FP6–004171 HEARCOM

Hearing in the Communication Society

INTEGRATED PROJECT

Information Society Technologies

D-9-1: User Requirements Specification for Assistive Applications on a Common Platform

Contractual Date of Delivery:	31 August 2004 +45 days
Actual Date of Delivery:	11 October 2005
Editor:	UK-RNID / J. Kewley
Sub-Project/Work-Package:	SP4/WP9
Version:	2.0
Total number of pages:	95

Dissemination Level		
PU	Public	PU
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	
Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		

Deliverable D-9-1

VERSION DETAILS	
Version:	2.0
Date:	11th October 2005
Status:	Ready for Submission

CONTRIBUTOR(S) to DELIVERABLE

Partner	Name
UK-RNID	Jo Kewley, Neil Thomas, Mary Henley
NL-VUMC	Adriana Zekveld, Marcel Vlaming
GR-ILSP	Theo Athanaselis
DE-UOL	Giso Grimm, Volker Hohmann
DE-FIT	
DE-OFFIS	Carsten Beth
ES-MOV	
FT-TCF	

DOCUMENT HISTORY

Version	Date	Responsible	Description
v10	31/08/05	RNID	Work still in progress
v11	14/09/05	RNID	Draft for final comments
v12	15/09/05	RNID	Final draft for review
V14	10/10/05	RNID	Final draft for submission

DELIVERABLE REVIEW

Version	Date	Reviewed by	Conclusion*
1.0	15-9-2005	Bastiaan Kleijn	Modify / accepted
1.0	15-9-2005	Mark Lutman	Modify / accepted

* e.g. Accept, Develop, Modify, Rework, Update

Table of Contents

List of Figures

List of Tables

Abbreviations

ASR	Automatic Speech Recogniser
BT	Bluetooth
CPU	Central Processing Unit
CIC	Complete In Canal (Hearing aid)
DECT	Digital European Cordless Telephone
DSP	Digital Signal Processing
FPU	Floating Point Unit
GPRS	General Packet Radio Service
GSM	Global System for Mobile communication
HMM	Hidden Markov Models
IP	Internet Protocol
ITE	In The Ear (Hearing aid)
LAN	Local Area Network
MFLOPS	Million Floating Operations Per Second
MHA	Master Hearing Aid
MIPS	Million Instructions Per Second
MMS	Multimedia Messaging Service
OS	Operating System
PA	Public Address
PC	Personal Computer
PCS	Personal Communication System
PDA	Personal Digital Assistant
PIM	Personal Information Manager
PHS	Personal Hearing System
RAM	Random Access Memory
SIMD	Single Instruction Multiple Data
SMS	Short Message Service
SW	Software
TTY	Tele Typewriter
USB	Universal Serial Bus
WLAN	Wireless Local Area Network
WP	Workpackage

References

Duchnowski, P., Lum, D.S., Krause, J.C., Sexton, M.G., Bratakos, M.S. & Braida, L.D. (2000) Development of speechreading supplements based on automatic speech recognition. *IEEE Transactions on Biomedical Engineering, 47, 4,* 487-496.

Leitch, D & MacMillan, T. (2003). Liberated Learning Initiative. Innovative technology and inclusion: current issues and future directions for Liberated Learning Research. *Year IV Research Report on the Liberated Learning Initiative*.

Mangold, H. (1988). Principles of automatic processing of speech signals and their application in medical technology and for aids for the handicapped. *Medical Progress through Technology, 14*, 39-56.

Siciliano, C., Faulkner, A. & Williams, G. (2003). Lipreadability of a Synthetic Talking Face in Normal Hearing and Hearing-Impaired Listeners*. Proceedings of the International conference AVSP 2003,* 205-208

Young, S.J. (1996). Large Vocabulary Continuous Speech Recognition. IEEE Signal Processing Magazine 13, (5), 45-57.

1 Executive Summary

This document specifies the requirements for the Personal Communication System (PCS) under development as part of workpackage 9 of the HearCom project. It is proposed that the PCS will serve as a platform that will host three assistive applications;

- A Personal Hearing System (PHS) that uses the increased processing power of the PCS to enhancing hearing in difficult situations. The PHS could also provide a wireless link to Internet and public address systems and connect and process audio input from other devices (mobile phone, TV etc.).
- An Automatic Speech Recognition (ASR) system that allows a visual display of an auditory source on a rolling text display allowing users to read what is being said or see keywords.
- A text display system could also connect to other technologies as well as the ASR to display other text-based information.

The technical aspects of each of these applications are discussed with respect to intended audience, scenarios, state of the art and options.

Users requirements for each of these technologies were gathered using a questionnaire that was administered to deaf, hard of hearing people and professionals in the UK, Netherlands and Greece.

The document concludes by incorporating the user requirements with the discussions about technical aspects, and proposes the steps that need to be taken to develop of these technologies. The technical requirements themselves will be specified in future reports.

2 Introduction

The HearCom project aims at reducing the barriers for full participation in the modern communication society. At present much mainstream technology has been developed without considering the needs of those who have difficulty with communication or receiving information. These difficulties are not only experienced by those with a hearing loss, but also second language users, causing them to be further isolated from society.

Assistive technologies have the ability to relieve many of these problems. This document starts by discussing the assistive applications that are available to deaf and hard of hearing people and how such applications are developed and made available.

Within the HearCom project, these problems will be addressed through the definition and prototyping of two complementary technologies;

- A common platform that can support several assistive applications, including ASR and text display systems. These will support comprehension through providing a rolling text display, speech to text conversion and advanced audio processing.
- A wireless link that can be used to connect hearing devices to other mainstream applications (in particular, 2G, 2,5G and 3G mobile systems, WiFi, and Bluetooth technologies). The requirements for these developments are covered by D-8-1.

The requirements for the first of these solutions are discussed in this report. These requirements will be taken from technical definitions of current solutions as well as feedback from user research carried out to investigate attitudes and experiences to the technology under development.

Through the development proposed in this workpackage it is hoped that an application can be defined that is available to a large group of people and yet can meet the requirements of individual listeners. The application is to remove the barriers that currently prevent participation in the communication society.

3 Assistive applications

3.1 General definition of assistive technology

The potential for technology to improve the lives of disabled people is massive. The development of better assistive technologies has long been regarded as a key mechanism towards full participation in society for all, regardless of abilities or preferences.

Assistive Technology is a generic term that includes assistive, adaptive, and rehabilitative devices. More specifically, it is used to describe any item, piece of equipment or system that is used to increase, maintain, or improve how a person performs a task.

The Hearcom project aims at full participation in the modern communication society by reducing the limitations in auditory communication. As such, the Hearcom project is particularly interested in assistive technologies that will help any individual communicate, or receive information. This is of particular interest to hard of hearing and deaf people, and is also of use to second language users, and anyone else who may have difficulty in communication, for example receiving auditory information in a noisy environment. See section below for some examples of assistive technology used by deaf and hard of hearing people.

3.1.1 Examples of current assistive technology

There are many types of assistive devices currently in use, or in development, for deaf and hard of hearing people. Figure 3.1 shows a hearing aid (with ear mould), a textphone, and a smoke alarm that uses visual and tactile alerts.

Figure 3.1: example assistive devices for deaf and hard of hearing people

(Photographs from RNID).

The Hearing Aid has been around in one form or another for many years. While a modern digital hearing aid may be a fairly recent development, descriptions of wooden hearing aids can be found as early as 1588, and many different designs of ear trumpets have been created over the ages. Modern hearing aids are based around highly specialised Digital Signal

Processing (DSP) technology, providing a system that can be tailored to give an individual the best performance possible according to their particular hearing loss (and with that product).

Most hearing aids are fitted with a 'T' setting, allowing the hearing aid to pick up sounds from an inductive field. This system is commonly used in at service counters (such as banks etc.), and in meeting rooms. This is an old, and often limiting technology (see Hearcom workpackage 8 deliverables for more information on this system and for plans within Hearcom to develop alternatives to it).

Another key area for assistive devices for hard of hearing and deaf people are alerting devices. There are wide ranges of devices that can alert people to the presence of a person at their front door, their alarm clock, the telephone (or textphone) or smoke detectors. These devices normally use a combination of audio, visual or tactile alerts.

People with severe or profound hearing loss may not be able to communicate using a voice telephone, even with additional amplification. A technology that has long been used as an alternative is the Textphone. These devices use basic modem technology to enable users to have real time, interactive conversations via text. Textphone users can also call hearing people using relay services, such as the RNID Typetalk[1] service in the UK.

In public locations textual information displays, such as dot matrix display systems used in many transport systems, can be of great use to deaf and hard-of-hearing people. However, these systems are not often updated with the latest information, which is instead normally only relayed to people in spoken messages.

As more professional companies and modern production and development techniques become more common, specialist assistive technologies are losing the reputation of being poorly designed, expensive products. Recent developments have seen the use of video communication to give access to sign language interpreters at short notice and new methods of interactive text communication is now available through mobile and IP based communication networks.

3.1.2 Development options for assistive devices

When looking at developing assistive technology, a number of different approaches can be considered. Inclusive design is one phrase that is often mentioned.

---

[1] www.rnid-typetalk.org.uk

> "Inclusive design is comprehensive, integrated design which encompasses all aspects of a product used by consumers of diverse age and capability in a wide range of contexts, throughout the product's lifecycle from conception to final disposal."
>
> British Standard 7000-6 "Managing Inclusive Design"

When developing a product for disabled people, three basic approaches can be taken. One option is inclusive design, whereby a mainstream product is designed so that it meets the needs of everyone, including disabled people (thus removing the need for additional assistive technology in this situation). Another option is to develop accessories to mainstream products so that they become useable by disabled people (examples of this include telephone amplification devices and neck loops for mobile phones). The third option is to make a new product, designed specifically as an assistive device.

There are many advantages and disadvantages to each method, and each can be valid in different situations. However, inclusive design, and the use of mainstream technology in general, is generally favoured over specialist devices wherever possible. This is because specialist products often end up becoming niche products with small markets. This can result in high prices, as development costs must be shared over a small volume of products and long product lifespan, leaving no revenue is for the re-design of products and for keeping them up to date. For this reason, much of the technology used in assistive devices, such as textphone technology often lags far behind the cutting edge of mainstream technology.

It is accepted that in most situations it is not possible to make a design that is 100% inclusive, so the market for accessories and/or specifically designed accessible technologies will always exist. A large number of companies around Europe now specialise in the design of assistive devices, and for markets such as hearing aids, these can be considerable in both size and turnover.

3.1.3 Access to Assistive Technology

In most modern societies access to at least some assistive technology is provided either free, or at a reduced rate, by central or regional government, or the national system of health insurance. The administrative procedures vary greatly from country to country, and often differ for different technologies (for example hearing aids and other assistive devices are often dealt with separately).

3.2 Specific definitions of applications in WP9

Despite the numerous assistive devices for the hearing impaired that are available (see section 3.1 above), the benefits of many of these assistive devices available are restricted. For example, they might only be used by a limited group of individuals that experience hearing problems, or they might only be used in a limited number of places, often causing many of these systems to be expensive. Other devices require specific input or output channels. All these factors limit the number of individuals that can benefit from these systems. This highlights the lack of an assistive device with a wide range of functionalities that is beneficial to a wide user group – with various needs and requirements.

WP9 aims to develop an assistive device that can be used by a large group of individuals that experience listening problems in various circumstances. The assistive device will be portable. Several functionalities will be incorporated in a mainstream mobile platform such as a personal digital assistant or mobile phone. The use of such a mainstream platform as a basis for the assistive technologies has several benefits: (a) mainstream platforms are made for the general public, which makes them relatively cheap, (b) mainstream technologies are rapidly developing; the use of them will enable relatively easy and cheap future upgrades. (c) Mainstream platforms already include standard functionalities such as telephone communication, address books, agenda, SMS, etc., and (d) a mobile platform makes the use of the device in various listening environments practical.

All these characteristics contribute to the development of an assistive device that is available to a large user group, but that nevertheless can meet the specific requirements that individual listeners have.

In WP9, four technologies will be developed and implemented in the platform. These functionalities will cooperate and together they will assist in various communication tasks. The first technology is the platform itself and the other three are applications that run on the platform. The technologies are:

- *The Personal Communication System* (PCS) is the platform that serves as the basis for the other three assistive applications. The platform will offer communication links with other technologies (e.g. telephones and wireless networks), it will have processing capabilities that can be used by the incorporated assistive techniques. It will have a display that can be used to provide rolling text.

- *A personal hearing system* (PHS) that enhances the hearing of the user in several listening environments. This software platform will be able to connect to and process auditory signals of various input sources. It is important to note that the relative large processing power of the PCS will enable a PHS that will be beneficial for individuals with large ranges of hearing loss. The sound processing characteristics will be easily adaptable to the specific needs of the listener. The PHS will connect to regular hearing aids or a mainstream headset (depending on the severity of the hearing loss of user) via wireless or cable-bound links. In contrast to the specific assistive devices that are already available, the PCS and PHS will offer additional functionalities, which are enabled by the connections with the various input sources. Speech and sounds from input sources like (mobile) phones, television and radio will all be amplified by one and the same assistive device. In addition, the device will be able to connect to wireless networks such as WIFI and WLAN, enabling access to the Internet and connection to public address systems.

- *An Automatic Speech Recogniser* (ASR) that works together with a rolling text display. Both functions will be explained in more detail below, but in general, the combination of the two functions will enable the visual presentation of information derived from an auditory source. For example, users will be able to read what other people are saying while communicating with others. Although the performance of present ASR systems is not perfect, visual displayed information derived from speech or other auditory sources will likely support the hearing of the user and will make listening less effortful. For example, the listener can use visually presented keywords during a telephone conversation to check whether he has understood the speaker correctly. This will make the conversation less problematic.

- *Visual assistive information* for the PCS. As described above, the PCS will be able to connect to multiple input sources. These sources will supply additional information that can support the user at various locations. For instance, a connection to the Internet and public announcement systems enables the visual presentation of information derived from these sources (e.g., announcements at a transport terminal). This will make the user less dependent on (poor quality) auditory information. Like the other technologies that will be incorporated in the device, the characteristics of the visual display (e.g. letter size) will be adaptable to the personal needs of the individual.

In Chapter 4, the specific applications and scenarios of the PCS, the PHS, the ASR system and the rolling text display will be described in more detail.

4 Scenario's and applications

4.1 Personal Communication system (PCS)

4.1.1 PCS General Description

The HearCom Personal Communication System (PCS) will be a platform that will assist individuals on communication tasks.

Initially the PCS will be targeted to individuals that have auditory communication problems. Later in the project, a more general use is foreseen in which hearing people can extend and optimise their communication performance in complex and/or adverse situations.

The PCS will include the HearCom Personal Communication Link as described in D-8-1. This link will provide the communication to information services and the connection between PCS and the ear, using hearing devices. This personal link will replace existing inductive loop (telecoil) applications; the PCS will be used in controlling the information for the personal link.

The hearing devices for communication between the ear and the PCS will be based on standard headphones or on devices as used by hearing impaired people (hearing aids and cochlear implants). The hearing devices should include the personal communication link or possibly a link that is compatible to that. For further details see D-8-1.

The PCS will be based on developments from mainstream technology such as PDA, mobile phone, notebook and wireless communication. By building on mainstream technology, the PCS will not be a specific device with limited lifetime that is specially developed for this project. Instead, the use of mainstream technology may provide a seamless migration to future technologies. This may include the following advantages:

- Integration of several assistive applications into one device allowing the interoperability between applications.
- Integration with existing mainstream applications (phone, wireless, personal data etc).
- Application (SW) portability and upgrading of applications.
- Flexible choice of platform: different types and makes.
- Reduced development and production costs.
- Increased acceptability by users and their environment.

4.1.2 General Platform requirements

The Personal Communication System will be a mobile device that easily can be used when on the move (walking, traveling). For being mobile the following requirements should apply:

- Easily portable for all day wear in pocket or small bag: small size and low weight;
- Powered for at least 12 hours of operation without battery change (mix of applications).

The PCS platform will be based on mainstream technology. It is considered that this technology should include the following functions:

- Communication functionality: mobile phone; wireless technology;
- Computing power that can be applied for speech processing, speech recognition, etc.;
- Graphical display for presentation of visual information (for rolling text display specific requirements may be required);
- Audio interfacing and processing;
- Standard operating system to allow easy addition of applications;
- Extendable to new and/or specific hardware (accessories, cards, interfaces).

The ideal platform will be a Personal Digital Assistances (PDA) or a mobile phone platform that includes PDA functionality (Smart Phone). However present PDA's and Smart Phones still have limitations with regard to processing power and real-time operating system capabilities. Therefore, other portable platforms may be used during the project having more processing power, but have larger size and weight, such as:

- Tablet or small notebooks PCs;
- Notebook PC.

Depending on the application, a different platform might be selected during the project for development and demonstration purposes. The final goal will be a single device that incorporates all applications.

4.1.3 PCS communication applications

Within the Project a number of key assistive applications will be prototyped to demonstrate the concept of a Personal Communication System. In principle the number of applications can be unlimited when linked to future mainstream developments.

The candidate applications for prototyping in the HearCom project are:

1. Public Address (PA) systems (theatres, churches, airports, stations);
2. Listening systems for TV and audio equipment;
3. Phone communication (fixed line and mobile);
4. Personal Hearing System;
5. Assistive rolling text display;
6. Speech to text conversion.

Applications 1-3 are based on existing assistive applications used by hearing impaired persons. These are based on the use of inductive loop technology. The PCS will generalize these applications by replacing this loop technology by a wireless communication link that will improve quality and versatility of usage. These applications will be described directly below in section 4.1.4 (wireless communication applications).

Applications 4-6 are new assistive applications that have not yet been possible due to limitations of technology and costs. These new applications may become feasible in the near future by the rapidly developing capabilities of mobile devices and by their widespread use. These applications will be described in sections 4.2 to 4.4.

4.1.4 PCS Assistive wireless communication applications.

The PCS will improve on existing assistive applications that are based on inductive loop communication. It is the ambition of the Hearcom project to replace inductive loop communication by a personal wireless communication link.

4.1.4.1 Public Address (PA) systems

The PCS will include communication with Public Address systems for use in theatres and churches. At present these systems are using (passive) inductive loop technology. This technology has a few disadvantages that will block further developments:

- Single broadcast channel; single stream of information without any control or selection.
- Limited usage area: only in the near vicinity of the inductive loop the information can be received. In use for theatres, church, home-listening systems and a few points of sale. Not applicable in large areas like stations, airports, exhibition halls etc.
- Low quality due to baseband technology; subject to interferences; noise, hum; limited bandwidth, level variations.
- Only used for hearing aids and cochlear implants.
- Difficult installation (constructional adaptations to install loop).

By replacing the inductive loops by wireless technology, significant improvements can be obtained and new methods of use and applications will be possible:

- Improved and stable quality of audio information.
- Multi-channel, two-way operation that will allow selection and control of information content.
- Compatibility with other wireless information systems.
- Increased coverage of area: 20 to 100+ metres using repeater networks (comparable to speaker based PA systems) directly by the link technology itself and/or by bridging to larger communication networks.
- Simple installation (connection of transponder to information source)

From the above advantages also some applications will be possible:

- Public address systems in larger areas like stations, airports, and shopping malls etc.
- Relaying of additional information (time tables, routing, on demand information etc.)
- Relaying to public communication and information services: phone, entertainment etc.

The Personal Communication System will act as an intermediate in those applications:

- Relaying of information between the wireless link of the hearing devices and the public PA link.

- Selection/Control of information.
- Display of additional information.

4.1.4.2 Phone communication

People using hearing aids or cochlear implants tend to have problems using fixed phones and mobile phones:

- Due to whistling. This is feedback between microphone and earpiece due to the enclosure by phone earpiece and the high amplification for hearing impaired persons.
- Interference noise (by digital mobile phones (e.g., GSM, DECT)). This is partially solved by modern hearing devices, but not sufficiently to handle high amplifications.
- The impossibility to use headsets. Headsets do not fit with the earpieces of hearing devices.

At present, these problems can be compensated by applying telecoil functionality as used in a large category of hearing devices (but not possible in Completely in Canal (CIC) and small In The Ear (ITE) hearing aids)). A serious problem is that modern telephone handsets do not produce sufficient magnetic field (due to loudspeaker coil as used in older handsets) anymore such that special telephone adapters should be used. When using mobile phones a special inductive loop could be connected to the phone. In general those solutions are not very popular due to extra handling.

A solution to these problems is the use of a direct wireless link integrated into the hearing device. This link will replace the telecoil. When using a bi-directional wireless link, it is also possible to apply the hearing device microphone for input to the phone. The Personal Communication System will be the interface between mobile phone, fixed line phone and the hearing devices. In case of a SmartPhone, the mobile phone function will be integrated into the PCS.

4.1.4.3 Listening systems

Listening systems for TV and audio equipment are used by hearing impaired persons who prefer undisturbed, low-noise, good quality music and speech information from TV, audio and other equipment (including microphones and auditory warning systems (e.g. doorbell)). At present an in-home inductive loop must be installed and connected to the audio equipment. Drawbacks are that the user is restricted to a limited area and that installation and wiring can be impractical.

By applying of a wireless connection, the quality can be improved and its installation can be simplified. For this the PCS will play an important role by relaying and controlling the information from different sources.

This concept has been explored within the BlueEar project[2]. For that project a portable device and an adapted Bluetooth link were developed. The adapted Bluetooth link provided the connection between audio equipment and portable device. The portable device was used for control and for relaying the information to the hearing device. In concept the link between a portable device and a hearing device is based on Bluetooth technology. However it was a concluded that BlueTooth technology was not feasible for the link with the hearing aid, mainly due to power consumption and size problems that prevent integration into hearing devices. Instead, the BlueEar project continued the use of an inductive loop between hearing device and portable device.

4.1.5 PCS user categories

The typical users of a Personal Communication System can be categorized in the following groups:

1 Persons using hearing devices (aid or cochlear implant) and wishing to have additional assistive communication support

2 Persons who have auditory communication problems, but do not use hearing devices. These persons may like to have assistive support instead of using hearing devices

3 Persons having mild auditory communication problems and not (yet) using hearing devices. These persons may like to have assistive support instead of using hearing devices

4 Persons who have no auditory communication problems, but like to optimize auditory communication by new methods

5 Any Persons who regularly encounter adverse communication conditions and who like to have additional assistive support..

4.1.6 State of the Art Platforms for PCS

This section gives an overview of devices that constitute possible platforms for a PCS. In the following subsections different classes of protable devices (PDAs, smart phones, tablet PCs and notebooks) are characterized and some examples are given for each class. The devices presented here are selected from the diversity of devices available at the market. To meet main requirements of the PCS to communicate with its

[2] http://www.BlueEar.org

environment, all chosen devices have a built-in capability of wireless communication (at least Bluetooth and/or WiFi). If a choice existed, the devices with higher computational performance and greater variety in available operating systems, communication interfaces and software were taken.

4.1.6.1 PDA

PDAs (Portable Digital Assistants) are small and lightly portable devices, which can be easily held in the hand or stowed away in a pocket. The average size is about 115 x 75 x 18 mm and the weight is about 170-200 g.

In this document a selection of six devices is described. All apart from Sharp's Zaurus SL-6000 have the ability to communicate with both wireless interfaces WiFi and Bluetooth, the Zaurus has no Bluetooth interface. Several other devices are available that are equipped with either Bluetooth or WiFi interfaces, a collection of these will be presented in Deliverable D-9-3 "Specification of PDA based Personal Hearing System".

4.1.6.1.a Applications

PDAs are mainly used for applications like address book, scheduler, task list, dictionary, picture viewer, etc., thus typical PIM (Personal Information Manager) applications. For PDAs with the ability to communicate by means of a wireless connection, e.g., Bluetooth, WLAN or GPRS, typical applications are also Web-Browsers and eMail-Clients. Apart from these, there are other software applications like audio players (e.g. MP3), voice recorders, text tools, games, etc.

4.1.6.1.b Processors

To support such applications a reduced processing power is sufficient compared to a fully featured PC. The most usual processors that are used mainly in the more powerful PDAs come from Intel's XScale PXA2xx family. In addition, some other processors are used, e.g., Texas Instrument's OMAP 1510, Samsungs 2410 and for Sony's Clié devices the "Sony Handheld Engine" (SHE). All these processors are mainly optimized to consume little power. The PXA2xx and the SHE can e.g. scale their frequency and voltage to adapt themselves to the actual requirements. In spite of their high clock frequencies of 400 MHz and more (Dell Axim x50v is equipped with an XScale PXA270 which is clocked with 624 MHz) they cannot be compared directly with common PC processors like Intel Pentium. The latter has build-in FPU (Floating Point Unit), MMX-(Multimedia Extension) and other SIMD-instructions (Single Instruction Multiple Data) to execute general floating-point (multimedia) instructions in parallel in dedicated hardware units. Up to date PC-processors are furthermore accelerated by additional techniques as e.g., out-of-order execution, pipelining, etc. None of the PDA processors are able to execute floating point calculations directly on dedicated hardware.

Since a trend to the convergence of portable devices and the integration of multimedia applications can be seen, the next generations of processors will be more and more equipped with additional hardware to support acceleration of digital signal processing for applications like wireless links and multimedia such as audio and video decoding. The processor cores of the newest XScale architecture generation, the PXA27x, go for example a step in that direction. They include Intel's "Wireless MMX" coprocessor and instruction set, a DSP extension comparable to the Pentium’s MMX but again without floating-point arithmetic. An other example is Texas Instrument’s OMAP 1510, which is a dual-core architecture. An ARM9TDMI core is designed for control intensive applications, like operating systems and the control of (user-) interfaces. The other core, a TMS320C55x DSP, is intended to be used for computation-intensive operations such as security, multimedia, and speech. Typical applications are video accelerators ((i)DCT, iDCT, pixel interpolation, motion estimation). The DSPs from such processors might be used for advanced signal processing when the PCS is developed as a product. For prototyping the PCS and to use the PHS as a development and test platform in the Hearcom project, there would be an extensive overhead. All algorithms implemented initially in floating-point arithmetic have to be transformed to fixed-point without adverse effect with respect to the sound quality, which is a time consuming procedure.

4.1.6.1.c Benchmarks

A comparison of the computational performance of the processors Intel XScale PXA270 and Intel Pentium III is shown in Figure 4.1. Four benchmarks out of the Sandra 2005 Benchmark collection[3] give an impression on the capability of the XScale architecture in comparison to the Pentium III. The Dhrystone ALU benchmark measures the number of integer operations per second (MIPS, Million Instructions Per Second) the ALU is able to execute. Floating-point performance is measured by means of the Whetstone FPU benchmark, which shows the number of floating point operations (MFLOPS, Million FLoating OPerations per Second) that the processor can calculate per second. The MultiMedia benchmarks generate a picture (640x480 pixel) of the Mandelbrot fractal, using 255 iterations for each data pixel, in 32 colours. Two versions of this benchmark are implemented in integer and floating point arithmetic. The values shown in Figure 4.1 express how many iterations of the algorithm are performed per second (its).

Because of differences between the processors’ architectures, the compilers, the platforms in which the processors are integrated, etc. these benchmarks do not unconditionally represent the true performance of a dedicated algorithm, but they are useful to get a general impression of the performance.

[3] http://www.sisoftware.net/

Processor	Intel Xscale PXA270		Intel Pentium III		Advantage of Pentium III
System	Dell X50v		ASUS P2B-S system		
Clock frequency (MHz)	624	1	400	1	
Dhrystone ALU (MIPS)	536	0.86	1372	3.4	4
Whetstone FPU (MFLOPS)	9	0.014	533	1.3	92
MultiMedia Integer (it/s)	2440	3.9	3484	8.7	2.2
MultiMedia Floating Point (it/s)	22	0.035	4142	10.4	294

Figure 4.1: Comparison of the computational performance of Intel XScale PXA270 and Intel Pentium III

The Benchmarks are performed on a Dell X50v with Windows Mobile 2003 in case of the XScale PXA270 and on an ASUS P2B-S main board running Windows operating system in case of the Pentium III. The clock frequencies are 624 and 400 MHz respectively. Figure 4.1 shows the benchmark results for both, the original clock frequency and the frequency normalized to 1 MHz. The last column shows how much faster the Pentium III performs the particular benchmark in comparison to the XScale based on the normalized frequencies. It can be seen that the Pentium III performs integer operations 4 resp. 2.2 times faster than the XScale. In the case of floating point operations the performance differences are substantially greater because of the missing floating-point hardware in the Xscale architecture. The Pentium III is 92 times faster in terms of MFLOPS and 294 times faster in terms of floating-point based multimedia operations.

For the processors of some of the devices, the results of an application oriented benchmark, the BDTImark 2000, are available[4] and noted in Figure 4.2. From these results it can be seen that the Intel XScale PXA270 has the best performance characteristics of the processors build in the devices shown here.

4.1.6.1.d Operating Systems

Most of today's PDAs are delivered with the Microsoft Windows Mobile Operating System (OS) in the current version 2003 SE. This applies to four of the devices introduced here. Exceptions are Sony's PEG TH55 which is equipped with Palm OS 5.2 and the Linux based Zaurus SL-6000 from Sharp. A description of operating systems and their properties can be found in D-9-3.

[4] http://www.bdti.com/bdtimark/chip_fixed_score.pdf

4.1.6.1.e Memory

The typical memory configuration of PDAs is 64 MByte RAM and 32 to 64 MByte Flash. Some devices, e.g., the well equipped LOOX 718 and HP's iPAQ H5505, come with 128 MByte RAM. Almost all devices' flash memory can be extended by SD/MMC memory cards.

4.1.6.1.f Interfaces

Typical interfaces of PDAs are USB (mostly just the slave function is implemented), IrDA and an SD/MMC expansion port. Some are also equipped with Bluetooth and WiFi interfaces to enable wireless communication. With the Fujitsu Siemens LOOX 718, HP's iPAQ hx4700 and Clié PEG TH55 the Bluetooth and WiFi interfaces can be used simultaneously. For the HP's iPAQ H5505 this is not possible. Whether Samsung's SGH-i750 is able to use both interfaces simultaneously could not be determined.

The user interacts with the PDA mainly by means of a touch screen and a few buttons. Most of the devices have small (e.g. 4-inch or less) full-colour TFT displays with a resolution of 240 x 320 or 480 x 640 pixels.

4.1.6.1.g Lifetime

The manufacturer data for battery lifetime reaches from 3 to more than 20 hours. But there are uncertainties within these values that make it difficult to compare them. At first, the lifetime is highly dependent on the application running on the device. The processors are able to scale down their voltage and clock frequency during lesser utilization of the processor that leads to a higher battery lifetime. But neither the processor nor the PDA manufacturers use standardized procedures to measure the power consumption of battery lifetime. Apart from that, the lifetime is dependent of the use of components and features of the device such as display backlight, WiFi and Bluetooth interfaces. Just to give an example, while testing[5] Dell's X50v a lifetime of 268 min (~4.5 h) was measured without the use of Bluetooth and WiFi. With both interfaces in use the lifetime dropped to 95 min (~1.6 h), which is less than a third. Unfortunately it is unknown for many devices for which conditions the given values are valid.

4.1.6.1.h Device Overview

Brand	Fujitsu Siemens	HP		Sony	Dell	Sharp
PDA Model	Pocket LOOX 718	iPAQ H5505	iPAQ hx4700	Clié PEG TH55	Axim X50v	Zaurus SL-6000
System						

[5] http://www20.tomshardware.com/mobile/20041231/axim_x50v-10.html

Processor	Intel Xscale PXA272	Intel Xscale PXA255	Intel Xscale PXA270	Sony Engine	Intel Xscale PXA270	Intel Xscale PXA255
Speed [MHz]	520	400	624	400	624	400
BDTImark2000	1783	930	2140	-	2140	930
RAM [MByte]	128	128	64	32	64	64
Flash [MByte]	64	64	128	32	128	64
Battery Lifetime [h]	12	3-6	6	> 20	4-5	10
Communications						
Irda	x	x	x	x	x	x
Bluetooth	x	x	x	x	x	-
Wi-Fi (802.11b)	x	x	x	x	x	x
BT and Wi-Fi simult.	x	-	x	x	?	-
USB	x	x	x	x	x	x
ext. headphones	x	x	x	x	x	x
Extensions	SD/MMC, CF II	SD/MMC, CF	SD/MMC, CF II	Memory Stick	SD/MMC, CF II	SD/MMC, CF II
Display						
Size	3.6"	3.8"	4"	3.8"	3,7 "	4"
Pixel	640 x 480	240 x 320	480 x 640	320 x 480	480 x 640	480 x 640
Colors	65536	65536	65536	65536	65536	65536
Touch panel	x	x	x	x	x	x
Backlight	x	x	x	x	x	x
Software						
Native OS	Windows Mobile 2003	Windows Mobile 2003	Windows Mobile 2003	Palm OS 5.2	Windows Mobile 2003	Linux 2.4
Opt. OS		Linux				
Java	x	x	x	x	x	x
Multimedia						
Audio	x	x	x	x	x	x
Camera	x (LOOX 720)	-	-	x	-	-
Weight [g]	170	207	187	185	175	284
Measures [mm]	122 x 72 x 15	138 x 84 x 16	131 x 77 x 15	122 x 73 x 15	119 x 73 x 17	158 x 80 x 23

Price	540 €	700 €	650 €	400 €	400 €	850 €

Figure 4.2: Overview of different PDAs

4.1.6.2 Smart Phones

Recent developments suggest that PDAs and cellular phones converge to single devices named Smart Phones. As a consequence, PDAs are equipped with communication interfaces like GSM/GPRS and cell phones are equipped with more processing power and memory to be able to execute additional applications that are typical for PDAs. In the following, we use the notation Smart Phones for cell phones with PDA functionality, as well as, PDAs with a GSM interface. Like PDAs Smart Phone are small and light handheld devices. They have an average size of about 115 x 64 x 21 mm and an average weight of about 170 g.

This document describes a selection of four devices that will be available soon. All devices have the ability to communicate with both wireless interfaces WiFi and Bluetooth. Many devices on the market are equipped with either Bluetooth or WiFi interfaces. A collection of these will be presented in Deliverable D-9-3 “Specification of PDA based Personal Hearing System”.

4.1.6.2.a Applications

First of all, Smart Phones can be used like other cell phones, to make phone calls and to exchange information like e-mail, web-pages, etc., because of the integration of the GSM- and GPRS-technologies. The phones can be differentiated by the particularities of the support of the GSM standard (Global System for Mobile Communications). Almost all of the devices support triple band or quad band GSM. While quad band phones can be used worldwide, triple band devices work in the European, African and either the American or Asian-Pacific areas. GPRS (General Packet Radio Service) and EGPRS (Enhanced GPRS) are standards for data transmission in GSM nets. GPRS is more common at the time of writing this document. All Smart Phones mentioned here fulfil this standard. EGPRS, which is based on the EDGE standard (Enhanced Datarate for Global Evolution), is less prevalent at this time. The maximum data rates available are 160 kbps for GPRS and 473.6 kbps for EGPRS (both without protocol overhead). These data rates can be reached under perfect conditions only. This implies an undisturbed medium that is available exclusively. More realistic data rates are 57.6 kbps (KC3 coding, four time slots) for GPRS and 200 kbps (MCS-8 coding, 4 time slots) for EGPRS.

4.1.6.2.b Processors

Like PDAs, the Smart Phones are equipped with adequate processors to support typical PIM applications. The four devices described here contain Intel XScale and TI OMAP processors and support clock frequencies up to 400 MHz (Siemens SX66 with Intel XScale PXA263) or 168 MHz (HP iPAQ

6340 with TI OMAP 1510). The information on what type of processor has been integrated into the Samsung SGH-i750 is not available. However, the specified clock frequency of this device is 400 MHz. No device with FPU support is available today but some processors are equipped with additional multimedia extensions or additional DSP cores (see description in 4.1.6.1.b).

4.1.6.2.c Benchmarks

The processors in the devices presented here offer less computational power then those build into the high-performance PDAs, e.g., like the Intel XScale PXA270 build in Dell's X50v.

By simply comparing the clock frequencies of the processors, it can be seen that the ARM9 based TI OMAP processors build into HP's iPAQ H6340 and Nokia's 9500 Communicator are less than half as fast as the 400 MHz processors of Samsungs SGH-i750 and Siemens SX66. (About the performance of the SGH-i750 no more statements can be made, because it is not known exactly which processor is used in this device.) The performance of the iPAQ H6340 was measured with the Spd-benchmark[6] together with Dell's Axim X30, which is based on an Intel XScale PXA270, the same processor at the same clock frequency as the X50v (see 4.1.6.1). The CPU index of the benchmark shows, that the X30 (CPU index = 2508) is about 3.5 times faster than the iPAQ H6340 (CPU index = 714). Because of the similar processor it is expected that the performance of Nokia's 9500 Communicator is close to that of the iPAQ H6340.

An estimation of Siemens SX66 performance can be made by means of the BDTI benchmark[7] and comparing its XScale PXA262 processor with the PXA270 in Dell's X50v. According to the benchmark the PXA270 at 624 MHz (X50v) is about 2.3 times faster than the PXA262 at 400 MHz (SX66) in performing fixed-point operations.

4.1.6.2.d Operating Systems

Common operating systems in the area of smart phones are Windows Mobile, Symbian and Palm-OS. The footprint of Linux based devices is very small. Motorola's A760 is based on MontaVista Linux. It only supports Bluetooth and it is not possible to run different applications on it other than the ones included in the native Linux. Three of the smart phones described here are being shipped with Microsoft Windows Mobile 2003. Nokia's 9500 Communicator operates on Symbian 7.0. A description of operating systems and their properties can be found in D-9-3.

4.1.6.2.e Memory

---

[6] http://www.ppc-phones.de/index.php?site=ppcphones/hp_ipaq/hp_ipaq_h6315_benchmark.htm
[7] http://www.bdti.com/bdtimark/chip_fixed_score.pdf

The memory configuration of the Smart Phones described here is 64 MByte RAM (except for Siemens SX66 with 128 MByte) and 64 MByte Flash (except for Samsung SGH-i750). The Flash memory of the SGH-i750 can be extended by a T-Flash card. The other devices support SD/MMC slots for memory upgrades.

4.1.6.2.f Interfaces

Beside the GSM interface the devices have typically USB and IrDA interfaces and they can be expanded by means with SD/MMC ports. The Devices described here are also equipped with both, Bluetooth and WiFi interfaces. While the GSM communication is independent from these, it is not possible for all the devices to communicate with both, Bluetooth and WiFi at the same time. According to the manufacturers HP's iPAQ H6340 and Nokia's 9500 Communicator can handle both interfaces simultaneously, whereas Siemens SX66 can handle only one interface at the time. For the Samsung's SGH-i750 no information could be determined to clarify this aspect.

All of the Smart Phones have touch screens and numeric keyboards for user interaction. The resolution of the small full-colour TFT displays is 240 x 320 pixels. Only Nokia's 9500 Communicator has two displays, one 128 x 128 pixel display at the front and a 640 x 200 display that is visible if the device is flipped open. In addition to, the numeric keypads typical for cell phones, all of the devices except for the iPAQ 6340 have an additional (mini) keyboard to enable more comfortable text input.

4.1.6.2.g Lifetime

As with PDAs, battery lifetime is highly application dependent. Most of the manufacturers differentiate between stand-by and talk time. They do not describe these two use-cases in more detail e.g. which interfaces are in use or what the processor utilization is. The Smart Phones shown here support talk times from 2.5 to 10 hours, the stand-by times reach from 150 to 300 hours (~6–15 days).

4.1.6.2.h Device Overview

Brand	HP	Samsung	Siemens	Nokia
Model	iPAQ H6340	SGH-i750	SX66	9500 Communicator
System				
Processor	TI OMAP 1510	?	Intel XScale PXA263	TI OMAP
Speed [MHz]	168	400	400	150
BDTImark2000			930	
RAM [MByte]	64	64	128	64
Flash [MByte]	64	128	64	80 (for the user)

Stand-by [h]	150	?	168	180-300
Talk time [h]	2.5	?	3.5	4-10
Communications				
GSM/GPRS	quad, GPRS	tri, GPRS	quad, GPRS	tri, GPRS
MMS				x
Irda	x	x	x	x
Bluetooth	x	x	x	x
Wi-Fi (802.11b)	x	x	x	x
BT + WiFi simultaneously	x	?	-	x
USB	x	x	x	2.0
ext. headphones	x		x	-
Extensions	SD/MMC	T-Flash card slot Mini Keyboard	SD/MMC Mini Keyboard	SD/MMC Keyboard
Display				
Size [mm]	3.5"	2.8"		
Pixel	240 x 320	320 x 240	240 x 320	128 x 128 and 640 x 200
Colours	65536	65536	65536	65536
Touch panel	x	x	x	-
Backlight	x	x	x	x
Software				
Native OS	Windows Mobile 2003	Windows Mobile 2003	Windows Mobile 2003	Symbian 7.0 S
Java	x	x	x	x
Multimedia				
Audio	x	x	x	x
Camera		x		x
Weight [g]	190	150	210	230
Measures [mm]	119 x 75 x 19	104 x 50 x 24	125 x 71 x 18	148 x 57 x 24
Price	600 €	not available	650 €	610 €

Figure 4.3: Overview of different Smart Phones

4.1.6.3 Tablet PCs

Tablet PCs are portable devices and they are very similar to notebooks in size, equipment, performance and interfaces. The main difference is that they can be operated without the usage of a keyboard. Some devices still include a keyboard, but usually the display can be flipped and turned down so that the keyboard is covered. The touch screen then serves as input device (e.g. for the recognition of handwritten text).

In the following section four up-to-date Tablet PCs are introduced. The Siemens STYLISTIC ST5021 and TATUNAG's TTAB-B12D are true tablet PCs in the sense that they do not have a build-in keyboard. The size of the devices is comparable with the size of notebooks; the average weight is about 1.8 kg. The two other devices described are the OQO's OQO model 1 and the Sony U70. Both are Tablet PCs as defined above, but they are optimised for size; they are in a near-PDA form factor.

4.1.6.3.a Applications

Tablet PCs are general-purpose computers like desktop PCs and notebooks. All applications that run on these also run on Tablet PCs.

4.1.6.3.b Processors

Most Tablet PCs are equipped with Intel Pentium M processors, which are developed for high computational performance while dissipating a minimum amount of power. The current version of the processor is build around the Dothan kernel, after the Banias kernel the second-generation kernel of Pentium M processors. They originally are derived from the Pentium III and are combined with a Pentium IV compatible bus interface. In contrast to the Pentium III, the Pentium M has a larger, more energy efficient 2nd level cache (Banias: 1024 KByte, Dothan: 2048 KByte) and it is optimized to have a high computational performance at relative low clock frequencies. The Pentium M has the ability to scale down its clock frequency and core voltage to consume less power whenever the load is low. Intel also sells special Low Voltage (LV) and Ultra Low Voltage (ULV) variants of this processor with less power dissipation.

The OQO Model 1 is equipped with a Crusoe TM 5800 [Ref.: http://www.transmeta.com/crusoe/crusoe_tm5800_tm5500.html], which is a processor released in 2001 by Transmeta. The TM 5800 provides, like other Crusoe processors, x86-compatible software execution by using dynamic binary code translation. The x86-code read into the processor is translated internally by a code morphing software to Crusoe specific code. Transmeta is a leading company in development of processors with high performance and low power dissipation (good performance/power ratio). Nevertheless Crusoe processors are not very common in the area of the device classes of Tablet PCs and Notebooks.

4.1.6.3.c Benchmarks

By comparing the benchmark results published at Standard Performance Evaluation Corporation[8] (SPEC) it can be seen that a Pentium M is more powerful than a Pentium IV at the same clock frequency. Two benchmark results are published for systems including Pentium M processors, one for the Hewlett-Packard server system ProLiant BL10e G2 based on a Pentium M 723 ULV clocked at 1.0 GHz and the other for the Dell Notebook Precision Mobile Workstation M60 with Pentium M 755 clocked at 2.0 GHz.

The benchmark results of the HP system are approximately comparable with 2.0 GHz and 1.5 GHz Pentium 4 systems with respect to integer and floating-point performance. Thus the Pentium M ULV is about a factor of 2 (1.5) faster than a Pentium IV with the same clock frequency.

Comparing the HP and the Dell systems brings up a contradictory picture. Scaling to the same clock frequencies the integer performance of the Dell system is higher by factor 1.12. Floating-point performance is almost the same for both processors (factor 0.98).

SPEC benchmark results for systems equipped with Transmeta's TM 5800 could not be investigated, but its performance is approximately comparable with that of a Pentium III-ULV at 600 MHz. Therefore, the TM 5800 reaches about half the performance of a Pentium M 723 ULV.

4.1.6.3.d Operating Systems

Since Tablet PCs are general-purpose computers like Desktop PCs, typical operating systems like Windows and Linux are applicable.

4.1.6.3.e Memory

Up-to-date devices are typically equipped with 256 or 512 MByte RAM and a 40 or 60 GByte hard disc. When required, the devices can be equipped with different memory size.

4.1.6.3.f Interfaces

Tablet PCs have a rich set of communication interfaces just like Notebooks. Obligatory are Ethernet (at least 100 MBit/s), analog Modem (56 KBit/s) and USB interfaces (except for the modem this applies also for OQO model 1 and U70). Furthermore, some Tablet PCs contain an additional IEEE 1394 (FireWire) interface. For wireless communication all of the Tablet PCs described here are equipped with WLAN (802.11 b/g) interfaces and all but the TATUNG TTAB-B12D and the Sony U70 are ready to communicate by means of Bluetooth. The Siemens Fujitsu STYLISTC SC5021 and Toshiba's Portégé M200 can operate WiFi and Bluetooth simultaneously. If the HP Compaq TC4200 or the OQO Model 1 are capable of this, could not be investigated.

---

[8] http://www.spec.org/cpu2000/results/

4.1.6.3.g Lifetime

Battery lifetime of the devices shown here vary from 4 to 6 hours and is therefore in the same limit as for Notebooks. The very small devices OQO model 1 and U70 can operate just 3 or 2.5 hours, where the U70 can be equipped with a bigger battery, so that the lifetime is extended to 5.5 hours. The same topics as described in section 4.1.6.1.g matter for Tablet PCs. It is expected that the lifetime will be lower than specified in the datasheets, if the processor utilization is high and/or several interfaces are in use at the same time. For example, in the specification of the Siemens Fujitsu STYLISTC SC5021 a battery lifetime of 6 hours is listed. According to the statement of an employee at the service hotline a lifetime of approximately 2.5 hours can be expected at high utilization and the continuous use of the WLAN interface.

4.1.6.3.h Device Overview

Brand	Futjitsu Siemens	HP Compaq	TATUNG	Toshiba	OQO	Sony
PDA Model	STYLISTIC ST5021	TC4200	TTAB-B12D	Portégé M200	OQO model 1	U70
System						
Processor	Intel Pentium M 733 (ULV)	Intel Pentium M 750	Intel Pentium M 738 (LV)	Intel Pentium M 725	Intel Pentium M 713 (ULV)	Transmeta Crusoe TM 5800
Speed [GHz]	1.1	1.86	1.4	1.7	1	1
RAM [MByte]	256	512	256/512	256	256	512
Hard disk [Gbyte]	40	60	60	40	20	20
Battery Lifetime [h]	6 (2.5)	5.5	4	4	3	2.5 (5.5
Communications						
Internal Modem	56 KBit/s V.92	56 KBit/s V.92	56 KBit/s V.92	56 KBit/s V.92	-	-
Ethernet	10/100/1000	10/100/1000	10/100	10/100	10/100	10/100
Irda	x	x	x	x	-	-
Bluetooth	x	x	-	x	x	-
Wi-Fi (802.11b)	x	x	x	x	x	X
BT + WiFi simultaneously	x	?	-	x	?	-
IEEE 1394 (Firewire)	x	-	x	-	x	-
USB	2 x 2.0	3 x 2.0	2 x 2.0	2 x 2.0	1 x 1.1	1 x 2.0
ext. Headphones	x	x	x	x	x	x
ext. Microphone	x	x	x	x		

Extensions						
SD	x	-	-	x		
SmartCard	x	x	-			
PC-Cards	x	x	x	x		
MemoryStick	x	-	-	-		x
Other						CF
Display						
Size [mm]	10.4 "	12,1 "	12,1 "	12,1 "	5"	5"
Pixel	1024 x 768	1024 x 768	1024 x 768	1400 x 1050	800 x 480	800 x 600
Colours	24 bit	?	32 bit	24 bit	24 bit	24 bit
Touch panel	x	x	x	x	x	x
Backlight	x	x	x	x	x	x
Software						
Native OS	Windows XP Tablet PC	Windows XP Tablet PC	Windows XP Tablet PC	Windows XP Tablet PC	Windows XP Professional	Windows XP Home Edition
Java	x	x	x	x	x	x
ıdio	x	x	x	x	x	x
Weight [g]	1560	2080	1400	2080	398	544
Measures [mm]	324 x 220 x 24	285 x 235 x 34	303 x 232 x 19	295 x 249 x 35	239 x 86 x 23	168 x 109 x 25
Price	2.200 €	1.599 $	1.680 €	1.760 $	~2000 $	~2000 $

Figure 4.4: Overview of different Tablet PCs

4.2 Speech recognition system

Automatic speech recognition (ASR) devices have been developed for purposes ranging from espionage to wrist injury prevention. Their main purpose is the transmission of information from humans to machines (McLeod, 1988). The systems are still being refined to meet desired levels of performance for these applications. Although it is not considered a major application, the potential ASR has for deaf and hard-of-hearing people has not gone unnoticed (Waibel & Lee, 1990; Stuckless, 1994). However, deaf and hard of hearing people are virtually never considered when the devices are developed, tested, and marketed. Deaf and hard of hearing consumers lack the resources to start their own research and development programs. Instead they must rely on deriving benefits from other ventures. Ergonomic analysis of their use environment is required to achieve the best implementation for this application and to provide realistic representation of ASR for deaf and hard-of-hearing users.

The goal of automatic speech recognition is the near-immediate display of legible text, accurately transcribing the desired speech signal, without interference from extraneous signals and noise, on a convenient, portable, and affordable device (Stuckless, 1994). Developers of ASR have sought to combine in the same system at least two of three main performance goals: continuous natural speech, not limited to particular speakers, and vocabularies that are not artificially limited (Kurzweil, 1990).

4.2.1 Intended audience

The intended audience of the speech recogniser are individuals who aim to communicate with other persons with hearing problems due to poor environmental conditions or a hearing impairment.

4.2.2 Scenarios

4.2.2.1 Assistive tool in a telephone conversation

The speech recognition module can be of great help in the case of a telephone conversation among hard of hearing people. The fact that speaker-independent speech recognition systems are available and that such systems need no prior training in order to function, makes them appropriate for the its use in such an application.

The hearing impaired person will be able to plug his assistive device into his telephone device and the audio signal of both channels (both parties) will be fed into the recognizer. The output of the recognition system will then be forwarded to the specially designed device for text display (e.g. rolling text display), where the transcription of of the speech will be displayed.

4.2.2.1.a Possible Applications:

- Telephone conversation
- Dialog systems (Telephone conversation with automatic systems)
- Videoconference

4.2.2.1.b Limitations:

This specific application of the speech recognition system imposes limitations such as the noise levels and the general audio quality of the speech signals. In the case of a noise-corrupted signal, the performance of the recognizer deteriorates, as well as the system's speed. This is also the case when both parties speak at the same time.

4.2.2.2 Voice Commands

The speech recognition module will be customized in order to serve as a voice command module, recognizing words and phrases of a limited range. The end-user will be able to activate the voice command service on his/her assistive device (PDA, Laptop), which then will be running in the background, trying to spot specific words or phrases. These words or phrases will be the voice commands that will be assigned to specific operations and functions of the assistive device.

4.2.2.2.a Possible Applications:

- Voice commands

4.2.2.2.b Limitations:

This specific application of the speech recognition system imposes limitations such as the noise levels and the general audio quality of the speech signals.

4.2.2.3 Assistive Tool for Recognizing Public announcements

The speech recognition module can be used in public announcements systems in order to give to the user a written version of what has been announced e.g. by the loudspeakers in a train-station. Nevertheless, in the case of such a use, there are specific limitations that must be taken into account. The high noise level and the bad audio quality will affect the results of the recognition process. It would then be better if the audio recognition module is interposed between the speaker's microphone and the loudspeakers and transmitted over a radio link. This suggests that this architecture must be adopted by all public announcements systems.

4.2.2.3.a Possible Applications:

- Train stations
- Airports
- General purpose public announcements systems

4.2.2.3.b Limitations:

This specific application of the speech recognition system imposes limitations such as the noise levels and the general audio quality of the speech signals.

4.2.2.4 Assistive Tool for TV, radio and similar devices

The ability of the available ASR system to be used without prior training, makes it useful and possible to be used for automatic recognition from external sources, such as TV, radio, cinema and other similar devices/sources. Nevertheless such a use imposes specific limitations and provisions about the audio quality and the noise added.

4.2.2.4.a Possible Applications:

- Cinema
- TV

- Radio
- Other similar devices/sources

4.2.2.4.b Limitations:

In the case where the ASR's input signal is provided by the loudspeakers, it obvious that it will be noise-corrupted, and this will affect the system's performance. Alternatively, it could be better to transcribe the speech signal directly from the source and then to be displayed on the handheld device's screen.

4.2.2.5 Assistive Tool for one-to-one conversation

The speech recognition module can be of great help in the case of a conversation among hard of hearing people. The fact that the available speech recognition system is speaker independent and that it needs no prior training in order to function, makes it appropriate for use in such an application.

The output of the recognition system will then be forwarded to the specially designed device for text displaying (e.g. rolling text display), where the transcription of what has been said will be displayed.

4.2.2.5.a Possible Applications:

- One-to-one conversation.

4.2.2.5.b Limitations:

This specific application of the speech recognition system imposes limitations such as the noise levels and the general audio quality of the speech signals. In the case of a noise-corrupted signal, the performance of the recogniser deteriorates, as well as the system's speed. This is also the case where both parties speak at the same time.
The case of two microphones will be investigated (one microphone on the assistive device e.g. PDA, and one headset microphone).

4.2.2.6 Dictation, taking notes

The speech recognition module can be used for dictation by the end-user for recording and transcribing texts, spoken notes etc. The available speech recognition system can serve as a "substitute" to the keyboard, as far as writing texts is considered. The end-user will be able to invoke the application and by recording on a headset microphone, he will be able to dictate to his assistive device and it will transcribe into written text what has been uttered. This will be a special text-editor with enhanced capabilities such as speech recognition features.

4.2.2.6.a Possible Applications:

- Text dictation
- Taking notes

4.2.2.6.b Limitations:

Noise-corrupted speech and audio signals may cause performance to deteriorate.

4.2.3 State of the art and options

4.2.3.1 State of the art Automatic Speech Recognition (ASR)

Automatic Speech Recognition (ASR) is technology that allows a computer to identify the words that a person speaks into a microphone or telephone. The "holy grail" of ASR research is to allow a computer to recognize in real-time with 100% accuracy all words that are intelligibly spoken by any person, independent of vocabulary size, noise, speaker characteristics and accent, or channel conditions. Despite several decades of research in this area, accuracy greater than 90% is only attained when the task is constrained in some way. Depending on how the task is constrained, different levels of performance can be attained; for example, recognition of continuous digits over a microphone channel (small vocabulary, no noise) can be greater than 99%. If the system is trained to learn an individual speaker's voice, then much larger vocabularies are possible, although accuracy drops to somewhere between 90% and 95% for commercially-available systems. For large-vocabulary speech recognition of different speakers over different channels, accuracy is no greater than 87%, and processing can take hundreds of times real-time.

The dominant technology used in ASR is based on Hidden Markov Models, or HMM. This technology recognizes speech by estimating the likelihood of each phoneme at contiguous, small regions (frames) of the speech signal. Each word in a vocabulary list is specified in terms of its component phonemes. A search procedure is used to determine the sequence of phonemes with the highest likelihood. This search is constrained to only look for phoneme sequences that correspond to words in the vocabulary list, and the phoneme sequence with the highest total likelihood is identified with the word that was spoken. In standard HMMs, the likelihood’s are computed using a Gaussian Mixture Model; in the HMM/ANN framework, these values are computed using an artificial neural network (ANN).

During the last decade, much research has been performed to improve speech recognition systems. The research can generally be classified into one of the following areas: robustness against noise, improved language models, multilingual approaches, and data fusion and multi-stream processing.

→Robustness against noise

The performance degradation in noisy real-world environments is probably the most significant factor limiting take up of ASR technology. A typical degradation of the performances on this task can be observed in Table 1.

SNR	-5 dB	0 dB	10 dB	15 dB	Clean
WER	90.2 %	72.2 %	20.0 %	8.0 %	1.0 %

Table 1 : Word Error Rate on the Aurora-2 database (Continuous digits in noisy environment for different signal to noise ratio).

-→Improved language models

One important issue for speech recognition is how to create language models for spontaneous speech. When recognizing spontaneous speech in dialogues, it is necessary to deal with extraneous words, out-of-vocabulary words, ungrammatical sentences, disfluency, partial words, hesitations and repetitions. These variations can degrade the recognition performance. For example the results obtained on the SwitchBoard database (telephone conversations) show recognition accuracy for the baseline systems of only 50 % [COH94].

4.2.3.2 Basic Principles of the Hearcom Speech Recognition Module

This module allows the processing of the speech signal and the feature extraction, by converting each speech frame into a set of cepstral coefficients. Then, acoustic phoneme models provide estimates of the probability of the features, given a sequence of words. Language modelling provides a mechanism for estimating the probability of some word in an utterance given its preceding words.

Parameter extraction: The prime function of the parameter extraction module is to divide the input speech into blocks; then for each block to derive a set of parameters that characterize a smoothed spectral estimate. (The spacing between blocks is typically 10 ms and blocks are normally overlapped to give a longer analysis window, typically 25 ms). In almost all cases of such processing, it is quite usual to apply a tapered window function (e.g. Hamming) to each block. Mel-Frequency Cepstral Coefficients (MFCCs) are used to model the spectral characteristics of each block.

Acoustic modelling: The purpose of the acoustic models is to provide a method of calculating the likelihood of any vector sequence Y given a word w. In principle, the required probability distribution can be found by finding repeated examples of each and collecting the statistics of the corresponding vector sequences. However, this is impractical for large vocabulary recognition (LVR) systems and, instead, word sequences are decomposed into basic sounds called phones, with each individual phone represented by a hidden Markov Model (HMM). Contextual effects cause large variations in the way that different sounds are produced. Hence, to achieve good phonetic discrimination, different HMMs have to be trained for each different context, instead of one HMM per phone. Our approach involves using triphones where every phone has a distinct HMM model for every unique pair of left and right neighbours. Moreover, state-tying techniques with continuous density HMMs are used.

Language modelling: An effective way of estimating the probability of a word given its preceding words is to use N-grams which simultaneously encode syntax, semantics and pragmatics. They concentrate on local dependencies, which make them very effective for languages where word order is important and the strongest contextual effects tend to come from near neighbours. The N-grams approach is widely accepted to be one of the most efficient ways to model language structure. The N-gram probability distributions can be computed directly from text data, yielding hence no requirement to have explicit linguistic rules (e.g. formal grammars).

Search engine: The basic recognition task is to find the most probable sequence of words given the observed acoustic signal (based on the Bayes' rule for decomposition). In our system, we use the breadth-first approach and specifically, beam search and Viterbi decoding (which exploits Bellman's optimality principle). The dynamic performance of this search engine provides a system capable of exploiting complex language models and HMM phone models, depending on both the previous and succeeding acoustic context, such as coarticulation. Moreover, it can do this in a single pass, in contrast to most other Viterbi-systems that use multiple passes (Young, 1996).

4.2.3.3 Output of speech recogniser

The speech recognition system will not only provide a single transcription of a spoken utterance but also a probability and the time stamp for each recognized word. This probability shows the confidence score of each word comparing to the language model.

Most speech recognisers provide confidence scores as a measure of confidence for the hypothesized word sequences. Confidence scores are given in the range 0-1. The indication of confidence scores is important, since errors occur frequently in speech recognition and can make applications such as spoken dialogue systems too cumbersome to use. An accurate confidence measure can help us determine when the recognition is incorrect so that we can take appropriate action.

4.2.4 Conclusions and recommendations

4.2.4.1 ASR constraints

In general, the Speech Recognition module has the following features. To guarantee the best possible speech recognition performance the following requirements should be met;

- Speaking mode: continuous speech
- Enrolment: speaker independent
- Sampling frequency for the input speech files should be 16kHz with 16-bit sample size.
- The speed of a person's speech must be kept stable.
- The speech recognition engine is customisable to allow adjustment for different speaking styles of individuals.
- The speech recognition engine supports a wide range of speech patterns and accents.
- The system continuously adapt to changing conditions (new speakers, microphone, application.).
- The system is robust, performance degrades gracefully as conditions become more different from those under which is trained.
- Signal to noise ratio >=15db
- Speaking style: read speech, Fluid speech (i.e., not pausing between words)
- Supported Languages: English and Greek
- Vocabulary size: 140000 words for English, 400000 words for Greek.

4.2.4.2 Bounds on ASR performance

- LVR dictation in noise free conditions for native English speakers achieves 8% WER.
- In adverse conditions when noise is assumed to be white and the SNR is lower than 18 dB the above figure increases. Indicatively the WER is 35% when the SNR is 10dB.

- When an out-of-vocabulary word is uttered the system fails for this particular word and for the following one depending on the language model.
- Using spontaneous speech, the speech recognition performance degrades and the WER drops up to 45%.
- The system works almost real time on a Pentium IV at 3.00GHz, 512 RAM. In adverse conditions the latency of the response increases by (0-20%) depending on the noise level.
- Confidence levels: the speech recognition system will not provide only a single transcription of a spoken utterance but also a probability for each word. That corresponds to each confidence score. The confidence score varies in the range (0-1). This word-based confidence score must be above a certain threshold in order to be labelled as correctly recognized. In case where the word based confidence score is in fact low the system may prompt the user to pay more attention to the audio information.

4.3 Rolling text display

WP9 will develop a personal communication system that will enhance speech communication of individuals experiencing communication problems. Communication can be enhanced by various means. Along with the evolving technology already in use, technological advancements can potentially provide individuals with some of the help they need to perceive speech.

Assistive devices presenting visual information as support for speech understanding have been shown to substantially improve communication, especially when the auditory signal is distorted. Furthermore, visual information can be helpful in several situations and it is likely that many individuals will benefit from visual cues, regardless of the degree of hearing impairment they might have. For example, some individuals encountering hearing difficulties in adverse listening situations do not need hearing aids; the availability of supportive visual information might already compensate for their communication problems.

4.3.1 Intended audience

The intended audience of the visually displayed assistive information are individuals with communication problems due to poor environmental conditions or a hearing impairment.

4.3.2 Scenarios

4.3.2.1 Assistive tool for TV and radio

The visual displayed text can help users to understand speech while watching TV when no closed captions are available (live transmissions) or when listening to the radio. Possible applications: cinema, radio, TV.

4.3.2.2 Telephone communication

The combined application of ASR and text display likely facilitates telephone conversations of a large group of users (wide range of communication difficulties and / or hearing impairments). The text of both parties or the text of one of the channels could be displayed. An important advantage compared to Tele Typewriters is the fact that no third party (relay service) has to be involved when a person using the system communicates with someone not using the system.

4.3.2.3 One-to-one communication

In many one-to-one communication situations the user might receive benefit from supportive visually presented information. Of course, in many one-to-one conversations, the speaker is visible; looking at the visual display might interfere with lip reading. However, using the visual information as a back up for listening and lip reading, might significantly improve communication without disturbing non-verbal communication.

4.3.2.4 One-to-many communication (i.e. the user of the system is member of an audience)

A microphone could be set up near the speaker, which would enable the user to follow the lecture with the communication system. Text might interfere with visual speech reading / nonverbal communication or attending to visual presented sheets / information. However, this interference might be reduced if text could be stored in memory. Afterwards, this would enable the user to get clarification of what was not understood. If the user knows that the information will be stored in memory, they do not have to worry about missing something.

4.3.2.5 Alarm-signals

The text display could be used to alert the user to states of emergency (e.g. fire alarm) and signals from their (mobile) phone, doorbell, etc. Fire alarms and evacuation signals typically combine bells for alarm states with verbal announcements (e.g. who needs to evacuate and who needs to stay where they are). High noise levels will affect the quality of the automatic recognition process, making the direct transmission of text by the alarm system desirable. The display and the personal communication system itself should easily attract the attention of the user (vibrating alarm function).

4.3.2.6 Public announcement systems

For a description of the scenario in which displayed visual information is obtained via direct links with public announcement systems see below (4.3.3.2.c).

4.3.3 State of the art and options

4.3.3.1 State of the art of assistive devices presenting supportive visual information

At present, several applications and assistive devices presenting additional visual information to support speech understanding have been described.

Most people are familiar with ‘closed captions’; subtitles broadcast with television programmes. The difference between closed captions and subtitles displayed with foreign language movies is that closed captions are optional. In the United States, television closed captioning is used by 28 million Americans who are deaf or hard of hearing; several millions more use it in the classroom or in noisy environments like bars, restaurants and airports.

Other available applications are specifically developed for telephone conversations. For example, text telephone systems (Tele Typewriter, TTY) are widely used. The TTY enables people who are deaf, hard of hearing, or speech impaired to converse on the telephone by typing messages that are sent through the telephone network. The person on the other end of the line can also use a TTY to decode the signal back into text. When a person who uses a TTY wants to converse on the phone with someone who does not have a TTY, a relay service has to be used. A major disadvantage of this system is the fact that many users of TTY do not like the participation of a third party (the typist) in their telephone conversation.

Another application designed for improving telephone communication is the IST Synface project (under development). In this application, the hearing impaired views a 3D model of a talking face on a PC screen. The oral movements made by the model are derived from the speech signal and are developed such that they contain as much information as possible (Siciliano et al., 2003).

Another system, specifically developed for the deaf population, displays automatically derived speech cues by superimposing animated hand shapes on the displayed face of the talker. This cued speech is used as a supplement for speech reading (Duchnowski et al., 2000).

Some other available systems are developed for use in educational settings of hearing impaired and deaf students. For example, Saint Mary's University, Canada has developed the 'Liberated Learning Initiative' for students with disabilities (Leitch & MacMillan, 2003). This system provides real-time speech-to-text transcription during lectures. It comprises a wireless microphone connected to a computer system. Specially designed classroom speech recognition software converts speech into text, which is displayed via a projector. The developers of the Liberated Learning Concept are aware of the potential benefits of a phonetic display of the speech; this would give the person a clue as to what word might have been said. Unfortunately, they did not further investigate this issue. The present project aims to give more insight into this issue and will examine the received benefit of phonetic displayed speech.

In conclusion, several systems displaying supportive visual information have been shown to be very helpful for individuals experiencing difficulties understanding speech. Unfortunately, most of the systems are designed for use in only one specific situation (like telephone conversations) and cannot be used in a wider range of listening environments. Another problem with some of the available systems is that they are specifically developed for only a small group of users (e.g. users that understand sign-language).

The present project aims at developing an assistive application on a mainstream mobile platform (PDA / SmartPhone). This enables the use of the system in several situations (e.g. telephone conversation, conversations at work) and also enables additional applications, like displaying announcements at train stations. Thus, in contrast to current systems, the personal communication system will allow the use in a wide range of communication situations. The system will provide several applications specifically developed for a wide user group (persons with communication problems) in addition to the functionalities associated with the platform itself (PDA / SmartPhone).

One of the applications under development is the visual presentation of supportive information on the display of the platform. The visually presented information will be either automatically extracted from the speech signal by means of Automatic Speech Recognition (ASR) or it will be obtained by cooperation with information sources like public announcement systems. The visual information will be optimised to both personal capabilities (aspects of human interface design) and quality of information (ASR performance).

4.3.3.2 Options for the rolling text display

4.3.3.2.a Presentation of word-output

The ASR system will analyse speech signals and its output will be presented at the display. Most ASR systems produce text as output, often together with confidence scores for each word. The performance of all ASR systems is degraded by disturbances in the acoustic environment. It is unknown whether displaying unreliable recognized speech will improve speech understanding. However, using the confidence scores to indicate the reliability of the ASR recognition may help the user to ignore parts of the sentences that are likely to contain errors. We will investigate the effects of the use of confidence scores to indicate reliability in order to optimise the received benefit from the visual information. Furthermore, effects of delay (delayed presentation of the text relative to the speech) and error rate will be investigated.

4.3.3.2.b Presentation of phoneme-output

In general, ASR systems can also (if adapted) produce 'phoneme-based' output. Automatic recognition of phonemes and displaying them in readable form could make a more optimal use of the user's linguistic skills and the computer signal analysis capability (Mangold, 1988). To ensure accessibility to all users, reading this phonetic output should be easy and the use of the output should be optional.

The results of a test with phonetic output indicated a possible reading rate of about 25 to 50 words per minute (results described in Mangold, 1988). This is lower than the average recognition rate of a normal hearing listener but it might be sufficient when the user uses the visual information as a backup source in addition to (impaired) hearing. In addition, the performance of ASR systems is significantly increased since the study of Mangold.

A phonetic display might be better than showing recognized words that have (very) low confidence scores. The impact of errors might be less when presenting phonemes instead of words (erroneously displayed words can be semantically unrelated to the pronounced words). Another benefit of displaying phonemes instead of words might be a decreased delay (for that the ASR systems can use a more simple and restricted language model).

4.3.3.2.c Visual presentation of information obtained via direct links with public announcement systems / information server

An additional application of the assistive rolling text display will be the presentation of information derived from a public address system. This information will be transmitted via wireless channels that can be captured by the assistive device. Since data will be transmitted (instead of auditory speech signals), the ASR system does not have to be used and the displayed text will not contain errors. This application can for example be used at public transport terminals or in case of an emergency. Additional links to a special information server or the Internet could provide additional information, e.g. in case of an announcement at a train station, information about alternative routes could be displayed.

In general, for the rolling text display application several characteristics of the display of the mainstream platform are important, such as it's size, contrast, luminance, resolution and whether the user can adjust e.g. text size. Specific requirements of the display imposed by the different options (e.g. the combination of ASR and The rolling text display) will be investigated.

4.4 Personal hearing system

The personal hearing system (PHS) is a portable device with enhanced hearing aid signal processing capabilities. Depending on the personal communication system (PCS) properties – floating point processing is required by the PHS –, the PHS and PCS can be integrated into one device or could be two separate devices with a link. The PHS allows connections to all audio channels of the PCS. Typical input streams into the PHS are the headset microphones, mobile phone audio streams and multimedia application output. The PHS allows a personalized preprocessing of these streams in a similar manner as modern digital hearing aids. The output of the PHS is connected to the receiver in the headsets. Signal processing schemes can be easily configured and exchanged without any modifications of the hardware, to reduce production costs and allow usage of state-of-the-art algorithms.

In an other application, the processing in the PHS can be split up into a signal path, which is completely integrated into the headset, and an analysis path with processing power demanding algorithms, running on the additional device. Differences between these applications are not visible to the end user.

4.4.1 Intended audience

The PHS is an extension of the personal communication system that focuses on hearing impaired listeners. Depending on the headset, subjects with mild hearing loss or even subjects with severe hearing loss can be helped.

4.4.2 Scenarios

The PHS provides multiple audio stream inputs, a stereo audio stream output and two control inputs. One control input is connected to a user interface to allow input and program selection. The other control input is intended for configuration of the PHS. It can be used by the user for individual configuration (self fitting), e.g. by a configuration tool, or for connection to fitting tools used by audiologists (professional fitting).

Two scenarios have to be distinguished. If subjects with a mild hearing loss use the PHS, self fitting can be applicable. In this case, a connection to professional fitting tools is not required. Furthermore, simple headsets as used in telecommunication applications can be used. Subjects with severe hearing loss will require an algorithm fitting by professionals. An interface to professional fitting tools is needed. This interface can be routed through any bus, e.g. USB, LAN or WLAN. High data rates or low delay are not required by the fitting interface. If the PHS is to be used by subjects with severe hearing loss, the usage of a special headset is required, to allow high amplification. Also, fallback processing capabilities in the headset are required to provide basic hearing aid signal processing in the case that the PHS is not available by any reason, e.g. battery failure or a disturbed connection between headsets and PCS.

4.4.3 State of the art and options

The HearCom PHS prototype is the HörTech Master Hearing Aid (MHA). The MHA runs on a Linux operating system. Audio streaming is performed over the JACK sound server, which allows multiple audio device inputs and integration into multimedia applications. Input selection can be controlled over a graphical user interface. Fitting and input selection can be performed over a TCP connection (LAN or WLAN). This allows fitting from a professional fitting environment as well as from simple configuration tools running on the local machine or on external PCs.

The PHS is intended to run on a portable device, e.g. PDA or SmartPhone. For now, this type of devices does not provide sufficiently high processing power. Until the processing power of those devices is sufficiently high, the PHS runs on a notebook or sub-notebook computer. DSP cores and MMX extensions of upcoming PDA/Smart Phone processors can support the necessary signal processing of the PHS, if the algorithms are adapted to the fixed-point architecture of these devices. This might be a option for end user devices, not for the use of the PHS as a algorithm development platform like intended for the use in the Hearcom project, since the time consuming adoption of the algorithms without audible quality degradation is a very time consuming task.

The PHS is used with cable bound hearing aid dummies, which allow usage even for subjects with severe hearing loss. Wireless headsets, which are compatible to standard PC hardware, can be used alternatively.

A detailed description of the MHA based personal hearing system can be found in the deliverable D-9-2.

5 User questionnaire

5.1 Aim

The aim of the user questionnaire was to gather information about the needs of users in relation to the technologies that are under development in Sub Project 4. This report summarises the results of the user questionnaire in relation to the technologies that are underdevelopment as part of workpackage 9. Professionals were also asked similar questions with regard to the needs of deaf and hard of hearing people in relation to these technologies. The results of this research are discussed in section 6.

5.2 Questionnaire design

All members of the workpackage (WP9) participated in the questionnaire development process. The questionnaire included sections asking about a number of different facets of everyday life and technology use, and also about users' thoughts on the new technologies that are being developed in WP9. The questionnaire was combined with the user requirements questionnaire for WP8, therefore the responses to some questions will not be reported here. Responses to questions more pertinent to WP8 will be described and discussed in D8_1.

The sections included in the questionnaire were:

- General questions (demographics etc.)
- Assistive technology use
- Activities of daily living
- Personal link (WP8)
- Speech recognition
- Text display systems
- Additional portable device

The first section, on demographics, enables an understanding of the population that responded to the questionnaire, and verification that it was a representative sample of the intended end user group. The remainder of the sections asked about users' lives and their experiences with technology.

By asking users about their experiences of similar technologies that are currently available, it is possible to highlight aspects of these technologies that are liked and disliked. This offers the technical development team guidance as to the types of technologies and features that users want and need the most. These questions are usually fairly straightforward for users to answer, as they relate to their everyday experiences, and to technologies that they have tried for themselves.

In addition, the questionnaire asked users their opinions on some of the ideas that are being pursued in the workpackage. While these questions are harder for users to answer, because they are more abstract and less related to activities in which the users have engaged, they do enable the users to express their initial opinions of the technical development teams' ideas.

5.3 Description of respondents

The questionnaire was distributed to deaf and hard of hearing people in the UK, Netherlands and Greece.

5.3.1 Description of respondents: The UK

The user questionnaire was distributed to deaf and hard of hearing people in the UK. The questionnaire was distributed to 373 deaf and hard of hearing people in the UK that had previously expressed an interest in helping RNID with its research. Of those that were sent the questionnaire 101 people completed and returned it in the freepost envelope that was supplied.

In the UK 48.5% of those that returned the questionnaires were male and 51.5% were female. In the UK 50% of those with a hearing loss are aged 65 or above. In the sample of those that completed the questionnaire in the UK, the distribution of ages was not representative of the general population with only 20.8% being aged 65 or above. Of the remainder of the sample, 49.5% were aged 46-65 years, 24.8% were aged between 31 and 45 and 5% were aged between 18 and 30 years.

To gain further insight into the demographics of this population, respondents were asked about whom they lived with and whether they were in full time employment. Results revealed that 21% lived alone, 62% lived only with people who are hearing, 11% lived only with other people that were also deaf or hard of hearing and 5% lived with deaf and hearing people. Results also revealed that 35% were in full time employment, 19% worked part time and 27% were retired. A small number of respondents were unemployed (3%), worked voluntarily (9%), and one participant was a student.

Thirteen percent of respondents did not have hearing aids or a cochlear implant (CI) and 4% had hearing aids but rarely used them. In the remainder, 77% of the total had a hearing aid in one or both ears and 6% had a cochlear implant in one ear. The type of aids people had was also varied with 35% having analogue aids, 59% having digital aids and 6%

having both an analogue and digital aid. Usage of hearing aids was also varied with 7% never wearing their aid. Of those that did use their hearing aids daily, 67% used them for more than 12 hours a day, 15% use them for 7-12 hours and 7% use their aids for 1-6 hours a day.

In the questionnaire respondents were asked to describe their hearing difficulties with and without their hearing aids. Responses are summarised in Figure 5.1 below. As would be expected a significant positive correlation was found between descriptions of the level of their hearing difficulty with and without an aid. With those who rated their hearing worse without an aid also rating their hearing worse with an aid. A surprisingly large number of respondents rated their hearing without an aid as "I am profoundly deaf", however this may be in relation to the fact that this was the only response available that did not define what an individual could or could not hear.

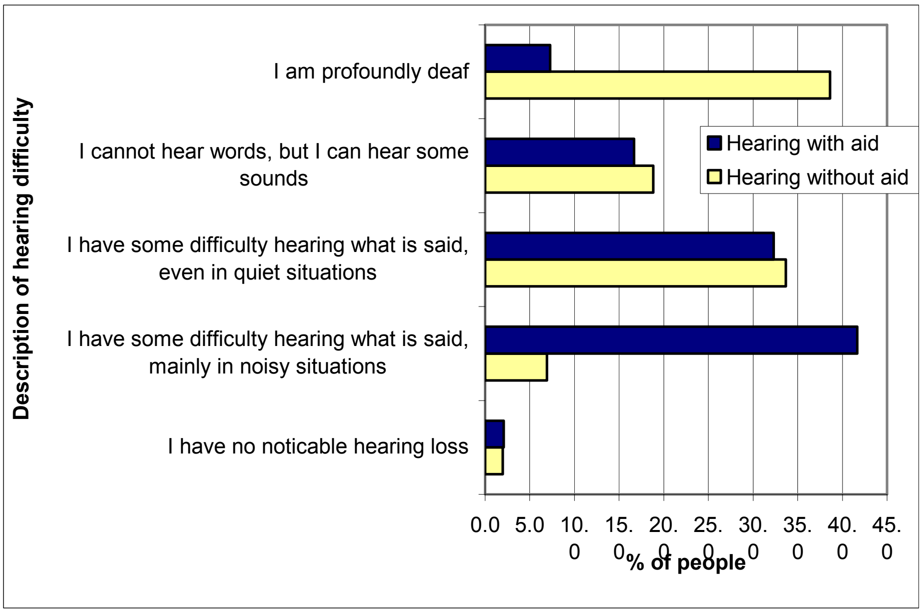

Figure 5.1: descriptions of hearing loss with and without aids for UK respondents

When asked when their hearing difficulties had started, 38% had started to have hearing difficulties prelingually (between birth and 3 years), 19% had developed hearing difficulties during childhood (4 to 17 years), with the remainder developing hearing difficulties during adulthood, with 16% between 46-64 years and 4% after they had turned 65. Seventy-five percent of respondents got their first aid over 10 years ago, and 14% got their first aid within the last 5-10 years.

Of those that completed the questionnaire 13% stated that Sign Language (BSL, SSE and finger spelling) was their preferred method of communication. A significant correlation ($p<0.001$) was also found between level of deafness without aids and preferred language, with those with greater hearing difficulties preferring sign language. When asked if participants were satisfied with their communication, 14% were not satisfied and 53% were only satisfied sometimes.

As vision could also affect the problems that respondents encountered, they were asked to describe their eyesight. However only 4% reported a difficult with their eyesight; in the remainder, 29% had good vision and 67% were able to read and see at a distance when using glasses.

5.3.2 Description of respondents: The Netherlands

The user questionnaire was distributed to 80 deaf and hard of hearing people in the Netherlands. Of these distributed questionnaires, 15 were given to hard of hearing people while they visited the department of Audiology of the VU University medical centre (Amsterdam) for hearing aid dispensing. Some of them completed the questionnaire during their visit, but most of them returned it in the freepost envelope that was supplied. Of those that were given the questionnaire, 12 returned it. Another 15 deaf and hard of hearing people were given the questionnaire during their visit of a hearing aid dispenser; 10 of them returned it. Another 50 questionnaires were sent to patients of the department of Audiology of the Erasmus medical centre (Rotterdam). Of them, 30 returned it in the freepost envelope that was supplied. Thus, of the 80 distributed questionnaires, 52 were returned.

Of the Dutch respondents, 27 were female and 25 were male.

The youngest respondent was 28 years of age, and the oldest respondent was 90 years of age. The distribution of the age of the respondents was skewed to older age; more than the half of the respondents were aged over 65. This is consistent with the increased incidence of hearing difficulties among older people.

Most of the respondents (71%) live with hearing people or alone (23%). The remaining 6% of the respondents live with other deaf or hard of hearing people. One respondent lives with both hard of hearing and hearing people. Most of the Dutch respondents are retired (61%), and about a quarter of the sample work full-time or part-time.

The respondents were asked to describe their hearing with and without the use of hearing aids or a CI. The described hearing with the use of aids was significantly ($p < 0.05$) correlated with the described hearing without aids: $r = 0.52$, $p < 0.01$, with those participants that reported greater hearing difficulties without their aids or CI, reporting greater difficulties with their aids or CI.

Figure 5.2 presents the description of the hearing (both with and without the use of aids) as given by the respondents.

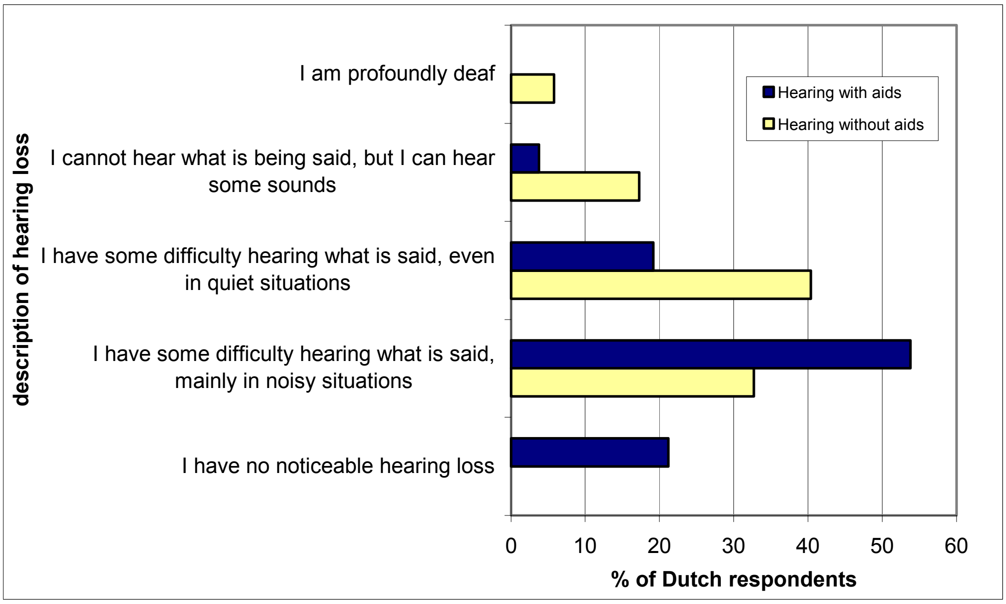

Figure 5.2: Descriptions of hearing difficulties with and without aids for Dutch respondents

Respondents were also asked to indicate their general satisfaction with their communication. Of the people that indicated that they have no noticeable hearing difficulties, 91% are satisfied with their communication. Of the people that indicated that they have difficulty hearing what is said in noisy situations, 79% are always and 14% are sometimes satisfied with their communication. Of the respondents that indicated that they even have difficulty hearing what is said in quiet situations, 50% are sometimes satisfied with their communication and 30% of them are not satisfied.

Most respondents had a hearing aid in both ears (62%) or a hearing aid in one ear (31%). Of the remainder, 2% had a CI, 2% had hearing aids but rarely used them, and 2% did not have hearing aids or a CI.

The number of years experience with their hearing aids varied widely among the Dutch respondents; almost half of them had got their first aid over 10 years ago, but 29% received their first aid less than one year ago. Of the remainder, most respondents got their first aid between 5 and 10 years ago.

Most of the respondents wear their aid(s) more than 12 hours a day (63%) or 7-12 hours a day (22%). A relative large number of Dutch respondents, 31%, do not know whether they have digital or analogue aids. Most other respondents indicated that they have digital aids (63%); the remaining 6% have analogue aids. All respondents prefer the use of Dutch above sign language.

The majority of the respondents (93%) are able to read and see at a distance; of them, 73% use corrective lenses. The other respondents use glasses but still have difficulty reading and/or seeing at a distance.

5.3.3 Description of respondents: Greece

The questionnaire was also translated into Greek and distributed by several professionals working with hard of hearing people in Athens and elsewhere in Greece. The final modified version of the Questionnaire were distributed electronically to the following groups of respondents:

- The Hellenic Federation for the Deaf (National Federation for the Deaf, Greece-HFD).

- The Greek National Foundation for the Deaf.

- The commercial sector: Epitropou Hearing Aids, Athens.

- Personal contacts willing to help in the distribution of the questionnaires; a researcher specializing in those who are Hard-of-Hearing, a graduate student of the Technical University of Athens and a user of hearing aids.

- Personal communication with elderly hard-of-hearing acquaintances, relatives and citizens contacted in local municipalities of the Athens area.

One hundred printed copies were distributed in addition to the electronically distributed questionnaires. The users contacted covered a wide age range and their occupations also varied widely; students and young professionals (18-30 years of age), full-time professionals (30-60 years of age), and retired citizens (over 60 years of age) were asked to fill in the questionnaire.

Despite the fact that several groups of respondents were contacted, it turned out to be very difficult to obtain answers from the users, at least within the given period of time.

One possible explanation of the observed delays or lack of responses is the fact that the questionnaire was distributed during the period of June and July 2005, during which many people are on holiday and schools in Greece are closed. It should also be noted that in Greece, due to high temperatures in the summertime, a large percentage of the elderly or retired citizens leave the cities during the summer and spend an extended period from June to September in a summer house or in their villages and are, therefore, not available for providing input in respect to the questionnaire. Thirty questionnaires were completed.

Of the 30 Greek respondents, 43% were male and 57% were female. Forty percent of the respondents were 18-30 years of age, 23% were 31-45 years of age, 13% were 46- 65 years of age and 23% were 65 years of age or older. Most Greek respondents have hearing aids in both ears (35%) or a hearing aid in one ear (28%). Thirty percent of the respondents do not have a hearing aid or CI; the majority of this group is over 65 years of age and is severely hearing impaired. One respondent has a hearing aid but rarely uses it, another respondent has a CI in both ears and one respondent has a hearing aid in one ear and a CI in the other ear.

The Greek respondents were also asked to describe their hearing difficulties with and without their hearing aids. Responses are summarised in Figure 5.3. In contrast to the results of the UK and the Netherlands, no significant correlation was found between their described hearing with and without hearing aids.

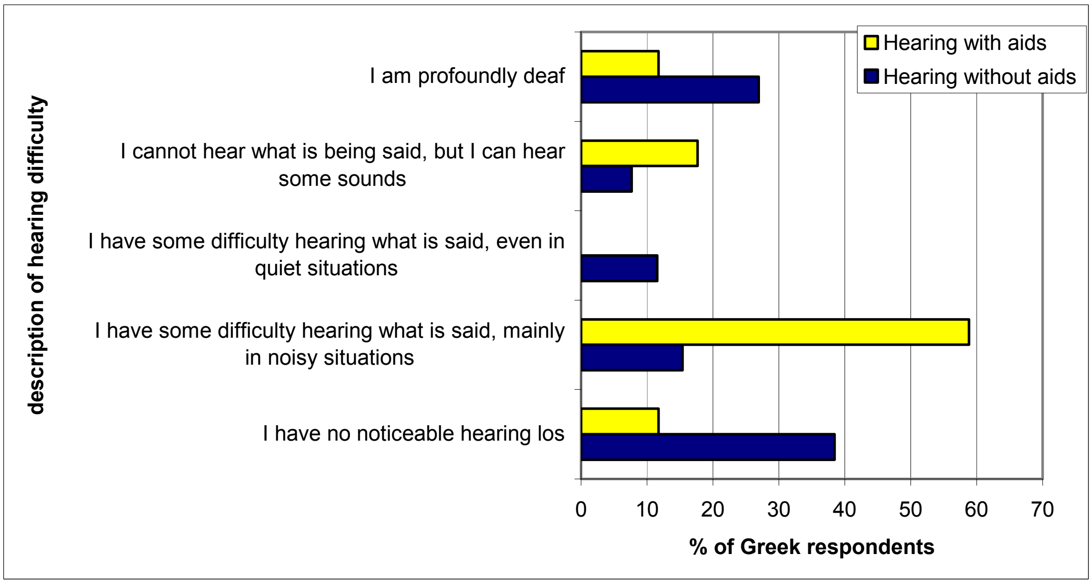

Figure 5.3: Descriptions of hearing difficulties with and without aids for Greek respondents

The majority of the Greek respondents (63%) live with people who are hearing, and 20% live alone. The remaining 13% of the respondents live with other deaf or hard of hearing people.

About one third (37%) of the Greek respondents work full-time, and about one third of the respondents (37%) are retired. Two Greek respondents are students, and also two respondents are unemployed. Two respondents are part-time employed; one of them is a student.

Respondents were also asked whether they are, in general, satisfied with their communication. Due to the relative low number of Greek respondents and the fact that 30% of them do not use a hearing aid, we have not specified the satisfaction with communication of subgroups that are based on the described hearing of the respondents.

Two-thirds of the Greek respondents are satisfied with their communication. Of the remaining 33%, only one (profoundly deaf) respondent was not satisfied with her communication; the others are sometimes satisfied with their communication.

Half of the Greek respondents started to have hearing difficulties prelingually (between birth and 3 years), and in another 13% of the respondents, hearing loss started between the age of 4 and 10. The remaining 37% became hearing impaired after the age of 65. Thus, onset of the hearing impairment of the Greek respondents is quite diverse, in most respondents, the hearing impairment started relatively early, while the hearing impairment of the remaining respondents started above the age of 65.

As expected, most the respondents who have been hearing impaired since childhood have used hearing aids for more then ten years. In general, most of the 70% of the Greek respondents that have a hearing aid, got their first hearing aid more then ten years ago (78%); 18% did get their first hearing aid between 5 to 10 years ago and only one respondent got his aid less than one year ago.

Of the Greek respondents that have a hearing aid, the majority wear their aid(s) more than 12 hours a day (78%). Two respondents wear their aids 7-12 hours a day, and also two respondents wear their aids 1-6 hours a day.

Almost half (46%) of the Greek respondents have a digital hearing aid. Twenty-seven percent indicate that they have an analogue aid, whereas the remaining 27% indicate that they do not know whether they have a digital or an analogue hearing aid.

The majority of the Greek respondents prefer Greek to sign language for face-to-face communication. Most respondents indicated that they use lip-reading during conversation.

Almost all Greek respondents are able to read and see at a distance, and slightly more than half of them (53%) use corrective lenses. Only one respondent reported that she has even difficulty reading and/or seeing at a distance when she uses glasses.

5.4 Results and analysis

As the questionnaire was translated into three different languages, the results from each country will each discussed separately, conclusions will then be drawn from this data.

5.4.1 UK User Questionnaire

5.4.1.1 Daily life

The questionnaire asked respondents about daily living and the level of problems that they encounter in different situations.

	No problems	Occasional problems	Frequent problems	Cannot manage in this situation	Do not encounter this situation
When watching sport, e.g. in a stadium	17%	4%	13%	15%	51%
Face to face conversation in quiet places	26%	65%	7%	2%	0%
When playing sport	12%	18%	8%	12%	50%
Watching television	20%	30%	32%	17%	1%
Work meetings	6%	27%	32%	12%	23%
Lectures or classes	2%	20%	38%	14%	26%
Communication with staff at shops, banks, etc.	8%	47%	39%	6%	0%
Over the telephone	10%	20%	41%	26%	3%
Conversation with others in the vehicle while driving	3%	24%	48%	24%	2%
Face to face conversation in noisy places	3%	21%	62%	14%	0%
At concerts, to hear the performance	17%	22%	13%	29%	19%
Listening to the radio	8%	22%	24%	38%	8%
At the cinema, to listen to the film	10%	19%	18%	41%	12%
At the theatre, to hear the performance	3%	14%	27%	42%	14%
Hearing announcements in public transport vehicles	2%	7%	34%	54%	2%
Hearing announcements in transport terminals	2%	4%	36%	56%	2%

Table 5.1: Activities of daily living and the percentage of UK participants that encounter problems

The results from the table above demonstrate that respondents find the most problems hearing verbal announcements in public places, with the most difficulty experienced when attempting to hear announcements in transport terminals, closely followed by a difficulty in hearing announcements in public transport vehicles.

Other public places where problems were experienced were in cinemas and at the theatre, where audiences have to listen carefully in order to understand what is being said. Respondents also stated that they cannot manage and encounter frequent problems in communication situations such as talking over the telephone and during conversations with others whilst driving, watching television and whilst listening to the radio.

Fewer problems are encountered in situations where face-to-face communication is possible, with face-to-face conversations in quiet places, as well as communication with staff in shops and other public places reported as being manageable for the majority of respondents. These findings highlight the importance of lip reading and visual feedback for deaf and hard of hearing people during communication. The importance of lip reading was supported by a comment made by one of participants; 'How can you lip read a tannoy?' in response to hearing announcements in public transport vehicles.

Participants' comments highlighted that driver and platform announcements are very unclear and therefore respondents claimed that they couldn't manage in these situations. Similar responses were given regarding hearing announcements in transport terminals, as respondents claimed that they have to rely either on third parties to inform them or information boards.

Participants' responses concerning going to the cinema support the findings in the table, as there was a strong agreement that they never went to the cinema unless the film is subtitled, otherwise the film is extremely hard to understand. Responses related to performances at the theatre display some similarities, with participants claiming that unless Stagetext (see description in section 5.4.1.3) is being used, they usually wouldn't go. Other reasons were that the infra-red systems or hearing loops rarely worked, and that lip reading is harder at the theatre as the stage lights distort their mouths. The responses to this question also provide further support for the importance of lip reading. 'I need to sit near the front to be able to lip read.'

Participants' comments also highlight that deaf and hard of hearing people find using the telephone extremely hard, finding unfamiliar accents and female voices particularly difficult to understand. Comments such as 'Even with T switch and amplified phone [I] am totally dependent on having a clear speaker' demonstrate that hearing aids are not guaranteed to improve communication over the phone.

In face-to-face conversations participants commented that when lip reading can be used, it is easier for the speaker to be understood, and also highlighted the importance of the clarity of the speakers' voice, as this largely determines whether they can be understood. In noisy situations, however, the participants agreed that lip reading was used more heavily, as the background noise drowns out any hearing that they might have.

As well as the situations where they encounter difficulties hearing what is being said, respondents were also asked about situations where they encounter difficulties being aware of things happening around them. The responses to these questions can be found in Table 5.2 below. By looking at the comments users made when answering these questions it is evident that respondents use a number of coping strategies to assist them.

To hear when someone is at the door, respondents reported using amplified doorbells, flashing lights, paging systems, and hearing dogs. However as can be seen in Table 5.2, 47% still encounter occasional problems and 27% encounter frequent problems. Problems such as being in a different room and not seeing the flashing light, using the T-setting on their aid to watch TV and being unable to hear the bell or when visitors knock rather than using the doorbell.

The majority of participants did not encounter needing to hear when a baby or child requires attention, however this is probably due to the distribution of ages in this sample. However those respondents that did encounter this situation, stated that they used a pager or baby adaptor, although Table 5.2 below, shows that such devices aren't always a solution with 7% unable to manage.

	No problems	Occasional problems	Frequent problems	Cannot manage in this situation	Do not encounter this situation
Awareness that your baby or child requires attention	10%	9%	4%	7%	71%
Waking up in the morning – using an alarm clock	46%	15%	12%	19%	8%
Awareness of events around your vehicle when driving	42%	32%	14%	6%	6%
Awareness that someone is calling your telephone	21%	43%	24%	9%	3%
Awareness that someone is at the door	18%	47%	27%	7%	1%

Table 5.2: Percentage of UK respondents that encounter problems being aware of things happening around them.

When hearing the telephone ring and waking up in the morning respondents again listed assistive devices that they used that helped some or all of the time. These included vibrating pagers, flashing lights, vibrating alarm clocks and relying on another person. When being aware of events whilst driving, assistive devices were not mentioned, however people commented that they compensate by being alert, using mirrors and relying on visual awareness, especially when they were unable to hear the sirens of emergency vehicles.

5.4.1.2 Speech recognition systems

As mentioned in section 3.2, a possible output of this workpackage may include an Automatic Speech Recognition systems (ASR). ASR systems are pieces of software that allow speech to be automatically translated into text. Questions were asked in relation to a new system that may work very quickly so that it can be used for telephone and face-to-face conversations.

So that the system can recognise voices accurately, people who respondents would regularly telephone or speak to may have to train the system to recognize their voice. This would involve them reading text into a computer or a telephone for a period of up to 10 minutes to ensure that the system can accurately recognise their voice. When asked if they would be willing to ask those whom they regularly speak to, to train a

Speech Recognition system, 70% were willing. When asked if they felt those they call would be willing to train such a system, only 19% felt that all would, 45% felt most would, 27% felt that only a minority would and 9% felt that no one would want to train such a system. These finding suggest that having to train the system, may deter many people from using the technology.

To use such a system for face-to-face conversations, the person that the deaf person is talking to may need to wear a headset microphone. When asked if this would this be acceptable, only 5% felt that everyone would find this acceptable and 38% felt that most would accept, 39% felt only a few people would accept wearing a headset microphone and 17% felt that nobody would accept. Although these findings are subjective and not representative of those who would be required to wear such a headset, again this is a factor that needs to be considered as it may affect who is likely to use the technology.

Only 13 respondents had used an ASR before and only one respondent was an experienced user. These users had used an ASR for dictation (correspondence, note taking) and communicating with friends. The majority of users were unaware of what ASR software they had used, with Dragon and IBM ViaVoice being the only brands of software that people named. From their experiences, the importance of accuracy and reliability was highlighted. The potential of the technology was summarised by one users comment, 'it works well when it works', however from their experiences this potential has not been reached with one user commenting that they 'had to use imagination to recognise some words.

5.4.1.3 Text Display systems

As has been discussed in previous sections (4), the output of the ASR and any other assistive information would need to be presented on some form of text display system. It was therefore decided that the questionnaires would look at the different text display systems that are used by deaf and hard of hearing people as well as asking respondents to consider where such systems may be of use.

Subtitles are provided on TV in the UK for deaf and hard of hearing viewers. Eighty-four percent of respondents stated that they use subtitles, with 75% of this group using subtitles 'all the time', 13% using them 'most of the time' and 12% 'just occasionally if they are available. When asked how much they rely on subtitles, 66% stated that they rely on them completely and cannot watch TV without them, 21% rely on for some programmes but not for others and 13% understand what they hear so just use subtitles for back-up.

The majority of those who didn't use subtitles stated that the reason was because they do not need the support, however 2 people stated that they did not use subtitles as they do not like reading subtitles and watching the pictures together and 1 person stated that they were unable to read the subtitles and watch the picture together. Twenty percent of those that use subtitles also stated that they do not always have time to read all the text. However the speed of subtitles appears to be a contentious issue as only 55% of those that use subtitles felt they were about right in terms of speed. Two percent stated that they felt subtitles are much too fast, and 23% a little too fast, and contrastingly 17% stated that they felt they are a little too slow and 2% felt they are much too slow.

In some programmes subtitles summarise what is said so that uses can get the meaning of what is said without having to read so much text. Of those that use subtitles only 19% stated that they liked this as it saves them having to read so much. Whereas 44% do not mind if speech is summarised in the subtitles or not and 37% would rather have the full text, even if it means reading it quickly.

Rolling text displays are already used in a number of devices and technologies. The questionnaire asked users about how successful users interactions with such technologies have been. The questionnaire also gave respondents the opportunity to provide additional comments about each of the technologies, however no comments were made.

The first technology the questionnaire asked about was textphones, which have a single line display where text moves across as new characters are typed. Only 30% had used textphone with a rolling text display before. Of the 34 respondents that had used such a textphone, none stated that they always encounter problems and 8 stated they sometimes have difficulty.

Another technology that involves a rolling text display is Palantype. Palantype is a method of machine shorthand used to provide a verbatim (word for word) transcript of meetings and presentations. A Palantype operator records speech on a special keyboard, which then appears on a monitor or screen for the deaf or hard of hearing person to read. Of the 52% of respondents that were aware of this technology, 45% had used it successfully and 10% had used it with limited success. The remainder were familiar with this system but hadn't actually used it.

The final existing rolling text technology that the questionnaire asked about was Speedtext. SpeedText is an electronic note taking service developed by RNID to support deaf and hard of hearing people in classrooms and meetings. A specially trained operator types a real-time transcript of what is being said, and this text is shown on a laptop to the deaf person. The majority (66%) of those that completed the questionnaire were not familiar with this technology, and of those that were familiar with the service, 67% had not used it. Of the 12 people that had used SpeedText, 5 felt that their experiences had been very successful, and the remaining 6 had used SpeedText with some success.

At this stage in the Hearcom project, partners were interested in investigating attitudes towards a system with a rolling text display on small handheld device similar to a mobile phone. The questionnaires asked about the situations where such system would be of use, the responses to which are summarised in the Table 5.3 below.

	Definitely of use to me	Likely to be of use to me	May be of use to me	Not of use to me
At transport terminals for announcements	61%	17%	18%	4%
Inside public transport vehicles for announcements	56%	20%	18%	6%
For telephone conversation	49%	19%	21%	11%
In lectures or classes	44%	16%	14%	26%
At the office and in meeting rooms for work	40%	20%	20%	20%
At ticket counters	38%	18%	33%	11%
At home for TV and radio	34%	23%	23%	20%
At other work locations, e.g. workshop, hall, outdoors	34%	23%	23%	20%
In car, e.g. phone use and listening to radio	33%	14%	19%	34%
Theatres and concert halls	33%	20%	24%	23%
At the cinema	32%	20%	23%	25%
Shops to communicate with assistants	22%	25%	33%	20%
While watching live sport to hear commentary	20%	10%	28%	42%
At home for conversation	19%	22%	32%	27%
Places of worship	17%	22%	23%	38%

Table 5.3: Situations where UK respondents felt a small handheld rolling text display may be of use.

From comparing participants' responses to these questions with the problems that they encounter in the daily lives (see table Table 5.1), results suggest that a device that provides text-based support would benefit deaf and hard of hearing people. From comparing these results it is also clear that the situations where participants were respondents were unsure or did not feel that textual support would be of benefit were also those situations where a higher percentage of participants did not encounter the situation.

	Text should be exactly the same as what is spoken	Text may be a summary of what is spoken	Text may be just keywords of what is spoken	Would not use in this situation
Telephone conversation	68%	19%	2%	11%
Work meetings	66%	17%	4%	13%
Television	58%	28%	2%	12%
Theatre and concert halls	54%	31%	1%	14%
Face-to-face conversation	54%	20%	2%	24%

Radio	47%	31%	2%	20%
Transport and other public announcements	43%	53%	2%	2%

Table 5.4: Percentage of UK participants that preferred each type of text output from the ASR in a number of different situations.

As with users' opinions towards when subtitles summarise what is said in TV programmes discussed above, the partners were also interested in the situations where respondents felt different levels of text display were suitable. The responses to these questions are summarised in Table 5.4 above. It is clear from these results that there are very few situations where users felt that just keywords recognised by the ASR would be enough. In the majority of situations, a large percentage of respondents stated that they would want the output from the ASR to be exactly the same as what is said. However for transport and other public announcements, a large percentage of participants would be happy with the output of the ASR to be a summary of what is spoken.

5.4.1.4 Personal Hearing System

The questionnaires also asked users about using a device that could offer users enhanced signal processing capabilities, to make it easier to hear in noisy places. Such a device could also have the capacity to be used in combination with other communication devices.

Respondents were asked in which location they felt that they would most likely need an additional device. Care must therefore be taken interpreting these results, as there was confusion answering this question, with a large number of participants ticking more than one option whereas other participants will have read the question correctly, and ticked only one option. Despite this, these percentages suggest that in many situations, especially those out of the home such a device may be beneficial.

- At home – 21%
- At work – 45%
- While travelling – 49%
- Public places (theatre, cinema, church etc…) – 63%
- During free time and leisure activities – 35%

Respondents were also asked about the types of features that they would like to see on such a device. Responses to these questions are summarised in Table 5.5 below.

	Must Have	Desirable	Of interest but not essential	Do not want this
Improve ability to hear speech in reverberant or echoey places like transport terminals or churches	59%	31%	7%	3%
Improve ability to hear speech and improve listening comfort in noisy situations, e.g. machine noises or while driving the car	71%	20%	4%	5%
Improve ability to hear speech when surrounded by many people, e.g. in a cafeteria or in the pub	75%	19%	2%	4%
Ability to connect to TV so that I hear the sound more clearly and without interference from background noise in the room	44%	33%	16%	7%
Ability to receive extra visual information on a screen e.g. the text of transport announcements or conversations	40%	38%	18%	4%
Ability to connect to my mobile phone so that I hear the sound more clearly and without interference from background noise in the room	33%	43%	15%	9%
Ability to connect to radio so that I hear the sound more clearly and without interference from background noise in the room	28%	32%	29%	11%
Ability to connect to doorbell to ensure that I hear it ring	28%	36%	29%	7%
Ability to connect to smoke detector to ensure that I hear if it goes off	42%	29%	24%	5%
Ability to connect to FM listening systems	13%	31%	32%	24%
Ability to connect to mp3 so that I hear the sound more clearly and without interference from background noise in the room	13%	21%	39%	27%
Ability to connect to HiFis so that I hear the sound more clearly and without interference from background noise in the room	29%	24%	38%	9%
Ability to connect to the internet so that I can use it as a web browser	15%	20%	42%	23%
Ability to connect to baby monitor to ensure that I do not miss sounds	11%	12%	16%	61%

Table 5.5: Preference for different features that could be incorporated into an additional device, from UK respondents.

All the statements that related to improving hearing and sound quality were all rated very positively by respondents. The ability to connect to a wide variety of devices was also rated highly. As discussed in D8.1, for the statements where a number of respondents have stated that they do not want a feature, this response is likely to have been chosen, as respondents do not feel they would encounter the situation, rather than such a device not being beneficial in such a situation.

The questionnaires also asked about the type of device that users would prefer. As can be seen in the responses summarised in Figure 5.4 below, a dedicated system that is simple to use was listed as a first choice by the highest percentage of people, however a device integrated into a mobile phone was more popular overall.

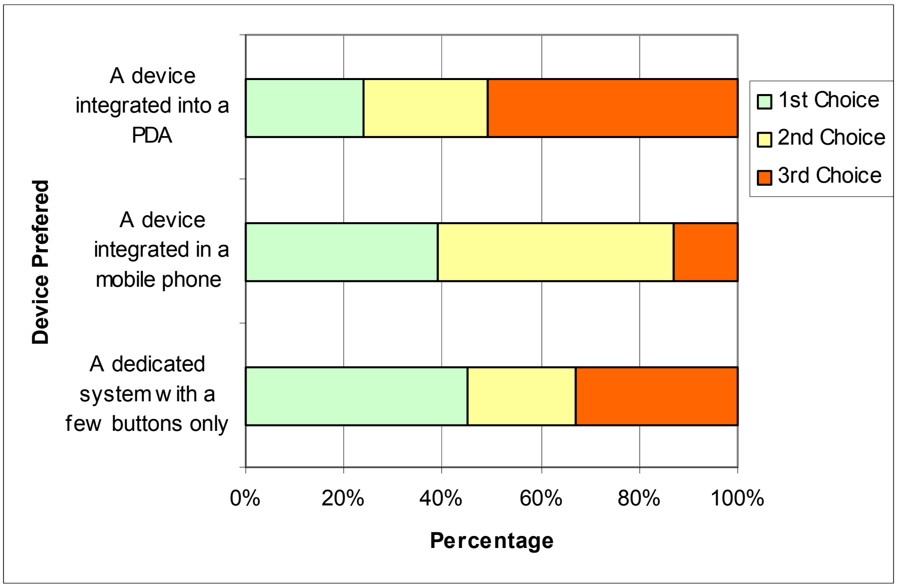

Figure 5.4: UK users preferences for the type of additional device they would be willing to carry

5.4.1.5 Additional devices

When asked about carrying an extra portable device that would help enhance hearing, 6% were not willing to carry an additional device. Most of those who were willing to carry an device, stated that they would want a small device, that was either small enough to be concealed in the palm of the hand (49%), or would be happy if it was visible, if it could be put on a table or held in hands whilst sitting (39%). Only 6% of respondents stated that they would be willing to carry a device the size of a laptop computer or small book.

When asked if they would be happy to carry more than one additional device to benefit from these extra facilities. Of those that were willing to carry an additional device 38% would only want to carry one, 47% were willing to carry up to two, and 15% were willing to carry up to 3 additional (mobile phone sized) devices.

Respondents were also asked about whether they already owned a mobile phone or personal digital assistant (PDA), and how often they carried these devices. Mobile phones were owned by 88% of respondents, with 2 of those who don't own a mobile phone planning to buy one, and only 4 not planning to. Of those that own a phone there was variety in how often users carried it, with:

- 63% carrying it every day all day long
- 7% carrying it every day and half the day
- 10% carrying it every day and less than 3 hours a day
- 20% only carrying it occasionally, not everyday (e.g. when traveling)

PDA's were less popular with only 10 respondents owning one, and only 2 planning to buy one, and 31 feeling that they maybe would buy a PDA. As with mobile phones how often those who owned a PDA carried it with them was varied with:

- 5 carrying it every day all day long and
- 2 carrying it every day and half the day
- 1 carrying it every day and less than 3 hours a day
- 3 only carrying it occasionally, not everyday (e.g. when travelling)

The tasks that PDA's were used for was also varied with 8 people using the agenda / calendar, 8 people using the address book, 7 people using email, 6 people using a text editor, 4 people using the internet and 1 person using a route finder.

5.4.2 Dutch User Questionnaire

5.4.2.1 Daily life

The questionnaire asked respondents about daily living and the level of problems that they encounter in different situations. The responses to these questions are summarised in Table 5.6 below. The colours indicate the answer category most frequently chosen by the respondents (but note that the answers on some of the questions were not normally distributed).

	No problems	Occasional problems	Frequent problems	Cannot manage in this situation	Do not encounter this situation
Lectures or classes	48%	10%	32%	8%	2%
Work meetings	67%	8%	18%	6%	0%
At the cinema, to listen to the film	41%	27%	16%	14%	2%
At the theatre, to hear the performance	39%	18%	22%	18%	4%
At concerts, to hear the performance	36%	28%	24%	10%	2%
When watching sport, e.g. in a stadium	68%	8%	10%	10%	4%
When playing sport	46%	16%	20%	18%	0%
Face to face conversation in quiet places	0%	77%	21%	2%	0%
Watching television	4%	37%	37%	20%	2%
Face to face conversation in noisy places	2%	14%	41%	39%	4%
Listening to the radio	8%	33%	39%	18%	2%
Communication with staff at shops, banks, etc.	0%	34%	44%	22%	0%
Over the telephone	0%	38%	40%	18%	4%
Conversation with others in the vehicle while driving	2%	28%	42%	26%	2%
Hearing announcements in transport terminals	16%	16%	22%	33%	14%
Hearing announcements in public transport vehicles	20%	16%	18%	33%	14%

Table 5.6: Activities of daily living and the percentage of Dutch respondents that encounter problems

In summary, most respondents have problems hearing announcements in public transport vehicles or public transport terminals. Communication in noisy places, with staff at shops, over the telephone, while driving and listening to the radio is also problematic for most respondents. Conversation in quiet places and watching television is less demanding. The other listening situations are not problematic for most respondents, although some respondents report frequent problems in lectures or classes. The amount of problems experienced by the respondents depends on the availability of an inductive loop. The frequency with which problems are experienced while watching television and listening to the film at the cinema strongly depends on the availability of subtitles.

Respondents were then asked to indicate the amount of problems and difficulty they experience with being aware of things happening around them. The question aimed at the listening situation with the use of aids. The results are presented in Table 5.7.

	No problems	Occasional problems	Frequent problems	Cannot manage in this situation	Do not encounter this situation
Awareness that someone is at the door	50%	27%	10%	2%	10%
Awareness that your baby or child requires attention	8%	6%	4%	0%	81%
Awareness that someone is calling your telephone	48%	35%	6%	4%	6%
Waking up in the morning – using an alarm clock	49%	10%	14%	8%	18%
Awareness of events around your vehicle when driving	55%	16%	4%	2%	22%

Table 5.7: Percentage of Dutch respondents that encounter problems with being aware of things happening around them

The majority of the respondents do not have any problems with being aware of things happening around them. About a quarter of the respondents (27%) indicated occasional problems with being aware that someone is at the door, 10% frequently experiences problems with being aware of that. In addition, quite some respondents (35%) indicated that they occasionally have problems with being aware that someone is calling their telephone or textphone; 14% of the respondents has frequently have problems with waking up in the morning using an alarm clock. Regarding the mean age of the respondents, it is not surprising that most of them do not encounter the situation that their baby or child requires attention. Respondents furthermore commented that the problems with being aware of events around their vehicle when driving could be compensated with the fact that many of these auditory events (e.g. alarm sounds of police and ambulance) attract their attention visually (e.g. flashing lights).

5.4.2.2 Speech recognition systems

Most of the Dutch respondents (56%) would feel comfortable asking people they regularly speak with to train the ASR system. However, 37% of the respondents think that a minority of the people would be willing to train and 20% think that nobody would accept that. The remaining 24% think that most people would be willing to train the system. None of the Dutch respondents has ever used automatic speech recognition software.

5.4.2.3 Text display systems

Half of the Dutch respondents do not need to use subtitles when they watch TV, but 13% did not know of this service. 23% of the respondents do use it with success and 6% use it although they do not always have time to read it all.

Of the respondents that use subtitles (16 respondents), the majority (63%) use them all the time that they are available. Half of the users rely on them for some programs and not for others; 25% uses them only as a backup source and 25% rely on them completely. None of the respondents think that the speed of TV subtitles is too slow, 75% think that the speed is about right, whereas 19% think that the speed is much too fast and 6% thinks that the speed is a little too fast.

Respondents were also asked what kind of subtitles they would prefer, e.g. whether they want the full text of what has been spoken or rather a summary of the speech. 44% of the respondents would rather have the full text instead of summarised text, even if that means reading quickly, 33% do not mind either way and 22% would like summarised text, as that would save them from having to read so much.

Respondents were also asked to indicate what kind of information they would prefer in several listening situations. The results are displayed in Table 5.8. For each listening situation, the percentage of respondents that would like a particular kind of text information to be provided on a rolling text display is presented. The majority of the respondents that would use the display in a given situation would like to have text that is exactly the same as what is spoken. Of the remainder, many respondents indicate that the text may be a summary of what is spoken. Few people indicated that the information may be just keywords of what is spoken.

	Text should be exactly the same as what is spoken	Text may be a summary of what is spoken	Text may be just keywords of what is spoken	Would not use in this situation
Telephone conversation	44%	19%	2%	35%
Face-to-face conversation	56%	10%	2%	32%
Transport and other public announcements	40%	40%	5%	15%
Radio	37%	30%	2%	30%
Television	42%	30%	2%	26%
Theatre and concert halls	59%	13%	5%	23%
Work meetings	46%	9%	6%	40%

Table 5.8: The percentage of Dutch respondents that would like information to be displayed in a particular way on an assistive rolling text display

Only one of the Dutch respondents uses a textphone that has a rolling text display. This respondent is the one that indicated that he is profoundly deaf when using no hearing aids. He has no trouble reading the text on his textphone.

Respondents were asked whether they would like to use a portable device with a rolling text display that display assistive information. They were asked to indicate the expected assistance in each of several listening situations. The results are displayed in Table 5.1. Colours indicate the answer category most frequently chosen. Note however that the answers to some of the listed situations are not evenly distributed. For example, most of the respondents do not like to use the display at ticket counters, but quite some of the respondents indicate that the use of the display in that situation would likely be of use to them.

	Definitely of use to me	Likely to be of use to me	May be of use to me	Not of use to me
Shops to communicate with assistants	7%	33%	31%	29%
Places of worship	18%	18%	18%	46%
Theatres and concert halls	19%	17%	26%	38%
Cinema	14%	11%	24%	51%
At office and in meeting rooms for work	11%	31%	8%	50%
At other work locations, e.g. workshop, hall, outdoors	11%	26%	21%	42%
In car, e.g. phone use and listening to radio	10%	23%	18%	50%
At ticket counters	19%	26%	23%	33%
At transport terminals to hear announcements	30%	32%	16%	23%
Inside public transport vehicles to hear announcements	33%	21%	16%	30%
At home for TV and radio	16%	22%	27%	36%
At home for conversation	9%	24%	22%	44%
While watching sport to hear commentary	7%	20%	22%	51%
For telephone conversation	35%	21%	12%	33%
Lectures or classes, to hear the teacher	26%	21%	11%	42%

Table 5.9: Situations where Dutch respondents felt a small handheld rolling text display may be of use

Both listening situations where most of the respondents would definitely use the display (i.e. inside public transport vehicles and for telephone conversation) are situations in which the speaker is not visible. Other situations for which most respondents indicate that the display would likely be of use are at shops to communicate with assistants and at transport terminals to hear announcements. In other situations, most of the respondents do not need a display, although quite a few respondents would like to use the display during lectures or classes.

More severe hearing difficulties (hearing with aids as described by the respondents) are associated with a higher need to use the display during lectures or classes, during telephone conversations or inside public transport vehicles to hear announcements.

Some of the respondents indicated that the use of a rolling text display in the car might be dangerous. Also, respondents commented that the use of a display at the cinema or theatre might be difficult, because it could interfere with looking at the film / performance.

5.4.2.4 Personal Hearing System

Respondents were asked to indicate where they would like to use a communication device that might offer enhanced signal processing capabilities and the capacity to be used in combination with other communication devices. The question listed five situations; respondents had to indicate where they would most need such a device. However, most respondents ticked more than one box. This indicates that the question might have been misunderstood by a number of respondents; therefore, results should be interpreted with caution.

The situation most often mentioned by the Dutch respondents was at public places: half of the respondents indicated that would like to use the device at places like the theatre and at the cinema. 37% of the respondents indicated that they would like to use the device while travelling and 31% would like to use it during free time and leisure activities. At home (25%) and at work (21%) were also mentioned quite often as places where the device would be of use.

Respondents were asked to indicate what kind of device they would prefer, e.g. a dedicated system or a device integrated in an already existing system. Three options were listed and respondents indicated their preferred and less preferred options by numbering the three possibilities. The results are presented in

Figure 5.5. As can be seen from the figure, in general the majority of the respondents prefer a dedicated system with a few buttons only. A device integrated into a mobile phone is the second choice of the majority of the respondents, whereas a device integrated into a PDA is the least preferred kind of device.

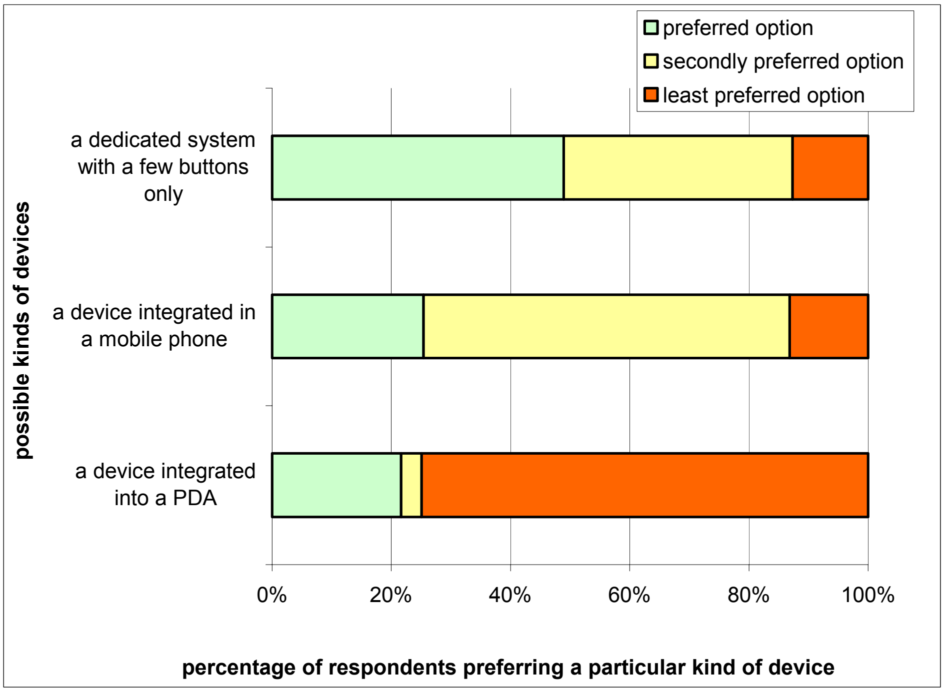

Figure 5.5: The kinds of assistive device preferred by Dutch respondents

The questionnaire asked the respondents to indicate whether they would like additional features to be incorporated in the assistive device. The results are presented in Table 5.10. The colours indicate the answer category most frequently chosen – if two answer categories were chosen by the same number of respondents, these two answer categories are both coloured.

	Must have	Desirable	Of interest but not essential	Do not want this
Improve ability to hear speech in reverberant places	41%	41%	16%	2%
Improve ability to hear speech and improve listening comfort in noisy situations	46%	41%	11%	2%
Improve ability to hear speech when surrounded by many people	56%	29%	9%	7%
Ability to connect to my mobile phone	24%	48%	21%	7%
Ability to connect to mp3 player	13%	21%	39%	28%
Ability to connect to radio	10%	44%	29%	17%
Ability to connect to TV	25%	43%	21%	11%
Ability to connect to HiFi	17%	31%	33%	19%
Ability to connect to baby monitor	5%	8%	45%	43%
Ability to connect to doorbell	29%	36%	20%	16%
Ability to connect to smoke detector	33%	33%	16%	19%
Ability to connect to the Internet	3%	23%	41%	33%
Ability to connect to FM listening systems	15%	29%	29%	27%
To receive extra visual information on a screen	21%	44%	21%	14%

Table 5.10: Percentage of Dutch respondents that would like several additional features to be included in the assistive device

The results show that the device must have a feature that improves the ability to hear speech when surrounded by many people; 56% of the respondents indicate this as an essential feature. Many respondents also indicated that a feature that improves the ability to hear speech and the listening comfort in noisy situations as important; 46% indicate that the device must have this feature and 41% indicate that this is a desirable feature. A feature that improves the ability to hear speech in reverberant places is indicated by 41% as a necessary feature and an additional 41% indicate that this is a desirable feature. Finally, the ability to connect the device to a smoke detector is often mentioned as a necessary (33%) or a desirable feature (33%). Less important features are the ability to connect the device to a baby monitor and the ability to connect the device to the Internet; respectively 45% and 41% of the respondents think these features are of interest, but not essential. Also quite a few respondents indicate that they do not want these features.

5.4.2.5 Additional Devices

Nineteen percent of the respondents indicated that they are not willing to carry any additional portable device that would enhance their hearing. 58% would be willing to carry up to one additional device, whereas 19% would be willing to carry up to 2 additional devices. None of the Dutch respondents would be willing to carry up to 3 additional devices.

Of the respondents willing to carry an additional portable device, 62% would want something small enough to be concealed in the palm of hand or keep in a pocket or ladies handbag. 19% felt that it would be acceptable to be visible – to be put on table or held in hands. No one felt it would be acceptable to be the size of a laptop or large book

Of the Dutch respondents, 81% have a mobile phone. Over a third (39%) only use it occasionally (e.g. when travelling) but almost as many respondents use it every day and all day long (37%). Half of the remaining 24% use their mobile phone half the day, and half of them use their mobile phone less than three hours a day. Of the ten respondents that do not have a mobile phone, only one is planning to buy one. Five respondents indicate that they may buy one; 4 respondents are not planning to buy one.

5.4.3 Greek User Questionnaire

5.4.3.1 Daily Life

The questionnaire also asked Greek respondents about daily living and the level of problems that they encounter in different situations.

	No problems	Occasional problems	Frequent problems	Cannot manage in this situation	Do not encounter this situation
Watching television	60%	17%	10%	13%	0%
When watching sport, e.g. in a stadium	27%	13%	13%	13%	33%
When playing sport	23%	20%	0%	7%	40%
Work meetings	20%	10%	17%	7%	47%
Conversation with others in the vehicle while driving	17%	17%	13%	10%	37%
At concerts, to hear the performance	23%	37%	20%	10%	3%
At the theatre, to hear the performance	27%	43%	7%	17%	17%
Face to face conversation in noisy places	33%	47%	17%	3%	10%
Over the telephone	17%	47%	17%	20%	0%
Face to face conversation in quiet places	33%	50%	10%	0%	7%
Communication with staff at shops, banks, etc.	27%	50%	17%	3%	3%
Hearing announcements in public transport vehicles	17%	40%	17%	23%	3%
Listening to the radio	17%	33%	23%	27%	0%
Hearing announcements in transport terminals	10%	37%	20%	30%	3%
At the cinema, to listen to the film	23%	57%	3%	33%	7%
Lectures or classes	3%	20%	23%	17%	30%

Table 5.11: Activities of daily living and the percentage of Greek respondents that encounter problems

As can be seen in Table 5.11 above, most Greek respondents frequently have problems with hearing during lectures or classes. The majority of the Greek respondents indicated occasional problems at most of the listed listening situations. Relatively easy listening situations are watching television, watching sports at a stadium, playing sport and work meetings.

Many users commented that they have few or almost no problems during a telephone conversation with friends and family, but may have problems during a conversation with strangers. Also, many respondents commented that the amount of problems that are encountered depend on factors such as distance, intensity of sound and availability of visual stimuli in contexts such as lectures and business meetings.

It is important to note that the questions related to problems encountered by the users in various places and situations were regarded very positively, once they had received the questionnaire, respondents were particularly keen on answering them.

As well as the situations where they encounter difficulties hearing what is being said, respondents were also asked about situations where they encounter difficulties being aware of things happening around them. The responses to these questions can be found in Table 5.12 below.

Almost half of the Greek respondents report frequent problems hearing that someone is at the door. However, almost a third of the respondents report no problems at all with being aware that someone is at the door. About twenty percent of the respondents report occasional problems being aware of events happening around their vehicles, but almost the same number of respondents do not have any problems. Four of the nine respondents that do encounter the situation that their baby or child requires attention, do not have problems with being aware of that. Almost half (43%) of the Greek respondents do not have problems with being aware that someone is calling their telephone. However, almost the same number of respondents either have occasional problems (20%) or cannot manage at all (20%).

	No problems	Occasional problems	Frequent problems	Cannot manage in this situation	Do not encounter this situation
Awareness that someone is calling your telephone	43%	10%	20%	20%	7%
Awareness that your baby or child requires attention	14%	7%	10%	0%	69%
Waking up in the morning – using an alarm clock	59%	0%	3%	27%	10%
Awareness of events around your vehicle when driving	20%	23%	0%	7%	50%
Awareness that someone is at the door	30%	10%	47%	10%	3%

Table 5.12: Percentage of Greek respondents that encounter problems being aware of things happening around them.

5.4.3.2 Speech recognition systems

Most Greek respondents (70%) would feel comfortable asking people they regularly speak with to train the ASR system. However, 63% of the respondents think that a minority of the people they would ask would be actually willing to train the system. Seventeen percent of the respondents think that all people they talk to would be willing to train the ASR system; also 17% thinks that most of the people they talk to would be willing to do that. One respondent think that no one would be willing to train the system.

Sixty percent of the Greek respondents think that a few of the people they talk with would be willing to wear a headset microphone, and 7% think that no one would accept this. Of the remaining 27%, 20% think that most people would accept wearing a headset, and 7% think that all people would accept that.

5.4.3.3 Text display systems

Most of the Greek respondents indicate that they heavily rely on TV subtitles; the majority of them are rather satisfied by their use.

TV subtitles are successfully used by 75% of the respondents, and 8% use them although they do not always have time to read all of the text. Of the other 17% of the respondents, 13% don't need to use subtitles, and one respondent does not use them because he does not like reading subtitles and watching pictures together.

As stated above, most of the respondents that use subtitles (83%) rely either completely (40%) or heavily (45%) on them. Fifteen percent uses them only for backup.

The need for subtitles when watching TV is also expressed in the number of respondents that use subtitles all the time that they are available: 70%; the other respondents use them most of the time that they are available.

None of the respondents think that the speed of TV subtitles is too slow, or much too fast. More than half (57%) think that the speed is a little too fast, whereas the other respondents indicate that they think that the speed of subtitles is about right.

Respondents were also asked what kind of subtitles they would prefer, e.g. whether they want the full text of what has been spoken or rather a summary of the speech. Although quite a lot of the respondents indicated that the speed of subtitles is a little too fast, most of the respondents (63%) would rather have the full text, even if that means reading quickly. Eleven percent of the respondents indicate that they would like a summary of what is said, because that would save them having to read so much, but 26% percent report that they would not mind either way.

Only two of the respondents have a textphone with a rolling text display; one of them has no difficulties reading the text on the textphone, whereas the other experiences sometimes difficulties to read the text on his textphone.

Those people contacted in Greece are not familiar with Speedtext and have never used Palantype.

Respondents were also asked to indicate what kind of information they would prefer in several listening situations. The results are displayed in Table 5.13. For each listening situation, the percentage of respondents that would like a particular kind of text information to be provided on a rolling text display is presented.

The majority of the respondents that would use an assistive display in a given situation would like to have text that is exactly the same as what is spoken. Of the remainder, many respondents indicate that the text may be a summary of what is spoken.

Some respondents indicate that they would use a rolling text display during telephone conversations, to listen to the radio, to watch TV and at the theatre and in concert halls. These respondents would like text to be exactly the same as what has been said. Only 63% of the respondents would use the system during work meetings, but also in this listening situation, most of the respondents prefer the text to be the same as what is spoken.

	Text should be exactly the same as what is spoken	Text may be a summary of what is spoken	Text may be just keywords of what is spoken	Would not use in this situation
Telephone conversation	63%	15%	19%	4%
Face-to-face conversation	50%	11%	7%	22%
Transport and other public announcements	56%	15%	11%	19%
Radio	67%	15%	4%	15%
Television	70%	22%	0%	7%
Theatre and concert halls	67%	19%	0%	15%
Work meetings	44%	7%	11%	37%

Table 5.13: The percentage of Greek respondents that would like information to be displayed in a particular way on an assistive rolling text display

Respondents were asked whether they would like to use a portable device with a rolling text display that displays assistive information. They were asked to indicate the expected assistance in each of several listening situations. The results are displayed in Table 5.14, with the colours indicating the answer category most frequently chosen.

Most respondents think that visually displayed assistive information would be of use in the listed situations. In particular, people think that they would use the device for telephone conversations and at home for TV and radio. In addition, most respondents would like to use the device at transport terminals and in transport vehicles to hear announcements. Less agreement is about the use of the device at places of worship and at work locations like workshops, hall and outdoors. Relatively few Greek respondents report that they would like to use it in the car (see Table 5.14).

	Definitely of use to me	Likely to be of use to me	May be of use to me	Not of use to me
Shops to communicate with assistants	60%	4%	12%	24%
Places of worship	33%	17%	33%	17%
Theatres and concert halls	40%	16%	24%	20%
Cinema	54%	13%	21%	13%
At office and in meeting rooms for work	44%	8%	16%	32%
At other work locations, e.g. workshop, hall, outdoors	39%	4%	17%	39%
In car, e.g. phone use and listening to radio	21%	17%	33%	29%
At ticket counters	60%	12%	20%	8%
At transport terminals to hear announcements	76%	8%	8%	8%
Inside public transport vehicles to hear announcements	64%	16%	8%	12%
At home for TV and radio	64%	20%	8%	8%
At home for conversation	40%	16%	24%	20%
While watching sport to hear commentary	40%	12%	16%	32%
For telephone conversation	76%	16%	8%	0%
Lectures or classes, to hear the teacher	56%	16%	4%	24%

Table 5.14: Situations where Greek respondents felt a small handheld rolling text display may be of use

5.4.3.4 Personal Hearing System

Respondents were furthermore asked to indicate where they would like to use a communication device that offers enhanced signal processing capabilities and the capacity to be used in combination with other communication devices.

Forty percent of the Greek respondents would like to use an additional portable device at home. Some respondents (28%) reported that they would like to use the device during free time and leisure activities, and of the remainder, most respondents (17%) would like to use it at work. Three respondents would like to use the device in public places, and only one person would like to use it while travelling.

Respondents were asked to indicate what kind of device they would prefer. Three options (a dedicated system or a device integrated in an already existing system) were listed and respondents indicated their preferred and less preferred options by numbering the three possibilities. As can be seen from Figure 5.6, the majority of the respondents prefer a dedicated system with a few buttons only. A device integrated into a mobile phone is the second choice of the majority of the respondents, whereas a device integrated into a PDA is the least preferred kind of device. This is despite the fact that the latter kind of device would include additional functionalities like an agenda, addresses and email. It is important to note that an interaction between gender and preference was observed; men were more inclined to use additional apparatus and to choose devices with a multitude of functions. In contrary, women preferred easy-to-use devices with few buttons.

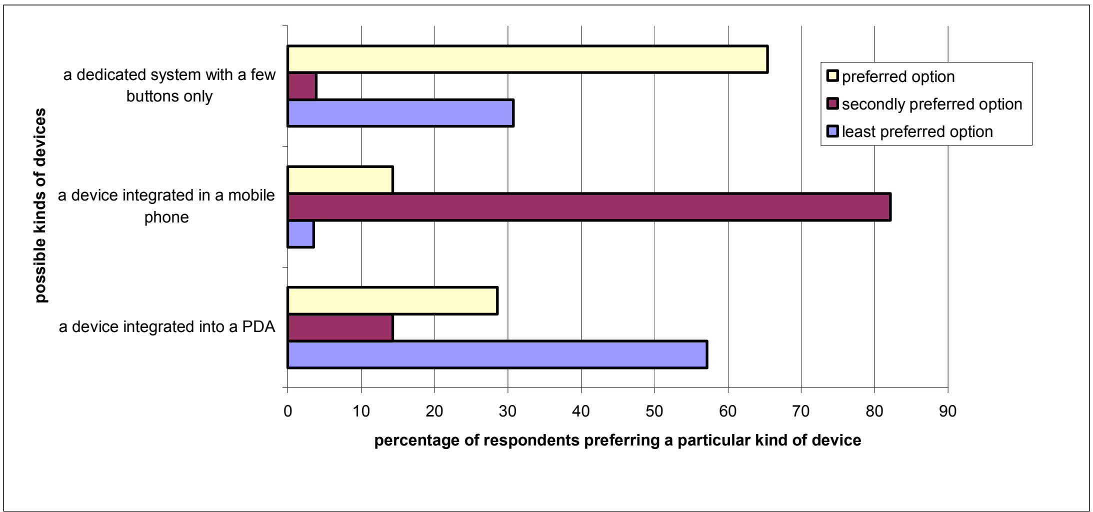

Figure 5.6: The kind of assistive device preferred by Greek respondents.

The questionnaire also asked the respondents to indicate whether they would like additional features to be incorporated in the assistive device. The results are presented in Table 5.15. The colours indicate the answer category most frequently chosen.

	Must have	Desirable	Of interest but not essential	Do not want this
Improve ability to hear speech in reverberant places	68%	21%	11%	0%
Improve ability to hear speech and improve listening comfort in noisy situations	64%	21%	7%	7%
Improve ability to hear speech when surrounded by many people	50%	36%	14%	0%
Ability to connect to my mobile phone	75%	18%	7%	0%
Ability to connect to mp3 player	25%	18%	50%	7%
Ability to connect to radio	54%	21%	14%	11%
Ability to connect to TV	64%	14%	21%	0%
Ability to connect to HiFi	32%	25%	39%	4%
Ability to connect to baby monitor	48%	15%	37%	0%
Ability to connect to doorbell	71%	18%	7%	4%
Ability to connect to smoke detector	68%	18%	11%	4%
Ability to connect to the Internet	18%	21%	46%	14%
Ability to connect to FM listening systems	25%	25%	43%	7%
To receive extra visual information on a screen	64%	29%	0%	7%

Table 5.15: Percentage respondents that would like several additional features to be included in the assistive device

As can been seen in Table 5.1, the Greek respondents think that many of the listed potential additional features that could be incorporated into the device are of importance.

The majority of the respondents wish additional features to be incorporated into their mobile phone. Also, the device should be able to connect to the doorbell and it should improve speech comprehension in reverberant places and when surrounded by many people. It additionally should improve hearing and listening comfort in noisy places. Features that enable a connection to a smoke detector, TV and radio are also important, like the ability to receive extra visual information on a screen. Slightly less important is a feature that would enable a connection to a baby monitor.

Less important features are features that enable connections to mp3 players, HiFi systems, the Internet or FM listening systems. Some respondents report that these features are of interest, but not essential.

5.4.3.5 Additional devices

Respondents were asked whether they would be willing to carry an extra portable device to help enhance their hearing. Only one Greek respondent indicated that he would not be willing to carry an extra device. The majority of the respondents (66%) would be willing to carry a very small device (small enough to be concealed in the palm of the hand) and 31% would be willing to carry an extra device that could be put on the table or held in hands when sitting. No one would be willing to carry a device with the size of a laptop computer or a large notebook. These results should be interpreted with caution, because when the users are asked how many devices they would be willing to carry if the devices were the size of a mobile phone, no less than 45% of the respondents indicate that they would not be willing to carry any device at all. Of the remainder, 48% would be willing to carry one device, while two respondents would be willing to carry up to two additional devices. It seems that the Greek respondents are only willing to carry very small additional devices – many are not willing to carry a device the size of a mobile phone.

More than three quarter of the Greek respondents (77%) has a mobile phone. Half of the 23% that has no mobile phone are planning to buy one. Most users that do not have a mobile phone are aged over 65 years and are mostly women.

Three quarter of the respondents that have a mobile phone carry it every day and all day long. Of the remainder, 17% carry their mobile phone less than three hours a day, whereas two respondents carry their mobile phone half the day.

Most respondents do not have a PDA, with the majority wishing to obtain one.

5.5 General conclusions

As can be seen from the descriptions of respondents (see section 5.3), there was a very varied mix of ages and levels of hearing difficulties amongst those that completed the questionnaire. Although in the UK the distribution of ages did not entirely match that of the general population, as the sample was obtained at random it is not felt that this affects the validity of the data.

The problems that respondents encounter in their daily lives highlight the individual nature of hearing difficulties. Factors such as hearing ability, aids used, age and support (assistive devices) all appeared to affect the amount and severity of problems encountered. Despite this variety, greater difficulty was reported in public and noisy locations, and those locations where visual stimuli are not available, such as being unable to see the other person to lipread. Assistive devices that gave visual or tactile feedback appear to play a large role in helping deaf and hard of hearing people become aware of what is happening around them. However not all respondents encounter all situations.

The large number of respondents that encounter problems understanding what is being said and being aware of what is happening around them, support the development of the Personal Communication System (PCS) proposed in this workpackage. However the responses to the questionnaire highlight that care needs to be taken during the development of the assistive applications that will be linked to the PCS, to ensure that they are used.

Very few respondents that completed the questionnaire had used Automatic Speech Recognition (ASR) systems, and even less had used such systems successfully. Users commented that they disliked the errors and inaccuracies made, with problems outweighing the benefits of the technology for many users. If such technology required training to produce accurate speech to text translations, not all users stated that they would be willing to ask others to train the ASR. Also only a small minority of users felt that all those they asked, would be willing to train an ASR system. The questionnaire also highlighted that if a system required the person whose voice was being converted to text to wear a headset, then only a few people would be willing to wear this. Therefore uptake and use of an ASR system is likely to be very low if it includes certain features.

Respondents' usage of existing text display systems highlight that text often provides valuable support to those with a hearing loss. Subtitles were used by a large number of respondents, with some being completely reliant on the subtitles, whereas others stated that they used subtitles to clarify what they were hearing. In contrast, rolling text displays had been used by more respondents in the UK than either the Netherlands or Greece, with the majority of respondents' experiences being successful.

Results highlighted that problems are sometimes caused by the speed of text display systems, with some finding them too fast and others too slow.

The situations where respondents felt such a text display was likely to be of use were those where the greatest problems were encountered, especially those where the speaker is not visible. However when asked if people would prefer text to summarise what is being said, the general consensus seemed to reflect that a large proportion would only want the full text, and very few respondents stated that they would be happy with just key words.

Support was also shown from respondents towards the enhanced processing capabilities and the ability to connect to a variety of other communication devices, as proposed with the PHS. With such a system seen as being more beneficial in public locations than at home and work, where other assistive devices are normally already available.

When asked about how they envisaged such a device, a dedicated system with only a few buttons was the preferred option, with a system integrated into a mobile phone also receiving a lot of support. A device incorporated into a PDA did not receive much support, however very few respondents owned a PDA or were considering buying one. One thing that did come from the results was that very few respondents were willing to carry more than one device, and the majority all wanted a small device that could be carried in the palm of a hand.

6 Professionals questionnaire

6.1 Aim

This questionnaire was intended to get the opinion of professionals, both in audiology and other related fields, on a similar range of issues to those examined in the user questionnaire.

6.2 Questionnaire design

The professional questionnaire was distributed to people, such as hearing therapists, who regularly engage with deaf and hard of hearing people. Similar in design to the user questionnaire, professionals were asked about their views with regards to the needs of users. These questions included;

- Activities of Daily living
- Text display systems
- Personal hearing system

6.3 Description of respondents

The professional questionnaire was sent to 50 hearing therapists in the UK, and 21 questionnaires were returned in the freepost envelope provided. All hearing therapists were taken from lists owned by RNID. The length of time they had been working in the profession, ranged from 1 year to 28 years with a mean of 13 years. The number of patients seen by each of the hearing therapists was varied with one hearing therapist seeing '7-10' patients in an average week and another seeing 'at least 60' patients in an average week, with the most common response being 20 – 30 patients.

The professional questionnaire was sent to five professionals working at the department of Audiology of the VU medical centre (Amsterdam). All distributed questionnaires were returned. Each of the professionals were selected to cover different areas of expertise, with two audiologists, one social worker, one assistant audiologist (acoepedist) and one psychologist / researcher.

The number of years that they had worked in their profession ranged from 2 to 39 years. In general, the professionals saw 10 patients a week (the number of patients however ranged from 1 to 40), and most of these patients are younger than 55 years of age.

6.4 Results and analysis

6.4.1 UK Professional Questionnaire

This section discusses the responses of the 21 professional hearing therapists that returned the questionnaire in the UK.

	Very few have trouble	Less than half have trouble	More than half have trouble	Most cannot manage in this situation
At concert halls	11%	58%	21%	10%
Watching TV	17%	56%	22%	6%
When participating in sports	21%	53%	21%	5%
When watching sporting events	21%	53%	21%	5%
Face to face communication in quiet places	48%	52%	-	-
At the theatre	5%	48%	43%	5%
At the cinema	29%	33%	33%	5%
Conversation while driving	-	10%	76%	14%
Work meetings	-	15%	75%	10%
Lectures or classes	-	21%	68%	11%
Communication with staff in shops, banks etc.	-	29%	67%	4%
Face to face conversation in noisy places	-	14%	67%	19%
Over the telephone	-	38%	57%	5%
Listening to the radio	5%	29%	57%	9%
Hearing announcements in transport terminals	-	5%	38%	57%
Hearing announcements in public transport vehicles	-	5%	38%	57%

Table 6.1: UK Hearing Therapists opinions of when their patients' hearing is not sufficient in different situations.

As can be seen in Table 6.1 above, the responses from the professionals reflected many of the same views as users, with regards to when patients encounter problems communicating. Both sets of responses highlight that more problems are encountered by deaf and hard of hearing people when trying to understand what is being said in public places. Comments made by the professionals also suggested that whether or not patients encountered problems was 'dependent on lip reading skills'.

	Very few have trouble	Less than half have trouble	More than half have trouble
Awareness that their baby or child requires attention	33%	50%	17%
Awareness of events around their vehicle when driving	22%	56%	22%
Waking up in the morning – using an alarm clock	24%	62%	14%

Awareness that someone is at the door	5%	67%	28%
Awareness that there is an incoming call on their telephone or textphone	9%	62%	29%

Table 6.2: When and where UK professionals felt their patients encounter difficulties being aware of things happening around them

Professionals were also asked about the situations where they felt that patients encounter difficulties being aware of things happening around them. The option 'Most cannot manage in this situation' was also given but none of the professionals chose this response. As can be seen from the results in Table 6.2 above, professionals highlighted that a number of respondents encounter problems with each of the situations. With more patients encountering difficulties with more common activities such as being aware of phone calls and the doorbell than with activities such as when a child or baby requires attention. Again professionals' opinions were very similar to those of their users with situations being ranked in a similar order.

	Very popular	Quite popular	Neither popular nor unpopular	Quite unpopular	Very limited interest
For telephone conversations	67%	33%	-	-	-
Lectures or classes	67%	33%	-	-	-
At transport terminals for announcements	60%	35%	5%	-	-
Inside public transport vehicles for announcements	57%	38%	5%	-	-
Theatres and concert halls	55%	35%	-	-	5%
Places of worship	45%	45%	5%	-	5%
At ticket counters	40%	50%	5%	-	5%
At the cinema	35%	50%	5%	-	10%
At the office and in meeting rooms for work	29%	71%	-	-	-
While watching sport to hear commentary	5%	75%	10%	5%	5%
At other work locations, e.g. workshop, hall, outdoors	19%	62%	14%	5%	-
Shops to communicate with assistants	14%	57%	10%	10%	9%
At home for TV and radio	33%	43%	14%	5%	5%
In car, e.g. phone use and listening to radio	10%	42%	37%	5%	5%
At home for conversation	20%	40%	25%	5%	10%

Table 6.3: UK Hearing therapists' opinions of locations where a rolling text display may be useful to those with a hearing loss.

Hearing therapists were asked to identify the locations where a rolling text display that displayed typed text or the output of an ASR system would be of benefit to deaf and hard of hearing people. Table 6.3 below illustrates their responses to these questions, and how the majority of professionals felt that a text display system would be popular in all situations. As with users' responses, the hearing therapists indicated that a text display system was likely to be more popular in the locations where greater problems are encountered.

Hearing therapists were also asked where they felt those with a hearing loss were most likely to require a device with advanced signal processing capabilities, such as echo removal and the ability to connect to other communication devices. Many professionals ticked more than one response, however the following percentage of professionals felt that such a device would be beneficial in each of the following locations:

- 33% at home
- 81% at work
- 57% while travelling
- 68% in public places (theatre, cinema, church, etc.)
- 24% during free time / leisure time

However as there was variation in how the different professionals responded to this question, care needs to be taken when drawing conclusions from this research.

The final questions that professionals were asked was in relation to the importance of different features that could be incorporated into an additional portable device, such as the PCS proposed in this workpackage. The responses to these questions are illustrated in Table 6.4 below.

As with the users' responses, professionals rated most features as desirable with preference for improved listening and sound quality. The ability to connect to a wide variety of devices was also rated positively, with such capabilities being seen as more beneficial in public locations than at home or work.

	Must have	Desirable	Not essential
Improve ability to hear speech in reverberant or echoey places like transport terminals or churches	48%	52%	-
Improve ability to hear speech and improve listening comfort in noisy situations, e.g. machine noises or while driving the car	71%	29%	-
Improve ability to hear speech when surrounded by many people, e.g. in a cafeteria or in the pub	81%	19%	-
Ability to connect to my mobile phone so that I hear the sound more clearly and without interference from background noise in the room	29%	71%	-

Ability to connect to mp3 player so that I hear the sound more clearly and without interference from background noise in the room	10%	38%	52%
Ability to connect to radio so that I hear the sound more clearly and without interference from background noise in the room	14%	62%	24%
Ability to connect to TV so that I hear the sound more clearly and without interference from background noise in the room	43%	52%	5%
Ability to connect to HiFi so that I hear the sound more clearly and without interference from background noise in the room	14%	71%	14%
Ability to connect to baby monitor to ensure that I do not miss sounds	62%	29%	9%
Ability to connect to doorbell to ensure that I hear it ring	38%	43%	19%
Ability to connect to smoke detector to ensure that I hear if it goes off	52%	29%	19%
Ability to connect to the Internet so that I can use it as a web browser	5%	62%	33%
Ability to connect to FM listening systems	24%	62%	14%
To receive extra visual information on a screen, for example the text of transport announcements or conversations	33%	53%	14%

Table 6.4:UK hearing therapists' opinions of the importance to users of different features that could be incorporated into an additional portable device

6.4.2 Dutch Professional Questionnaire

In general, the professionals found it quite difficult to answer the questions. In addition, the data of only six completed questionnaires were available. Therefore the available data for many of the questions is insufficient to present detailed results, so only the general comments made by the professionals will be described.

Professionals were asked to indicate in which situations the hearing of their patients is not sufficient to understand what people are saying. In Table 6.5, the results are presented. The colours indicate the answer category most frequently chosen for each listed location or listening situation. The professionals commented that the severity of problems encountered by their patients strongly depends on the characteristics of the environment, such as the opportunity to lip-read the speaker.

Situation	Legend
Face to face, quiet	Most have no trouble (dark green)
Waking up - alarm clock	< 50 % have trouble (light green)
Awareness events around vehicle	> 50 % have trouble (light orange)
Cinema	Most cannot manage (orange)
Playing sports	
Watching TV	
Communication staff at shops noisy	
Conversation while driving	
Awareness someone is at the door	
Awareness that baby / child requires attention	
Awareness incoming call	
Lectures or classes	

Work meetings
Announcements in transport vehicles
Announcements in transport terminals
Face to face, noisy
Theatre
Concert halls
Watching sport
Radio
Over the telephone

Table 6.5: Dutch professionals' opinions of the number of patients that experience hearing problems in different listening situations

Professionals were asked in which of a given list of listening situations their patients would like to use an assistive device in which an automatic speech recognition system and a display that presents additional information are implemented.

The professionals report that a device in which a speech recogniser and a display are implemented is likely to be helpful at places of worship, at the office and in meeting rooms for work and at ticket counters. Also, the professionals think that their patients would like to use it at other work locations, for telephone conversations and during lectures or classes. One professional suggested that the use of an automatic speech recognition system might be helpful during visits to the doctor or at the hospital. Several professionals furthermore commented that the use of a display while driving might be dangerous. The use of an assistive display at the cinema or theatre might also interfere with watching the film or performance.

Professionals were asked at which location their patients would mostly need an additional portable device. The data on this question also do not permit a detailed analysis. The professionals found it very difficult to answer this question, because they think it strongly depends on the individual situation of the hearing impaired person. For example, a retired person does not need the device at work, but for the working hard of hearing people, the need for an assistive device at work might be substantial.

Finally, professionals were asked to rate the importance of several additional features that could be included in the assistive device. According to them, the device must have a feature that improves the ability to hear speech when surrounded with many persons. Also of importance is a feature that improves the ability to hear speech in reverberant or echoey places and a feature that would improve the ability to hear speech and improve the listening comfort in noisy situations. The ability to connect the device to the doorbell is also rated as important. Less important features are the ability to connect the device to a mobile phone, smoke detectors or the Internet.

6.5 General conclusions

Despite the small sample of professionals that completed the questionnaire, their opinions were based on interactions with a large number of patients over many years.

Professionals reported very similar views to users with regard to the problems that patients encounter, namely difficulty understanding what is said in public and noisy locations or where visual cues and assistive devices are not present. Comments made by professionals also supported the individual nature of peoples hearing losses, with the problems patients face being affected by the situations they encounter and the coping strategies they use as well as their level of hearing loss.

Similarities were also found between the locations where professionals and users felt that an ASR system that converts what is said into text could be used. With such a system being of greater benefit to patients in locations where a greater number of problems are encountered. These locations included public locations, and those where visual cues are not available. However such a system was not seen as beneficial in the home, and professionals commented that when watching TV or whilst at the cinema or theatre, a display on a separate device may distract or interfere with the performance.

The advanced processing capabilities of the PCS were also considered beneficial to patients in a wide variety of locations. However comments highlighted that the locations where this would be needed were likely to be dependent upon the situations that each individual patient encounters. The features that users would want on such a device were also related to their individual needs, however, improved clarity and sound quality to assist listening in noisy and public locations, and the ability to connect to a variety of other devices were all considered important.

7 User requirements

7.1 Requirements based on the user and professional research

The results gained from the users and professionals who completed the questionnaires, highlight the problems that deaf and hard of hearing people encounter understanding what is being said and being aware of what is happening around them. These findings also support the need for the development of the PCS and assistive devices proposed in this workpackage.

The increased processing power and connectivity of the PHS were rated as very important features on such a device. Such a system has the potential to allow people to adapt and use the device according to their own individual needs. However as was seen with the comments made about existing technologies, care needs to be taken that all devices meet the needs of users and do not create additional problems, which are likely to prevent uptake and usage of the technology.

One of the assistive technologies linked to the PHS is an Automatic Speech Recognition (ASR) system that allows a visual display of auditory source on a rolling text display allowing users to read what is being said or see keywords. Responses from users highlighted that not all users would be willing to ask people to train such a system and that not everyone would be willing to train such a system if asked. The person whose speech is being converted to text having to wear a headset was also seen as a factor that may deter people from using such a device.

Both professionals and users stated that they felt a text display system would be beneficial in noisy locations and those locations where visual cues are not available. For example replacing announcements in public transport terminals, where the speaker is not visible with text. However from users' experiences with existing text displays care needs to be taken in selecting the speed at which the text moves across the display. A large proportion also stated that they would not want the text to summarise what is being said.

In general users stated that they were willing to carry an additional device. However comments highlighted that this needs to be small and simple to use to ensure that it is acceptable to as many people as possible. Therefore despite users desire and potential need for a wide variety of features, care needs to be taken to ensure features are not included for features' sake. Any features that are included need to carry out their purpose without creating additional problems if users are going to try and keep using them.

As a number of features are likely to be on one device, care needs to be taken to ensure that the interface between these features is clear and simple to use.

It is therefore recommended that users be involved as much as possible throughout the development process. This will ensure that the final device meets users' needs. If this does not occur it is likely that users will not be satisfied with the performance of the device, deterring them from using it.

7.2 User requirements in relation to technical aspects

Below some of the technical aspects of user requirements are discussed based on the questionnaire results. The technical requirements themselves will be specified in future reports.

7.2.1 PCS and PHS

The user requirements gathered support the development of a device that can link with other devices (The PCS is described in detail in section 4.1) and has improved signal processing capacity (The PHS is described in detail in section 4.4). The advantages that are possible through such a device could have a great impact on the lives of those who encounter communication problems. Users preference for greater processing capacity before connectivity could also be of special interest to hearing aid developers.

Ideally users will want the device to be as small, lightweight and as easy to use as possible. Due to limitations in existing devices it is likely that early prototypes will be demonstrated using an existing platform with a larger size and weight. However, it is important that all software is developed according to standards, so that as other smaller and more powerful devices become available the software can be transferred to new devices. Such devices are also likely to have different controls. Thus, care needs to be taken to ensure that the software is usable on all devices. One possibility to do so is the usage of software frameworks such as .net or OSGi, which have the disadvantage of slowing down software execution because there interpreting / runtime compiling nature. Another option is the restriction to ANSI-C.

The requirements in relation to the personal communication link that allows the PCS to connect to hearing devices is discussed in greater detail in D-8-1. As the PCS will allow users to connect to a wide variety of different technologies, such as phones, listening systems and public address systems the selection and control of these devices needs to be simple, clear and easy. Otherwise man-machine interface problems similar to those encountered with many existing technologies are likely to occur.

As many of devices, such as PDA's and notebooks have their own additional functionality, care needs to be taken during evaluation of prototypes to ensure that the prototypes themselves are being evaluated, rather than the device on which they are being run.

7.2.2 Speech recognition system

ASR technology has the potential to change the lives of those with communication problems by providing them with textual information of what is being said. However, the technical limitations of state-of-the-art ASR technology currently prevent many of these benefits from being realized. As described in section 4.2, the most crucial issue for efficient speech recognition is the speaking style of the user. It well known that in spite of the remarkable recent progress in Large Vocabulary Recognition (LVR), ASR is still far behind the ultimate goal of recognising free conversational speech uttered by any speaker in any environment. For a state of the art speech recognition system in noise free conditions the WER is about 8%, but the system's performance degrades and drops up to 45% for spontaneous speech.

The ASR's time response depends on the quality of the input speech file. The speech quality affects the speech recognition performance and the system's time response. This implies that the better the quality of the captured audio, the higher the recognition rate and the faster the response.

Users highlighted their concerns with regards people's willingness to train an ASR. The speech recogniser that has been developed by ILSP does not require a training session for a new speaker/user. The system is speaker independent and a short speaker adaptation procedure is incorporated into it. Therefore, this system's feature meets the user's requirements for no training. However comments from those users who had used an ASR, illustrate the high levels of accuracy that are expected. Errors produced by the ASR reduce the benefits of the technology.

Users also indicated that they were unsure if others would be prepared to wear a headset microphone when using an ASR to convert what they are saying into text. The use of a headset microphone improves the speech recognition performance since the captured audio signal is of better quality. Although in some cases a headset microphone is needed, for example many PDA's have incorporated microphones that seem to work perfectly. However if not using a headset microphone is likely to affect the performance of the ASR, then this needs to be made clear to users.

The speech recognition system will not only provide a single transcription of what the user has uttered but also a confidence score per each recognised word. The speech recognition result is more reliable when the per word confidence score is high. This gives the possibility to the user to ignore low confidence scored words.

7.2.3 Rolling text display

The outputs of the ASR and other textual information can be presented to users using a rolling text display. Displaying information visually has the potential to improve communication for a large number of people in noisy or reverberant environments as well as generally for those with hearing difficulties. The development of text displays for a number of the scenarios (see section 4.3) was also supported by the locations where users and professionals felt problems were encountered. However, many users felt that displaying text obtained by speech recognition on a handheld device would be distracting at the cinema, theatre or TV.

With a large number of deaf and hard of hearing people being over the age of 65, it is very likely that they will also experience visual problems. Therefore, any text display developed should allow for control of text size. From comments about existing rolling text displays, some users may also prefer to be able to control the speed at which text moves across a device.

It has been suggested that the ASR could be used to produce keywords or phrases from the incoming audio. Such a system received very little support from users. Many stated, that they would want the full text even if they were unable to read it all. The reasons for this are unclear, and further research would be needed to discover whether displaying unreliable recognised speech would be detrimental to comprehension. Research would also be needed to discover if phoneme based output would assist users in understanding what is being said.

8 Dissemination and Exploitation

The potential for exploitation of a Personal Communication System (PCS) and new assistive applications for people that have communication problems will be high. However, it will take time to encourage the many actors in this area.

The processing power of present PDA's and Smart phones as basis for a PCS gives serious limitations on performance. However, the development of small tablet PCs show that these limitations are likely to be overcome in a few years.

The PHS system can already be used for field-testing of new algorithms. The PHS can also be an alternative for present day hearing aids for some people. In the long run the application and exploitation potential of the PHS may improve considerably when wire-less links with headphones, earpieces or hearing aids are available.

The potential of supporting visual text information in parallel to audio information is promising, but still in the research phase. Its application in practice is not likely for the first years. For the longer-term, text display algorithms, personalized to the individual communication needs, are expected to be used in combination with real-time wireless text services and with speech recognition.

The usefulness of automatic speech recognition (ASR) for hearing impaired people is still very limited due to the high error rates at present. In the long term, practical use will become possible when recognition models improve and are tailored to the assistive needs of hearing impaired people. The development of a client-server version of the ASR will be a first step towards the practical application for hearing impaired persons.

The results of the user questionnaires show interesting results that should be presented to the scientific world through presentations at meetings and through publications.

At this moment a scientific paper is under preparation on the first results of a study on the combined presentation of text and speech under noisy conditions for normal hearing people.