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Legislation, Standardization and Technological Solutions for Enhancing e-Accessibility in e-Health

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1. Introduction

"It is usual to consider human dignity as the basis for human rights. In this sense, this term is used to refer to a number of features that characterize humans and that serve to express their uniqueness. […] Thus, the idea of human dignity rests on a human being characterized by his or her capacity and performance in carrying out a particular social role. This has been translated into the conception of rights. Indeed, human rights theory has been founded on a model of the individual, characterized mainly by his or her "capacity" to reason, "capacity" to feel and "capacity" to communicate. It is this model that is (and which has traditionally been) the prototype of the moral agent, that is the prototype of a subject able to participate in moral discourse. […] This is what we often refer to as moral "capacity", being also a trait of individuals as moral agents" [1].

In recent decades advances in Assistive Technology (AT) and in Information and Communication Technology (ICT) have influenced the lives of people with disabilities or special needs. Developments in the knowledge and understanding of disability, and changes in the social and legal framework —as a result of the "Rights of People with functional diversity " and the "Right to an Independent and Dignified Life"— have led to Electronic Accessibility (e-Accessibility) and Universal Design (design for all).

For years, the terminology used in the field of functional diversity resulted, more often than not, in undesirable results both at the legal level and in the sphere of political action. For this reason, since the mid 1970's people with functional diversity have voiced their objections to words such as "disability" and "handicap", words which were too closely confined to a medical and diagnostic approach and which barely reflected the shortcomings and imperfections of society itself in its response to the phenomenon of disability.

In 1980, the World Health Organization (WHO) [2] created the International Classification of Impairments, Disabilities, and Handicaps (ICIDH) to provide a unifying framework for classifying human functioning and disability as health components. After international revision efforts coordinated by the WHO, the World Health Assembly on May 22, 2001, approved the International Classification of Functioning, Disability and Health (ICF). Functioning and disability are viewed as a complex interaction between the health condition of the individual and the contextual factors of the environment as well as personal factors.

The picture produced by this combination of factors and dimensions is of "the person in his or her world." The classification treats these dimensions as interactive and dynamic rather than linear or static. It allows for an assessment of the degree of disability, although it is not a measurement instrument. It is applicable to all people, whatever their health condition. The language of the ICF is neutral as to etiology, placing the emphasis on function rather than condition or disease. It also is carefully designed to be relevant across cultures as well as age groups and genders, making it highly appropriate for heterogeneous populations. The ICF puts the notions of 'health' and 'disability' in a new light. It acknowledges that every human being can experience a decline in health and thereby experience some degree of disability. Disability is not something that only happens to a minority of humanity. Thus, the ICF 'mainstreams' the experience of disability and recognizes it as a universal human experience. By shifting the focus from cause to impact it places all health conditions on an equal footing allowing them to be compared using a common metric – the ruler of health and disability. Furthermore, the ICF takes into account the social aspects of disability and does not see disability only as a 'medical' or 'biological' dysfunction. By including contextual factors in which environmental factors are listed, the ICF allows the impact of the environment on a person's functioning to be recorded [3].

As the XXI century progresses, so too does the concept of design for all which involves contemplating the possible requirements of all patients including the elderly and people with disabilities. Design for all is "*the intervention in environments, products and services with the aim that everyone, including future generations, regardless of age, gender, capabilities or cultural background, can enjoy participating in the construction of our society, with equal opportunities participating in economic, social, cultural, recreational and entertainment activities while also being able to access, use and understand whatever part of the environment with as much independence as possible*" [4]. This new concept appears a suitable way to ensure equal opportunities for all citizens and their active participation in society. Design for all means overcoming the stigma of difference that has been traditionally associated with people with functional diversity and it assumes that their conditions regarding the environment are on the same level as other more common and shared conditions such as age, the ability to undertake activity or the temporary restriction of some function. This assumes that the human dimension is not defined by capabilities, or measures, but should be viewed more generally in such a way that diversity is the norm rather than the exception. Therefore, the values of this new paradigm lead to a new culture in which disability-related needs (even if they remain the guide and the motivation) are no longer the absolute centre and reason for action. Everyone is susceptible to limitations or conditioning factors at certain times. Therefore, the idea of design for all is to think of those with the greatest needs and thus benefit everyone. Thus, products such as phones with increasingly large keys, remote controls with large and simplified buttons, talking lifts, etc. have become increasingly popular in recent years.

Within the broad field of disability, e-Accessibility is one aspect that is becoming increasingly relevant at present. The problems involved in bringing technology to people with functional diversity makes it necessary to implement a user experience along with an interface specific to their needs, avoiding any kind of a problem with the hardware required to interact with medical devices in telemedicine cases. While the potential of AT and ICT is growing, e-Accessibility is more urgently necessary to enable people with disabilities to take part in almost any living environment. In 2006, the International Conference on Computers Helping People with Special Needs (ICCHP) [5] summarized this process with an equality equation (Equality = e-Quality) [6] symbolizing how much equal opportunities in society depend on e-Accessibility. Providing e-Accessibility should be seen as a global challenge in the global economy. Given these challenges, the ICCHP puts special emphasis on the problems of people with disabilities in countries with political, economic and social difficulties. It is in those countries where access to AT and ICT is most hindered.

The computer world is also a market in which people with disabilities are becoming very important potential customers (as demonstrated, for example, by Microsoft's international agreements [7] to adapt its operating system and carry out awareness campaigns about the importance of accessibility in new technologies). In this context, the ISO 9241 family of standards provides for accessibility in communication, directly or indirectly. These standards cover the design of equipment and services for people with a wide range of sensory capabilities, physical and cognitive, including those who are temporarily disabled and elderly people. The technological requirements to be met by services and applications in order to be e-accessible are described in this family of standards.

With this background, a scheme of ideas is proposed below in Figure 1, divided into six sectors, which details the relationship between the different fields that a person with

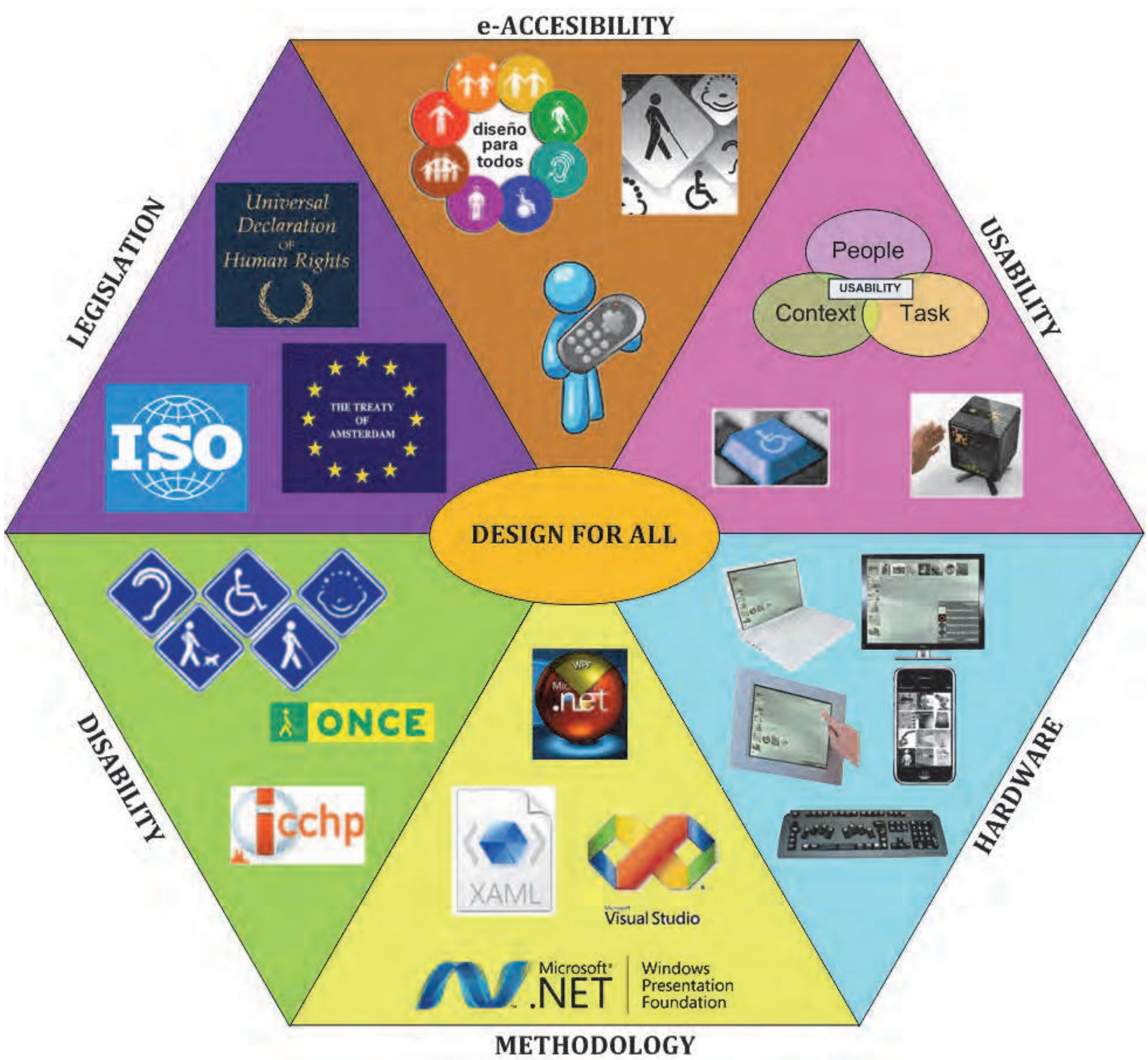


Fig. 1. Outline of ideas for e-Health solutions design based on the paradigm of design for all

functional diversity finds around him. This outline of ideas follows the paradigm of design for all, taking people with special needs as the centre of the design, which will determine the developed software applications. In this broad context, the first sector in Figure 1 covers types of disabilities, the barriers faced and their foundations. In the area of legislation, all the laws that protect the rights of people with disability are reviewed. In the section on e-accessibility, the concept of design for all allows new designs to be developed according to recommendations on how to bring new technologies closer to the specific requirements of people with disability. The area of usability defines the ease with which people can use a particular tool or other human-made object to achieve a particular goal. Thus, the design of new e-Health solutions has to comply with the specific characteristics of usability for people with disability. The hardware section covers the design of a graphical interface that applies to any platform and has the necessary adaptive hardware for people with disability. Finally, the methodology area covers technical guidelines to be followed with different systems, programming tools and communication standards.

To conclude this introduction, it should be noted that great efforts have been made in recent years by major international companies driving the development of AT, design for all and the adoption of open standards to enable people with functional diversity to improve their opportunities for independence and employability through technology. This tremendous boost has been led in recent years by various initiatives, institutions, companies and organisations, some of the most important of which are shown in Table I.

	Accessible Technology	http://accessibletech.org
	ADA. Americans with Disabilities Act	http://adaresources.org
	Disability.gov	www.disability.gov
	DPI. Disabled Peoples' International	www.dpi.org
	European Congress on Visual Disability	www.eurovisionrehab.com
	ICCHP. International Conference on Computers Helping People with Special Needs	www.icchp.org
	ICDVRAT. International Conference Series on Disability, Virtual Reality and Associated Technologies	www.icdvrat.reading.ac.uk
	International Women and Disability Congress	www.micongreso.gva.es
	ISLRR. International Society for Low Vision Research and Rehabilitation	www.islrr.org
	NFB. National Federation of the Blind	www.nfb.org
	ONCE Foundation. Spanish National Organization for the Blind	www.fundaciononce.es
	WFD. World Federation of the Deaf	www.wfdeaf.org
	WFDB. The World Federation of the Deafblind	www.wfdb.org
	WID. World Institute on Disability	www.wid.org
	World Congress of Inclusion International	www.inclusion-international.org

Table 1. International initiatives that promote e-Accessibility and usability

This chapter presents a comprehensive review of the most recent advances in legislation, standardization and technological solutions for enhancing e-Accessibility in e-Health. In Section 2, the current state of the legislation in this field is reviewed. Section 3 describes and analyzes the main characteristics of ISO 9241, the standard that regulates the legal implementation of the design requirements for e-Accessibility. Finally, the recommended technology requirements, as well as the specialized medical devices and products for each type of disability, are presented and discussed in Section 4.

2. State of the art. Legislation

This section analyzes and details the current state of the international law on e-Accessibility, usability and disability. Accessibility of ICT products and services has become a priority in Europe as a result of demographic change. Due to the fact that people are living longer, it is calculated that by the year 2025 there will be 113.5 million people over the age of 65 in the European Union [8]. It is estimated that there are approximately 100 million elderly people and 50 million people with disabilities in Europe, 15% of the total population (800 million approx.). To this percentage must be added the population which is temporally disabled due to illness or injury, and people that have disabilities such as dyslexia or allergies. A recent study in the United States [9] revealed that 60% of working-age adults could benefit from using accessible technologies because they experience impairments or difficulties when using current technologies.

The concept of disability has undergone a profound transformation in recent years. Historically perceived from a health and social protection perspective, it is currently based on a bio-psycho-social vision. Society cannot and should not ignore the contributions, expertise and creativity of each and every one of its members. Thus, and according to the recent United Nations Convention, people with functional diversity are "those people with long-term physical, mental, intellectual or sensory impairments which, in interaction with various attitudinal and environmental barriers, hinders their full and effective participation in society on an equal basis with others"

The directives of the European Union (EU) state that the equal treatment principle requires the absence of any direct or indirect discrimination based on religion or belief, racial or ethnic origin, disability, age or sexual orientation. The principle of non-discrimination is a general principle of EU law included in several legal texts. Disability as a human problem that affects all of us equally, regardless of the factors surrounding us, is a principle encoded in Human Rights documents that protect all of us. The principles of non-discrimination and human rights have been enshrined in several fundamental texts.

The Universal Declaration of Human Rights of 1948 established that: *"everyone is entitled to all the rights and freedoms set forth in this Declaration, without distinction of any kind, such as race, colour, sex, language, religion, political or other opinion, national or social origin, property, birth or other status. Furthermore, no distinction shall be made on the basis of the political, jurisdictional or international status of the country or territory to which a person belongs, whether it be independent, trust, non-self-governing or under any other limitation of sovereignty" [Article 2] and that "all are equal before the law and are entitled without any discrimination to equal protection of the law. All are entitled to equal protection against any discrimination in violation of this Declaration and against any incitement to such discrimination"* [Article 7] [10].

The juridical basis of non-discrimination for disability is detailed in the Treaty of Amsterdam [October 2nd, 1997]. The Intergovernmental Conference that drew up the Treaty of Amsterdam

offered an even stronger guarantee by including a declaration in the Final Act stating that Community institutions must take account of the needs of people with a disability when adopting measures to be incorporated into Member States' legislation: "w*ithout prejudice to the other provisions of this Treaty and within the limits of the powers conferred by it upon the Community, the Council, acting unanimously on a proposal from the Commission and after consulting the European Parliament, may take appropriate action to combat discrimination based on sex, racial or ethnic origin, religion or belief, disability, age, or sexual orientation*" [Article 13] [11].
Furthermore, the Charter of Fundamental Rights of the EU –proclaimed during the Nice Summit of December 7th, 2000– states the principle of non-discrimination for people with disability: "*any discrimination based on any ground such as sex, race, colour, ethnic or social origin, genetic features, language, religion or belief, political or any other opinion, membership of a national minority, property, birth, disability, age or sexual orientation shall be prohibited*" [Article 21] [12].
Subsequently, the Commission of the European Communities presented the *e*Europe 2002 Action Plan [13] to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions. This Action Plan was focused on exploiting the advantages offered by the Internet and therefore on increasing connectivity. Three years later the *e*Europe 2005 Action Plan [14] was adopted with the main objective of stimulating the development of services, applications and contents, while accelerating the deployment of secure access to broadband Internet. The ongoing *i*2010 [15] deals with the growth and deployment of the Information Society and audiovisual policies in the EU. Its purpose is to coordinate the actions of the member states to facilitate digital convergence and to face the challenges linked to the Information Society. For developing this strategic framework, the Commission has carried out extensive consultations about previous initiatives and instruments such as the aforementioned *e*Europe projects and the "*Communication on the future of European regulatory audiovisual policy*".
Figure 2 shows a timeline providing a graphic summary of the legislation discussed in this section.

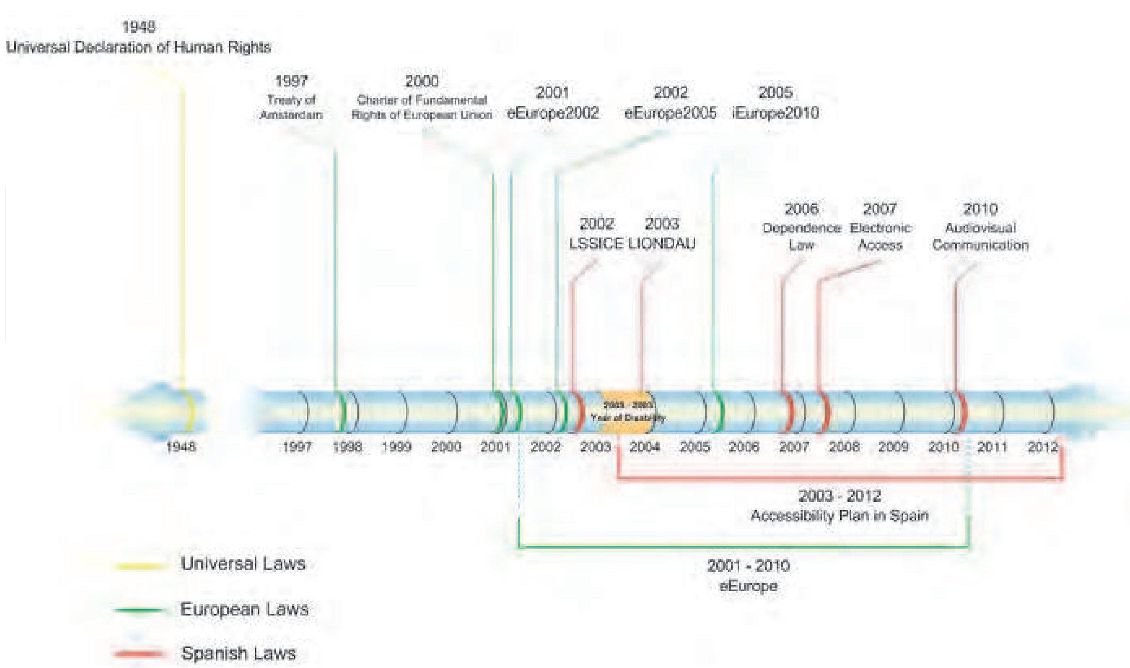


Fig. 2. Timeline summary of the legislation

3. Standardization on e-Accessibility for e-Health. ISO 9241

The standard that regulates the legal implementation of the design requirements in the area of e-Health is ISO 9241 [16]. ISO 9241, among other specifications, provides design guidelines for human-centred web-based user interfaces with the aim of increasing e-Accessibility and usability. ISO 9241-151:2008 [17] provides guidance on the human-centred design of software Web user interfaces with the aim of increasing usability. Web user interfaces address either all Internet users or closed user groups such as the members of an organization, customers and/or suppliers of a company or other specific communities of users. ISO 9241-171:2008 [18] provides ergonomics guidance and specifications for the design of accessible software for use at work, in the home, in education and in public places. It covers issues associated with designing accessible software for people with the widest range of physical, sensory and cognitive abilities, including those who are temporarily disabled, and the elderly. It addresses software considerations for accessibility that complement general design for usability as addressed by ISO 9241-110 [19], ISO 9241-11 [20] to ISO 9241-17 [21], ISO 14915 [22] and ISO 13407 [23].
Finally, ISO 9241-20:2008 [24] is intended for use by those responsible for planning, designing, developing, acquiring, and evaluating information/communication technology (ICT) equipment and services. It provides guidelines for improving the accessibility of ICT equipment and services such that they will have wider accessibility for use at work, in the home, and in mobile and public environments. It covers issues associated with the design of equipment and services for people with a wide range of sensory, physical and cognitive abilities, including those who are temporarily disabled, and the elderly.
Thus, depending on the type of disability involved, the ISO 9241 standard-based design will require other technologies (in addition of assistive products and equipment) to be consistent for the user. Figure 3 shows a relationship diagram for different types of visual, hearing, physical and speech disabilities.

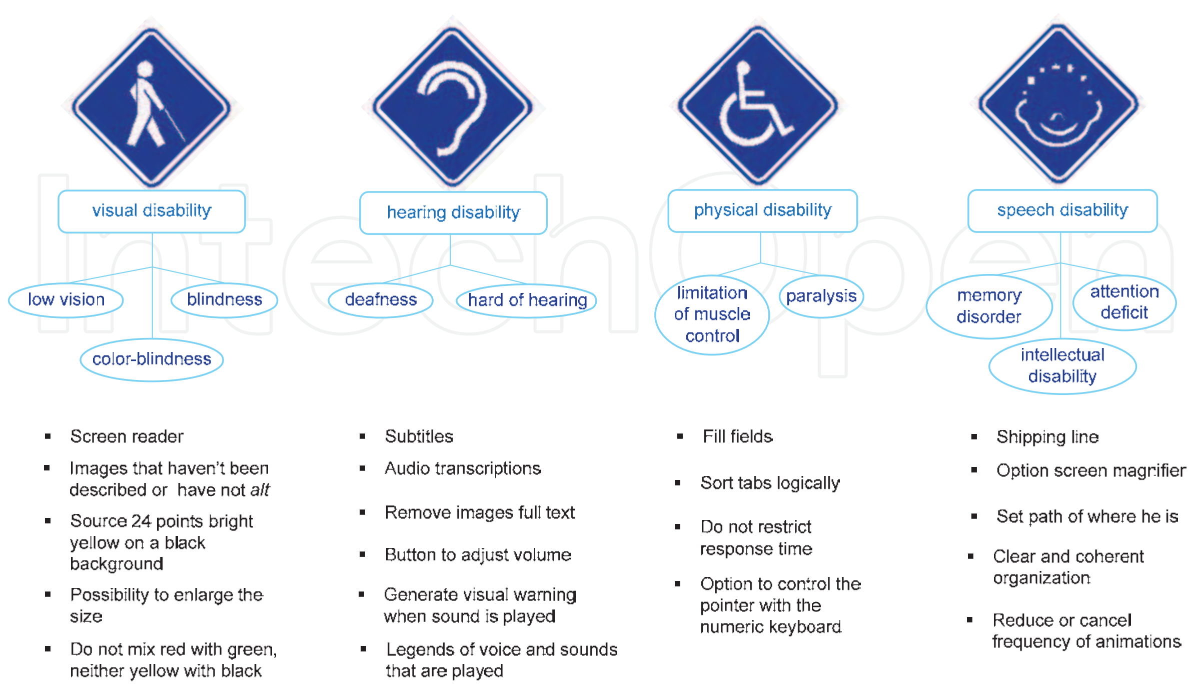


Fig. 3. Relationship diagram “technology - type of disability”

Independently of the type of functional diversity, there are a number of technological requirements that apply equally to all categories because they affect the overall philosophy of communication between man and computer: ergonomic design, customizable settings, multiple channels, etc. Here are the main general requirements to be considered in the design for all established by ISO 9241:

- **Messages**: an interface must be concise, coherent and consistent in order to reduce the effort required by the user to work with his or her computer. Short, simple messages are recommended. It is also desirable that the same message always has the same text, appears in the same area of the screen and has the same compositional elements. The reaction time to events is highly variable from one user to another. Therefore, it is counterproductive to display messages that automatically disappear over time. The speed with which the message is generated is also very important and this particularly affects voice messages. There should be consistency between what we hear and what actually occurs.
- **Channel redundancy:** this solves many of the problems of accessibility. It is commonly used as an indicator that a task is finished or as a warning of some kind of error. Hearing-impaired users lose this information so it should be accompanied by a visual signal of the event. Not only must there be a redundant output channel, but also in the input. It should be possible to operate with the mouse only, with the keyboard only, only with push button only and with speech recognition systems only.
- **Data entry:** this is done similarly in text mode or graphics mode user interfaces, although in the latter case an "edit box" item must be created. In both cases, the written text must be able to be scrolled by the cursor so that the screen reader can synthesize it to voice mode or convert it into Braille. For data entry fields, the accompanying identification labels must be aligned horizontally with the first line of the field so that they can be readily associated by screen reader users.
- **Customising the keyboard:** the keyboard is an essential peripheral so that all aspects of accessibility must be considered carefully. Users must have access to any element of the interface from the keyboard. Also, the use of simultaneous actions should be avoided or else an alternative sequential method should be provided to achieve the same result. To speed up keyboard operations, menus should be circular.
- **Icons:** for people with visual impairments it is uncomfortable to perceive icons and other small objects in the workspace, so the operating system should be enabled to change their sizes and positions, either independently or in groups. Icons must also have an associated label, facilitating the identification and understanding of their role.
- **Windows**: the management tasks of the windows (refresh, move, resize, etc.) are usually operated with the mouse but for users with low accuracy skills or who are blind, the use of the mouse is a disadvantage. Therefore, the standard requires that all these operations should also be able to be done with the keyboard. In the specific case of toolbars, which cannot be accessed by keyboard, it requires that all operations be accessible through the menu option.
- **User support services**: operating systems provide support services used by many applications. This assistance is usually in text format, but must also include the possibility of incorporating pictures or sign language.
- **System services:** in general, the standard requires that the operating system should provide the user with access to any input device that it uses and recommends that it also provide a voice recognition system. Similarly, output data should be handled by

both video and audio so that blind users can access the same information. All options should be activated on an optional basis so that the same software platform can be used interchangeably by a wide range of users with different needs. In addition, the services of the operating environment should be designed so as to be able to ensure that applications built upon it can be accessible.

- **Keyboard controller:** this is responsible for communications between computer and keyboard, and is a point at which many features that facilitate accessibility can be incorporated. People with accuracy problems in the use of their arms, fingers or hands have greatest difficulty in the use of the keyboard, followed by people with mental and visual functional diversity. These different issues need to be considered.
- **Mouse driver**: this must be able to modify the movement direction of the pointer so that the user can operate it in the most ergonomically comfortable manner. Likewise, it should be possible to modify the speed and acceleration of the pointer, differentiating between horizontal and vertical speed, click acceptance time and the time between two clicks.
- **Applications:** it should be borne in mind that, despite recent advances, users with accessibility issues sometimes need to use special devices or programs, so the standard requires applications to cooperate with these access tools. To avoid problems of consistency and coordination between applications, every application should have a choice of finish. Moreover, to achieve a completely accessible interface, all the services and requirements set forth so far are not enough. In addition, applications should be designed so that the number of steps required to access any option is minimized and do not require the simultaneous use of more than one input device, with particular emphasis on the most frequently used options. Thus, any user will achieve greater efficiency.

The principal requirements established by ISO 9241 for each type of functional diversity are as follows:

- **Visual disability.** The main barrier for people with visual impairment in accessing information is that such information is presented visually. Many users use screen readers to communicate with computers. Screen readers provide a description in either speech or Braille of windows, controls, menus, images, texts and other information that may appear on the screen. Some of the barriers for blind people in accessing content on the web are:
  - Images without alternative texts to describe their content.
  - Complex images, such as bar charts or statistics, without detailed descriptions.
  - Multimedia (videos, animations, etc.) without text or audio descriptions.
  - Tables whose content is incomprehensible when read sequentially (cell to cell in the order they appear in the code language or complete lines as presented on the screen).
  - Lack of independence of devices that cannot properly use the application with input devices other than the mouse (e.g., keyboard). The mouse is a pointing device impossible to use for people who cannot see where the cursor is.
  - Non-standard formats of documents that can be problematic for screen readers.
  - Font size with absolute measures that cannot be altered.
  - Design of pages when changing the font size leads to layout problems and difficult navigation.
  - Low-contrast images or text that cannot easily be changed using a user style sheet.

  - Text added by images rather than directly which makes it difficult to increase the size for easy reading.
  - Using colour to highlight text without using other additional formatting elements (such as italic, bold or underlining).
- **Hearing disability**. People with hearing difficulties but who are not deaf have problems with changes and certain frequency ranges, and in identifying and distinguishing certain sounds. They typically use the "Show Sounds" option already provided by some operating systems that offers visual information related to the sounds generated in the use of the computer. Besides having problems detecting auditory information, deaf users are often unable to speak in ways that are recognized by computer speech recognition systems. The barriers are:
  - Lack of subtitles or transcripts of audio content.
  - Lack of pictures to help understand the content of pages. Pages with too much text and no pictures can hinder understanding for people whose primary language is sign language rather than spoken or written language.
  - Need for voice input on some websites.
- **Physical disability**: physical disabilities are those that affect the proper mobility of people. Chronic degenerative diseases are characterized by the following symptoms: tremors (hands, arms, legs, jaw and face), rigidity in the limbs and trunk, slowness of movement and postural instability. Some of the barriers affecting people with functional motor disabilities are:
  - Icons, buttons, links and other elements of interaction are too small, making them difficult to use for people with limited dexterity in their movements.
  - Lack of independence of devices that cannot properly handle web pages with the keyboard instead of the mouse.
- **Ageing disability**: ageing is associated with a gradual loss of skills that can turn into a decrease in vision, hearing, memory, coordination and physical skills. The limitations derived from the environment cannot be considered as disabilities, but rather as environmental conditions that restrict opportunities of access to new technologies. Some limitations derived from the environment are:
  - Small screens, making visualization of applications designed for higher resolutions difficult.
  - Monochrome or black and white monitors that mask information based on colour alone.
  - Working environments that do not allow the perception of sound content of the application (high level of background noise, etc). To overcome this limitation, it is necessary to provide transcripts or subtitles.
  - Environments with poor lighting or limited visibility conditions that require increasing the font size, zoom, and contrast or changing the style of web pages.
  - Absence of a mouse to use the computer so that the keyboard must be used. Applications should be designed to enable device independence.

4. Technological solutions for disability in relation to e-Health

ICTs have improved our quality of life and recent progress in e-Health issues is already evident. However, people with visual, hearing, physical and speech disabilities do not completely enjoy all the potential benefits of e-Health, since these e-Health designs or developments do not consider their specific needs.

The aids provided by specific technological requirements for people with disabilities are classified according to the logic of the operation: alternatives (to allow replacement of a methodology or tool method, or tool "alternatives" that can be used by the subject), enhancement (to supplement the shortage of functional resources in subjects to perform an action or to "enhance" the low productivity of these) and substitutes (to allow the replacement of an absent or damaged functionality in the subject by another which the subject does have) [25].

This section will present and discuss the recommended technology requirements for each type of disability:

- **Psycho-cognitive diversity and ageing people**: providing solutions to the difficulties people have in learning and understanding abstract or complex concepts, the establishment of relationships between concepts, carrying out tasks with complex structures, the use of short term memory, interpretation and memorization of long sequences of operations, the ability of understanding of language, etc. These include many resources of the ICT environment: environment control, safety control, telemedicine, telecommuting, distance education and training, adapted jobs, etc.
- **Physical diversity:** incorporating solutions to issues related to mobility and manipulation including mobility and transportation, hygiene and personal care, household tasks, computer access, support for autonomy, etc.
- **Sensory diversity:** very different solutions that target visual diversity (including mobility aids, reading aids, writing aids) and hearing diversity (personal communication, telephony, communication in general, etc…)

There is great awareness in companies about new developments conforming to the standards that establish guidelines to implement the idea of design for all [26]. The general objective is to develop technologies for building channels of communication and interaction between people with some kind of special need and their environment. Different products and assistive devices [27] include many technological resources that are explicitly designed, manufactured in standard mode, or adapted from those already manufactured. These products can help people with functional diversity to overcome or mitigate their disabilities, providing access to greater autonomy and improved quality of life. An analysis of the most significant specialized medical devices and products is given below grouped by type of functional diversity [28]-[30].

4.1 Psycho-cognitive disability and ageing people

Some of the recent advances in this context of e-Health include special types of mouse with devices that allow moving the digital cursor over the screen through foot movements, or context keyboards (see Figure 4). These context keyboards are designed with pictograms instead of letters on every key in order to develop the augmentative communication of the patient through images that help to represent her/his needs [31].

Another milestone is the photo-sharing model, used by many parents with autistic children, which allows children to construct sentences through a book containing photographs of real objects collected through their own experiences. Grace [32] is an iPhone application based on a system of communication through images with which it is expected to help autistic people improve their social skills. It has more than 300 symbols and pictures stored on the iPhone terminal reflecting current day-to-day vocabulary of society. It also allows new pictures to be added at any time as the vocabulary grows.

Among applications for elderly people, the Cogknow project [33] aims to help minimize the overall risk of exclusion of older people with dementia, focusing the action on several aspects of their lives: memory, continuity of social contact, ability to perform daily activities, and increased safety. A mobile device (Smartphone or Pocket PC) has been developed which allows the elderly to remember their daily activities (using images), and to easily contact their families by simply clicking on the picture of the person they want to communicate with. Furthermore, the same device will act as a Global Positioning System (GPS) locator so that the carer or relative can monitor the movements of the user.
The large touch screens that allow applications to be opened and managed with a simple hand gesture are only a foretaste of what our relationship with technology will be in the coming years. Some other highlights of the technology applied to user interface design are shown in [34], and an example of these advances is the Gesture Cube [35], see Figure 5. While touchpads are now handled by dragging the fingers over the screen according to certain paths and geometries, the interface of the future will be handled by gestures alone. As its name suggests, the Gesture Cube senses and interprets hand movements and it can operate with various devices. The user moves the hand towards or away from the cube or waves the hand in front of it, while a series of sensors instantly detect the hand position and transmit the coordinates to the electronics installed in the interior. Thus, certain preset movements can be programmed to perform certain actions such as opening a program.

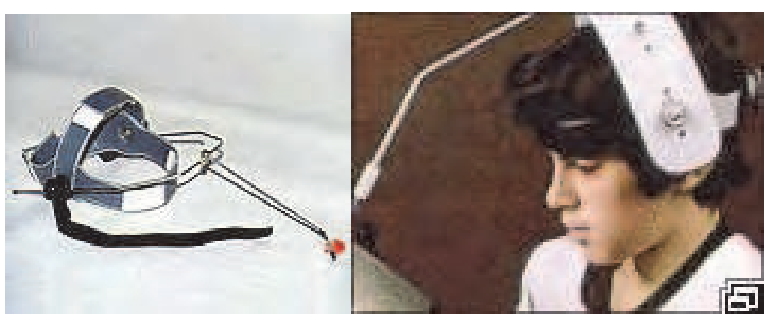
Fig. 4. Context keyboards (figures extracted from their respective websites, see references)

Fig. 5. Gesture Cube (figure extracted from website, see references)

4.2 Physical disability

There have been many medical advances in this field. Some highlights are glucose analyzers/meters (with strips including a capillary action that automatically acquire the blood and a beep to warn that the application is completed, the test result appearing on the display and also spoken through a synthetic voice), digital talking body thermometers (suitable for armpit, oral and rectal use with memory of the last measurement), or Head Pointer systems (suitable for people who have good head control and are able to use the computer keyboard with the head). The most significant advances are listed below:

- **Licorn**. This is a helmet with a built-in metal rod holding a small stylus or pencil. This is for operating the computer keyboard for people with good head control.
- **Ergonomic mice and push-buttons**. Special ergonomic mice operated by ball, tablet or plaque, keys, even the floor, wireless, head, joystick, push buttons, touch screen, voice, eyes, etc. With head mice, the user's head movements are processed by the system that moves the cursor on the computer screen. In mouse control by the iris, the system allows the user to place the mouse pointer anywhere on the computer screen simply by looking at that point. There are also virtual mice whose movement and click options appear on the screen operated by a push-button.



(a) Licorn

(b) Ergonomic mice

(c) Push-buttons

Fig. 6. Hardware devices for physical disability (figures extracted from their respective websites, see references)

4.3 Sensory (visual, hearing and speech) disability

Typhlotechnology is the adaptation and accessibility of ICTs for their use and implementation by people with blindness and visual impairment. A very detailed review of technological advances in typhlotechnology developed for people with visual functional diversity was given in [36]. Some other highlights of the technology applied to visual impairment were reviewed for this work and are collected in [37]-[46]. The most significant are listed below:

- **USB Braille keyboard** [47], for people with visual disability. As shown in Figure 7(a), this allows Braille letters to be entered, either completely replacing the conventional keyboard or working simultaneously with it. Braille input keys are arranged in a central ergonomic manner in two groups of 4 keys. The extra keys around the Braille keys correspond to a standard MF2 keyboard regard in terms of their function and form. The keyboard allows the combination of cells of six and eight points to generate characters following the American National Standards Institute (ANSI) Braille table.
- **CdBraille** [48], see Figure 7(b), is a relief printing system for Compact Disc (CD) and Digital Video Disc (DVD). This technology allows printing the surface of CDs and DVDs in Braille language.
- **Nokia Braille reader** [49], see Figure 7(c), is an application for touch screen phones that allows people with blindness or reduced vision to be able to write, read and send text messages. This system operates through software that displays on the screen a series of black and white circles on which the fingers can rest. Light vibrations can be felt that allow users to decipher the message. This is a Braille reader that translates text messages and reproduces them on touch screen phones with haptic feedback.
- **Loadstone GPS** [50] is a program to help blind people; it combines GPS and voice recognition systems, developed by two blind programmers. It is free and open source with the aim of "helping the blind to get from point A to point B". Another option also based on GPS is Mobile Geo [51], which is still in development.

(a) USB Braille Keyboard (b) CdBraille (c) Nokia Braille

Fig. 7. Advances for physical disability (figures extracted from their respective websites, see references)

Some other highlights of the technology applicable in cases of hearing disability have been reviewed for this work and are collected in [52]-[53]. The most significant are listed below:

- A recent example, made in Spain, is the Barakaldo phone 010, which serves people with hearing and speech disabilities [54]. These groups can communicate with their local councils or authorities through a new system. Through their mobile phones and Personal Digital Assistants (PDAs), they can chat with the operators of the service.
- The Telesor system [55], allows public and private organizations to provide telephone services to people with hearing or speech disabilities, in a manner equivalent to that offered to a hearing person through voice phone. This ensures that all inhabitants with hearing or speech disabilities can communicate through their mobile devices (cell

phones and PDAs) with public and private telephone services. This communication is always made in real time via text and character to character communication mode. It is necessary to install a free widget on the mobile phone that will provide the functionality and user interface required.

- The cochlear implant is a device designed to reproduce the function of the cochlea through implanted electrodes. It uses a few external components (microphone, processor and transmitter) whose function is to collect, process and transmit sound to the electrodes. Cochlear implants, therefore, are designed to help people with profound deafness who are unable to benefit from hearing aids.

Finally, specific medical devices adapted for sensory disabilities and their associated hardware are described below (see Figure 8):

- Glucose analyzer (see Figure 8(a)). The strips are equipped with a capillary action that automatically places the blood in the alveoli of reaction. Very little blood is required. A beep alerts the user that the application of the blood has been completed. After 30 seconds the test result appears on the display in large print and is spoken by a synthetic voice.
- Talking thermometer (see Figure 8(b)). The talking digital body thermometer has an audible alert and memorises the last measurement.
- Talking blood pressure monitor (see Figure 8(c)). This uses a digital Liquid Crystal Display (LCD) and an oscillometric measurement method. The measurement process is accompanied by the addition of brief pre-recorded messages. There are also sound signals to indicate the end of the measurement. There are other models with facilities for language selection or disabling playback voice messages. The monitor announces the results shown on screen, whether they are valid as if there is an error. The date and time of measurements stored in the memory are recorded.
- Braille blood pressure monitor (see Figure 8(d)). Shenzhen ND Industrial Design has developed this blood pressure monitor made of a soft, flexible material which can be placed around the wrist. The results are shown in Braille by means of dots corresponding to the data being generated on the surface. Designed for people who have impaired vision, blindness, difficulty in hearing or who are completely deaf [56].
- Medicine dispenser (see Figure 8(e)). Adapted to the thread on a medicine bottle, this dispenses 5 ml doses of the liquid. The fluid passes through a small chamber with 5 ml capacity to facilitate accurate measurement.
- Pill organizer (see Figure 8(f)). On the upper side are the initials of the days of the week in Braille. Each day has four boxes with the Braille letters "a", "b ", "c" or "d", corresponding to 4 different times of day (morning, noon, afternoon and evening) when the medication is taken.
- Braille keyboard (see Figure 8(g)). Tecnalia has developed for ONCE a small wireless Bluetooth technology Braille keyboard. This application may be used by people with visual disabilities in both desktops and laptops as well as on PDAs and mobile phones [57].
- Screen magnifier (see Figure 8(i)). This type of adaptation is probably the first that appeared on the market and involves enlarging the characters and other content on the screen by up to six or seven times their normal size. This application requires screen magnifier software and manual handling equipment.
- Image magnifier. This equipment has an expansion chamber which projects the image of the object captured on a screen. Depending on their visual ability, the image magnifier allows users to adjust contrast, colour, sharpness, brightness and focus,

according to their own needs. For older people, the use of the magnifier means recovering their eyesight for many tasks that allow them to be independent.

- Screen magnification software. This software extends by up to twenty-five times the original size of the objects visible on the screen in all Windows applications. The screen magnifier ZoomText is character magnification software that allows the user to see text and drawings through a virtual magnifying glass at the size required.
- Voice reader (see Figure 8(h)). The Korean Sungwoo Park has developed an audible reader for the blind and called it Voice Stick. The device is a handheld scanner that combines Optical Character Recognition (OCR) and text-to-speech technology. It can read literally any text and convert it into audio which the user receives through headphones [58].
- Screen readers. These are a form of AT potentially useful for people who are blind or have vision problems, or learning difficulties. They are often combined with other AT applications such as screen magnifiers. The choice of screen reader is determined by several factors, including the platform or the cost. There are so many that we summarize the most important in a descriptive table (see Table 2).

Name	**Author**	**S.O.**	**Notes**
95Reader	SSCT	Windows	Japanese.
Blindows	Audiodata	Windows	Supports *Microsoft* Active Accessibility and Java Access Bridge.
HT Reader	HT Visual	Windows	Include support for MSAA and PDF.
iZoom	Issist	Windows	Screen Magnifier. Includes support for Mozilla Firefox.
Linux Screen Reader	GNOME	GNOME	Supports AT-SPI.
LookOUT	Choice Technology	Windows	Also available integrated with screen magnifier.
Magic	Freedom Scientific	Windows	Magnifier that can be used with JAWS.
Mobile Speak	Code Factory	Symbian, Windows Mobile	Supervisor by cells.
PC-Talker	Kochi System Development	Windows	Japanese Reader. Supports MSAA and Flash.
PCVoz	EzHermatic	Windows	Supports MSAA.
Simply Talker	EcoNet International	Windows	Trial version available.
Virgo	BAUM Retec AG	Windows	Supports MSAA and Java Access Bridge.
Virtual Vision	MicroPower	Windows	Supports MSAA.
VoiceOver	Apple	Mac OS X	Distributed with Mac OS X, uses the Apple Accessibility API.
Window-Eyes	GW Micro	Windows	Supports MSAA.
ZoomText	Ai Squared	Windows	Magnifier that includes support for voice synthesizer.

Table 2. Medical devices for physical disability

(a) Glucose Analyzer (b) Talking Thermometer (c) Talking Blood Pressure
(d) Braille Blood Pressure (e) Medicine dispenser (f) Pill organizer
(g) Braille Keyboard (h) Voice Reader

Fig. 8. Medical devices for physical disability (figures extracted from their respective websites, see references)

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