the planning of what users will do with the system and how the system will enable them to do it. Here are some mandatory rules (MR) and rules of thumb (RT) proposed by Bernsen et al. in [43] for systems that are task-oriented:

- *MR: Find out if the task is familiar to the target users.*
- *RT: If the task is familiar, find out which sub-tasks it includes in their minds and include those in the task model.*
- *MR: If the task is familiar, find out if the users structure the task and what the structure is.*
- *RT: If the task is familiar and is structured, model the structure.*
- *RT: If the task is unfamiliar, structure the task if possible and give the users sufficient clues to the task structure and the sub-tasks to be done.*
- *RT: If the task is ill-structured, only add structure if this does not conflict with user beliefs and preferences. Give the users sufficient clues to the task structure and the sub-tasks to be done.*

User: This is related to the specification of the target users for the system in the form of a user profile. The purpose of user profile analysis is to identify and describe with reasonable reliability the group of people the system is meant to fit. This analysis allows understanding what's important about the target users with respect to the system we are going to develop. Empirical investigation of the target user group may support the specification of this aspect of the model.

Devices: The goal of device analysis is to identify and select usable device candidates. It is important to have an idea of the modalities to be used before selecting device candidates, however devices may also arise constraints to other aspects of the model so it must not be taken too lightly.

Environment of Use: The objective behind the analysis of use environments is to determine the setting in which the system is to be used and the characteristics associated to that setting. This can concern physical, psychological or social elements. This is an especially relevant part of this model since it allows developers to account for special situations the system must adapt to, related to the environment it will be used on.

To reach conclusions about each aspect of the model we have to analyze its seven aspects one by one but reminding the functional relation between parts and the whole. This leads to the probable scenario where more conclusions or constraints will arise after the analysis of the remaining aspects of AMITUDE and their own constraints.

2.4.2. Evaluation Methods

According to [15], *evaluation tests the usability, functionality and acceptability of an interactive system*. It should occur throughout the design life cycle, with the results feeding back into modifications of the design.

An evaluation method must be chosen carefully and must be suitable for the job. [15]

2.4.2.1. Expert Evaluation

Some approaches are based on expert or designer evaluation and are normally used to assess early designs and prototypes. These include analytic methods like Cognitive Walkthrough, review methods, such as Heuristic Evaluation, and model-based methods. Below we will present the definition of some of those approaches.

2.4.2.1.1. Cognitive Walkthrough

Cognitive walkthrough consists of a detailed review of the steps an interface requires the user to perform to accomplish some known task. This method allows evaluators to find out and describe why some step is not adequate to a new user of that system.

To perform this kind of evaluation some prerequisites exist: A detailed specification or a prototype of the system, a description of the task the user is supposed to perform, as well as the detailed list of steps needed to complete that task, and a profile of the systems' target users, mentioning who they are and what kind of experience and knowledge can be assumed about them.

2.4.2.1.2. Heuristic Evaluation

Heuristics can be perceived as guidelines or general principles that can be used to guide the evaluation of a system. This type of evaluation must be done by more than one evaluator in order to find violations to any of the previously established heuristics and thus, come up with potential usability issues. Following are the ten general principles, or heuristics, for user interface design proposed by Nielsen, J. [53] and also referred in [15]:

Visibility of system status: The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

Match between system and the real world: The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

User control and freedom: Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

Consistency and standards: Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

Error prevention: Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

Recognition rather than recall: Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

Flexibility and efficiency of use: Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

Aesthetic and minimalist design: Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

Help users recognize, diagnose, and recover from errors: Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

Help and documentation: Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

2.4.2.1.3. Model-based Evaluation

This type of evaluation is done with the help of models that allow combining design specification and evaluation into the same framework. The AMITUDE model presented in the previous section, for example, can be used to filter particular design options, since it is constraint-based and allows detection of conflicting aspects on the design specification stage.

2.4.2.2. User Evaluation

Other approaches comprise user participation and are normally used with a completed prototype but can also contribute to the earlier design stages, such as requirements gathering, where observation and surveying users are important. These include experimental, observational and query methods. Next we will present definitions for each one of those types of evaluation methods.

2.4.2.2.1. Experimental Evaluation

In experimental evaluation the objective is to reach empirical evidence that support a hypothesis. For that the evaluator must first define the hypothesis to test. Later on, the analysis of the measured or dependent variables (e.g., time taken, number of errors) may assist in proving the hypothesis. However, some factors must be carefully considered, as described in [15]:

> *Participants should be chosen to match the expected user population as closely as possible: they must be representative of the intended user population. The sample size must also be large enough to be representative of the intended user population.*
>
> *Variables come in two main types: those manipulated (independent) and those measured (dependent). The values of the independent variable are known as levels. More complex experiments may have more than one independent variable.*
>
> *Hypotheses are predictions of the outcome of an experiment, framed in terms of dependent and independent variables, stating that a variation in the independent variable will cause a difference in the dependent variable. The aim of the experiment is proving the hypothesis, which is done by disproving the opposite null-hypothesis.*
>
> *Experimental design consists of different phases: the first stage is to choose the hypothesis and define the dependent and independent variable. The second step is to select the experimental method: between-subjects, in which each participant is assigned to a different condition, and within-subject, in which each user performs under each condition.*
>
> *Statistical measures: the data should first of all be saved to enable performing multiple analyses on the same data. The choice of statistical analysis depends on the type of data and the questions we want to answer. Variables can be classified as discrete (which can take a finite number of values and levels) and continuous variables (which can take any value between a lower and upper limit)*

2.4.2.2.2. Observational Evaluation

This method allows gathering information about the use of a system by observing users interacting with it. In this process the evaluator must watch and record the users' actions.

However, to validate how well the system meets users' requirements some other techniques must be applied, such as asking the user to talk through what they are doing, i.e. thinking aloud, since simple observation may not allow understanding their decision processes or attitudes. Another approach that helps reducing biased views by users and encourages them to criticize the system is cooperative evaluation [54] in which the user has the role of a collaborator in the evaluation rather than a simple experimental participant. Additionally the participant may be asked questions in the end of the evaluation session in order to collect missing information.

2.4.2.2.3. Query Evaluation

Queries consist on asking the users about the interface directly. Although this can be used in an evaluation stage of a system, it is particularly useful when collecting information about user requirements and tasks.

This method allows reaching the users' viewpoint directly, potentially revealing issues not considered by the designer. However it also leads to subjective views and may limit the scope of the information that can be obtained. So, this method is best applied to provide useful supplementary information to other methods.

The main types of query techniques are interviews and questionnaires and the styles of questions that can be included are: general background questions, open ended questions, scalars, multi-choice questions and ranked questions.

2.5. Conclusions

In this chapter we have looked into the role of accessibility in a systems' success, and presented examples of accessibility tools, as well as gave an insight on social media accessibility. That allowed us to conclude that accessibility must not be overlooked on any system, because it provides a significant part of the human population access to services and contents that would, otherwise, be out of their reach.

Likewise, we have investigated the concept of Ambient Assisted Living (AAL) and presented some advantages that approach brings, as well as discussed the parts that may benefit with it. Projects in that area were also used to illustrate possible application scenarios. With this investigation we have concluded that the concept of AAL may be useful for the development of safer and more effective solutions to help users interact with the environment that surrounds them in a simpler and more effective way.

We have also overviewed Multimodal HCI systems, their characteristics, and possible advantages and provided some examples of existing solutions, concluding that those systems can be effective while providing alternative modalities to access computational systems, helping simplify and expand HCI possibilities.

Finally, we have discussed methodologies for User-Centered Design and Development and Usability evaluation, which were seen as providing effective tools to design, develop and evaluate systems that aimed at being accessible and usable.

Chapter 3. Requirements Analysis

In this chapter we present the results obtained from a requirements analysis study, which aimed at gathering information about the main problems faced by the elderly while using the computer and the current GUIs for audiovisual communication services and SMSs and thus, allowed to define a list of key MMUI requirements to be considered. In this study we have asked the participants to complete a few tasks using the previous version of the Living Home Center (LHC) prototype ([17], [55] and [56]) so we could gather information about which modalities would better satisfy the needs of the elderly, and also obtain some data concerning the participant's reaction and opinions about the current LHC version GUI.

The goal was to compile a set of MMUI user requirements that allowed developing a version of the above referred LHC for the population in general, but taking also into account the senior population needs as well the restrictions we must consider while adding access, namely to audiovisual conferencing services and SMSs.

The requirements analysis sessions were conducted between the 18th and the 21st January, 2011 in collaboration with ten senior citizens who are also students at the Lisbon University for Elderly (*ULTI – Universidade de Lisboa para a Terceira Idade*). A total of 10 interviews were made, these interviews consisted on the following parts:

1. Written questionnaire aimed at the determination of computer and mobile phone/smartphone frequency of use, nature of use and skills, as well as habits of usage of audiovisual conferencing services and SMSs;
2. Predefined tasks with current GUIs for audiovisual conferencing services and SMSs, aimed at performing an usability evaluation of such interfaces and services;
3. Usability evaluation of HCI modalities using the previous version of LHC, designed for mobility impaired citizens. This part was composed of a series of tasks, followed by a questionnaire concerning the interaction with the prototype. As referred above, this part also allowed gathering information about ease of interaction and satisfaction with the design of the previous version of the LHC prototype.

Our methodology included individual interviews, questionnaires and observing users while they performed the sets of predefined tasks mentioned above. For the creation of the experimental tasks and decision of the analysis methods we have followed the guidelines provided by Dix et al. (chap. 9) [15].

As a corollary to this user study we were able to derive user requirements of MMUI for audiovisual communications services and SMSs, following Universal Design guidelines that include accessibility of elderly individuals.

In the beginning of each interview the participants were asked to sign a consent form (See Appendix A.1). In that document the context and purpose of the study was explained and the participant was informed that the interview would be recorded for further analysis.

In the following sections I'll present relevant data about the seniors that participated in the study, as well as the goals and results of each part of the interviews.

3.1. User Study Participants

Ten elderly people took part in this requirements study. As mentioned, all the participants were volunteers from the ULTI - Lisbon University for Elderly (http://ul3i.com.sapo.pt/). The selection of the participants was done randomly, however with a few restrictions:

A. Some introductory level of computer skills was required;
B. Age distribution between participants was the following: 60% between 55 and 65 years, 10% between 65 and 75 years and 30% between 75 and 85 years.
C. Level of literacy was the following: Average to Good

The study group was composed of 2 males and 8 females all volunteers from ULTI, with an average age of 66.3 years old and with different professional careers. As requested, most of the participants presented high education levels, since that aspect "*plays a significant role in the way the user interacts with computers*" [16]

In the table below (Table 3.1) we present the relevant data about each participant. To gather this data we have asked the participants to fill in their personal information below the consent form.

TABLE 3.1 – REQUIREMENTS STUDY PARTICIPANTS

Participant	Gender	Age	Former Profession
Control 1	Female	21	Student
Control 2	Male	26	Linguist
P1	Female	59	Secretary
P2	Female	83	Public Servant
P3	Male	78	Commercial Manager
P4	Female	61	Bank Employee
P5	Female	55	Teacher
P6	Female	61	Teacher
P7	Male	57	Teacher and Author
P8	Female	59	Translator
P9	Female	72	Clerk
P10	Female	78	Administrative Assistant

Despite the differences, almost all the participants were retired. Only P7 and P8 were not retired, but they teach at the same university, finding themselves in daily contact with the target group.

In order to know of eventual health problems, the participants were requested to fill in that information, along with their personal information. However, most of them stated that they had no limitations due to health problems. None of the participants suffered from major vision accuracy losses, even though most of them needed glasses, or other impairments, like hearing accuracy, for example. Only participant P6 showed a significant disability: her hands had more fingers than normal, making the ergonomic design of the mouse and keyboard not applicable to her case. She stated that it was difficult for her to adapt to conventional mouse and keyboard, even though she also said that she eventually got used to those peripherals, after having to use them for professional reasons.

Control tasks were made by subjects with less than 30 years of age and with average to good computer usage skills. Control 1 subject did the first tasks using current GUIs for conferencing services and SMSs. Control 2 subject did the tasks that required the previous version of the LHC prototype.

3.2. Participants Generic ICT Usage and Skills

The first part of the interviews consisted of a written questionnaire with 6 multiple-choice questions. The goal of this questionnaire was to determine computer, mobile phone and smartphone frequency of use, nature of use and demonstrated skills, as well as habits of usage of audiovisual communication services and SMSs. This part was exclusively self-assessing. The obtained results can be found in Appendix A.2.1. Next we present an analysis of those results.

3.2.1. Computer Related Results

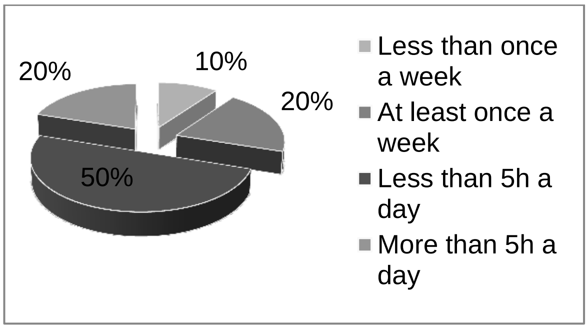

FIGURE 3.1 – FREQUENCY OF COMPUTER USE

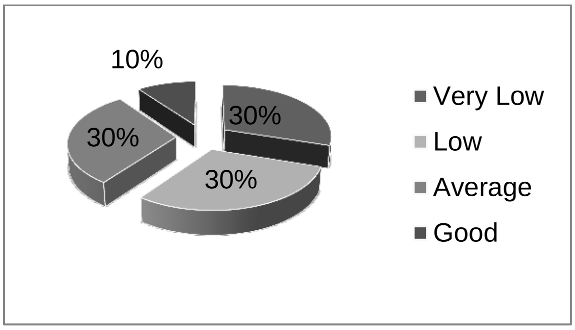

FIGURE 3.2 – COMPUTER SKILLS

From Figure 3.1 it is possible to determine that most of the participants do not spend much time using the computer, however they do spend a few hours a week interacting with it. Only one participant said that he uses the computer less than once a week, while half of the participants said they use the computer more than once a week, but less than 5 hours a day.

As visible in Figure 3.2, the users show different computer skills. This was in fact, a requirement for the participants' selection stage: they should not have the same level of computer expertise. 30% of the participants considered themselves as users with very low computer skills, whilst other 30%

considered they were a bit more skilled but not enough to be above the Low classification. The same number of participants assessed their computer skills as Average. Just one of the participants considered he had good computer skills, being that assessment confirmed after his performance was evaluated on a later stage of the interview.

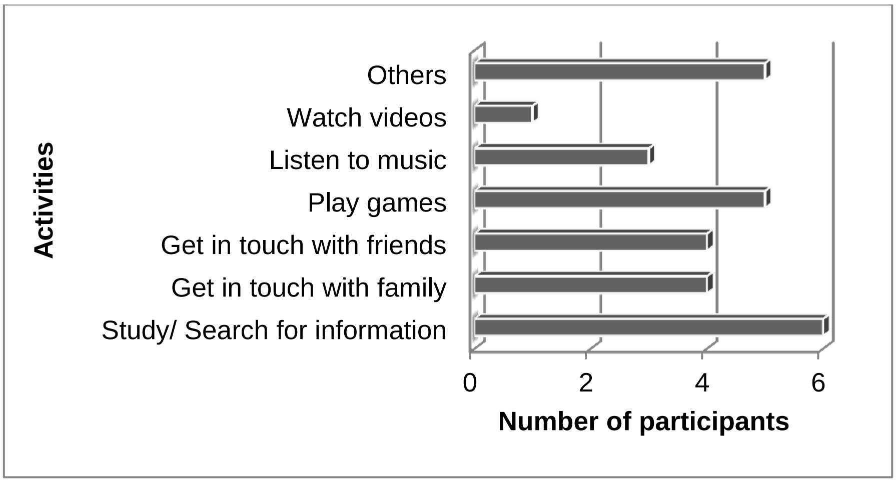

FIGURE 3.3 – NATURE OF COMPUTER USE

More than half of the participants stated they used the computer for studying or searching information. This is probably due to the fact that all the participants were students from the previously mentioned University for Elderly (Figure 3.3). Half of them also said that they use it for playing games and to write (Others category).

However, only 40% of the participants said they use the computer for communication purposes (Get in touch with friends and Get in touch with family). The common explanation mentioned the difficulties they found on understanding the current audiovisual conferencing services GUIs. They often said that they could not get those kind of programs to work, or that they had a hard time trying to add a contact to their friends list or establishing calls.

Listening to music and watching videos was the least chosen option: it was selected by one and three participants, respectively.

TABLE 3.2 – DIFFICULTIES WITH COMPUTER USAGE

P1	The keyboard is the main issue.
P2	For what I do with it I do not have any difficulties. But it's hard to make something that is out of the ordinary.
P3	I used the computer very few times, so I do not quite know what my difficulties are, besides having a hard time trying to write anything and pointing at something with the mouse.
P4	I find it hard whenever I try to access the Internet
P5	I never had any training in ITs. I learn to use what I need by my own, so I do not know much.
P6	I get upset by the waiting times and it gets confuse to find a way to do something I thought was simple.
P7	I do not have any difficulties with what I do, but the waiting times annoy me
P8	No difficulties, but the latency on some programs bores me
P9	I have a hard time formatting text when I'm writing my poetry
P10	My main difficulty is trying to use social networks sites, like Facebook. It's too confusing.

The answers participants gave when asked about their main difficulties they had using the computer are summarized in Table 3.2. It's possible to see that participants P2, P7 and P8 considered they had no difficulties at all with the features they're used to, they just complained about latency and not being able to explore more features because of their complexity.

The remaining testimonials were diverse, highlighting difficulties with peripherals like the keyboard and mouse and difficulties accessing the Internet and SMSs.

Only two of the participants had already used accessibility features. Has a way to explain what was an accessibility feature to those who said they did not know, we have demonstrated the following accessibility tools of Microsoft Windows 7: the Magnifier and the On-Screen Keyboard.

Participant number 7, who tried a TTS engine before, said he did not enjoy the experience because it did not represent an advantage for him, since it took much longer to listen to a sentence than for him to read it himself. He also said he tried it for curiosity only. Participant number 10 said she quite enjoyed using the Magnifier, since it lets her read her documents much easier. The rest of the group never used such features and many did not even know they were available in Windows.

3.2.2. Mobile Phone /Smartphone Related Results

All the participants use a mobile phone. Most of them use simple mobile devices and make use of few of its features.

None of the participants used a Smartphone, and most of them did not know what that was until we showed them the *Samsung Omnia II* that was used to demonstrate and test the mobile version of the previously available LHC prototype.

After seeing the Smartphone, most participants said that they think that kind of device is especially suitable for younger people but not for them, as they considered it as being too much confusing and with too many features. This "a priori" opinion was given before they interacted with the smartphone and with the mobile version of the above mentioned prototype.

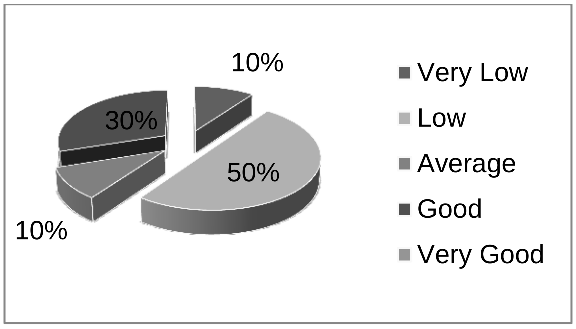

FIGURE 3.4 – MOBILE PHONE SKILLS

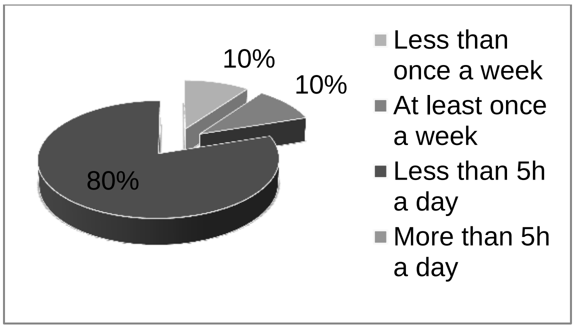

FIGURE 3.5 – FREQUENCY OF MOBILE PHONE USE

When asked to assess their mobile phone skills the participants classified themselves in a 5-point scale ranging from *Very Low* to *Very Good*, as shown in Figure 3.4.

Half of the group considered they had low skills concerning a mobile phone usage. Those participants referred that they use the mobile just for making and receiving calls; they do not even send text messages or use the calendar feature. They also said that the features they used sufficed their needs perfectly and that they had no intention of exploring the other features of their devices. Just one participant classified himself as having average skills, since he was able to use the most common features of these devices and did not have much trouble with that, however he did not explore more than he needed fearing he might damage the device.

On the other hand, 30% of the respondents considered they had good mobile phone skills. Most of those said that they not only know how to send SMS as they also use the phone's calendar to set up appointments and reminders. No participant classified as having very good skills and only one self-assessed as Very Low in the given scale.

Figure 3.5 shows how frequently the respondents used their mobile phones. The majority of the participants said that they use the device everyday but less than 5 hours a day. Only two participants said they use the phone in a less regular basis as shown in the above chart.

None of the participants classified themselves as intense users, i.e., none uses the mobile phone more than 5 hours a day.

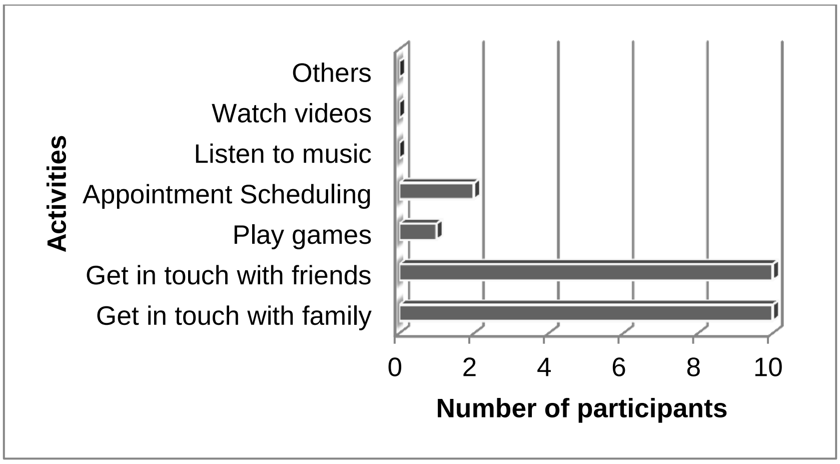

FIGURE 3.6 – NATURE OF MOBILE PHONE USE

As mentioned above, the participants responded that they use the mobile phone mostly to make and receive calls; more specifically they use it to contact family and friends, as visible in Figure 3.6. Only two participants use the Calendar feature to manage their appointments, and none of them seems to have an interest on sending SMS, even though some of them said they knew how to do it.

Just one of the participants said that she uses the mobile phone for amusement, as she plays games on it frequently. On the other hand, none of the contributors uses that device to listen to music or watch videos. The category others was also left blank by all the participants.

Generally, participants considered they had no difficulties when using the mobile; this is due to the fact that most of these users confine to use the voice call feature only and do not explore the remaining features of the device.

Most of the participants completed this answer verbally, saying that they had no difficulties with what they normally use, but if they were asked to use some different feature of their phone, they would, probably, find it harder to do.

3.2.3. Audiovisual Conferencing and Social Media Services Related Results

3.2.3.1. Audiovisual Conferencing Services Results

Our study also revealed that 60% of the participants had already used an audiovisual conferencing service, like Windows Live Messenger (WLM) or Skype (see Figure 3.7). The remaining participants said they never used this service, for various reasons. For example, P2 never used it, even though her daughter tried to teach her, because she said that whenever she needed to talk to someone that was far she preferred to use the phone, since that’s a natural way of communicating for her, as she witnessed the development of this technology during her life.

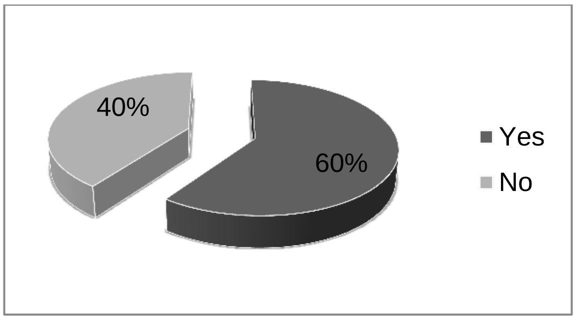

FIGURE 3.7 – AUDIOVISUAL CONFERENCING SERVICES USE

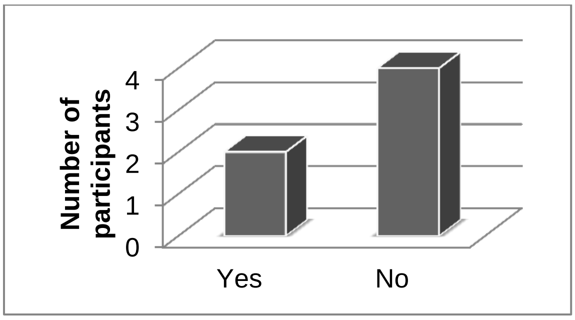

FIGURE 3.8 – PHOTOS/VIDEOS IN AUDIOVISUAL CONFERENCING SERVICES

Below are excerpts from the answers participants gave when asked about the difficulties they felt with the above mentioned services:

- “It's hard to find some buttons and understand how to perform actions like adding a contact and so on.”
- “When I see all the options of that program (WLM) I fear I will damage the computer if I do something wrong, so I try not to change anything and ask my daughter to help me whenever I need to do something different.”
- “The confusing options and my lack of patience makes me quit before I can do something, I always think I’m wasting time.”
- “I’ve been using this service for some years now, so I have no problem interacting with it.”
- “I cannot establish a communication via video or audio call, I’ve tried several times but there’s always some error.”

From the six participants that had already used audiovisual conferencing services, only two of them said they used it to share photos or videos (see Figure 3.8).

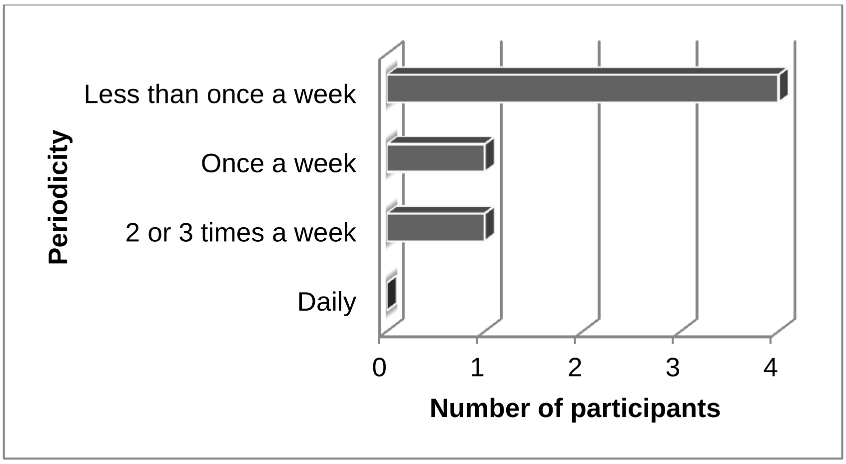

FIGURE 3.9 – FREQUENCY OF AUDIOVISUAL CONFERENCING SERVICES USE

Figure 3.9 shows that this group does not use audiovisual conferencing services very often, this may be due to the fact that all of them were very active citizens that stayed at home very little time, as they were involved in a lot of different activities like volunteer jobs in hospitals, for example.

Only P4 and P10 spent a more significant amount of time using these services. P10 said she used it a lot to send information to their students, as she also gave introductory ITs classes in the University for Elderly, besides being a student there.

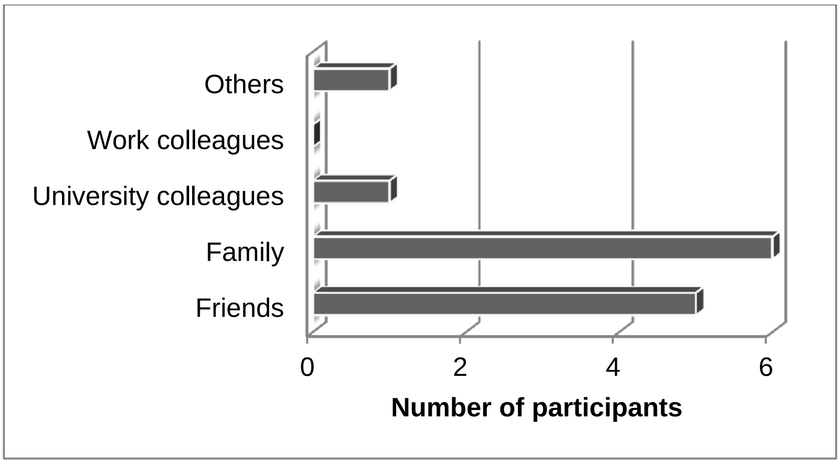

FIGURE 3.10 – AUDIOVISUAL CONFERENCING SERVICES CONTACTS

The group of users who used audiovisual conferencing services said that they mainly contacted family and some close friends through these services (Figure 3.10).

Only P10 contacted students (Others category) and P9 contacted University colleagues.

Most of the participants considered that these kind of applications, if they were easier to use, could be a nice tool to get in touch with relatives that are not near them, since many said they had relatives that emigrated and that they only contacted with them through the phone.

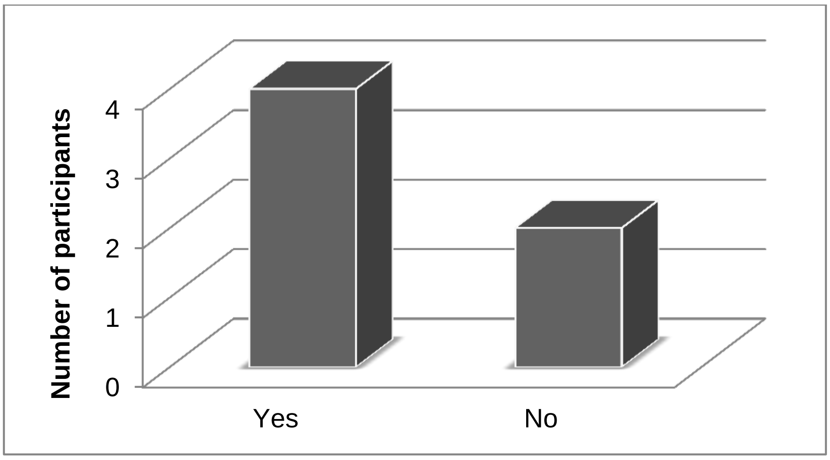

FIGURE 3.11 – AUDIOVISUAL CONFERENCING SERVICES VOICE AND VIDEO CALL FEATURES USE

Figure 3.11 allows understanding that most of those users already tried to use voice and /or video call features of the audiovisual conferencing services they interacted with, however most of them said they could not get these features to work and if they could, it was only because they had the help of others to do it, like relatives or friends.

Participants considered that they would use the service a lot more if they could understand how it worked. The other reason they gave for not using it that much, was that, since they could not get the audio and video calls to work in their computers and to write took them a lot more time and was a lot more tiring, they often preferred to talk over the phone.

3.2.3.2. Social Media Services Results

Social Media Services have become a true phenomenon in the last few years. Interestingly, we were able to confirm this fact with our user panel, since even participants that have low skills and minimal knowledge about ICT, knew what SMSs are and were aware of at least one of such services. In particular all the participants said they had heard about Facebook. Only P6, P8 and P9 said they also knew Twitter and Hi5.

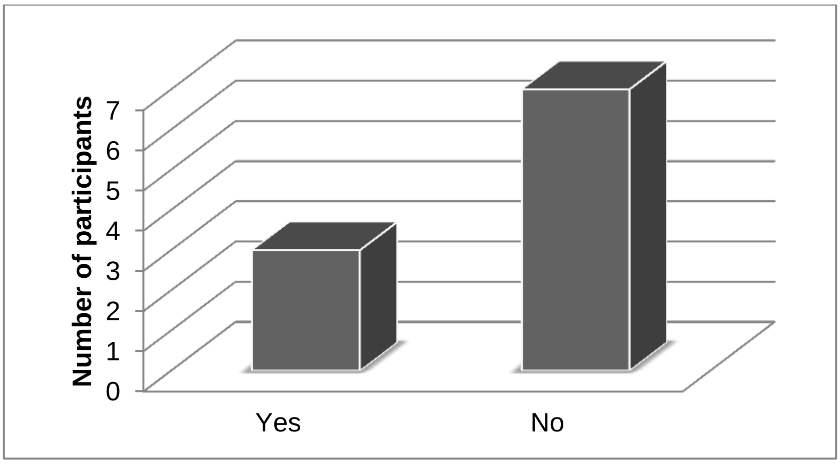

FIGURE 3.12 – SMSS USAGE

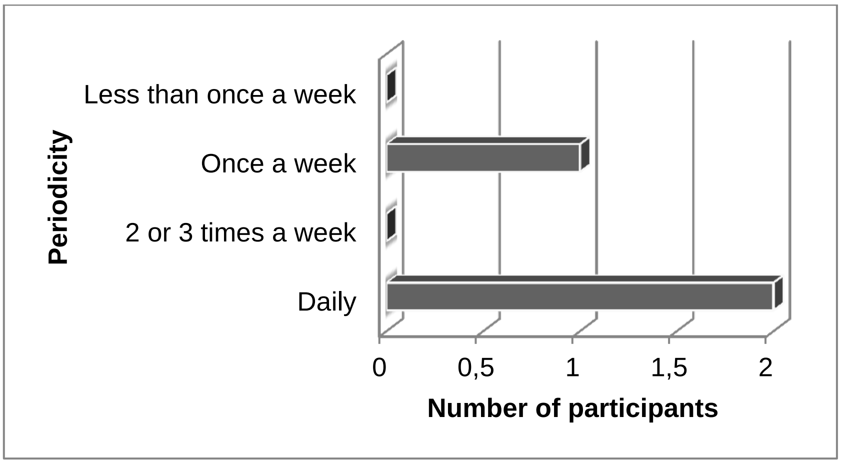

FIGURE 3.13 – PERIODICITY OF SMSS USE

Even though all of the participants knew of Facebook, only three actually used it before our study (Figure 3.12).

There was an identical response of almost every participant that did not use any SMS. They argued also that they heard too many times in the news and through friends that using such a service might be dangerous and could lead to unpleasant situations, if they did not know exactly what they were doing. More than one participant showed worries about the fact that someone might deceive them into thinking they were talking to a relative or family and ask them for private information like, credit card numbers, addresses, and so on.

From the three participants that used Facebook, two said they use it on a daily basis, and one only makes use of it, on average, once a week (Figure 3.13).

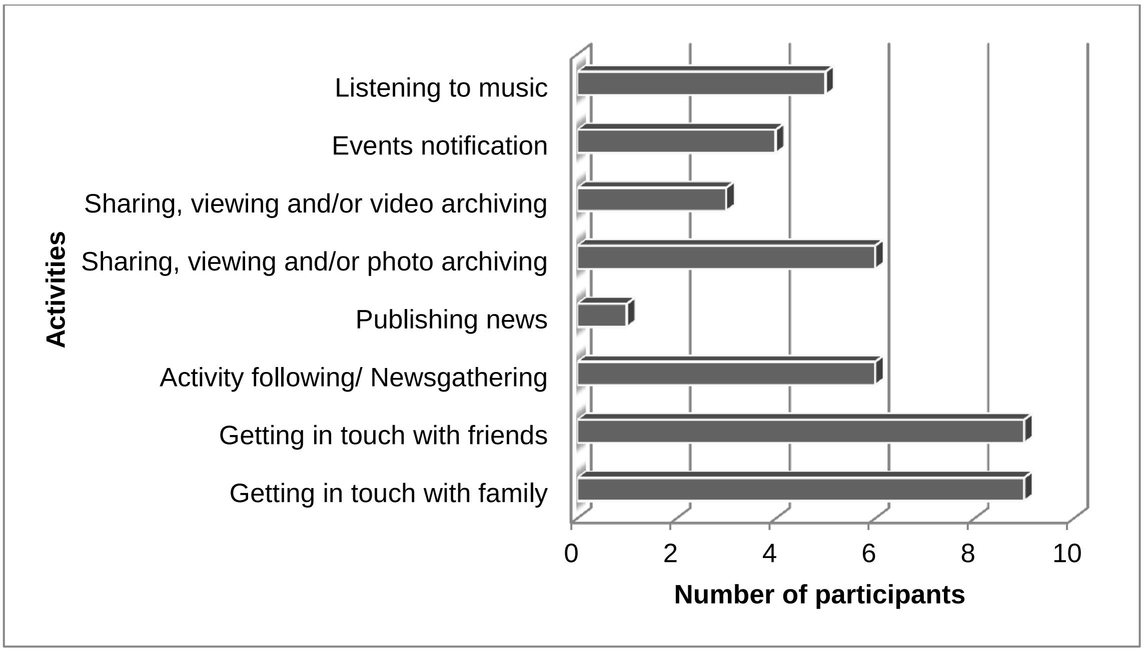

FIGURE 3.14 – SMSS ACTIVITIES

For this question we have asked participants to forget about their preconceptions about SMSs, and consider that the service would be easy enough for them to use with the certainty that they're not doing anything wrong, since that's one of our objectives, to simplify and make the use of SMSs transparent, reliable and safe.

The results are shown in Figure 3.14. 90% of the total said they would like to use such a service to contact with family and friends through private and public text messages; 60% also said they would enjoy being able to share photos, as long as they could be commented by their contacts, and to get news about their acquaintances and about other matters of interest to them;

50% also expressed that they would enjoy having the possibility of listening to music that their friends could share.

Events notification and video sharing was voted by four and three participants, respectively. These activities did not stimulate much interest. Likewise, just one participant said that he would like to share news, not about him or his life, but about the University and some other institutions he was involved with.

3.2.4. Results Discussion

From the population sample that was interviewed it is possible to draw a set of characteristics of the elderly population, concerning computer and mobile phone patterns of use, nature of use and skills, as well as habits of use of audiovisual conferencing services and SMSs.

3.2.4.1. Computer Related Results Discussion

From this group of questions it's likely to conclude that, generally, elderly users that remain socially and intellectually active spend a few hours per week in front of the computer. These users have diverse computer skills, however those skills only go from very low to average, never reaching the very good skills classification, showing evidence of these low skills difficulties while interacting with current computer systems.

Additionally, they do not use the computer for communication purposes much, because of their lack of skills and because these programs aren't, usually, designed to be used by the elder public, but by the young, young adult and regular adult, which are generally more skilled. Another explanation given by the participants in the study, was that they got used to the phone as their primary means for communication, so adapting to a service that is, in their opinion, much more complicated to use, is hard, even though they recognize that those kind of services may bring many advantages, like being low cost to use and having features that the conventional phone does not provide.

Elderly users also do not seem to listen to music or watch videos on the computer because they also got used to the Radio/Hi-Fi Systems and the TV, so they do not explore those kind of services, and many probably do not even know how to do it.

It's also noticeable that most seniors do not use the common accessibility features, since those are not yet considered as an advantage for them. Even though they have some health problems, most of them believe that it's more complicated to get those features to work and that it would get them even more time to complete tasks, than by the conventional way.

It is also common for elderly users to state they do not have any difficulties when using the computer, however when asked to complete some different tasks, they realize that it is in fact very difficult to complete those successfully without help. It is also evident that they experience difficulties using the mouse and the keyboard, even those who use the computer more often. These figures will be addressed again and evidenced at a later section of this chapter.

3.2.4.2. Mobile Phone Related Results Discussion

The results obtained from this first part of the study, allowed us to understand how important elderly think the mobile phone is and how much they use it.

It has been established that, generally, elderly consider the mobile phone an important device and that they carry it with them regularly, since most of them use one on a daily basis. Even so, most participants classified themselves as having low to average mobile-phone usage skills, whilst only 30% considered having good skills. This could be due to the lack of interest or information on all the features of the mobile phone, since the exploration and usage of some features like the Calendar could improve their skills and make their life easier. Also, when asked about Smartphone usage, all said that it is not an interesting device for them, since it has too many features and it is too complicated to be used. This idea may come from the fact that they only know common applications that were not thought to satisfy their needs.

It was also possible to conclude that elderly did not make use of the SMS feature of their phones. This could be due to the fact that they used the phone all their life and got used to it. It was also referred by more than one participant that it is much more natural to listen to a response than to read it and that it’s hard for them to write with such small buttons, therefore they prefer to call someone instead of inputting text.

It is also our opinion that the biggest difficulty these users have is the fact that they do not have interfaces built with their limitations and requirements in mind. Most of these are actually not very elderly friendly, with small buttons and complicated processes to complete what in essence are simple tasks, and requiring the user to remember too many steps.

3.2.4.3. Audiovisual Conferencing and Social Media Services Related Results Discussion

Concerning audiovisual conferencing services usage, which has also been addressed in section 3.2.3.1, there is still a considerable number of elderly participants that prefer not to use them or cannot understand how to do it. Those who do use them do not do it frequently, and use few of their features. When using instant text messaging, they often declare that they get bored of writing and quit after just a few minutes and that they cannot figure out how to use voice or video call features. Many of them did not even know that such features were available.

It is easily understood that these users do want to find an alternative to the costly phone calls, since they need to contact their family and their friends who are not near them. However, they need something different from some of the current applications, because those do not seem to be adequate for this public.

Regarding SMSs usage, these participants, normally do not make use of them yet. There is a common feeling of mistrust and a misconception of the services’ objectives. For example, they often consider Facebook as a dangerous service, because they heard stories, either by friends or in the news, about people who got tricked into giving out personal information. They also fear that their lack of expertise and skills could lead them into doing something that is detrimental to them.

On the other hand, those who eventually join the service end up by using it frequently, even though they recognize some difficulties while interacting with it.

Generally, elderly show interest in using these services for contacting family and friends by messages, either public or private, and also on being able to publish photos and discuss those published by others, as well as to get access to news about matters of interest to them. They show a special interest on sharing photos with their family, since they’re used to accompany the growth of grandchildren through photos they get in the mail, so this feature would be a much easier and interesting way to share that information.

3.2.5. Conclusions

Interestingly, with this study, we have registered that the computer is not yet seen as a tool to communicate with others, since elderly participants mentioned having difficulties understanding the current communication services GUIs. They often said that they could not get those kind of programs to work, or that they had a hard time trying to add a contact to their friends list or establishing calls. The majority of the considered sample also declared not using any SMS even though they knew of these services’ existence. They argued that they heard too many times in the news and by friends that using such a service might be dangerous and could lead to unpleasant situations, if they did not know exactly what they were doing. Concerning the usage of mobile devices, participants recognized using them, however the adherence to smartphones was null, mainly due to confusing GUIs, too many features and small icons and text.

These experimental results allow us to determine that our multimodal HCI solution (desktop/laptop based), must provide access to an easy-to-use, simple communications service, with few and clear options, in order to mitigate the difficulties mentioned above with current solutions. The new HCI must be developed concerning these user's needs, so they can explore them without much effort.

We also acknowledged that the current SMSs have too many features, as far as elderly are concerned, and require too much attention and skills. Therefore we propose providing access, in the first place, to the features elderly considered most relevant (e.g., photo sharing and messages), while still proposing interaction with more advanced features of audiovisual communication (videoconference and video sharing), to be subsequently validated with a thorough usability evaluation study. The new multimodal HCI should be kept simple, easy and as seamless to use as possible, thus trying to diminish the observed feeling of insecurity while using SMSs.

Bearing in mind that the smartphone is not too much different, regarding form factor, than the mobile phones the study participants are accustomed to use, and that their price is dropping to the same levels of mobile phones, we still propose a mobility solution that may increase their quality of life. Therefore, we plan to develop a smartphone version of our application that suits their requirements of easy access to features and reduced learning curve. This can be accomplished by following the similar design guidelines as those mentioned before for the computer (desktop/laptop) version of the application.

3.3. Audiovisual Conferencing and Social Media Services

In the second part of the user study we have asked the participants to perform three different tasks (see

Table 3.5), using current audiovisual conferencing and SMSs interfaces in a PC environment. The goal of these tasks was to perform a usability evaluation study of those kinds of interfaces concerning its usage by senior citizens.

3.3.1. Methodology

For this test and to be able to compare times of execution more precisely, we have decided to use only WLM 2011 and Facebook, since these were the applications interviewees were more accustomed to and featured all the desired modules for testing. Also, all the sessions took place in the same building, using the same network and that same equipment (see Table 3.3), thus maintaining exactly the same conditions for all participants.

TABLE 3.3 – SPECIFICATIONS OF THE EQUIPMENT, NETWORK AND BROWSER

- Computer
  - Toshiba A300
  - Intel Core 2 Duo CPU P8600 @2.40 GHz
  - 4GB RAM
  - Windows 7 Professional 64bit
  - 300 GB Toshiba Hard Drive
  - Screen Resolution: 1280 x 800
- Network and Browser
  - WiFi Network
  - Internet Explorer 9 Beta

After completion of each task we asked participants to answer the questions listed in Table 3.4. The answers to those questions were also video-recorded for further analysis**.** The most relevant input made by participants and our own observations of each task can be found on Appendix A.2.3.

TABLE 3.4 – VERBAL QUESTIONS ASKED AFTER EACH TASK

1. Do you like the interface? Is it easy to use?
2. If not, what could be improved?
3. If you could interact with this application using another modalities (e.g. speech, touch), do you think that interaction would be better?
4. Give examples of how you can use new modalities in this application.

The system accounts created for these tasks were the same for every participant and were restored to original parameters after each participant finished the tasks that needed that account.

3.3.2. Tasks

The next table contains a script with the steps needed to complete each task.

Before starting any task, participants were asked to read the script from start to finish, so they got an idea of what they were supposed to do and could ask questions about the terminology. The tasks were performed by the subjects in random order.

TABLE 3.5 – REQUIREMENTS STUDY AUDIOVISUAL CONFERENCING AND SOCIAL MEDIA SERVICES TASKS DESCRIPTION

Instant Messaging Task	1. *Login* to Windows Live Messenger with the account credentials above 2. Open a new conversation with the user that is *online* 3. Write the text: **Olá, estou a testar o serviço de mensagens instantâneas.** 4. Send the previous text 5. Close the conversation
Audiovisual Conference Task	1. Open a new conversation with the user that is *online* 2. Start a new voice call 3. Stop the voice call 4. Start a new video call with the same user 5. Stop the video call
Social Media Task	1. Open the Facebook Website (See table above for address) 2. Login to Facebook with the account credentials in the table above 3. Access you profile and edit your location and date of birth 4. Create a new album and publish the photo available on the Desktop 5. View the photo you just published 6. Send a private message to the user **Amigo Fcb** Text: **O meu e-mail é: teste.lhc.senior@hotmail.com** 7. Publish a public message, in the previous users' profile Text: **Olá, estou a testar um serviço de redes sociais.**

3.3.3. Results

In order to evaluate a task, both qualitative and quantitative results will be presented.

For quantitative results, we have considered the following:

- **Time to complete a task** – time (in minutes and seconds) since participant was instructed to do a task, until task termination.
- **Number of helps** – number of times participant asked for help or was helped.

For qualitative results we have considered:

- **Result** – it could be:
  - **Completed** – participant successfully terminated the task.
  - **Completed with errors** – participant completed the task but committed some errors
  - **Incomplete** – participant was told to terminate the task (e.g. if the task was taking longer than expected or if an application failed.)
  - **NA** – participant did not do the task.
- **Observations** – Our point of view of participants' actions, considering interaction with hardware and software.
- **Participants' opinion** – Some opinions given by participants about the task, in reply to questions referred on Table 3.4.

Below we present the results for each task.

TABLE 3.6 – IM TASK RESULTS

Participant	Time to complete (mm:ss)	Number of helps	Result
Control	01:10	0	Completed
P1	02:49	1	Completed
P2	09:03	4	Completed
P3	11:33	6	Completed
P4	03:11	0	Completed
P5	05:25	2	Completed
P6	05:55	3	Completed
P7	03:11	0	Completed
P8	03:38	2	Completed
P9	08:21	3	Completed
P10	03:30	1	Completed

TABLE 3.7 – AUDIOVISUAL CONFERENCE TASK RESULTS

Participant	Time to complete (mm:ss)	Number of helps	Result
Control	00:30	0	Completed
P1	01:32	1	Completed
P2	02:17	3	Completed
P3	03:41	3	Completed
P4	01:52	1	Completed
P5	02:07	1	Completed
P6	01:34	1	Completed with errors
P7	01:31	0	Completed
P8	01:42	1	Completed with errors
P9	01:58	1	Completed
P10	01:37	0	Completed

TABLE 3.8 – SOCIAL MEDIA TASK RESULTS

Participant	Time to complete (mm:ss)	Number of helps	Result
Control	03:58	0	Completed
P1	10:20	3	Completed
P2	13:49	5	Completed
P3	28:05	7	Completed
P4	09:13	2	Completed
P5	12:05	1	Completed
P6	14:33	4	Completed
P7	06:20	0	Completed
P8	09:27	2	Completed
P9	12:41	3	Completed
P10	08:35	2	Completed

3.3.4. Results Analysis

As a way to evaluate the results we turned to statistical analysis, calculating the average amount of time participants took to complete a task and also the standard deviation from the control results, as well as the differences between different groups of subjects considered.

To investigate the differences between participants in different age ranges we have divided them into three different groups:

- General – All 10 participants;
- Younger Participants – All those below 60 Years old;
- Older Participants – Those above 60 Years old.

This division was made based on observations during the sessions, on which it was possible to understand that generally speaking, younger elderly showed better performance than the older ones. A division based on the self-assessment of the users' skills was also tried, leading this, however, to less conclusive results.

3.3.4.1. Instant Messaging Task Results Analysis

This task was designed to evaluate the usability of the IM feature of WLM.

Participants were asked to login to the program, being this also a way to evaluate if they could insert special characters, like the '@' character. Then, the objective was to send a message to the only contact that was available in the list of contacts. That message had also some special characters and punctuation.

TABLE 3.9 – IM TASK STATISTICS (TABULAR FORM)

Subjects	Mean Task Duration	Standard Deviation of Task Duration	Mean Differences
Control	01:10	-	04:30
General	05:40	03:11	
Younger Participants (<60)	03:46	01:50	03:10
Older Participants (>60)	06:55	04:04	

Generally participants took, in average, 4 minutes and 30 seconds more than the Control subject to perform the task, as shown in Table 3.9. Older participants were the ones that took more time to complete this task, taking, in average, 3 minutes and 10 seconds more than the younger participants, which is also shown in Table 3.9. This difference is mainly due to the different writing speeds in the text production part of the Instant Messaging task, and to differences in prior experience with the application.

The main questions the participants asked were those below:

1. "How to insert the '@' character?"
2. "How do I know which one is the right contact"
3. "How to start the conversation?"
4. "How to insert the '^' character?"
5. "How to send the text after writing it?"

Older participants requested for help more frequently, mostly when they had to insert a special character and to send the message.

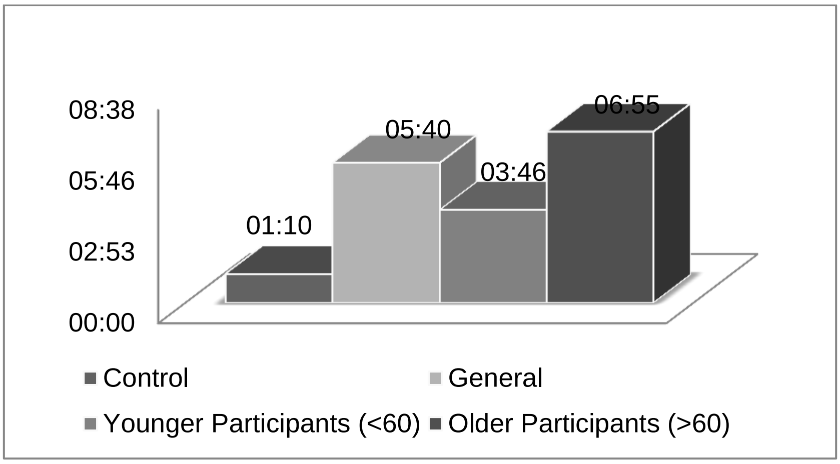

FIGURE 3.15 – IM TASK AVERAGE EXECUTION TIMES (GRAPHICAL FORM)

Figure 3.15 also shows the differences between the groups considered. Even though Younger participants showed a good performance, they still took about 2 minutes and 36 seconds more than Control, to complete the task.

When answering to questions referred on Table 3.4, most participants thought that using touch instead of a mouse would bring better performance. The use of speech for command & control and dictation was considered as a way to improve their performance and the easiness of use of this application.

From our perspective, it was possible to determine that the application had some flaws, concerning this type of public. The color code used to identify the status of contacts may not be enough for those who are not used to these services, since it does not clearly state the current presence status of that contact, and, also the fact that some buttons are hidden or simply do not exist, forcing the user to guess which key does the intended action, may make a simple task take much longer than expected.

It has also been possible to see that older participants had more difficulty using the mouse and finding keys on the keyboard, as well as reading text information on the screen, like the name of the contact and the end call option.

3.3.4.2. Audiovisual Conference Task Results Analysis

With this task we intended to test the voice and video conference features of the current version of WLM, with the senior citizens. Participants were asked first to start a voice call and then, after ending that call, were prompted to start a video call.

Almost all of the participants could not find the voice call button and two of them, P6 and P8, even started a video call instead of a voice call. This may be caused by the fact that the voice call option is hidden behind the video call option and they had to press a very small arrow to see that option.

TABLE 3.10 – AUDIOVISUAL CONFERENCE TASK STATISTICS (TABULAR FORM)

Subjects	Mean Task Duration	Standard Deviation of Task Duration	Mean Differences
Control	00:30	-	01:29
General	01:59	01:03	
Younger Participants (<60)	01:43	00:52	00:27
Older Participants (>60)	02:10	01:11	

Although this task looked simple, participants still took, on average, 1 minute and 29 seconds more to successfully complete it than Control. Once again younger participants had better results than older ones (which were expected), but the difference to Control was smaller: only 27 seconds on average. (See Table 3.10)

The questions participants mostly asked were:

1. “How to start the audio call?”
2. “How to end the calls?”

Participants P2 and P3 also requested help, since they did not remember how to open a conversation.

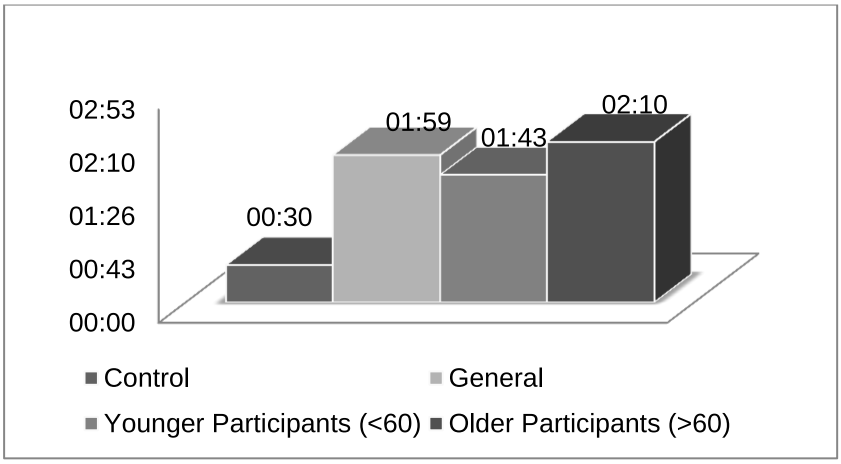

FIGURE 3.16 – AUDIOVISUAL CONFERENCE TASK AVERAGE EXECUTION TIMES (GRAPHICAL FORM)

Figure 3.16, shows that participants achieved similar results for this task, maybe due to the fact that they did not have to write anything. As mentioned above, younger participants were just a few seconds quicker than the older ones.

The answers received to the questions listed on Table 3.4, revealed, once again, that touch and speech interaction could improve the usability of the considered services/applications (touching the screen instead of using a mouse and issuing speech commands to start or end calls with their contacts).

Once again, our observation of the tasks, allowed us to stress the importance of avoiding hidden buttons, small buttons and small font sizes in the GUI.

We have also noticed that the explicit presence and identification of GUI buttons is very important for elderly, since they tend to forget how to do some actions, even if they've done it in the previous step. E.g., participants often did not know how to end the video call, even though we had explained how to do it before.

3.3.4.3. Social Media Task Results Analysis

The goal of this task was to evaluate the usability of a SMS interface and some of its features. For that purpose we only selected the Facebook service, since it was the only one all the participants had previous knowledge of. The first step was to open the Facebook website, then to login with the given account credentials. After login, participants were asked to edit their profile, changing their location and birthdate. The next steps were to upload a photo and to view it. Following that they were asked to send private and a public message to a specific Facebook contact.

TABLE 3.11 – SOCIAL MEDIA TASK STATISTICS WITH P3 RESULTS (TABULAR FORM)

Subjects	Mean Task Duration	Standard Deviation of Task Duration	Mean Differences
Control	03:58	-	08:33
General	12:31	06:03	
Younger Participants (<60)	09:33	03:57	04:56
Older Participants (>60)	14:29	07:26	

This task was the one that took more time to complete and that led to more questions being asked by the participants. On average, the participants took 8 minutes and 33 seconds more to complete the task than Control. The reported difference between the older participants and the younger ones was very big, almost 5 minutes (see Table 3.11); however that's due to the fact that P3, which is in the older participants group, took more than 28 minutes to complete this task. The subject rarely used the computer in his life and the Facebook was very hard for him, so if we exclude his results and consider those void (by classifying him as an outlier), because it took longer than expected, we get the results shown on Table 3.12.

TABLE 3.12 – SOCIAL MEDIA TASK STATISTICS WITHOUT P3 RESULTS (TABULAR FORM)

Subjects	Mean Task Duration	Standard Deviation of Task Duration	Mean Differences
Control	03:58	-	06:49
General	10:47	04:49	
Younger Participants (<60)	09:33	03:57	02:13
Older Participants (>60)	11:46	05:31	

Now, the difference between younger and older participants has been reduced to less than half of the previous value: 2 minutes and 13 seconds.

Concerning this task, the more frequent questions were the following:

1. "How to find the 'Edit Profile' option?"
2. "How to upload a photo, from the desktop?"
3. "How to find the public message option?"

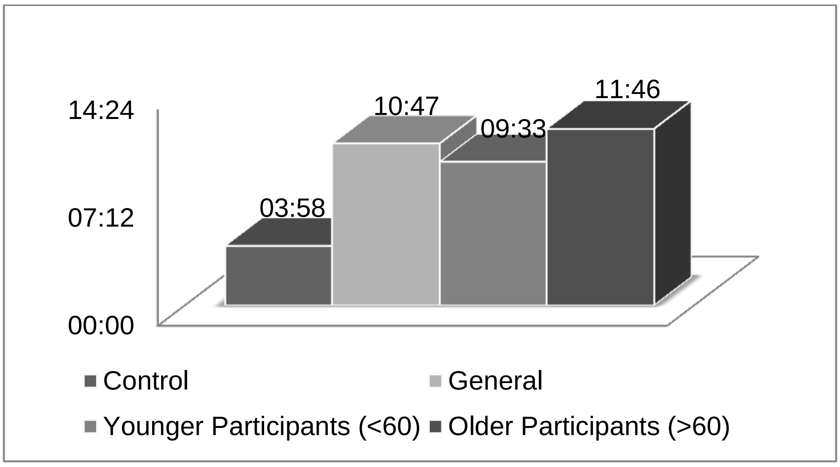

FIGURE 3.17 – SOCIAL MEDIA TASK AVERAGE EXECUTION TIMES WHITHOUT P3 RESULTS (GRAPHICAL FORM)

As we can see from Figure 3.17, the differences between the participants and a Control subject are very significant. To justify the large amount of time they took to complete the task, participants said that the Facebook's interface just has too much information and the GUI text and buttons are too small. The usage of service specific jargon and complex procedures to complete a task, makes the users spend even more time searching for what they think is the right option and understanding the steps to complete that task (e.g., Upload Photo procedure).

Once more, when answering questions from Table 3.4, participants said that the adoption of natural modalities could improve their user experience. However, this time around, they frequently said that touch would be the most important modality to consider for this service. Speech would be less important and could be used only for dictation and to issue some simple commands.

3.3.5. Conclusions

On the second part of the user study we asked the participants to perform three different tasks using current audiovisual communication and social media services GUIs: (1) instant messaging task; (2); audiovisual conferencing task and (3) Facebook task. The goal of these tasks was to perform a usability evaluation of those kinds of services available in the Internet and accessed from a PC, by a small sample of the elderly population.

The participants observations and our evaluation of the tasks they have performed, allowed us to derive a number of user requirements that must be taken into consideration when designing new multimodal HCI, for universal use including the elderly population.

After the evaluation of an instant messaging task using WLM, we have confirmed the results of the previous section. In what concerns audiovisual conferencing systems, we consider that it is important to change the way information is shown in current GUIs. Text and buttons should be bigger, so it becomes easier to find a contact or an option. There should be buttons for tasks like opening a new conversation and submitting an instant message, avoiding the need for double click, double tap or use of a special keyboard key, since we have realized that elderly have difficulties performing and remembering those actions. Furthermore, it is important to have an easy way of inserting special characters, since most participants were unable to insert the ‘@’ and ‘€’ characters using the keyboard. Touch and speech interaction should be considered for this audiovisual communication. Speech should work for command and control, but especially for dictation when writing an instant message, since tests have demonstrated that participants tend to be less productive when writing on a keyboard. It is also essential that contacts are well identified, with name, picture and a number. Next to the name, there should be buttons with suggestive images that should allow users to start an audio call or a video call seamlessly.

Generally speaking, we have also confirmed that there is the need to make icons and text bigger and to organize these better in the screen, since the GUI elements of the current solutions are too small and do not always follow the same logic of space organization, from screen to screen.

After completing a task that tested Facebook’s usability, participants confirmed that this service had too many features, as mentioned in the previous section, so we should basically consider as with higher priority those of interest for them, like for example, Photo sharing with the option of adding comments.

3.4. Usability evaluation of HCI modalities using LHC V1.0

In the third part of the first study, we have introduced participants to the previous mobile and desktop versions of the LHC prototype (LHC V1.0) [17], which were designed specifically for mobility impaired individuals. After showing the subjects how those applications worked and which modalities were available in each one, we have asked them to perform some more tasks described in Appendix A.2.4.1. Tasks were designed with the objective of testing all the available HCI modalities and also to understand how participants performed using those modalities, aiming at concluding the limitations and strengths of the mentioned prototype. The tasks were performed by the subjects in random order.

3.4.1. Methodology

To perform the above mentioned tasks, participants had to use specific devices and network conditions, described in Table 3.13, which were kept constant across the user study, in order to avoid differences on performance caused by those aspects.

TABLE 3.13 – SPECIFICATIONS OF THE EQUIPMENT AND NETWORK

- Computer
  - HP TouchSmart 600 PC
  - Intel Core 2 Duo
  - 4GB RAM
  - Windows 7 Home Premium
  - 23’ 1080p Full HD widescreen with multi-touch technology
- Smartphone
  - Samsung Omnia 2
  - Windows Mobile 6.5
- Network
  - Ethernet Network

After the participants had finished each task, they were asked a new set of questions, in order to get their visions about the multimodal HCI of the application and the way it behave. We have also recorded these answers in order to consider them for later analysis. (See Appendix A.2.4.5)

The e-mail task was the one that more participants completed successfully. Some tasks were not completed by some participants because there was a bug in the application caused by changes made in Twitter’s API that prevented the participants from being able to use some features. This bug was only discovered and fixed after the third interview. Participants P9 and P10 could not do this task because of time limitations from their part.

In the next sub-section we highlight the most relevant qualitative and quantitative results obtained in each of the tasks performed in this part of the study. The remaining results can be found on Appendix A.2.4.2 and A.2.4.3.

3.4.2. Results Analysis

3.4.2.1. E-mail Task

This task enabled us to capture what the subjects felt about some new HCI modalities, since it allowed participants to use Touch to select buttons or text boxes, Speech to issue commands and dictate text and also allowed them to use the mouse and the keyboard (virtual or physical), whenever they wanted to.

TABLE 3.14 – E-MAIL TASK RESULTS

Participant	Time to complete (mm:ss)	Number of helps	Result	Modality count		
				Speech	Touch	Hardware
Control	03:39	0	Completed	8	8	4
P1	05:39	1	Completed with errors	1	15	8
P2	08:28	3	Completed with errors	0	8	12
P3	14:12	3	Completed	7	17	0
P4	09:51	1	Completed	4	17	2
P5	08:20	1	Completed with errors	17	5	0
P6	10:26	2	Completed	6	19	3
P7	05:36	1	Completed	19	5	0
P8	06:33	2	Completed	12	9	2
P9			NA			
P10			NA			

Although most participants completed the task successfully, some committed some errors while writing the message, as shown in Table 3.14. All of them tried the speech interaction modality, but only a few were successful using it. This is due to the fact that the Acoustic Model - AM of the speech recognition system was designed for a younger population (up to 60 years of age) and that the Language Model – LM was also designed for a different usage scenario (the design of the LM included essentially the recognition of isolated words of the Portuguese vocabulary, telephone numbers, proper names of people, business names and addresses of the Portuguese culture and market), than the Short Message Dictation scenario of the communication service. Elderly speech presents some specific characteristics that younger voices do not have [57] [58]. So the fact that Speech Recognition, especially for dictation, would be less effective for this elderly sample (Table 3.15) was expected. There's current work being done to address that issue in a Microsoft/MLDC's project [18], however that topic exceeds the scope of this thesis.

TABLE 3.15 – SPEECH RECOGNITION RESULTS FOR THE E-MAIL TASK

Participant	Command & Control		Dictation	
	Usage	**Recognition Result**	**Usage**	**Recognition Result**
P1	Yes	Somewhat effective	No	-
P2	Yes	Failed	No	-
P3	Yes	Somewhat effective	Yes	Failed
P4	Yes	Somewhat effective	Yes	Failed
P5	Yes	Effective	Yes	Somewhat effective
P6	Yes	Somewhat Effective	Yes	Somewhat effective
P7	Yes	Effective	Yes	Somewhat effective
P8	Yes	Effective	Yes	Somewhat effective
P9	-	-	-	-
P10	-	-	-	-

So, when participants could not use speech interaction, they quickly changed their interaction focus to touch. Only subject P2 seemed to prefer continuing using the mouse and the keyboard.

Participant P3 took more time than the remaining when performing this task. Once again, this can be explained by the fact mentioned before: P3 almost never used the computer before, so he needed more time to understand how to perform actions and requested help more frequently (see Table 3.14). When answering to questions placed after completing this task, participants gave the opinions below:

1. All of them liked the interface because of its organization and because of the size of text and buttons. They even agreed that size and type of GUI organization in the screen, are just what they need.
2. Most of them did not know what to say concerning the improvement of the already existent features; however they all mentioned that they would like to use Speech as one of the main

interaction modalities. They recommend the improvement of user experience using this modality.

3. Subjects also said that the most confusing actions for them were the activation of the dictation mode, the attachment of a file and the launch of the on-screen virtual keyboard.
4. They all mentioned that this application was very well designed in general, and confirmed that they would use it if it was available.

It was also possible to observe that participants got much more interested in the tasks concerning the LHC usage, than in the ones in the second part of the user study (Section 3.3). They seemed really satisfied after finishing each task, and many of them also said, joking, that they wanted to buy the application already.

3.4.2.2. Questionnaire Results Analysis

Below we present some results obtained from the answers to the final questionnaire. The remaining results can be found on Appendix A.2.4.4. To obtain these results we have considered all the participants answers, including those of P9 and P10, because, even though they did not complete the tasks, they saw a demonstration of the application and tried every modality at least once on their own.

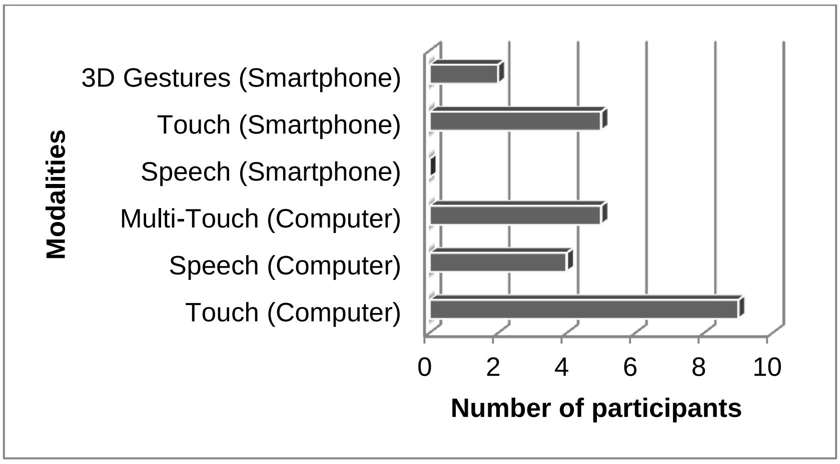

FIGURE 3.18 – PREFERRED MODALITIES

Regarding the choice of preferred modality, 90% of the subjects selected Touch on the computer application; 50% of those also selected Touch on the mobile version of the application and Multi-touch on the computer as modalities they enjoyed using. Speech on the Smartphone was not available, caused by a bug on that version that needed to be fixed at the time of the study. Only 40% of the participants chose Speech on the computer as a modality they liked. This result was expected and may have to do with the fact that this modality failed more than the remaining ones available, due to the restrictions in the AM and LM, mentioned in the previous section. However, we could observe that the Command and Control mode worked very well with 80% of the participants: only P1 and P2 had more difficulties commanding the application by voice. What really did not work for most participants was the Dictation mode, as they could not get the application to write what they wanted and eventually recurred to the conventional keyboard or the virtual one.

TABLE 3.16 – PARTICIPANTS REQUESTS FOR THE LHC VERSION FOR ELDERLY

P1	I think you should improve the speech recognition, for it was the modality that failed more times.
P2	Improve speech recognition
P3	Keep or improve Social Media Services feature
P4	Improve speech recognition
P5	Improve speech recognition
P6	Improve speech recognition
P7	Spontaneous help, whenever a user gets stuck with an action for a longer time than supposed. (A big popup with information would suffice, I believe)
P8	More explicit help
P9	Improve speech recognition
P10	Add access to Messenger and Facebook

Table 3.16 shows that, in general, participants enjoyed the experience. When they were asked to be more precise in their comments, they just asked for the speech recognition to be improved.

3.4.3. Conclusions

This part of the study allowed us to conclude that the elderly would be satisfied with an application designed following similar guidelines, as the previous LHC version for mobility impaired individuals. We have registered good levels of performance and high levels of satisfaction when we have asked the test subjects to use it. We have also observed that subjects felt much more relaxed using the prototype than the previously tested commercial solutions in similar tasks, so it became obvious that this application has the potential to contribute for a more enjoyable user experience, including the elderly individuals as well.

We have likewise determined that touch would be a critical modality to consider, since the design of this application is completely adequate for touching, due to the size and organization of the GUI items on the screen. However, by observing the subjects performing the assigned usability tasks, we could conclude that the surface of the screen should be kept tilted so the arms muscles of the participants would not get tired. This is also a known limitation phenomena of gesture interaction, referred to as the “Gorilla Arm Syndrome” [59].

Nonetheless, we have considered speech as a must-have modality too, as some of the elderly are less able to use touch, due to health problems such as arthritis [12]. Additionally, we could conclude that enabling a rewarding user experience using Speech, would increase the acceptance of the application because all the participants alleged it was the most attractive way of interacting, allowing a more relaxed interactive experience and a joyful one too.

3.5. Deriving User Requirements

As a corollary of our 3-phased user study, where we were able to observe, gather and analyze the participants' performances, opinions and restrictions in carrying assigned tasks and after an additional analysis of the structured questionnaires given to the same studied user sample, we were able to derive a set of User Requirements for a multimodal HCI, interacting with an improved LHC version, providing audiovisual communications services and SMSs and following Universal Accessibility Design guidelines that include the specific requirements of elderly citizens in addition to the requests previously collected from mobility impaired users [17].

User Requirements for multimodal HCI are presented on the tables below.

TABLE 3.17 – GENERAL MULTIMODAL HCI REQUIREMENTS

1	Users should be able to interact with all features using any of the available modalities, including speech, touch, gesture, keyboard/mouse.
2	Feature names must be carefully chosen, since users tend do get confused with loanwords.
3	Text and buttons should be large enough in order to be readable by users with a decrease in vision accuracy or some sort of vision impairment.
4	There should not be too much information per screen, so to keep interface clean and simple.
5	Users should be able to touch the name of a box, and not only inside the box area to select it.
6	If a user freezes for a while on a task or makes too many errors, spontaneous help should be launched either using applications' synthetic voice or a pop-up screen.
7	Touch and speech interaction should be emphasized, over Gesture and Multi-touch.

TABLE 3.18 – INSTANT MESSAGING FEATURE REQUIREMENTS

8	Contacts must be identified with name and photo, if available, and have their status well identified.
9	Contacts should be grouped by categories with a different number for each one.
10	It should be possible to start a conversation by saying the name of the contact or his/her given number.
11	If contact is not available, application must tell the user to call that contact on the phone or try again later, either using applications' synthetic voice or a pop-up screen.
12	The typing area and the Send Button must be well identified.
13	It should be possible to dictate instant messages.
14	It should be obvious how to start and end a conversation with a dedicated button for that purpose.

TABLE 3.19 – AUDIOVISUAL CONFERENCING FEATURE REQUIREMENTS

15	Video and Audio Call Buttons of the GUI should be large and simple to distinguish.
16	End call button should also be large and simple to distinguish.
17	The buttons should have images semantically associated to their actions.

TABLE 3.20 – SOCIAL MEDIA SERVICES FEATURE REQUIREMENTS

18	Edit profile option should be in the beginning of the menu and well identified with a big icon.
19	Text size must be large enough to be readable by users with a decrease in vision accuracy or some sort of vision impairment.
20	Type of message options should be well distinguished and easy to select.
21	It should be possible to see comments associated with a published photo and also to publish comments on photos.
22	Service specific jargon should be avoided.
23	Only those features that participants preferred should be considered with higher priority (Messages, Photos and Activity Following).
24	It should be possible to see a live feed of the friends updates, including recent published photos.

TABLE 3.21 – SPECIFIC MOBILE VERSION REQUIREMENTS

25	“Back” and “Options” GUI buttons should be larger and easier to touch.
26	Devices should have capacitive displays to simplify touch interaction.

3.6. Conclusions

In this chapter we have presented a user study to gather user requirements of multimodal HCI interacting with an improved LHC prototype for the elderly, following Universal Accessibility Design guidelines. In this study we have evaluated senior citizens interaction skills, habits and difficulties while using ICTs, audiovisual conferencing services and SMSs. We have also performed a usability evaluation of HCI modalities. In each of the three parts of the study, we have presented the adopted methodology, along with the results and reached conclusions.

Firstly, we have identified and interviewed a group of ten senior citizens, all members of ULTI, in order to understand their habits and limitations concerning ICTs, audiovisual conferencing services and SMSs usage. It was possible to determine that elderly have difficulties when accessing those services, from a computer or a mobile device. Most of the user interfaces are inadequate or too difficult for them to understand and require too much know-how and training.

Secondly, we have asked participants to perform a set of simple tasks with current GUIs for existing audiovisual communication and Social Media services. The conclusion was that these services have too much visual information on screen, which turns the comprehension of the interaction state hard and were not developed with the concern for potential impairments users might have with vision, for example.

Thirdly, we were able to draw conclusions about which HCI modalities might be more promising for increasing our applications' usability, by asking participants to perform a new set of tasks with the previous version of the LHC, which was specially created for mobility impaired users, following the same Universal HCI Design principles. We have discovered that Touch is a very well accepted modality, along with Speech. This last modality is the one were consensus was reached, regarding "a wish to have modality", although the current implementation includes important limitations in the AM and LM that prevent a fully rewarding user experience, with speech for the elderly.

Finally, we have compiled a set of new user requirements for the development of the mentioned multimodal HCI for the elderly, accessing an improved LHC V2.0 prototype. Additionally we have set-up a plan to improve the LHC in this context, with new service features, such as Instant Messaging and Facebook content access.

Chapter 4. LHC V2.0 Prototype Specification

Based on the results of the previous user study we have gathered requirements that enabled us to extend and improve the LHC prototype in order to provide a tool that enabled elderly to access SMSs and audiovisual conferencing services in a natural and simple way. In this chapter we will present LHC V2.0 prototype's architecture, specifications and features.

4.1. General Description

With the conclusions of the user study at hand, a detailed plan was set-up decided to create feature specifications derived from the user requirements. We have created three mains Feature Areas (FAs), namely: (a) improvement of the UI flow; (b) support of more SMSs (Facebook and Instant Messaging) and on the prototype's performance enhancement, while keeping the same system architecture for the previous version of LHC, with client, server and cloud elements adhering to Microsoft technology, as described in [17] and depicted in Figure 4.3. These three FAs were developed both for a multi-touch desktop environment and for a smartphone with some multi-touch capabilities.

Even though no major changes on the desktop application GUI were required, for us it was clear that elderly could benefit from the integration of Facebook's content in the prototype, since that is one of the most popular SMSs to date, with currently more than 750 million active users [23]. We have concluded that elderly would welcome also an IM service, due to its popularity. Bearing that in mind, we have added features allowing access to Facebook's messages, profiles and also supporting media access and management, such as photo albums. We have also added support for the insertion of comments and likes on messages, albums or photos, from both the LHC users and people in their social network. IM was also integrated in the Conference module of the existing prototype.

We have also developed a new version of the prototype for the Windows Phone 7 (WP7) platform (migrating from Windows Mobile 6.5 (WM6.5)), benefitting from the increased stability of that OS, the larger memory and processing power supported devices offer, the ability to use multi-touch and more importantly, the capacitive display of the newer devices. The fact that these do not have resistive displays is seen as an advantage because, in a previous study, presented in [17], authors showed that those displays cast some barriers to the users, since they need a given pressure to be applied and most of the times the usage of a stylus is necessary. Capacitive displays do not rely on this principle and can be used with very light touch, thus becoming more responsive and easier to use [60].

4.2. Services APIs

In this section we will present the available APIs for integration of Facebook features and IM, as well as some of the limitations and choices made.

4.2.1. Facebook C# SDK

To support Facebook Graph API [61] access, the last stable version at the time of writing of this thesis, of the Facebook C# Software Development Kit (SDK) [62] was used. An abstraction layer was developed to simplify access through web services, enabling the developer to retrieve or publish data from/to Facebook by just calling one method on the web service.

The Facebook C# SDK works with both Web (ASP.NET), desktop, Silverlight and WP7 applications uses OAuth 2.0 [63] for authentication and supports a convenient way of making calls to the new Graph API using the OAuth 2.0 access token. Sample applications and documentation are also provided by the SDK developers.

Figure 4.1 presents an example of the code needed to retrieve the current user's first name, last name and email from his/her Facebook profile, using the Facebook C# SDK methods, while Figure 4.2 exemplifies how to retrieve the current user profile using the abstraction layer mentioned before.

```
// Using IDictionary<string, object> (.Net 3.5, .Net 4.0, WP7)
var client = new FacebookClient();
var me = (IDictionary<string,object>)client.Get("me");
string firstName = (string)me["first_name"];
string lastName = (string)me["last_name"];
string email = (string)me["email"];
```

FIGURE 4.1 – FACEBOOK C# SDK EXAMPLE CODE FOR DATA RETRIEVAL

```
private SMSUser GetUserProfile(string token)
{
FacebookProfile prf = ServiceClient.GetUserProfile(token);
return prf != null ? new SMSUser(prf, GetName(), ServiceName) : null;
}
```

FIGURE 4.2 – FACEBOOK HCI DATA RETRIEVAL EXAMPLE CODE

Even though this is a powerful tool to retrieve and publish data and allows performing most actions, Facebook still imposes some restrictions to third party applications which limited some of the features developed. Some of the limitations imposed are:

- No access to private messages between users, both reading and writing;
- No access to contact management;
- Cannot edit user profile;
- Cannot edit published Albums, photos or videos details.

4.2.2. Windows Live Messenger Connect

The Windows Live software development kit (SDK) contains a set of interfaces that can be used to connect applications to Windows Live users and their devices. The most comprehensive programming interface to Windows Live services and data is Windows Live Messenger Connect (WLMC).

WLMC provides JavaScript and Representational State Transfer (REST) APIs. The Live Connect JavaScript API, together with the REST API, enables applications to read, update, and share user data by using the JavaScript programming language. The JavaScript API provides methods for signing users in and out, getting user status, subscribing to events, creating UI controls, and calling the Representational State Transfer (REST) API. The Messenger Connect REST API service enables developers to access a set of Windows Live resources for data storage and sharing, social networking, and communication such as commenting and tagging. The resource model describes resources such as contacts, photos, and profile information.

JavaScript API is especially useful for websites with code embedded on the client side layer, while other websites or desktop apps can also use the RESTful endpoint which allows the client or server to call directly to WLMC backend.

According to *[64]*, *WLMC Connect enables three core scenarios for websites and app developers:*

- ***"Identity** – makes it easy for users to sign in and sign up to your web site using their Windows Live ID.*
- ***Social distribution** – lets users share the things they do on your website with their friends. Activities appear in Messenger, Hotmail, and across Windows Live properties, and other places Messenger social is displayed (including Windows Phone 7 and the very popular Windows Live Messenger iPhone app).*
- ***Realtime shared experiences** – lets users share an experience in real time with their friends."*

Even though it presented great possibilities, the version available at the time of the development of this project was especially directed to a web experience rather than desktop and requires too much custom coding for being able to manage IM calls, since a JavaScript solution would have to be wrapped to work with the application, thus being classified as time consuming.

However for proving the concept and testing requirements compliance, IM was still considered and included via the, already available and used in the previous version of the prototype, Microsoft Unified Communications Managed API 2.0 SDK (UCMA 2.0), which is a managed-code platform that provides access to and control over instant messaging, telephony, audio/video conferencing, and presence. It is intended to support the development of middle-tier applications targeting Microsoft Office Communicator and Microsoft Office Communications Server 2007 R2.

4.3. Physical Architecture

Figure 4.3 below, presents the deployed physical architecture for the LHC prototype. It is divided in two main regions: **Home** – where the home devices and some logic are represented; **Backend** – which represents the backend remote hosted and cloud-based services.

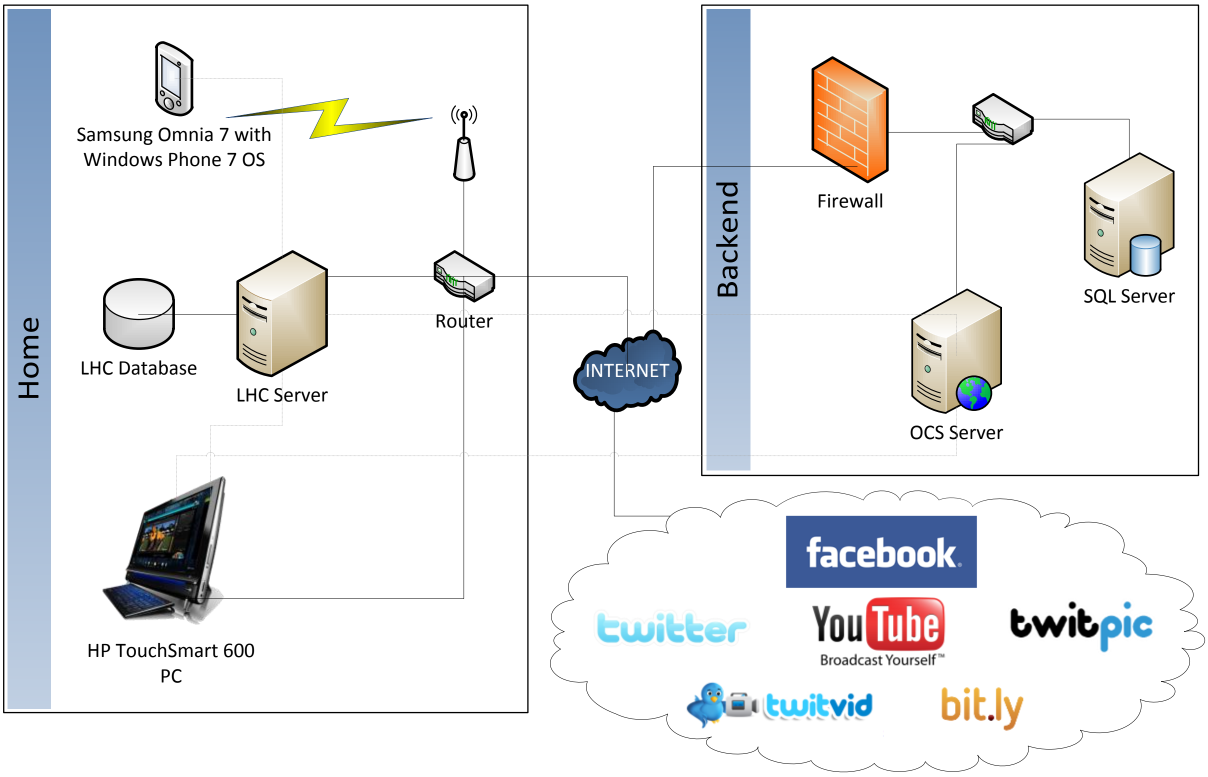

FIGURE 4.3 – PHYSICAL SYSTEM ARCHITECTURE

For home devices we have considered a smartphone mobile device, a desktop device enabled with multi-touch screen and a server that works as an intermediary between user devices at home and backend services.

The home devices act as front-ends, having all the UIs, control methods and a small logic layer that translates UI actions into remote invocations to the LHC Home Server, as well as action requests sent by the LHC Home Server into local UI actions

Both applications were developed on .Net 4.0 Framework with C# programming. Visual Studio 2010 was used to develop the logic components and Expression Blend 4 to develop the GUIs.

In the next sections, details about each component of this architecture will be presented.

4.3.1. Mobile device

The smartphone mobile device chosen to develop and test the prototype's mobile application was Samsung Omnia 7. That device was chosen due to its state-of-the-art capacitive 4.0" Super AMOLED WVGA (800X480) display, it's good processing power (1GHz CPU) and also due to the fact that it supports WP7, that was the chosen OS for the new version of the mobile application, migrating from the WM6.5 OS. Besides supporting touch functionality and 3D gesture implementation, this newer OS offers increased stability, speed and more design possibilities.

When developing a Windows Phone application, we can select one of two programming development environments, Silverlight or XNA. However, XNA is oriented to the development of 2D and 3D computer graphics and gaming applications, thus not being suitable for the task at hand, which deals specially with text and audiovisual information access, via multimodal interaction. On the other hand, Silverlight for Windows Phone is completely adequate and a powerful tool to develop the required UIs. It is similar to Silverlight 3 (SL3) [1] that has been released for web development. Here are some characteristics of Silverlight for Windows Phone:

- Uses the same base class library as SL3;
- Has been modified for performance;
- Is Integrated with the hardware;
- Is integrated with the operating system;
- Contains specific API for the device (accelerometer, GPS, etc.);
- Uses out-of-browser model.

To develop mobile GUIs Expression Blend 4 [65] was used since it is a powerful tool for those purposes. It supports Silverlight for Windows Phone and integrates features that enable using interesting architectural patterns. According to [65]:

> *“Support for Model View View Model (MVVM) provides a streamlined workflow for developers using these types of patterns to structure a Silverlight or Windows Presentation Foundation application ensures that UI objects are as decoupled as possible from the application’s data and behavior. This makes it even easier to work simultaneously on both the user interface and core architecture without one breaking the other to further streamline your workflow.”*

Because of technical limitations regarding the non-existence of an application controllable OCS client on WP7, it wasn’t possible to directly interoperate mobile devices to the backend Office Communications Server (OCS). As such, a development of a simpler solution that resorts to audio file streaming to the backend through a web-service was achieved.

4.3.2. Desktop device

For the desktop application, a HP TouchSmart 600 PC with Windows 7 Home Premium was used. In addition to single touch interaction support, by mapping touch hits as mouse clicks, it also allows multi-touch by being able to detect two points of contact with the screen and translate 2D gesture into actions, like pinch-to-zoom, for example. Another advantage of that device is its 23” widescreen (1080p).

The desktop application was developed using C# and the Windows Presentation Foundation (WPF) framework. WPF offers 2D and 3D graphics support, hardware-accelerated effects, scalability to different form factors, interactive data visualization. Windows 7 features including multi-touch, and content readability. According to [66] some of the most important changes that were brought by WPF are:

[1] Note that, at the time of writing of this thesis, Silverlight version for desktop is SL4.

***"A rich drawing model** - Rather than painting pixels, in WPF you deal with primitives—basic shapes, blocks of text and other graphical ingredients. You also have new features, such as true transparent controls, the ability to stack multiple layers with different opacities, and native 3-D support.*

***Declarative user interface** - Although you can construct a WPF window with code, Visual Studio takes a different approach. It serializes each window's content to a set of XML tags in a XAML document. The advantage is that your user interface is completely separated from your code and graphic designers can use professional tools to edit your XAML files and refine your application's front end (XAML is short for Extensible Application Markup Language [67])."*

As with the mobile application, Expression Blend 4 was used to modify existing GUIs and create new controls.

The previous version of the Desktop application used Office Communicator 2007 as a mediator to do audio streaming on the desktop, using UCMA 2.0 on server-side. This meant that Communicator had to be running on the desktop device so a call could be established; the video conference window had to be the communicator window that appeared in front of the prototype application, preventing a seamless integration. In order to surpass such limitations we have decided to use the Unified Communications Client API (UCCA) [68], which enabled us to make LHC V2.0 a custom-brand communication client capable of supporting voice and video calls, IM and presence services, in short UCCA allowed us to add the Office Communicator capabilities and features to the desktop application, allowing for a friendlier user experience and a more integrated one also, without having to have Office Communicator running or even installed in that machine.

4.3.3. LHC Home Server

The LHC Home Server runs Microsoft Windows Server 2008 with Internet Information Services 7 (IIS7) and is set up for web services hosting, with ASP.NET environment [69]. As mentioned above, it acts as an intermediary for communications between client devices and hosted or cloud-based services. Web services were used to provide data exchange between the devices and LHC Home Server.

The LHC Home Server contains all logic components used to interact with SMSs and issue remote UI interaction commands, as well as some speech interaction components, such as the desktop and mobile speech servers, described in more detail in the next section.

For speech support this server uses UCMA Speech 2.0 [70] to provide TTS and ASR, using the current version of the Microsoft TTS and ASR pt-PT (European Portuguese) engines [71]. Audio data transfer between the server and the desktop application is done using UCMA Core 2.0, which enables the establishment of calls between OCS and the application. Due to the abovementioned limitations on the mobile platform, audio data transferring between server and the mobile device is done by exchanging wav files through web services (a kind of simplified audio streaming service).

Speech processing (TTS and ASR) is performed server-side so clients do not need to have or configure locally the TTS/ASR engines. Requests for speech processing (speech synthesis or speech recognition), require the LHC Home Server to communicate with a backend OCS server that in turn requires access to a Microsoft SQL Server database, to retrieve user account information regarding the connecting client. Speech or text data can then be sent from the client device to the OCS. The OCS will in turn reply with respectively, a recognized string to the LHC Home Server, or a voice stream to the client device with the result of the speech synthesis process.

4.3.4. Hosted Backend

The server hosted Backend includes the aforementioned Microsoft Office Communications Server 2007 R2 (OCS) and a Microsoft SQL Server 2008 (SQL Server).

This backend infrastructure contains the majority of the system's logic layer, thus reducing development duplication when using multiple platforms. A set of available web services provide all the needed methods for authentication operations with SMSs, user contact management and listing, message publishing and access and media gallery management.

OCS also provides support for audio and video calls, as abovementioned and SQL Server is responsible for data storage on the SDK, be it user credentials and SMS settings, or media collections

4.4. Logical Architecture

Figure 4.4 below presents a logical view of the developed system and reveals in greater detail how the diverse components interconnect.

Changes from the previous version of the architecture include an extended logic web service that communicates with more SMSs, and also the removal of the Microsoft Office Communicator 2007 client from the desktop client devices, acting it directly as an Office Communications Server 2007 R2 client, result of having used the UCC API, mentioned on section 4.3.2.

LHC Home Server contains the main connection endpoints for the devices, the logic web service and the speech servers.

Client devices communicate with the web service via a stub on that device. The web service is used primarily by the client devices to initiate and maintain sessions on the LHC Home Server. After the devices have successfully initiated a session on the LHC Home Server, this component maintains all sessions to SMS services that have been previously registered on the user's account stored in the server's database.

The web service also provides methods for the client to get data from those SMSs, such as received messages, photo albums or contacts. It also allows publishing data to the SMS, like comments on a friend's post, for example. To enable this communication the web service makes use of a set of libraries that interact with SMS APIs, whether using simple GET or POST HTTP requests or HTTP REST [72] Requests and Replies.

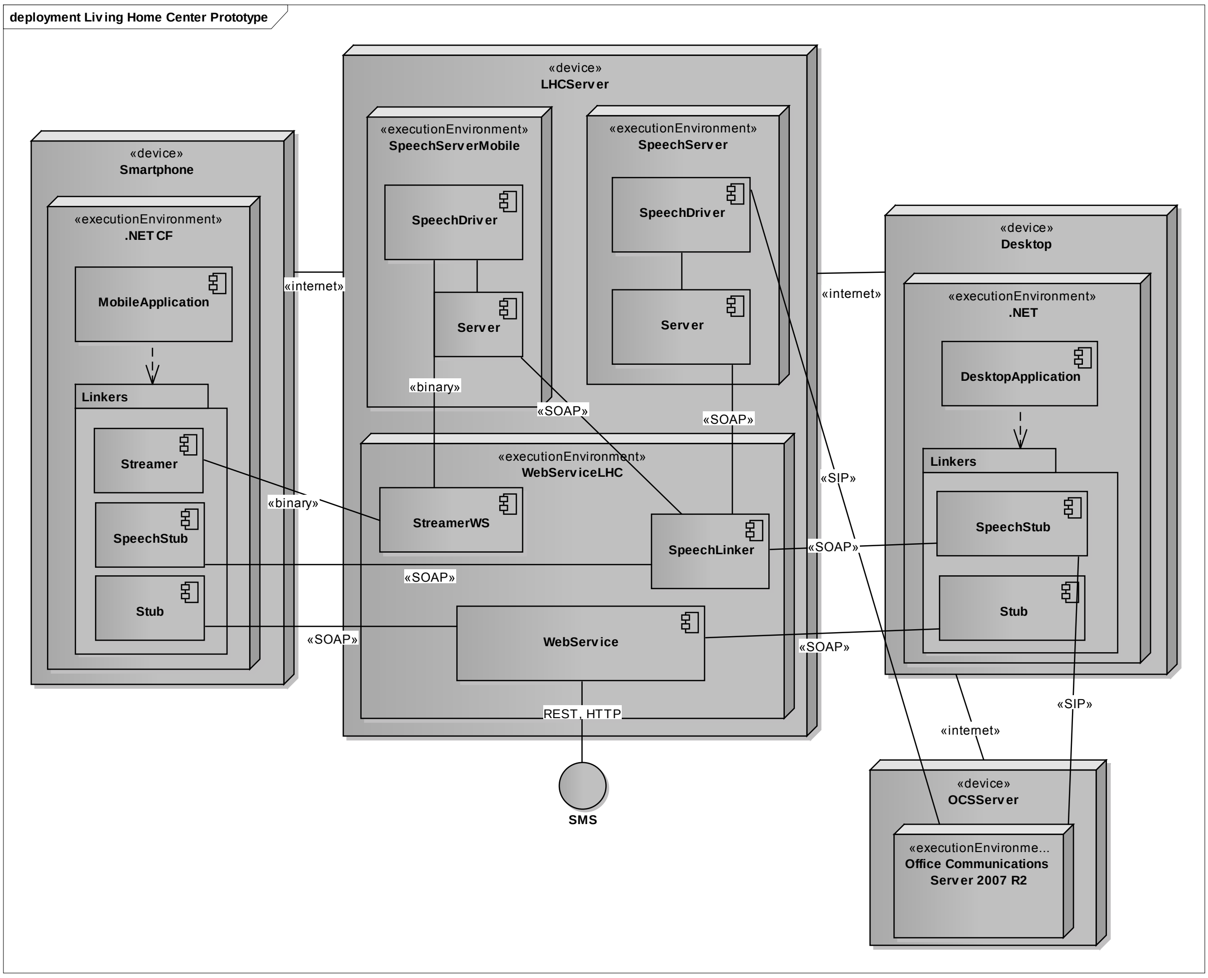

FIGURE 4.4 – LOGICAL SYSTEM ARCHITECTURE

Speech Server of the LHC Home Server, is divided into two different modules, one for devices that support voice communications using the UCC API and another for those who do not support it, such as the WP7 devices.

For clients that do not support the UCC API or the Office Communicator Client, a different approach must be considered. The adopted solution for those clients determines that for ASR, the device must send recorded WAV files to a queue running on the web service, called the *StreamerWS* in the diagram. That queue is consumed by the *SpeechDriver* on the *SpeechServerMobile* environment, which submits the WAV file to the speech recognition engine. The result is then sent to a queue running on the *SpeechLinker* component, in the web service. That queue is then emptied by the client on regular polling intervals. Speech synthesis for these clients starts with the client invoking a method on the *SpeechLinker* web service, which populates a queue with pending text. The speech *Server* polls this web service for new messages which are then submitted to the speech synthesis engine. The result of that process is submitted to the original web service (*SpeechLinker*) which will be polled regularly by the device.

To handle notification events, both clients use a pooling thread that generates an event when some information is available. This link is also used to control the conference state sending and receiving events for when the interface on the desktop changes. Even though the mobile device could not work properly on the mobile device, because of the inability to create a Session Initiation Protocol (SIP) channel with any other component, it was possible to make it work as a remote control for the conference main interface, which was available on the desktop device.

For those devices that support the UCC API, such as the desktop device mentioned before, the *SpeechStub* on the device just needs to establish a SIP call to the *SpeechServer* running on the LHC Server, using the backend OCS Server. All voice communications will then be made via this channel. This solution allows for continuous ASR, thus avoiding the need to use push-to-talk in these devices. ASR is performed on the *SpeechServer* that receives audio streams from the device and, using the UCMA, will perform speech recognition using the selected engine. Results of that process are sent to the *SpeechLinker* running on the web service, which will also be polled in regular intervals of time by the client device. Speech synthesis works in a similar way with both types of devices, with the difference that the resulting synthesis for the desktop is sent directly to the client device via the previously mentioned SIP channel, avoiding going through the web service again.

4.5. Proof of Concept Applications

Two prototype applications were considered, one developed for Windows Desktop environments and another for Windows Mobile environments, respectively, Windows 7 (Win7) and WP7. Both applications allow accessing email, agenda, conference and SMSs; however email and agenda will not be addressed in this thesis since this work focused mainly on the SMSs and conference modules, multimodal HCI adaptation for the elderly users, as well as services expansion, improvement and test. Information about the previously developed modules can be found in [17].

The previous version of the prototype (LHC V1.0) included the following features:

- E-mail client (Not addressed on this thesis);
- Agenda/calendar (Not addressed on this thesis);
- Conference (Voice and video calls);
- SMSs Module
    - Twitter profile, messages, contacts and search
    - YouTube videos and search
    - Local photos upload to TwitPic

On the newer version (LHC V2.0) we added the following features:

- Instant Messaging on the Conference module;
- Access and management of Facebook profile, messages, comments, *likes* and contacts on the SMSs module;
- Access and management of Facebook photo albums (with comments integration) on the SMSs module.

Besides the new features on the desktop application, we also migrated the previous version of the mobile application to Windows Phone 7 environments, inserting almost all the new features as well, with the exception of the photos feature, which still needs to be completed.

4.5.1. Desktop Application

The overall design of the desktop application just needed some required GUI corrections, since the requirements capture stage showed that the available features were adequate both for the impaired and the elderly as well, as mentioned in the last chapter. The input and output modalities were also kept basically the same, with some coding enhancement, stabilization and bug corrections. It’s possible to use speech, touch and keyboard/mouse interaction in all windows to generate input. Multi-touch can be used to manipulate photos in Photo Albums feature of the SMS module. Output is issued either by presenting the content on the device’s screen or through speech synthesis. For example, after a user requests help using touch, speech or mouse+keyboard, help is provided by speech synthesis.

FIGURE 4.5 – MAIN WINDOW

FIGURE 4.6 – CONFERENCE WINDOW

FIGURE 4.7 – CONFERENCE IM WINDOW

In addition to the previously available voice call and video call features, we have added an IM feature to the Conference module, which enabled users to send text messages to IM contacts. Figure 4.6 illustrates the main screen of the Conference window with all the available call options.

As requested by users, no loanwords were used and buttons for each type of call were redesigned to be large and well identified. After the beginning of a call a button for ending the call also appeared, as depicted in Figure 4.7.

FIGURE 4.8 – SMS WINDOW

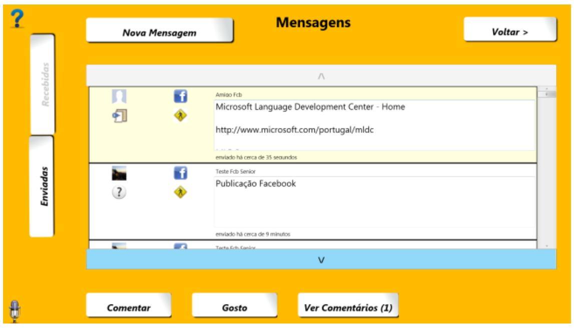

FIGURE 4.9 – SMS MESSAGES MAIN WINDOW

The SMS module enable users to access social messages management, currently from Twitter (LHC V1.0) and Facebook (LHC V2.0), manage their contacts on those services, search for content on YouTube and Twitter and manage media both locally and on the internet, i.e., manage local and YouTube video albums and local and Facebook photo albums. Figure 4.8 presents the SMS module main window from where all the above mentioned features can be accessed.

Figure 4.9 depicts the SMS Messages main screen where the received messages can be seen on a central list, ordered by date. In that list the user can read the Facebook and Twitter Posts made by their contacts or themselves and see any links, videos or images attached to a post, via a context menu.

FIGURE 4.10 – COMMENT SMS MESSAGE WINDOW

FIGURE 4.11 – SMS MESSAGE COMMENT VISUALIZATION WINDOW

A Facebook post can be commented (Figure 4.10) and it is possible to attach images or shortened links to that comment. Comments are visible by pressing a large button on the bottom of the messages main screen, indicating the number of comments made on that post (See Figure 4.9). Comments are presented in a container similar to the one used for received messages, as depicted in Figure 4.11.

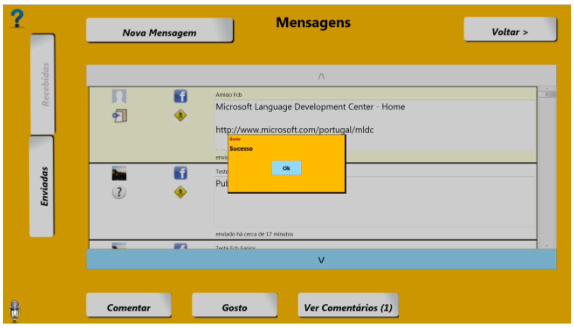

FIGURE 4.12 – SMS MESSAGE LIKE BUTTON INTERACTION

FIGURE 4.13 – NEW SMS MESSAGE WINDOW

Just like in Facebook, users can *Like* a certain publication. That interaction is illustrated in Figure 4.12.

The New Publications feature can be accessed pressing a dedicated button on the SMS Messages main screen. It is possible to publish messages on the Facebook wall of the current user or of his/her contacts, by selecting the profile message radio button. All text boxes are selectable using speech, by saying the name of the field, touch, by touching the box or the name and by mouse interaction, by clicking the text box. Messages can be written with physical or virtual keyboard and by using speech, by specifically activating the dictation mode. A sidebar with all the special characters was included in order to facilitate their introduction; Figure 4.13 illustrates the new Message window.

FIGURE 4.14 – AUDIOVISUAL WINDOW

FIGURE 4.15 – PHOTO ALBUMS WINDOW

The Audiovisual feature of the SMS module allows to access two types of media, videos and photos, as depicted in Figure 4.14. These items are organized in albums which are manageable by the system's users.

Photo albums include local and social albums. Local albums are the ones that are created and stored in the LHC Home Server database and are not visible to others on the internet. Social albums are in fact Facebook albums. Figure 4.15 illustrates the albums cover flow visualization and the options available.

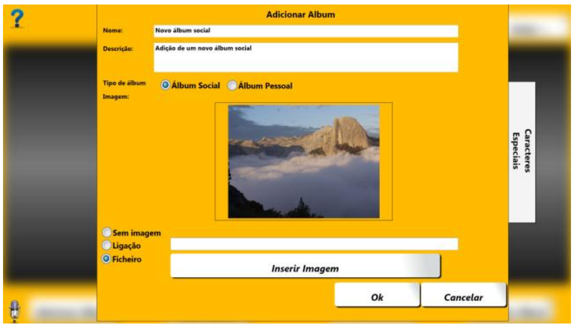

FIGURE 4.16 – ADD PHOTO ALBUM WINDOW

FIGURE 4.17 – COMMENT PHOTO ALBUM WINDOW

When adding an album a user can choose its name, a description, the type of album and an optional cover photo. That kind of interaction is illustrated in Figure 4.16.

Social Albums can also be commented as depicted in Figure 4.17. The cover photo for that album is shown in order to prevent the user to comment the wrong album.

FIGURE 4.18 – SOCIAL ALBUM PHOTOS WINDOW (COVER FLOW)

FIGURE 4.19 – SOCIAL ALBUM PHOTOS WINDOW (MULTI-TOUCH)

Photos can be scrolled in *cover-flow* mode or in *multi-touch* mode. In the last mode, the photos are randomly dispersed in a canvas and the user can use pinch-to-zoom, drag and rotate photos freely.

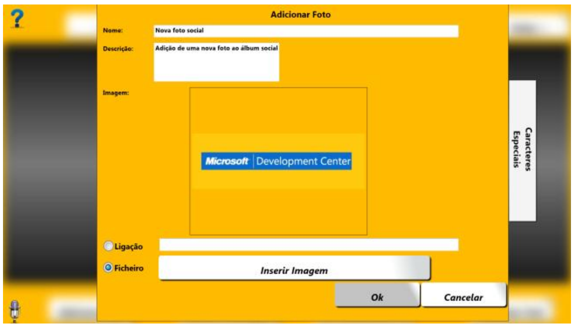

FIGURE 4.20 – ADD PHOTO TO SOCIAL ALBUM WINDOW

FIGURE 4.21 – VIEW PHOTO WINDOW

Adding a photo is done by inserting a name, a description and choosing a photo from the computer or inserting a hyperlink to one that is online (See Figure 4.20). Photos can be opened to view a bigger size and its details, this action can be triggered with a voice command or with touch. (See Figure 4.21)

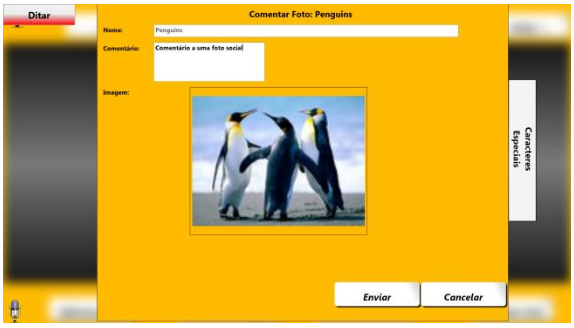

FIGURE 4.22 – COMMENT PHOTO WINDOW

FIGURE 4.23 – PHOTO COMMENT VISUALIZATION WINDOW

Similar to what happens with SMS's Messages a social photo can also be commented. Figure 4.22 depicts the action of inserting a new comment, whilst Figure 4.23 illustrates the visualization of a photo's comments.

4.5.2. Mobile Application

FIGURE 4.24 – MOBILE APPLICATION MAIN SCREEN

As previously mentioned, as a result of this thesis work, the mobile application (LHC V1.0 mobile), using Windows Mobile 6.5, was migrated to the WP7 environment, with the reasons presented before: increased stability of that OS, the capacitive display of the newer devices, the larger memory and processing power those same devices offer, as well as the ability to use multi-touch. Figure 4.24 show the mobile main page GUI. The virtual button with the microphone icon on the bottom center is the push-to-talk button which, after pressed, enables users to issue voice commands. Touch is available in every screen, as is speech interaction. 3D gesture (tilt rotations of the device), can be used to scroll up or down on a list, a vibration feedback is felt every time a gesture is issued and provokes an action on the GUI.

The GUI was developed so a user would not have UI learning difficulties when going from the desktop version the mobile, or vice-versa. That was achieved respecting similar design guidelines in both applications, with some differences inherent to the different platforms and device's screen sizes.

FIGURE 4.25 – MOBILE CONFERENCE SCREEN

FIGURE 4.26 – MOBILE CONFERENCE'S IM FEATURE

FIGURE 4.27 – INTERACTION WITH MOBILE IM FEATURE

Figure 4.25, Figure 4.26 and Figure 4.27 illustrate the interaction with the mobile application IM feature. As with the desktop version, every call option is presented in a big visible button. After the call is established there are also big, visible and well identified buttons to send the text and end the call.

FIGURE 4.28 – MOBILE SMS MAIN SCREEN

FIGURE 4.29 – MOBILE SMS MESSAGES SCREEN

FIGURE 4.30 – MOBILE SMS MESSAGES OPTIONS

Figure 4.28 illustrates the mobile SMS main screen, which was also developed to be similar to the desktop experience, containing icons for the same main modules in a similar screen layout.

SMS messages list (Figure 4.28) feature is also similar to its desktop version and can also be triggered in the same ways, using touch or voice commands. Large buttons where inserted with up and down arrows so the user can scroll through messages easily. It is also possible to use 3D gesture with this component. To keep the visualization list with a font large enough and similar to the desktop version, the remaining options had to be placed in a collapsible menu bar depicted in Figure 4.30. Those options can also be accessed by voice commands and touch.

FIGURE 4.31 – MOBILE SMS PROFILE (SERVICE SELECTION)

FIGURE 4.32 – MOBILE SMS PROFILE EDIT SCREEN

The same SMSs services are integrated in both desktop and mobile applications, as shown in Figure 4.31. It is therefore possible to edit a user profile on those services. The user can edit the same fields of the profile like in the desktop version, as depicted in Figure 4.32. In this page it also possible to scroll up and down touching arrows, issuing voice commands or using a 3D Gesture.

4.6. Requirements Compliance

As presented in section 3.5 a list of user requirements was determined for this work. Below we present an insight on the compliance with those same requirements in the current version of the prototype.

4.6.1. General HCI Requirements

Concerning this group of requirements (Table 3.17), only requirement number 6 was not considered. That item mentioned the need to launch spontaneous help using applications' text synthesizer or a pop-up screen if a user took too long or made too many errors during the execution of a task, like sending a message. However that requirement was considered of low priority, since help is always available in all screens of the GUI with a dedicated button. Additionally, we would need the study and measure the conditions that would provoke the launch of such an output, so that it wouldn´t be inadequate, for a given interaction context.

4.6.2. Instant Messaging Requirements

As mentioned above, the Instant Messaging feature was added recurring to UCMA 2.0 and should be seen as a way to prove the concept and test some requirements compliance, as it is somewhat simple. Even thought WLM was not used, most of the requirements were still considered, such as the usage of dedicated buttons to start and end the conversation, the possibility to use both speech and touch to interact and the clear identification of all the buttons.

The ones that were not considered in this thesis were requirements 8, 9, and 11 of Table 3.18. These include the visualization of the contacts' photos, grouping of contacts by categories and the voice feedback when a contact is not available. These items should be addressed in the next version of the prototype, which will include User Experience Expert Review that may lead to changes on the graphical user interface by a professional graphics designer.

4.6.3. Conference Requirements

In this module most of the requirements were also respected. For future versions, the only change needed will be the inclusion of graphical icons representing each action available (item 17 on Table 3.18), in addition to the already identifying text. Likely, this will also be done in the forthcoming redesign of the GUI.

4.6.4. SMS Feature Requirements

All the requirements for this module were considered in this version of the prototype (See Table 3.20).

4.6.5. Specific Mobile Version Requirements

The requirements for the mobile application included the change of "back" and "options" buttons sizes and/or location, as well as the development for devices with capacitive displays (See Table 3.20). Both these requirements were considered, since the back button is now assigned to the devices' hardware button with that function and the options button is more easily accessible, taking advantage of the new development platform considered. This same platform (WP7 + Silverlight) allowed us also to develop an application especially suited for devices with capacitive displays, which let us take advantage of the lighter touch needed for that type of interaction and thus better system responsiveness.

4.7. Conclusions

In this chapter we have presented some details about the developed V2.0 prototype architecture as well as its features and an insight into which software and hardware technologies were used.

This prototype was developed with the objective of mapping the derived users' requirements, presented as a result of Chapter 3. In the next chapter we will present a usability evaluation study of the new version of the prototype, with a selected sample of elderly users.

Chapter 5. Usability Evaluation Study

We have conducted a usability study, following the methodologies proposed by [15], to evaluate how the enhanced LHC V2.0 prototype performed, when used by a group of elderly individuals. Additionally, we have gathered that group's impressions about the prototype and their evaluation about its value when considered as a tool to promote social integration.

Additional information about the study can be found on Appendix B.

5.1. Study Participants

For this study we have asked for the collaboration of ten participants, this time around from the Social Welfare Institute for the Armed Forces (IASFA) [73], based in Lisbon, Portugal.

The study group comprised 5 males and 5 females, with an average age of 77.9 years old and different careers (See Table 5.1below).

TABLE 5.1 – USABILITY STUDY PARTICIPANTS

Participant	Gender	Age	Former Profession
Control	Female	22	Student (Marketing)
P1	Male	78	Nurse
P2	Male	89	Soldier (retired due to injury)
P3	Male	88	Admiral
P4	Female	72	Public Servant
P5	Female	80	Public Servant (Manager)
P6	Female	73	None (Housewife)
P7	Male	73	Navy Sergeant
P8	Female	85	Office Clerk
P9	Male	80	Navy Sergeant (Mechanic)
P10	Female	61	Occupational Therapist

For the selection of elderly, we have maintained the requirements described on section 3.1 and have also requested for participants with different literacy levels, since we wanted to register the differences between those with lower and higher levels of education, while using the prototype. For calibrating the study tasks and for comparing results, a neutral user, called the control subject, performed the structured tasks too. The control subject was a female with 22 years old, who studied Marketing, had high computer skills and had never been presented to the prototype before, hence being in the same conditions as the study participants.

5.2. Tasks and Methodology

5.2.1. Tasks

Six different tasks were created to test different features of the improved LHC V2.0 prototype. Three tasks were designed to be performed on the mobile client and another three designed for the desktop client. In the table below are the specifications of each of the devices used to run the applications.

TABLE 5.2 – SPECIFICATIONS OF THE USABILITY STUDY EQUIPMENT AND NETWORK

• **Computer**
  ○ HP TouchSmart 600 PC
  ○ Intel Core 2 Duo
  ○ 4GB RAM
  ○ Windows 7 Home Premium
  ○ 23" 1080p Full HD widescreen with multi-touch technology
• **Smartphone**
  ○ Samsung Omnia 7
  ○ Processor Qualcomm QSD8250 1GHz
  ○ Windows Phone OS 7
  ○ Display: 4.0" Super AMOLED, WVGA (800X480)
• **Network**
  ○ Ethernet Network

Table 5.3 presents a description of all the tasks for both clients. Tasks focused on the usage of conference's IM and video-call features, SMS profile feature, SMS messages feature and SMS audio-visual feature. Besides hardware (keyboard and mouse), other different HCI modalities were always available for each task and client platforms, such as speech, touch and 3D gesture in certain mobile application contexts.

TABLE 5.3 – USABILITY STUDY LHC V2.0 TASKS DESCRIPTION

Conference Task (Mobile)	1. Open the **Conference** menu 2. Start a new IM Conversation with the user from the contacts list with the **online** status 3. Write the text: **Olá, estou a testar o serviço de mensagens instantâneas.** 4. Send the message 5. Close the conversation and go back to the Main menu

SMS Profile Task (Mobile)	1. Open the **Social Networks** menu and then the **Profile** menu 2. Select the **Facebook** service 3. Update your current location to **Porto Salvo** 4. **Save** and go back to the **Main** menu
SMS Messages Task (Mobile)	1. Open the **Social Networks** menu 2. Select the **Messages** menu 3. Select the **third** message and view it 4. Check the **Sent** messages 5. Go back to the **Main** menu
Conference Task (Desktop)	1. Open the **Conference** menu 2. Start a new **Video call** with the user from the contacts list with the **online** status 3. End the call 4. Go back to the **Main** menu
SMS Messages Task (Desktop)	1. Open the **Social Networks** menu 2. Select the **Messages** menu and then **New Message** 3. Create a **private message** to the user named **Test User** with the text: **O meu e-mail é: teste.lhc.senior@hotmail.com** 4. **Send** the message 5. Select **New Message** again 6. Create a **profile message** to the user named **Amigo Fcb** with the text: **Olá, estou a testar um serviço de redes sociais.** 7. **Send** the message 8. Go back to the **Main** menu
SMS Photos Task (Desktop)	1. Open the **Social Networks** menu 2. Select the **Audio-visual** menu and then **Photos** 3. Open the **second** photo album 4. Choose the option that lets you add a new photo 5. In the **Name** textbox insert: **Fotografia de teste** 6. In the **Description** textbox insert: **Teste aos álbuns de fotos** 7. Push the button to upload a photo **from the computer** 8. In the new window select the file named **test.jpg** placed on the Desktop 9. Confirm with **OK** 10. Find the uploaded photo and open it 11. Go back to the **Main** menu

5.2.2. User Study Protocol

To be able to gather relevant information and maintain the same conditions for every participant, a protocol was created and followed for all the sessions[2].

1. Participant was firstly introduced to the objective of the study and asked for consent for recording sound and video;
2. Participant signed a consent form (See Appendix B.1) and filled the initial questionnaire about computer and mobile phone usage habits and skills;
3. Participant assisted a live demo of the prototype's features and was taught how to use each HCI modality;
4. Afterwards, the participant was requested to navigate freely the applications interface using the modalities the researcher asked;
5. Then, the participant performed a free test with each of the devices, so to get used to the system;
6. Participant was then given a document containing the aforementioned numbered tasks. The order of the tasks was random, having been previously calculated by a random number generator algorithm. The tasks did not specify which HCI modality should be used at any time, so the participant was responsible for the choice of the modality, thus allowing us to determine the preferred modalities in each context by simply observing their behavior;
7. After each task the subject was instructed to stop and answer some open questions concerning the completed task (Table 5.4);

TABLE 5.4 – VERBAL QUESTIONS ASKED AFTER EACH TASK

1. Do you like the interface? Why?
2. What could be improved?
3. Do you felt difficulties? Which ones?
4. Do you like more this interface or the one you usually use? Why?
5. Would you use this interface in your daily life?
6. Why did you use more often modality X? (If applicable)

[2] The protocol creation was guided by the work of [15]

5.2.3. Study Questionnaire

After completing all tasks, each participant answered a final questionnaire (Table 5.5), with open and closed questions, with the objective of determining the satisfaction gained with each HCI modality in terms of easiness and enjoyment, and also to evaluate the efficiency of the UI and the considered prototype features.

TABLE 5.5 – MODALITIES AND PROTOTYPE EVALUATION QUESTIONNAIRE

1. Please rate in terms of easiness/difficulty the following modalities (according to scale A):
   a. Touch (desktop)
   b. Speech (desktop)
   c. Multi-touch (desktop)
   d. Speech (mobile)
   e. Touch (mobile)
   f. 3D gesture (mobile)
2. Please rate in terms of satisfaction the following modalities (according to scale B):
   a. Touch (desktop)
   b. Speech (desktop)
   c. Multi-touch (desktop)
   d. Speech (mobile)
   e. Touch (mobile)
   f. 3D gesture (mobile)
3. From all the following modalities which did you like most? (You can select more than one):
   a. Touch (desktop)
   b. Speech (desktop)
   c. Multi-touch (desktop)
   d. Speech (mobile)
   e. Touch (mobile)
   f. 3D gesture (mobile)
4. And which did you enjoy less?
   a. Touch (desktop)
   b. Speech (desktop)
   c. Multi-touch (desktop)
   d. Speech (mobile)
   e. Touch (mobile)
   f. 3D gesture (mobile)
5. Do you think that this prototype could improve your daily life?
6. Do you find the prototype's interface easy to use and intuitive? Why?

7. Which prototype's version do you liked most? Why?
    a. Desktop version
    b. Mobile version
8. What do you think is essential to include or change so the application is according to your needs?

Scale A:

1. Impossible
2. Very difficult
3. Difficult
4. Reasonable
5. Easy
6. Very easy

Scale B:

1. Did not like it
2. Liked it a little
3. Liked it
4. Liked a lot
5. Loved it

5.2.4. Analysis methods

Both qualitative and quantitative results were taken into consideration, following the same recommendations as the tests made with the previous version of this prototype, depicted in [17]. Although quantitative results were gathered these must not be seen as the most relevant data, because of the reduced number of participants considered, which turns the sample statistically unrepresentative. However, it should be seen as a pre-test or a guide, to a future test with a more statistically representative sample.

As for qualitative results we have considered the following:

- **Result**, that could be:
    - **Completed**- participant successfully completed the task;
    - **Incomplete** - participant did not perform all tasks successfully;
- **Observations** - our point of view of participants' performance on doing the task;
- **Participants' opinion** - opinions given by participants about the task in reply to questions referred on Table 5.4.

For quantitative results we have considered:

- **Time to complete a task** - time (in minutes) since the participant was instructed to do a task until task completion;
- **Number of helps** - number of times the participant asked for help or was helped;
- **Modality count** - number of times a modality was used to accomplish a single action (select a text box or a button). A modality was counted only when the following modalities were available:
    - **Speech** – the participant could use command and control to select a text box or a button or dictation to write a text;
    - **Touch** – the participant could use touch to select a text box or a button or a virtual keyboard to write a text;
    - **Hardware** – the participant could use traditional hardware input devices such as mouse and/or keyboard

As a way to evaluate the results we have used simple statistical analysis, calculating the average amount of time (and the standard deviation), participants took to complete a task, as well as the variations between different groups of subjects, that were identified.

To investigate the differences between participants, we have considered the following different segmentation:

- General – All 10 participants;
- Skilled Participants – All those that stated having experience with computers (Five participants);
- Non-skilled Participants – Those who did not have experience with computers (Five participants.

Based on the information given by the participants we have considered P3, P5, P7, P8 and P10 as skilled computer users and the remaining as non-skilled computer users (See Appendix B.2.1, question I.2). This division was confirmed accurate during the sessions, on which it was possible to understand that, generally, skilled computer users had a slightly better performance than the non-skilled ones, as we´ll see later in this chapter.

5.3. Results Analysis

In this section we present the analysis of the results of this user study.

Results for all tasks, the answers to the final questionnaire and to the questions on Table 5.4, as well as our observations of each task per participant can be found on Appendix B.2.2.

5.3.1. Tasks Results Analysis

5.3.1.1. Mobile Experiment

Results for the mobile application tasks show that the difference on the average times of execution, between the control subject and the participants varied from 1:14m to 1:56m, while differences between skilled and non-skilled computer users would not exceed 35 seconds. The task that required the visualization of the received and sent social messages was the one with the better results, as depicted in Table 5.8.

TABLE 5.6 – CONFERENCE TASK (MOBILE) TIMES ANALYSIS

Subjects	Mean Task Duration	Standard Deviation of Task Duration	Mean Differences
Control	01:10	-	01:37
General	02:47	01:09	
Skilled	02:31	00:57	00:33
Non Skilled	03:04	01:21	

TABLE 5.7 – SMS PROFILE TASK (MOBILE) TIMES ANALYSIS

Subjects	Mean Task Duration	Standard Deviation of Task Duration	Mean Differences
Control	01:08	-	01:56
General	03:04	01:22	
Skilled	02:47	01:10	00:35
Non Skilled	03:22	01:34	

TABLE 5.8 – SMS MESSAGES TASK (MOBILE) TIMES ANALYSIS

Subjects	Mean Task Duration	Standard Deviation of Task Duration	Mean Differences
Control	01:11	-	01:14
General	02:25	00:52	
Skilled	02:16	00:46	00:19
Non Skilled	02:34	00:59	

The number of aids was similar to all the tasks. Only 5 participants out of 10 requested help, and the aids did not exceed 1 for each one of those participants. The preferred modality of interaction in mobility was Touch, with an average of 10 uses per task per participant. Most participants argued that the “push-to-talk” (PTT) mechanism available in the mobile version for the Speech modality was complicated to use and was of little help for achieving the desired action. Other issues pointed to the mobile application included the fact that the virtual keyboard is not large enough to enable elderly users to hit a key at a time and also, the fact that some buttons are hidden and not obvious enough, such as the *Save Profile* button in the SMS's Profile screen.

5.3.1.2. Desktop Experiment

Desktop tasks analysis revealed that participants took, in average, from 1 minute to 4:26m more than the control subject to complete the tasks, whereas computer skilled participants were 12 seconds to 1:32m faster than non-skilled participants (See Table 5.9, Table 5.10 and Table 5.11).

TABLE 5.9 – CONFERENCE TASK (DESKTOP) TIMES ANALYSIS

Subjects	Mean Task Duration	Standard Deviation of Task Duration	Mean Differences
Control	00:36	-	01:00
General	01:36	00:42	
Skilled	01:29	00:38	00:12
Non Skilled	01:42	00:47	

TABLE 5.10 – SMS PHOTOS TASK (DESKTOP) TIMES ANALYSIS

Subjects	Mean Task Duration	Standard Deviation of Task Duration	Mean Differences
Control	03:34	-	02:25
General	05:58	01:42	
Skilled	05:13	01:10	01:32
Non Skilled	06:44	02:15	

TABLE 5.11 – SMS PHOTOS TASK (DESKTOP) TIMES ANALYSIS

Subjects	Mean Task Duration	Standard Deviation of Task Duration	Mean Differences
Control	03:34	-	02:25
General	05:58	01:42	
Skilled	05:13	01:10	01:32
Non Skilled	06:44	02:15	

The task that required the users to establish a video-call with a specific contact was the most enjoyed and that feature was reported as the most useful in the application. It was also the fastest task and the one with fewer differences between user categories, as shown in Table 5.9. The video-call task was also the one that registered less aids, with only 5 participants requesting help one time Table B.4, Appendix B. The remaining tasks registered the average of an aid per participant per task (Table B.5 and Table B.6, Appendix B). However, if we consider that those aids had mostly to do with them asking how to bring up the built-in virtual keyboard, we could overlook these data.

The most used modality of interaction was *touch,* followed by *speech*. In average, the first was used 3 times more than the latter and 15 times more than *hardware (keyboard and mouse) (*Table B.4, Table B.5 and Table B.6, Appendix B*)*.

The only issue reported by users had to do with the fact that dictation with the current European Portuguese speech recognition engine is still far from being 100% accurate, especially with the elderly voice. An existing R&D project (LUL) is still on-going with the objective of collecting speech corpora for the elderly, to train a specific acoustic model of European Portuguese, aiming at improving the word error rate of Speech Recognition for elderly users in command and control scenarios. Satisfaction with the appearance and organization of the GUI was also noticeable, as most participants commented that the appearance and organization of the screens was appealing and easy to understand.

5.3.2. Questionnaire Results Analysis

This questionnaire was based on the one applied on the previous usability study made with mobility impairment users [17].

The answers to the first question revealed that participants generally considered all modalities easy or reasonably easy to use and only on some cases difficult, as demonstrated in Figure 5.1.

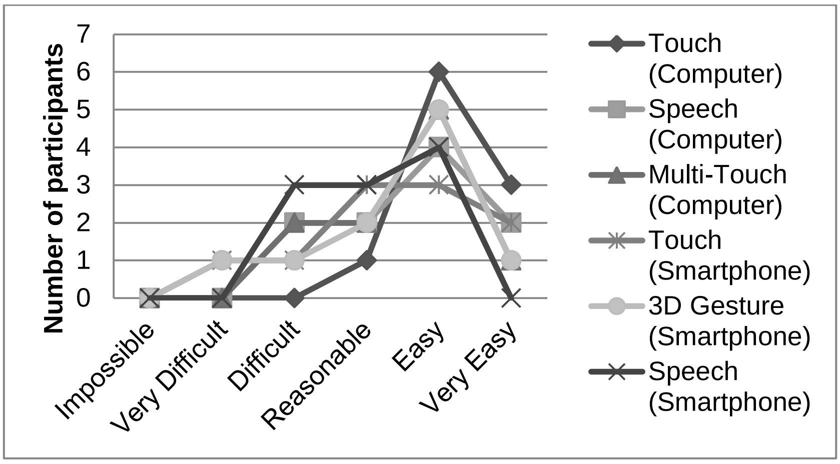

FIGURE 5.1 – QUESTION 1: EVALUATE, IN TERMS OF EASINESS/DIFFICULTY OF INTERACTION, THE FOLLOWING MODALITIES

The second question answers' depicted on Figure 5.2, has shown that participants enjoyed using almost all modalities, tending to prefer *touch* and *speech* on the desktop version.

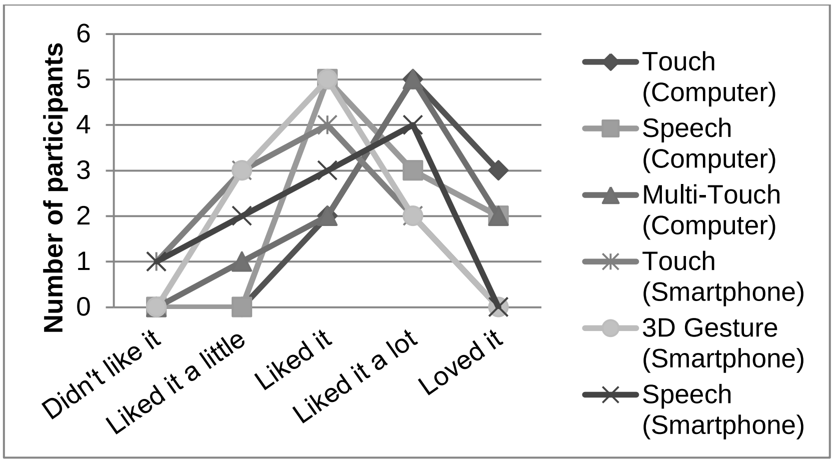

FIGURE 5.2 – QUESTION 2: EVALUATE, IN TERMS OF SATISFACTION THE FOLLOWING MODALITIES

When asked about their preferred modality/modalities of interaction, eight participants manifested preference for *Touch* on the desktop application, as Figure 5.3 shows. *Speech* on the desktop, selected by 4 participants, was the second preferred modality.

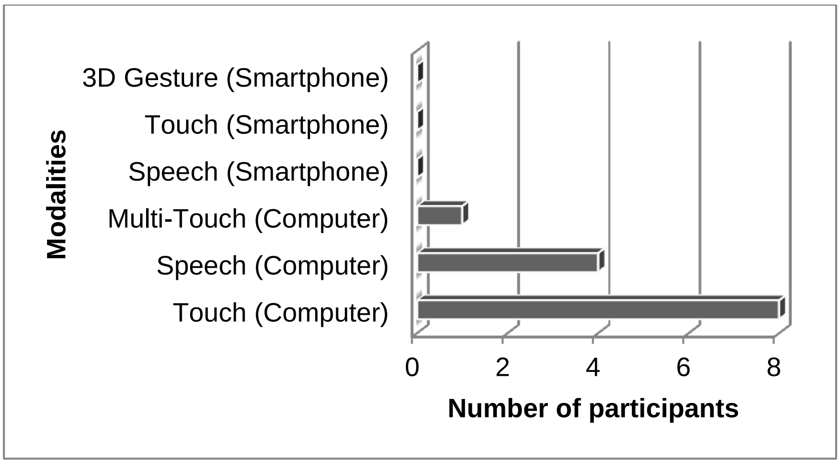

FIGURE 5.3 – QUESTION 3: WHICH MODALITY(IES) DID YOU LIKE MOST?

On the other side, the less enjoyed modalities were *touch* and *3D gesture* on the smartphone Figure 5.4. Touch on the smartphone was normally underrated because the keyboard layout has proven to be small for the elderly to use it effectively. 3D gesture was seen as a modality only suited for very restrict cases and even almost useless and a bit confuse for the considered user group.

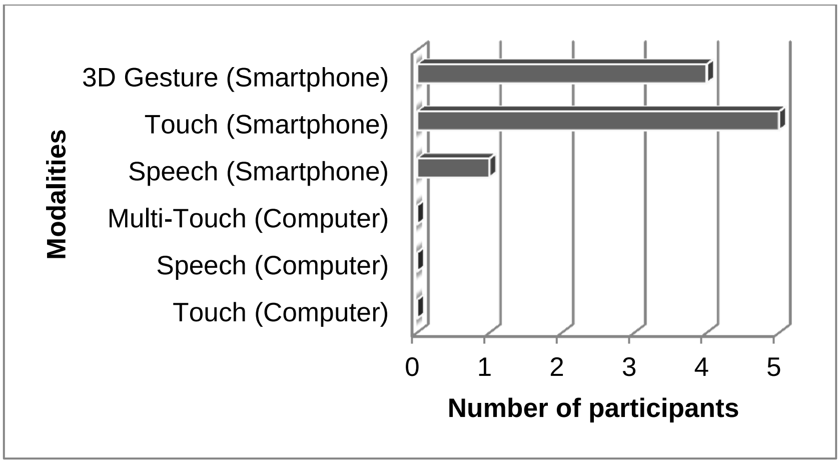

FIGURE 5.4 – QUESTION 4: WHICH MODALITY(IES) DID YOU LIKE LESS?

With the fifth question we wanted to find if participants felt that the prototype could somehow improve their quality of life. The answers were similar to all participants and the tendency was to classify it as providing an easier and more enjoyable experience than current interfaces. Below are all the participants' answers.

TABLE 5.12 – QUESTION 5: DO YOU THINK THAT THIS PROTOTYPE COULD IMPROVE YOUR DAILY LIFE?

P1	I believe so. It's a good entertainment center, and a nice tool to communicate with the world.
P2	I believe it would make it easier to communicate and share with my family.
P3	Yes, at least the computer version would be very welcome. It is a joy to use it.
P4	Yes, it's much faster than using the mobile phone and much more entertaining.
P5	I like the fact that I can touch, it feels very natural. I also love its design and organization.
P6	I do not think I'd find usage to all its features, but the conference feature would be very welcome.
P7	Yes. If I had the choice between this and the conventional I'd choose this without a doubt.
P8	It's quite easier to use than the conventional interfaces, so yes, I believe it would be a very welcomed addition.
P9	It would be very nice to have this application. Communicating with my grandchild would be so much easier.
P10	I believe so. Not for the accessibility features, because I'm quite healthy and capable, but for the entertainment it provides.

We have also asked participants if they felt the prototype interface was easy and natural to use, obtaining positive response from all the participants. Most of them justified this by stating that they did not take much time to understand how the applications worked and that they were able to perform the required tasks quite fast and easily, without having to resort to help many times (See Appendix B.3, question II.6).

The preferred version of the prototype was, unanimously, the one developed for multi-touch desktop computers, mainly because of its screen size and definition, allowing for bigger clearer text and graphical information, as well as allowing for all the available options on a given context to be visible rather than collapsed on a submenu (See Appendix B.3, question II.7 0).

Finally, when asked what they thought we should change or add to the prototype, so it would behave according to their needs, participants responded diversely, as can be confirmed in Table 5.13. Some comments were that would like us to change the mobile keyboard layout and enhance (European Portuguese) speech recognition in general, for command and control and dictation (See Table 5.13). One user stated that the Microsoft synthetic voice for European Portuguese (Hélia) was too fast.

TABLE 5.13 – QUESTION 8: WHAT DO YOU THINK IS ESSENTIAL TO INCLUDE OR CHANGE SO THE APPLICATION IS ACCORDING TO YOUR NEEDS?

P1	I do not have the experience required to give you this answer. I believe it's very good as it is now.
P2	The desktop version is good as it is. You should try to make the font bigger on the mobile version and change the keyboard.
P3	I cannot recall anything besides an improvement on the mobile keyboard and font size.
P4	I believe that the computer's voice is too fast, and help could be enhanced with visual hints.
P5	I believe some of the icons you use for the buttons could be better and also add some for big buttons that have only text on them, I also believe you could make the voice of the assistant warmer if you used a more informal language
P6	Maybe you could make some changes to the help function so I would feel that I was not doing anything wrong and improve the recognition of speech, since I do not like the keyboard.
P7	I believe the keyboard of the mobile is its biggest issue. Everything else is fine.
P8	I believe it's almost complete as it is now, but I'd like to test it with a better speech recognizer.
P9	I cannot think of anything.
P10	I believe it's a good advance of what I've seen so far, but maybe you could add some typical games for entertaining reasons (Like card games, chess…)

5.4.3. Usability Evaluation Conclusions

The usability evaluation allowed us to derive the following conclusions:

(1) The LHC V2.0 prototype GUI was considered as adequate by the elderly, being classified as simpler, more natural and more enjoyable than current GUIs (e.g., WLM and Facebook).

(2) Multimodality and universal design can play an important part on the adoption of audiovisual communication and social media services, thus fighting e-exclusion, since all the participants revealed to be relaxed, entertained and effectively using the prototype, achieving relatively complicated actions with little effort. Also, allowing different users to choose the modality that was most suited on different contexts, made the application usable for both low and high skilled participants, in what computing is concerned.

(3) The availability of touch, on both clients, is very important and has a direct impact on the elderly performance and level of satisfaction.

(4) Speech is seen as an important modality. However, because the accuracy of the current *speech engine* for *European Portuguese* for elderly is still undergoing improvements, participants became somewhat disappointed with the current dictation capability, describing its enhancement as a must-have feature and a good solution to their limitations when trying to use a keyboard.

(5) The desktop client version is the one that better suits the current elderly population, since its use did not present difficulties to most of the participants. Regarding the mobile version, there are some improvements to be made, such as the simplification and augmentation of the virtual keyboard. The latter was also seen as a tool for the elderly of the future, since those will have more experience with such devices.

(6) The easy and natural multimodal access to audiovisual communication and social media services, enabled by the LHC V2.0 prototype, can bring the potential in fighting social exclusion, by improving the elderly ability to communicate and share. As an example, users regarded the usage of the video-call feature on LHC V2.0 as much simpler than with common systems, and believed it would be one the most useful services to enable communication with family and friends.

Bearing in mind that the control subject had much higher computer skills than all the participants, the results obtained in the usability study can already be interpreted as very good indicators for further research.

5.5. Conclusions

In this chapter we have presented the results and discussions of the usability evaluation of the LHC V2.0 prototype. The user study had the participation of ten elderly, who performed a set of predefined tasks and provided an evaluation of the system’s usability. Even though conventional HCI modalities were available during these tasks, they were almost never used by participants’ choice, proving that they considered the alternative modalities easier to use and more effective. We also observed that all the participants were able to finish the required tasks in relatively fast times, showing no signs of boredom or fatigue during and in the end of the sessions. With these results in hand, we concluded that the fact that the developed system respected the elderly requirements and resorted to alternative HCI modalities made it an effective tool for those users to access important communication and social sharing services that were out of their scope before and that allow them to reach others and express themselves in an easier and broader way.

Chapter 6. Conclusions and Future Work

6.1. Conclusions

This dissertation focused on evaluating whether Multimodal Human-Computer Interaction (MHCI) systems designed with Universal Accessibility principles, taking into account elderly specific requirements, facilitate the adoption and access to popular Social Media Services (SMSs) and Audiovisual Communication Services, thus potentially contributing to elderly social and technological integration.

In Chapter 2 we were able to conclude that accessibility must not be overlooked on any system, because it provides a significant part of the population access to services and contents that would, otherwise, be out of their reach. Likewise, we have concluded that the concept of AAL may be useful for the development of safer and more effective solutions to help users interact with the environment that surrounds them in a simpler and more effective way. We have also determined that Multimodal HCI systems can be effective while providing alternative modalities to access computational systems, helping simplify and expand HCI possibilities. Lastly, we have discussed methodologies for User-Centered Design and Development and Usability evaluation, which were seen as providing effective tools to design, develop and evaluate systems that aim at being accessible and usable.

In Chapter 3 we have presented the initial user requirements study. This study had the objective of understanding what are the elderly difficulties and habits while using ICTs, audiovisual conferencing services and SMSs. We have also performed a usability evaluation of HCI modalities. With this study we were able to conclude that elderly have difficulties when accessing those services, from a computer or a mobile device. Most of the user interfaces are inadequate or too difficult for them to understand and require too much know-how and training. We have also concluded that GUIs for existing audiovisual communication and Social Media services have too much visual information on screen, which turns the comprehension of the interaction state hard and were not developed with the concern for potential impairments users might have with vision, for example. Finally, we have discovered that Touch is a very well accepted modality, along with Speech. This last modality is the one were consensus was reached, regarding “a wish to have modality”, although the current implementation includes important limitations in the AM and LM that prevent a fully rewarding user experience, with speech for the elderly.

With the gathered results from the initial study we have compiled a set of new user requirements for the development of the mentioned multimodal HCI for the elderly, accessing an improved LHC V2.0 prototype. Additionally we have set-up a plan to improve the LHC in this context, with new service features, such as Instant Messaging and Facebook content access.

In Chapter 4 we have presented some details about the developed V2.0 prototype architecture as well as its features and an insight into which software and hardware technologies were used. The prototype was developed with the objective of mapping the derived users’ requirements, presented as a result of Chapter 3.

To verify the possible benefits of a multimodal human-computer interface that allow access to audiovisual communication services and SMSs, and thus, test our hypothesis, we designed an evaluation study, as described in Chapter 5. In this study we asked a panel of participants to perform some tasks that focused on the usage of the developed prototype's conference module features and on the new SMSs features. Having gathered relevant experimental data and after some simple statistical analysis, we have confirmed our thesis statement: "Multimodal (elderly) user interaction for accessing audiovisual and conferencing services and SMSs over the Internet, is more adequate than traditional WIMP and keyboard interaction", since the use of alternative modalities, such as touch and speech, to access social media and communication services proved to be more effective than using traditional ones, like keyboard and mouse. Additionally, we believe that this type of prototype has the potential to improve elderly ability to integrate socially and technologically. We have also concluded that the design of both applications is adequate for the elderly, but the mobile version still needs to go under some improvements to be usable by all.

6.2. Future Work

As mentioned throughout this document, dictation with the European Portuguese speech recognition engine is still far from being 100% accurate, especially with the elderly voice, since a parallel project [18] is still on-going with the objective of collecting those voice characteristics for the augmentation of the aforementioned engine capabilities. So, future work should consider the evaluation of the improved speech engine for the elderly voice. It is also desirable to add dictation support for the mobile application and also evaluate the impact of such an extension on that application usability, since one of the main concerns pointed by users was the small and difficult to use on-screen keyboard of the mobile version of the prototype.

The mobile version of the prototype should also go under some improvements pointed out by the users, such as changing the color of the application general background, change some of the icons and improve voice interaction support by removing the push-to-talk mechanism currently available, by providing voice streaming capabilities.

It's also desirable to investigate if the prototype would be welcomed and usable in a real-life scenario for a wider period of time, such as a nursing home or volunteer user homes. To confirm the achieved results, a larger group of users should also be considered in a future study.

In a more multidisciplinary work, that could include disciplines such as Social Psychology, Sociology and Gerontology, it would be appropriate to test if the developed prototype could succeed as a tool to enhance the quality of life of elderly and if it would really help improving elderly ability to socially integrate.

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Appendix A. Requirements Study Sessions Additional Data

A.1. Requirements User Study Consent Form

Requirements study for developing the prototype Living Home Center targeted at the elderly population

Consent Form (Original)

First of all thank you for participating in this study. Your collaboration is essential to the success of our project.

This study falls within the Master's thesis of the researcher Vítor Teixeira, whose aim is to study new ways of interacting with the devices, using multimodal interfaces (which include various modes such as voice, touch and gesture). The thesis is focused on access to different services concerning the senior population. Examples include social networks, like Facebook, and other organizational and communication services, such as calendar, email and audio / video conferencing. In the end we intend to develop a working prototype to test the results of the study.

The thesis is supervised by Prof. Miguel Sales Dias from Microsoft and ISCTE-IUL and Prof. Eduarda Mendes Rodrigues from FEUP.

During this session we will ask you to perform some simple tasks with which you should be comfortable, and also try some devices. At the end of the session we will gather your observations.

This session will be filmed and recorded. All data in video and audio collected is confidential and accessible only to people involved in this study (referred above). However, for illustrative purposes only, do you allow some images / videos collected here, to be published in the thesis, in conferences or journals? [ ] Yes [ ] No

We request that you fill in the following data (the data provided is strictly confidential and is intended only to statistical analysis):

- Name: ____
- Age: ____
- Former Career: ____
- Known health problems: _________ ______________________________

[ ] Check the box if you want to receive updates on this study in the future? (If yes, please provide us your email: ____)

I have read and understood the objectives of this session, participating willingly in it.
Signature: ____

The researcher:
Vítor Teixeira: ____

A.2. Interviews Transcription and Sessions Additional Data

A.2.1. Requirements Study Participants Generic ICT Usage and Skills Questionnaire Results

I.1. On average, how would you describe your computer usage habits:

a. Never used
b. Sporadic usage (less than once a week)
c. Weekly usage (at least once a week)
d. Daily usage (less than five hours a day)
e. Intense usage (more than five hours a day)

P1	d
P2	d
P3	b
P4	d
P5	b
P6	c
P7	e
P8	d
P9	c
P10	e

I.2. How would you rank your computer skills:

a. Very Low
b. Low
c. Average
d. High
e. Very High

P1	b
P2	b
P3	a
P4	c
P5	a
P6	a
P7	c
P8	b
P9	c
P10	d

I.3. Do you use a mobile phone?

P1	Yes
P2	Yes
P3	Yes
P4	Yes
P5	Yes
P6	Yes
P7	Yes

I.4. Do you use a Smartphone?

P1	No
P2	No
P3	No
P4	No
P5	No
P6	No
P7	No

P8	Yes
P9	Yes
P10	Yes

P8	No
P9	No
P10	No

I.5. How would you rank you mobile phone /Smartphone skills:

a. Very Low
b. Low
c. Average
d. High
e. Very High

P1	b
P2	d
P3	b
P4	C
P5	a
P6	b
P7	d
P8	b
P9	b
P10	d

I.6. On average, how would you describe your mobile phone /Smartphone usage habits:

a. Never used
b. Sporadic usage (less than once a week)
c. Weekly usage (at least once a week)
d. Daily usage (less than five hours a day)
e. Intense usage (more than five hours a day)

P1	d
P2	d
P3	c
P4	b
P5	d
P6	d
P7	d
P8	d
P9	b
P10	d

I.7. What do you usually do on your computer?

a. Study/ Search for information
b. Get in touch with family
c. Get in touch with friends
d. Play games
e. Listen to music
f. Watch videos
g. Others_____________

P1	a, b, c
P2	d, g
P3	NA
P4	b, c, d, e
P5	a
P6	a, d, g
P7	a, b, c, d, e, f,

I.8. What do you usually do on your mobile phone /smartphone?

a. Get in touch with family
b. Get in touch with friends
c. Play games
d. Appointment scheduling
e. Listen to music
f. Watch videos
g. Others____________

P1	a, b
P2	a, b
P3	a, b
P4	a, b, c
P5	a, b

	g
P8	a
P9	a, b, g
P10	c, d, e, g

P6	a, b
P7	a, b, d
P8	a, b
P9	a, b
P10	a, b, d

I.9. What are your main difficulties when using a computer?

P1	The keyboard is the main issue.
P2	For what I do with it I do not have any difficulties. But it's hard to make something that is out of the ordinary.
P3	Since I have little usage time I cannot answer this question
P4	I find it hard whenever I try to access the Internet
P5	I never had any training in Its. I learn to use what I need by my own, so I do not know much.
P6	I get upset by the waiting times and it gets confuse to find a way to do something I thought was simple.
P7	I do not have any difficulties with what I do, but the waiting times annoy me
P8	No difficulties, but the latency on some programs bores me
P9	I have a hard time formatting text when I'm writing my poetry
P10	My main difficulty is trying to use social networks sites, like Facebook. It's too confusing.

I.10. What are your main difficulties when using a mobile phone /Smartphone?

P1	None
P2	None
P3	None
P4	None
P5	None
P6	None
P7	Small screen and keyboard
P8	None
P9	I do not explore it's features because I fear I will damage it
P10	None

I.11. Have you ever used accessibility programs or features?

P1	No
P2	No
P3	No
P4	No
P5	No
P6	No
P7	Yes
P8	No
P9	No
P10	Yes

a. If yes. What did you like about them?

P7	Nothing
P10	The fact that it lets me read documents much easier (Magnifier)

b. If yes. What did not you like about them?

P7	It does not represent an advantage for me (Screen reader)
P10	Nothing

A.2.2. Audiovisual Conferencing and Social Media Services Questionnaire Results

II.1. Have you ever used Instant Messaging services?

P1	Yes
P2	No
P3	No
P4	Yes
P5	No
P6	Yes
P7	Yes
P8	No
P9	Yes
P10	Yes

a. If yes. What are your main difficulties when using those services?

P1	It's hard to find some buttons and understand how to perform actions like adding a contact and so on
P4	When I see all the options of that program (WLM) I fear I will damage the computer if I do something wrong, so I try not to change anything and ask my daughter to help me whenever I need to do something different.”
P6	The confusing options and my lack of patience makes me quit before I can do something, I always think I’m wasting time
P7	I’ve been using this service for some years now, so I have no problem interacting with it.
P9	I cannot establish a communication via video or audio call, I’ve tried several times but there’s always some error
P10	I have few problems using WLM.

b. If yes. Do you use those systems to share photos or videos?

P1	No
P4	Yes
P6	No
P7	No
P9	No
P10	Yes

c. If yes. How often do you use those services?

i. Daily
ii. 2 or 3 times a week
iii. Once a week
iv. Less than once a week

P1	iv
P4	iii
P6	iv
P7	iv
P9	iv
P10	ii

d. If yes. With whom do you keep in touch through these services?

i. Friends
ii. Family
iii. University colleagues
iv. Work colleagues
v. Others

P1	i, ii
P4	i, ii
P6	ii
P7	i, ii
P9	i, ii, iii
P10	i, ii, v

II.2. Have you ever used those services voice or video call features?

P1	Yes
P4	Yes
P6	No
P7	Yes
P9	No
P10	Yes

a. If not. Why?

P6	New technologies annoy me
P9	Cannot get those features to work on my PC

II.3. Have you ever heard of Social Media Sites?

P1	Yes
P2	Yes
P3	Yes
P4	Yes
P5	Yes
P6	Yes
P7	Yes
P8	Yes
P9	Yes
P10	Yes

a. If yes. Which ones do you know of?

P1	Facebook
P2	Facebook
P3	Facebook
P4	Facebook
P5	Facebook
P6	Facebook, HI5 and Twitter
P7	Facebook
P8	Facebook, HI5 and Twitter
P9	Facebook and Twitter
P10	Facebook

II.4. Have you ever used any of those Social Network Sites?

P1	No
P2	No
P3	No
P4	Yes
P5	No

P6	No
P7	Yes
P8	No
P9	No
P10	Yes

a. If yes. Which one(s) do you use?

P4	Facebook
P7	Facebook
P10	Facebook

b. If yes. What are the main difficulties you find when using those services?

P4	The fact that the interface is a bit confusing does not let me go beyond the usage of the few features I learnt how to use.
P7	None
P10	My lack of knowledge about the features and the fact that I do not explore it much do not let me go further. However I think that would be surpassed if I spent more time trying to get used to it.

c. If yes. How often do you use those services?

i. Daily
ii. 2 or 3 times a week
iii. Once a week
iv. Less than once a week

P4	i
P7	i
P10	iii

d. If yes. How often do you use those services?

i. Friends
ii. Family
iii. University colleagues
iv. Work colleagues
v. Others

P4	ii
P7	i, ii
P10	i

II.5. For which one(s) of the following activities do you use/would like to use SNSs for?

a. Getting in touch with family
b. Getting in touch with friends
c. Activity following/ Newsgathering
d. Publishing news
e. Sharing, viewing and/or photo archiving
f. Sharing, viewing and/or video archiving
g. Events notification
h. Listening to music

P1	a, b, e, h
P2	a, b
P3	a, b, c, h
P4	a, b, e, f, h

P5	a, b, c, g
P6	a, b, e, g
P7	a, b, c, d, e, f
P8	a, b, e, f
P9	a, b, e
P10	c

A.2.3. Observations and Opinions about Audiovisual Conferencing and Social Media Services Tasks

TABLE A.1 - INSTANT MESSAGING TASK OBSERVATIONS

Participant	Observations	Participant's opinions/suggestions
P1	Participant knew the WLM interface, but took long time writing.	I'd like to begin a conversation by calling the contacts name or nickname. I would also like to use dictation mode, instead of having to write. If I could use touch, I would do everything that I do with the mouse, since it's easier and faster to touch.
P2	Oldest participant (83) had trouble with the mouse in the beginning.	The buttons should be more visible and actions should be clearer and not so hidden. I would like to use touch instead of the mousse and speech to start conversations.
P3	Participant never used the computer before, so he had trouble with the mouse and keyboard.	Using the mouse takes me a lot of time, so touching would be nicer. I'd also like to be able to Dictate text.
P4	Participant is used to WLM.	Options should be more visible.
P5	Young participant, but with little experience and skills.	Text size should be bigger. I'd like to be able to ask for help when needed.
P6	Participant said that for her to gain interest in some application it had to be much more intuitive than those of nowadays.	The text could be bigger and buttons should all be visible and easily understood. I'd like to use speech as a way to command the application to do what I wanted.
P7	Skilled participant.	Touch would be a nice replace to mouse interaction.
P8	Participant was very	I believe buttons should be more visible and better identified.

	quiet and somewhat bored at this stage.	
P9	Participant could not find voice/video call buttons. Took a long time to perform the task; had trouble with keyboard.	Use bigger size buttons and text and do not include hidden items. Block construction of interface is not very intuitive for the user.
P10	Participant had average computer skills. Needed little help.	Options are a bit hidden, I used it easily because I'm used to it. It should also have more graphical icons than text only buttons.

TABLE A.2 - AUDIOVISUAL CONFERENCE TASK OBSERVATIONS

Participant	Observations	Participant's opinions/suggestions
P1	Participant just had trouble finding the Audio Call Button	Same as previous task.
P2	Also needed help with voice and video call buttons. Easily forgot how to perform an action.	Voice and video call buttons should be larger and not hidden.
P3	Participant perform a could not double click, using the mouse	Same as above, plus options cannot be so hidden.
P4	Started a video call instead of a voice call.	Small buttons cause a bit of a confusion.
P5	Needed help with voice and video call buttons.	I prefer video calls, to voice or IM because it's safer to know who is on the other side.
P6	Started a video call instead of a voice call.	Same as previous task.
P7	Same as above.	The interface of this version is more confusing than last ones; things are more hidden and not well identified.
P8	Needed help with voice and video call buttons.	Same as above, plus options cannot be so hidden.
P9	Needed help with voice and video call buttons	I like video conferencing because it is a more personal way of communicating.
P10	Same as above.	Same as above.

TABLE A.3 – SOCIAL MEDIA TASK OBSERVATIONS

Participant	Observations	Participant's opinions/suggestions
P1	Did not know where to open the website. Could not find the "Edit profile" option. Needed help to understand how to upload a photo.	Command and dictation would save me a lot of time and effort. I like private messages, because even if someone is not online I can send him a message, and it's easier than sending an email.
P2	Need help with: Login to Facebook Finding the 'Edit profile' option Finding the specific friend Finding the private message button How to share a public message.	Maybe having fewer things on each screen would be less confusing.
P3	Participant preferred the touchpad instead of the mouse. Needed a lot of help.	Facebook interface is not intuitive to use in a first time, without help I could not find anything.
P4	Stated that the size of the font is very small on Facebook, while performing the task.	Buttons should be bigger and have less information on the page, it may become confusing.
P5	Need help with: Find the 'edit profile' option Find the photos button Share public message.	I like the photo sharing option.
P6	Needed help with: How to open browser and page 'at' character (did not remember) Upload photo process Find Send private message button.	It's not very easy for someone who uses it for the first time. You've got to be persistent to complete the task you want to do.

P7	Did not need any help.	Facebook is a very good solution for sharing, but it is not though for elderly. Font is too small and organization is confusing.
P8	Needed help with: Editing the profile Uploading a photo.	The organization of Facebook is not very simple; it also seems to assume that the user must have some skills with computer systems.
P9	Needed help with: Upload photo process Find specific friend How to share a public message	I like Facebook, but I find it difficult to use.
P10	Needed help finding edit profile button and go to the contacts section.	Most seniors have a hard time to write, so dictation would be very important in this application.

A.2.4. Usability evaluation of HCI modalities using LHC V1.0 - Additional Data

A.2.4.1. Tasks

TABLE A.4 - REQUIREMENTS STUDY LHC V1.0 TASKS DESCRIPTION

Email Task (Desktop)	1. Open your e-mail inbox 2. Open any message on your Inbox 3. Create a new e-mail with the following parameters: a. Subject: ***Email de teste*** b. Message: ***Olá, este é um email de teste! Bem responde-me.*** ***PS: Será que escrever o símbolo do euro é complicado? Deixa cá ver: €*** c. Attach the image on the Desktop d. Recipients: i. To: **Two contacts of your choice** ii. Cc: **A different contact from the previous two**
Agenda Task (Desktop)	1. Open your Agenda 2. Create a new appointment for tomorrow with the following parameters:

	a. Subject: **Ir ao cinema** b. Description: **Ir ao cinema ver um filme** c. Place: **Colombo** d. Start Time: **16h00** e. Duration: **2 (h)** 3. Delete the appointment you just created
Photo Albums Task (Desktop)	1. Open the Social Networks menu and then 'Audiovisual' 2. Select the Photos menu 3. Open the first photo album 4. Access the multi-touch mode and try to control the available photo (Drag, zoom, rotate)
Mobile Task (Smartphone)	1. Open your e-mail inbox 2. Tilt the Phone to select a message 3. Open the submenu **'Opções'** 4. Close **'Opções'** 5. Go back to the main menu 6. Select **'Agenda'** 7. See **'Vista mensal'**, select the current month and then the day of tomorrow 8. Select and view any appointment 9. Access the Social Networks menu 10. Select **'Mensagens'** e view them

A.2.4.2. Tasks Results

TABLE A.5 - AGENDA TASK RESULTS

Participant	Time to complete (mm:ss)	Number of helps	Result	Modality count		
				Speech	Touch	Hardware
Control	02:23	0	Completed	4	10	2
P1			NA			
P2			NA			
P3	05:29	1	Completed	7	14	0
P4	04:10	1	Completed	0	18	1
P5	07:10	1	Completed	11	6	0
P6	04:20	1	Completed	3	16	2
P7	05:18	1	Completed	16	5	0
P8	03:39	1	Completed	9	12	0
P9			NA			
P10			NA			

TABLE A.6 – PHOTOS TASK RESULTS

Participant	Time to complete (mm:ss)	Number of helps	Result	Modality count		
				Speech	Touch	Hardware
Control	00:59	0	Completed	0	7	0
P1			NA			
P2			NA			
P3			NA			
P4	02:28	1	Completed	4	3	0
P5	01:51	0	Completed	4	2	0
P6	01:11	1	Completed	0	6	0
P7	01:53	1	Completed	8	1	0
P8	01:27	1	Completed	0	10	0
P9			NA			
P10			NA			

TABLE A.7 – MOBILE TASK RESULTS

Participant	Time to complete (mm:ss)	Number of helps	Result	Modality count		
				Speech	Touch	3D Gesture
P1	02:50	1	Incomplete	NA	13	1
P2	03:42	1	Incomplete	NA	12	2
P3			NA			
P4	03:13	0	Completed	NA	16	4
P5	02:54	0	Completed	NA	13	2
P6	03:32	0	Completed	NA	13	2
P7	03:04	0	Completed	NA	11	3
P8	02:30	0	Completed	NA	10	4
P9			NA			
P10			NA			

A.2.4.3. Tasks Results Analysis

TABLE A.8 - EMAIL TASK STATISTICS (TABULAR FORM)

Subjects	Mean Task Duration	Standard Deviation of Task Duration	Mean Differences
Control	03:39	-	04:59
General	08:38	03:32	
Younger Participants (<60)	06:32	02:02	04:12
Older Participants (>60)	10:44	05:01	

TABLE A.9 - AGENDA TASK STATISTICS (TABULAR FORM)

Subjects	Mean Task Duration	Standard Deviation of Task Duration	Mean Differences
Control	02:23	-	02:38
General	05:01	01:52	
Younger Participants (<60)	05:22	02:07	NA
Older Participants (>60)	04:40	01:37	

TABLE A.10 - PHOTOS TASK STATISTICS (TABULAR FORM)

Subjects	Mean Task Duration	Standard Deviation of Task Duration	Mean Differences
Control	00:59	-	00:47
General	01:46	00:33	
Younger Participants (<60)	01:44	00:32	00:06
Older Participants (>60)	01:49	00:36	

A.2.4.4. Questionnaire Results

III.1. Evaluate the modalities, in terms of easiness/difficulty of interaction, according to the following scale:

1. Impossible
2. Very difficult
3. Difficult
4. Reasonable
5. Easy
6. Very easy

Modality	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Touch (Computer)	5	5	4	5	6	5	6	5	6	6
Speech (Computer)	4	1	3	4	4	4	5	4	6	5
Multi-Touch (Computer)	NA	NA	6	5	6	5	6	5	4	5
Speech (Smartphone)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Touch (Smartphone)	6	5	NA	6	6	5	6	4	6	5
3D Gesture (Smartphone)	6	5	NA	5	6	5	5	4	5	5

III.2. Evaluate the modalities, in terms of satisfaction, according to the following scale:

1. Did not like it
2. Liked it a little
3. Liked it
4. Liked a lot
5. Loved it

Modality	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Touch (Computer)	4	3	3	4	5	5	4	4	5	5
Speech (Computer)	3	2	2	2	4	5	4	4	5	5
Multi-Touch	NA	NA	4	5	5	5	4	4	5	5

(Computer)										
Speech (Smartphone)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Touch (Smartphone)	4	5	NA	4	5	5	4	4	5	4
3D Gesture (Smartphone)	4	5	NA	4	5	5	4	3	4	4

III.3. Which modality (ies) did you like most?

Modality	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**
Touch (Computer)	✓	✓	✓	✓	✓	✓	✓	✓		✓
Speech (Computer)						✓		✓	✓	✓
Multi-Touch (Computer)			✓	✓		✓	✓			✓
Speech (Smartphone)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Touch (Smartphone)	✓			✓	✓			✓		
3D Gesture (Smartphone)				✓						

III.4. Which modality (ies) did you like less?

Modality	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**
Touch (Computer)									✗	
Speech (Computer)	✗	✗	✗	✗	✗		✗			
Multi-Touch (Computer)										
Speech (Smartphone)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Touch (Smartphone)										
3D Gesture (Smartphone)						✗		✗		✗

III.5. Do you think this prototype could improve your quality of life?

P1	I think, in the future, and with the needed changes, this system could be very useful.
P2	Maybe, if the speech recognition gets improved.
P3	Yes. The fact that I can access Social Media so easily is very attractive.
P4	It would improve it in a great way. It's a very praiseworthy work.
P5	I do. I even think this kind of applications can easily replace the current ones.
P6	Yes, it even made me change my mind about new technologies.
P7	Not mine, because I'm very used to other interfaces and I take less time making something in comparison with the usage of PLA. However I think it can be very useful to people with special needs, like elderly and mobility impaired.
P8	It could improve the quality of life of people with more serious needs than mine.
P9	Yes, I do.
P10	Yes, it would improve it a lot.

III.6. Do you think this prototype interface is easy to use?

P1	Yes
P2	Yes
P3	Yes
P4	Yes
P5	Yes
P6	Yes
P7	Yes
P8	Yes
P9	Yes
P10	Yes

a. Why?

P1	It's always very easy to perform an action. Everything is very clear.
P2	It's not confusing at all, and everything is very readable.
P3	Being able to touch the screen is nicer and more intuitive than using a mouse.
P4	NA
P5	It's fun to use. It's a useful set of tools that entertains as it was a game.
P6	It's so easy to use that I lost the fear of damaging the computer by doing something wrong.
P7	It's very intuitive. After a little while practicing and getting used to it, I believe anyone can use it.
P8	NA
P9	NA
P10	I think it is so easy to use that this must be the future of computer applications.

III.7. Which version did you like most?

Version	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Desktop		✓	✓	✓	✓	✓	✓	✓	✓	✓
Mobile	✓									

a. Why?

P1	Being mobile is very important to me. I can easily carry it everywhere I go.
P2	Is more entertaining.
P3	NA
P4	I liked both, because they are both useful in different situations. However I liked the computer version most because it is easier to use, due to the big screen.
P5	I liked both of them. But the computer version is more enjoyable.
P6	The big screen makes it easy to do every task.
P7	Because of its size.
P8	Because of its size.
P9	NA
P10	Everything is clearer, and I do not think I would need a mobile version.

III.8. What do you think is essential for us to add or change so the prototype is according to your needs?

P1	I think you should improve the speech recognition, for it was the modality that failed more times.
P2	Improve speech recognition.
P3	Expand Social Media Services features.
P4	Improve speech recognition.
P5	Improve speech recognition.
P6	Improve speech recognition.
P7	Spontaneous help, whenever a user gets stuck with an action for a longer time than supposed. (A big popup with information would suffice, I believe).
P8	More explicit help.
P9	Improve speech recognition.
P10	Add Windows Live Messenger (IM) access

A.2.4.5. Observations and Opinions about Previous version of LHC Tasks

TABLE A.11 – LHC EMAIL TASK OBSERVATIONS

Participant	Observations	Participant's opinions/suggestions
P1	Needed help to attach an image.	Although I'm used to the other interfaces, I think I prefer this one, it just presents what is needed and it's easy to find everything.
P2	Application could not recognize participants' voice.	I'd like voice recognition to work with me; I would enjoy commanding the application with my voice.
P3	App had trouble understanding participants' voice. Had to retry a few times.	I like it a lot, even having enjoyed the interfaces on the other computer, I recognize this one is much simpler to use.
P4	Participant thought that this interface is very amusing and said that her mind became fully interested in the task, different from other conventional interfaces.	I like this a lot, because it's very easy to use and the size of the buttons are just perfect. I like touching the screen, it's so much easier.
P5	Worked well with the participants' voice.	I like it a lot; it's easy to use and has nice aesthetics as well as a nice size. I enjoyed speech and touch interaction. Every keyword is present and helps a lot to interact.
P6	The participant tried to use speech, but it became difficult in some cases, especially with dictation.	I think it's easier to access these services through this GUI. We do not need to know much about computers, or even make a big effort to perform any action.
P7	Application responded very well to the participants' voice.	I was very amused by the application. Speech interaction is very rewarding, and touching is very simple.
P8	Application responded well to the participants' voice.	I enjoyed using the application a lot. Touch is very useful instead of using the mouse and speech recognition is the way to go.
P9		
P10		

Appendix B. Usability Evaluation Study Additional Data

B.1. Usability Evaluation Study Consent Form

Usability study of the prototype Living Home Center targeted at the elderly population

First of all thank you for participating in this study. Your collaboration is essential to the success of our project.

The study is part of the Master thesis of the researcher Vítor Teixeira. The aim is to study new ways for a senior citizen to interact with services available on the internet, using multimodal interfaces (which include various modalities such as speech, touch, among others). This will focus, primarily, the access to various electronic services using the developed prototype. Examples are social media like Facebook and Twitter, and other communication services, such as audio/video conferencing.

During the session we will ask you to perform some simple tasks, and also try some devices. At the end of the session we will collect your opinions.

The sessions will be recorded for later analysis. All video and audio collected data is confidential and accessible only to people involved in this study (above).

However, for merely illustrative purposes, do you authorize that some images/videos collected, are published in this thesis, in conferences or journals? [ ] Yes [ ] No

We request that you fill in the following data (the data provided is strictly confidential and is intended only to statistical analysis):

- Name: ____
- Age: ____
- Former Career: ____
- Known health problems: _________ ___________________________________

[ ] Check the box if you want to receive updates on this study in the future? (If yes, please provide us your email: ____)

I have read and understood the objectives of this session, participating willingly in it.

Signature: ____

The researcher:
Vítor Teixeira: ____

B.2. Usability Evaluation Study Interviews Transcription and Sessions Additional Data

B.2.1. Usability Evaluation Study Participants Generic ICT Usage and Skills Questionnaire Results

I.1. On average, how would you describe your computer usage habits:

a. Never used
b. Sporadic usage (less than once a week)
c. Weekly usage (at least once a week)
d. Daily usage (less than five hours a day)
e. Intense usage (more than five hours a day)

P1	a
P2	a
P3	d
P4	a
P5	d
P6	b
P7	b
P8	c
P9	a
P10	d

I.2. How would you rank your computer skills:

a. Very Low
b. Low
c. Average
d. High
e. Very High

P1	a
P2	a
P3	c
P4	a
P5	c
P6	a
P7	b
P8	c
P9	a
P10	d

I.3. Do you use a mobile phone?

P1	Yes
P2	Yes
P3	Yes
P4	Yes
P5	Yes
P6	Yes
P7	Yes
P8	Yes
P9	Yes
P10	Yes

I.4. Do you use a Smartphone?

P1	No
P2	No
P3	No
P4	No
P5	No
P6	No
P7	No
P8	No
P9	No
P10	No

I.5. How would you rank you mobile phone /Smartphone skills:

a. Very Low
b. Low
c. Average
d. High
e. Very High

P1	a
P2	a
P3	b
P4	b
P5	c
P6	c
P7	b
P8	c
P9	c
P10	d

I.6. On average, how would you describe your mobile phone /Smartphone usage habits:

a. Never used
b. Sporadic usage (less than once a week)
c. Weekly usage (at least once a week)
d. Daily usage (less than five hours a day)
e. Intense usage (more than five hours a day)

P1	d
P2	d
P3	d
P4	d
P5	d
P6	c
P7	c
P8	d
P9	c
P10	d

B.2.2. Usability Evaluation Study - Additional Data

B.2.2.1 Tasks Results

B.2.2.1.1. Mobile

TABLE B.1 - CONFERENCE TASK (MOBILE) RESULTS

Participant	Time to complete (mm:ss)	Number of helps	Result	Modality count		
				Speech	Touch	3D Gesture
Control	01:10	0	Completed	0	9	0
P1	04:58	1	Completed	0	8	0
P2	03:10	1	Completed	1	11	0
P3	02:55	0	Completed	0	7	0
P4	02:35	1	Completed	0	10	0
P5	02:47	0	Completed	1	9	0
P6	03:17	1	Completed	1	8	0
P7	02:26	1	Completed	0	9	0
P8	02:52	0	Completed	0	10	0
P9	01:20	0	Completed	0	9	0
P10	01:34	0	Completed	1	8	0

TABLE B.2 - SMS PROFILE TASK (MOBILE) RESULTS

Participant	Time to complete (mm:ss)	Number of helps	Result	Modality count		
				Speech	Touch	3D Gesture
Control	01:08	0	Completed	0	9	0
P1	03:56	1	Completed	0	9	1
P2	02:43	1	Completed w/ Errors	1	6	0
P3	03:34	0	Completed	0	7	1
P4	03:36	0	Completed	1	9	1
P5	02:21	0	Completed	3	8	2
P6	03:02	1	Completed	3	7	0
P7	02:42	1	Completed	4	11	0
P8	03:02	1	Completed	1	8	1
P9	03:31	0	Completed	2	7	2
P10	02:15	0	Completed	5	10	0

TABLE B.3 - SMS MESSAGES TASK (MOBILE) RESULTS

Participant	Time to complete (mm:ss)	Number of helps	Result	Modality count		
				Speech	Touch	3D Gesture
Control	01:11	0	Completed	0	8	0
P1	03:38	1	Completed	0	9	0
P2	02:39	1	Completed	2	7	1
P3	02:43	1	Completed	0	9	0
P4	01:13	1	Completed	0	9	0
P5	02:37	1	Completed	4	6	0
P6	03:39	1	Completed	0	10	1
P7	02:17	1	Completed	0	8	1
P8	02:04	0	Completed	4	5	0
P9	01:42	0	Completed	0	9	0
P10	01:37	0	Completed	2	6	1

B.2.2.1.2. Desktop

TABLE B.4 - CONFERENCE TASK (DESKTOP) RESULTS

Participant	Time to complete (mm:ss)	Number of helps	Result	Modality count		
				Speech	Touch	Hardware
Control	00:36	0	Completed	0	5	0
P1	01:15	1	Completed	0	5	0
P2	01:36	1	Completed	1	8	0
P3	01:08	0	Completed	1	4	0

P4	02:05	1	Completed	1	4	0
P5	01:34	1	Completed	1	9	0
P6	02:24	1	Completed	0	6	0
P7	02:05	0	Completed	0	5	0
P8	01:46	0	Completed	0	5	0
P9	01:09	0	Completed	1	4	0
P10	00:54	0	Completed	0	5	0

TABLE B.5 - SMS MESSAGES TASK (DESKTOP) RESULTS

Participant	Time to complete (mm:ss)	Number of helps	Result	Modality count		
				Speech	Touch	Hardware
Control	03:59	0	Completed	4	13	0
P1	09:16	2	Completed	5	9	2
P2	08:01	1	Completed	5	11	1
P3	07:40	1	Completed	4	12	2
P4	08:45	2	Completed	3	14	1
P5	09:12	1	Completed	4	10	2
P6	09:51	2	Completed	6	12	0
P7	09:04	0	Completed	0	21	0
P8	07:57	1	Completed	4	12	2
P9	07:44	1	Completed	3	18	1
P10	06:42	0	Completed	5	12	0

TABLE B.6 - SMS PHOTOS TASK (DESKTOP) RESULTS

Participant	Time to complete (mm:ss)	Number of helps	Result	Modality count		
				Speech	Touch	Hardware
Control	03:34	0	Completed	1	19	0
P1	07:07	2	Completed	1	17	2
P2	07:17	2	Completed	5	9	2
P3	07:06	0	Completed	4	14	0
P4	04:36	1	Completed	7	12	0
P5	04:16	0	Completed	7	13	0
P6	07:50	2	Completed	8	13	0
P7	04:28	1	Completed	8	12	0
P8	06:16	0	Completed	3	15	2
P9	06:52	2	Completed	3	16	0
P10	03:57	0	Completed	4	14	1

B.2.2.2 Observations and Opinions about Usability Study Tasks

TABLE B.7 – CONFERENCE TASK (MOBILE) OBSERVATIONS

Participant	Observations	Participant's opinions/suggestions
P1	Participant had a hard time trying to insert text with the smartphone virtual keyboard.	Change the keyboard layout or use a stylus to enable the user to write easily.
P2	Oldest participant. Vision and mobility issues.	Text should be a little bigger. Virtual keyboard should also have bigger keys.
P3	Participant had a little trouble using the virtual keyboard.	Use of a stylus to write on the keyboard
P4	Participant showed interest in completing the task accurately.	It is easy to use, because the presentation of components is sequential and according to the order of actions we must do.
P5	Participant enjoyed this version, but preferred the desktop for its size.	Increase the font a little
P6	Participant was a little nervous.	Increase the keyboard size.
P7	Trouble trying to write the message on the virtual keyboard.	Increase keyboard or use a stylus
P8	Participant said the application was appealing and well presented	Make the keyboard a little bigger.
P9	Did well on this task as well, even though having some trouble with the keyboard.	Increase the keyboard size.
P10	Participant mentioned some difficulties of her patients and agreed that this could help some of them using such devices with less effort.	Increase font size and change the keyboard to a different size or layout.

TABLE B.8 – SMS PROFILE TASK (MOBILE) OBSERVATIONS

Participant	Observations	Participant's opinions/suggestions
P1	See previous task	See previous task
P2	Had trouble using the virtual keyboard	3D gesture is useful for me, since I cannot use my right hand.
P3	See previous task	See previous task
P4	Had trouble using the virtual keyboard	Increase the font size a little.
P5	See previous task	Increase the font size.
P6	See above	Increase the font size and reduce the number of available fields.
P7	Participant seemed to enjoy the interaction with the application.	Increase keyboard size or use stylus.
P8	Participant did not enjoy the push-to-talk mechanism	I think it is very simple to edit all the fields and navigate on the list, using the elements available on-screen. Like the large down and up buttons
P9	Very low skilled participant; achieved good results.	Keyboard should be a little bigger, because the finger usually hits two keys or more accidentally.
P10	See previous task	See previous task

TABLE B.9 – SMS MESSAGES TASK (MOBILE) OBSERVATIONS

Participant	Observations	Participant's opinions/suggestions
P1	See previous tasks	Increase the font size and change its color inside the message boxes
P2	See previous tasks	Have numbers for each message.
P3	Participant had little doubts and was very effective	I have no suggestions for this feature. I enjoyed it a lot.
P4	Participant had to put the device closer to her to be able to read.	Increase the font size a little.
P5	See previous task	See previous task
P6	Participant did not like the push-to-talk mechanism.	Change font size and color.
P7	See previous task.	Increase the font size for messages a little.

P8	Participant seemed enjoying touch interaction.	This is easier to use than my mobile phone. Navigation is very intuitive.
P9	Same observations as the previous task	
P10	See previous task	Increase the size of the message text, even if by doing that only one message is visible at a time.

TABLE B.10 – CONFERENCE TASK (DESKTOP) OBSERVATIONS

Participant	Observations	Participant's opinions/suggestions
P1	Needed help to select a contact	I believe it is very easy to use this conference feature, after this I could do it by myself without any doubts.
P2	Needed help to select a contact	The size and organization of elements is very good for me.
P3	It was very easy for participant to perform this task	This feature is great, the presentation of components is very adequate. I prefer this to Skype.
P4	Participant preferred this to the smartphone version	This is very interesting, I like to be able to use speech without the push-to-talk mechanism.
P5	Participant seemed fascinated by the application.	I enjoyed this a lot. Especially using touch. I do not think I'd change anything in here.
P6	Participant seemed to enjoy this task more than the others.	It is all very simple and well presented.
P7	Very little doubts or hesitations.	I believe everything is well presented. I'd like to use this to get in touch with my family.
P8	Participant had previously used WLM.	I like this feature a lot, it would be very useful for me.
P9	Participant never used a computer before, but did quite well.	I like this so much that I think I wouldn't even need ICT classes to use this by myself.
P10	Participant mentioned that the fact that screen tilted was very important to avoid the "Gorilla Arm" syndrome.	The size and presentation of the elements are right. I also agree that access to this services and content may be of value for elderly.

TABLE B.11 – SMS MESSAGES TASK (DESKTOP) OBSERVATIONS

Participant	Observations	Participant's opinions/suggestions
P1	Needed help choosing the right contact	Good tool to communicate, it is easy to understand what each item does.
P2	Participant looked amused while performing the task.	I have no suggestions, you did a great work.
P3	Participant was also very effective while performing this task.	I believe this is a nice feature, being able to share is important. But more important is to be able to do it with confidence.
P4	Participant had very little experience.	I felt no difficulties, but I get a little nervous and get on my own way sometimes.
P5	Se previous task	I like the large textboxes and buttons sizes.
P6	Inexperienced and unconfident participant.	I enjoyed touching the computer, it´s easier than using the mouse or even speaking.
P7	Doubt when trying to insert the 'at' character.	I do not really like social media sites, but this is much more interesting and easier to use.
P8	Participant seemed to enjoy writing with the on-screen keyboard.	It is much easier and more rewarding to write in here, than in other interfaces I've used.
P9	Participant preferred using touch.	I have nothing to suggest here.
P10	See previous task	See previous task

TABLE B.12 – SMS PHOTOS TASK (DESKTOP) OBSERVATIONS

Participant	Observations	Participant's opinions/suggestions
P1	Needed help selecting photo album to open.	I enjoy using touch because it is much more intuitive.
P2	Needed help to open the right photo.	I really would like to have this in our institution; I believe it is very entertaining.
P3	No help required.	The interface is perfect, simple and intuitive.
P4	Participant seemed very focused and amused.	The interface is very appealing and simple to use.
P5	See previous task.	This feature is very appealing. I could be here for hours exploring it.
P6	Did not feel relaxed, needed a little more time to perform the	I cannot think of any suggestion. It is very good as it is.

	task.	
P7	Participant seemed to prefer interacting with touch.	I like this, it is very well designed.
P8	Participant seemed more interested in the desktop version of the prototype.	I think this is so easy that I'd like to have one already if it was available.
P9	Participant enjoyed interacting with multi-touch.	I always thought that computers were extremely complicated to use, but now you've proven me wrong. At least with this prototype I do not feel like it is too difficult for me.
P10	See previous task	See previous task

B.3. Questionnaire Results

II.1. Evaluate the modalities, in terms of easiness/difficulty of interaction, according to the following scale:

1. Impossible
2. Very difficult
3. Difficult
4. Reasonable
5. Easy
6. Very easy

Modality	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Touch (Computer)	4	5	5	6	5	5	5	5	6	6
Speech (Computer)	3	4	5	6	3	5	5	4	6	5
Multi-Touch (Computer)	5	3	3	5	4	4	6	5	5	5
Speech (Smartphone)	3	5	5	4	3	3	5	4	5	4
Touch (Smartphone)	4	4	3	5	6	4	5	5	6	2
3D Gesture (Smartphone)	4	5	5	6	3	5	4	5	5	2

II.2. Evaluate the modalities, in terms of satisfaction, according to the following scale:

1. Did not like it
2. Liked it a little
3. Liked it
4. Liked a lot
5. Loved it

Modality	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Touch (Computer)	3	4	4	5	5	4	3	4	4	5
Speech (Computer)	3	3	4	5	4	3	3	5	4	3
Multi-Touch (Computer)	4	3	3	4	4	2	4	5	4	5
Speech (Smartphone)	3	4	4	4	3	1	3	2	4	2
Touch (Smartphone)	2	3	2	3	4	1	3	4	3	2
3D Gesture (Smartphone)	3	3	3	4	3	3	2	4	2	2

II.3. Which modality (ies) did you like most?

Modality	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Touch (Computer)	✓	✓		✓	✓	✓	✓		✓	✓
Speech (Computer)			✓	✓				✓	✓	
Multi-Touch (Computer)										✓
Speech (Smartphone)										
Touch (Smartphone)										
3D Gesture (Smartphone)										

II.4. Which modality (ies) did you like less?

Modality	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Touch (Computer)										
Speech (Computer)										
Multi-Touch (Computer)										
Speech (Smartphone)						✘				
Touch (Smartphone)	✘	✘	✘	✘						✘
3D Gesture (Smartphone)					✘		✘	✘	✘	

II.5. Do you think this prototype could improve your quality of life?

P1	I believe so. It's a good entertainment center, and a nice tool to communicate with the world.
P2	I believe it would make it easier to communicate and share with my family.
P3	Yes, at least the computer version would be very welcome. It is a joy to use it.
P4	Yes, it's much faster than using the mobile phone and much more entertaining.
P5	I like the fact that I can touch, it feels very natural. I also love its design and organization.
P6	I do not think I'd find usage to all its features, but the conference feature would be very welcome.
P7	Yes. If I had the choice between this and the conventional I'd choose this without a doubt.
P8	It's quite easier to use than the conventional interfaces, so yes, I believe it would be a very welcomed addition.
P9	It would be very nice to have this application. Communicating with my grandchild would be so much easier.
P10	I believe so. Not for the accessibility features, because I'm quite healthy and capable, but for the entertainment it provides.

II.6. Do you think this prototype interface is easy to use?

P1	Yes
P2	Yes
P3	Yes
P4	Yes
P5	Yes
P6	Yes
P7	Yes
P8	Yes
P9	Yes
P10	Yes

a. Why?

P1	Even though I have no experience with computers I managed to perform the required tasks, and in the end of it I even got a sense of satisfaction.
P2	After a while one gets used to the way it works and it becomes easy.
P3	One can find out how to perform the desired action just by taking a quick look at the screen.
P4	The fact that there aren't too many options on screen and the visual component, make it very attractive.
P5	Except for the writing and size of elements on the mobile version, everything is easy to use after just a while getting used to it.
P6	I believe it is easy enough to use, just takes a bit of time to get used to it, but a lot less than the conventional ones.
P7	After using it for a while you start performing tasks without having to think much about it
P8	You learn just by experimenting a little.
P9	Even I that have never used a computer before was able to perform the required tasks, and I did not feel like it was too difficult too.
P10	After a bit getting used to the way it works, it's easily usable.

II.7. Which version did you like most?

Version	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**
Desktop	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Mobile										

a. Why?

P1	Because of the size and the fact that everything is visible all the time, there's almost anything hidden or collapsed, like in the mobile version
P2	Because it is bigger and easier to use, it does not require as much attention
P3	It seems easier to use than the mobile version. The mobile version requires greater effort
P4	It's easier to see where everything is, and it has a nicer graphic interface.

P5	Mostly because of its design, it's very appealing.
P6	Because of being in a bigger screen it is more eye-catching and everything is easier readable.
P7	It's more appealing.
P8	The fact that it is bigger is more appealing.
P9	The computer seems to have a more complete interface, more satisfying.
P10	I believe it's more useful than the small smartphone as well as easier to use, and more entertaining too.

II.8. What do you think is essential for us to add or change so the prototype is according to your needs?

P1	I do not have the experience required to give you this answer. I believe it's very good as it is now.
P2	The desktop version is good as it is. You should try to make the font bigger on the mobile version and change the keyboard.
P3	I cannot recall anything besides an improvement on the mobile keyboard and font size.
P4	I believe that the computer's voice is too fast, and help could be enhanced with visual hints.
P5	I believe some of the icons you use for the buttons could be better and also add some for big buttons that have only text on them, I also believe you could make the voice of the assistant warmer if you used a more informal language
P6	Maybe you could make some changes to the help function so I would feel that I was not doing anything wrong and improve the recognition of speech, since I do not like the keyboard.
P7	I believe the keyboard of the mobile is its biggest issue. Everything else is fine.
P8	I believe it's almost complete as it is now, but I’d like to test it with a better speech recognizer.
P9	I cannot think of anything.
P10	I believe it's a good advance of what I've seen so far, but maybe you could add some typical games for entertaining reasons (Like card games, chess…)