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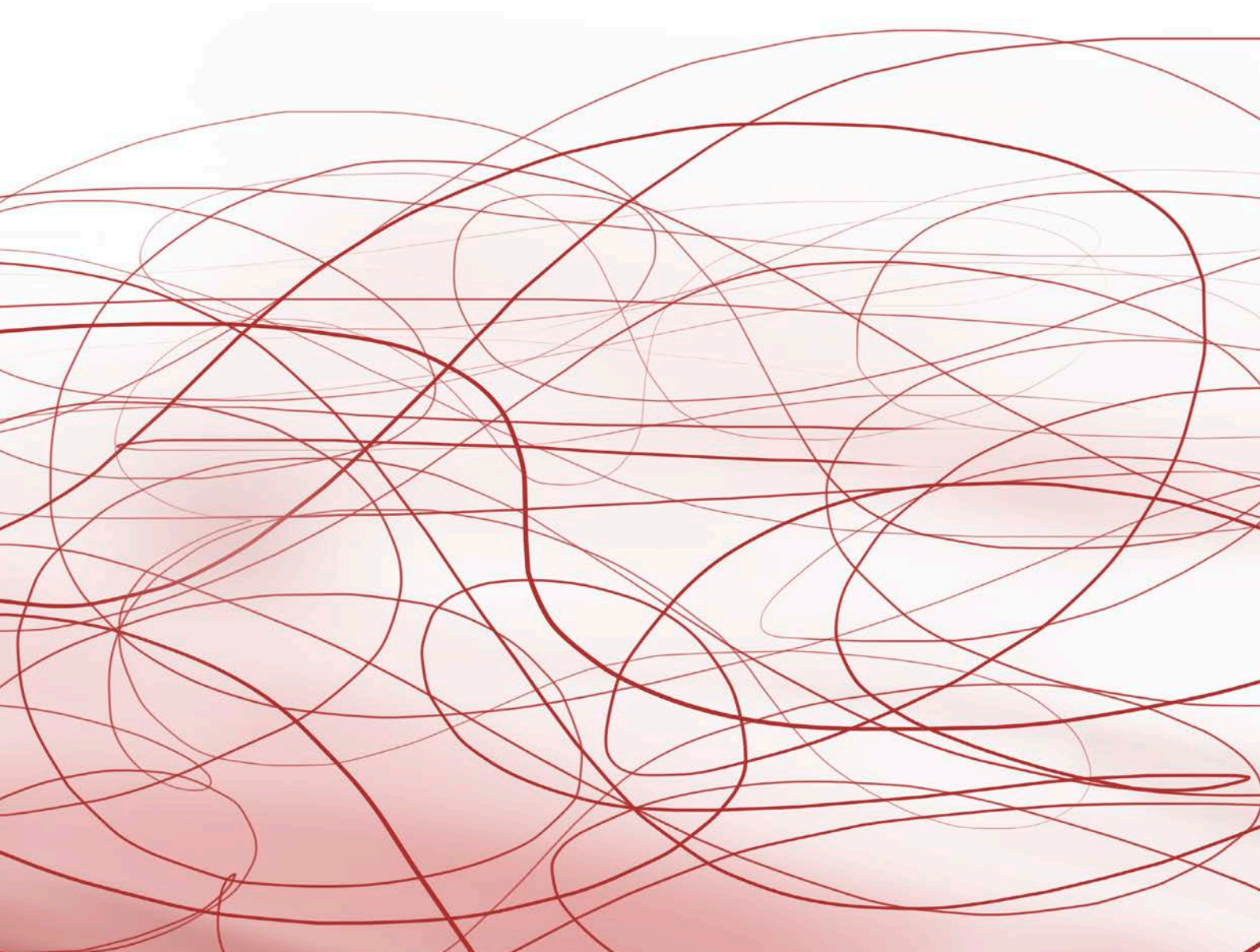

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EDITOR'S LETTER

This volume 4, number 3 is composed by seven articles where 34 researchers explain their findings. They are from universities, foundations, government centers and companies in 3 different countries. All researches presented here have in common the aim of creating a more accessible world. Thanks to all of them this number of JACCES sees the light of day.

Firstly, this issue includes an article of Society and Economics section. This study is related to accessibility legislation in Spain, and it investigates whether the existence of accessibility legislation per se, is enough to ensure its practical application.

Secondly, there is a set of studies based on a selection of works from the 4th Edition of the International Congress of Design, Research Networks and Technology for All (DRT4ALL). This congress took place at Madrid in 2013 promoted by the ONCE Foundation. Its goal is to show latest advances in Domotics, Robotics and Remote-assistance, and how these areas can work together to make everybody's life easier and improve social integration for people with disabilities. Thus, these papers are included in the Engineering section, and they are related to concepts such as interfaces for programming robots, audio description in Spanish DTT, human-computer interaction for cognitive rehabilitation and accessible payment systems.

Finally, in Health and Medical Care section are gathered articles regarding gaming for cognitive stimulation and virtual reality for rehabilitation of patients with spinal cord injuries.

After introducing this publication, just remains to invite you to discover all innovative and exciting findings compiled on it.

Daniel Guasch Murillo

Accessibility Chair Director UPC-BarcelonaTech

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Universal Accessibility Director-Fundación ONCE

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Editorial

Articles

Journal of Accessibility and Design for All

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ASSESSMENT OF THE ACCESSIBILITY LEGISLATION IN SPAIN AND ITS EFFECTIVE APPLICATION

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***Abstract*:** The existence of legislation on accessibility does not always imply it is enforced effectively. This article aims to answer the following question: Is the existence of accessibility legislation enough to make physical environments truly accessible?

This study assesses the current Spanish legislation as well as any existing voluntary regulations in the country. This assessment is done chronologically, so as to show the historical evolution of the accessibility regulations in Spain.

In order to determine whether accessibility legislation has been truly effectively enforced, the issue is studied as it affects Spanish municipalities with respect to urban planning, public buildings, public transportation and websites.

The conclusion of this study is that the existence of accessibility legislation per se is not enough to ensure its practical application, and ultimately, to render physical environments, products and services accessible to the majority of the population regardless of their functional capabilities.

Keywords: legislation, accessibility, regulations, municipalities, urban planning, public buildings, public transportation, and websites.

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Introduction

Accessible physical environments, products and services improve the quality of life of all people, regardless of their functional capabilities. Obviously, accessibility is an essential condition for people with disabilities to be able to exercise their basic rights as citizens on equal terms with the rest of the population. This is why while the struggle to attain accessible physical environments, products and services originated in the disability rights movement; it has doubtlessly become a fundamental right for all citizens. According to the 1st National Accessibility Plan approved by the Spanish Government in 2003, 40% of the population benefits directly from accessibility (IMSERSO, 2003). Let's also bear in mind the European Institute of Design and Disability's motto, which is shown in its Stockholm Declaration and reads as follows: "Good design enables, bad design disables" (EIDD, 2004).

The principal original demands of the accessibility rights movement were focused around the creation of a body of law powerful enough to force both the public administration and the private sector to introduce accessibility "Design for All" criteria, which would then achieve its greatest possible reach. While a priori it might seem obvious that the existence of a legal framework should create the conditions for a seamless incorporation of accessibility elements into surroundings, products and services, the reality can be very different.

It is, therefore, important to assess first, whether the existing Spanish legislation on accessibility is sufficient, and second, whether its practical application is proving truly effective.

Spanish Legislation

The Spanish legislation on the removal of architectural barriers and universal accessibility is analysed below.

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The first Spanish legislation to introduce the concept of barrier removal was Act 13/1982, of April 7 on the Social Integration of the Disabled (Spanish Government, 1982); its treatment of the accessibility issue is however very superficial, as only a small part of the Law (section 1, title IX) refers to it. The physical environments the law deals with in terms of objectives for accessibility improvement are basically urban, with the responsibility to develop specific accessibility legislation assigned to the Autonomous Communities of the country.

The next legislation approved in Spain regarding the removal of barriers was the Royal Decree 556/1989 of May 19, which establishes minimum accessibility requirements in buildings.

It was only in the late 1980's and in the 1990's that each Autonomous Community exercised its mandate by passing its laws on the removal of urban, architectural, transportation and communication barriers. These laws focused particularly on tending to the needs of people affected by limits in their motor functional capabilities, but neglected the needs of citizens with sensory, mental or intellectual limitations.

Despite the national and regional governments' efforts to regulate architectural, urban and transportation accessibility, these laws were drafted without a penalty system. This meant that any infringement of such laws did not result in a penalty, which lead to widespread non-compliance. This situation was reflected in the 1st National Accessibility Plan, approved on July 5, 2003 and effective from 2004 through 2012: "The field work carried out to prepare the Plan revealed that the measures currently being undertaken to improve accessibility in Spain are often disjointed and uncoordinated, producing an unsatisfactory overall result." (IMSERSO, 2003)

Overall, this Plan was established, as the ruling document, to promote accessibility in Spain during its period of effectiveness. In addition, it established both specific goals and a cross-sectional methodology appropriate for the development of the Plan's motto: "Achieving Equal Opportunity and Full Participation through Design for All." It is in this document that the concept of "barrier removal" is replaced with the

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concept of "Design for All." In general, the terminology used was revised, with a view to replace negative terms with more positive and inclusive ones. However, as pointed out in the "Guide to Gender Mainstreaming in Public Disability Policies; Chapter 3: 'Accessibility' (Hernández-Galán et al)," the Spanish term "diseño para todos," as used in this Plan, which is a literal translation of the English term "Design for All," is considered a sexist terminology. Consequently, a more "politically correct" translation, such as "diseño para todas las personas" (Design for All People) is suggested.

The Plan defines Design for All as "the approach through which products, services and built environments should be designed right from their inception so that they can be used by as many people as possible." Thus, both the concept of "equal opportunity" as well as that of "Design for All", which constitute the two core ideas driving the struggle for accessibility in the last few years, appear together in the Plan's motto.

This concept establishes a pro-active attitude geared towards overcoming the stigma attached to the different way in which people with disabilities have traditionally been treated. In addition, it emphasizes the need to take into account the diversity of individual functional capabilities as it incorporates them in the process of designing physical environments, products and services. Incorporating the Design-for-All approach cross-sectionally to the processes of designing, project drafting and planning is essential in order for their results to be truly usable by everybody (Kercher, 2007).

One concept that has not yet been incorporated into legislation but is being made part of the design processes is that of "Design Thinking." This concept applies a much more holistic vision to the design process, and strives to resolve more complex problems than those exclusively focused on form and functionality. It also incorporates solutions to problems related to tending to the needs of the most vulnerable, such as social collectives at risk of exclusion, people living in extreme poverty, etc. (Brown and Wyatt, 2010).

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Both the concept of "Design for All" and that of "Design Thinking" are undoubtedly convergent, even though they differ in origin and focus on solving different problems.

A few months after the National Accessibility Plan became effective, on December 2, 2003, a new law was approved by the Spanish Government: "Act 51/2003 on Equal Opportunity, Non-Discrimination and Universal Accessibility for People with Disabilities (LIONDAU)". This law aims to establish measures to both guarantee and make effective equal-opportunity rights for people with disabilities.

In addition, the law establishes that, within a period of two years, basic accessibility requirements would be determined for the following fields:

- Basic accessibility and non-discriminatory requirements for public administrations;
- Basic accessibility and non-discriminatory requirements for the access and use of technologies, products and services related to the information society and to social communication media;
- Basic accessibility and non-discriminatory requirements for the access and use of transportation;
- Basic accessibility and non-discriminatory requirements for the access and use of public urban areas and buildings;
- Basic accessibility and non-discriminatory requirements for the access and use of goods and services available to the public.

In order to institute quality management in the use of public resources, all of the above-mentioned basic accessibility and non-discriminatory requirements must also be applied to protected natural areas.

Even though the government was legally bound to follow up LIONDAU with specific regulations within a period of two years, it was not until 2007 that they were put in place through the following Royal Decrees:

- RD 366/2007 of March 16, which establishes the accessibility and non-discriminatory requirements for people with disabilities in their dealings with public administrations;

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- RD 505/2007 of April 20, which approves the accessibility and non-discriminatory requirements for people with disabilities for the access and use public urban areas and buildings;
- RD 1494/2007 of November 12, which approves the Regulations on the basic requirements for people with disabilities' access to technologies, products and services related to the information society and to social communication media;
- RD 1544/2007 of November 23, which regulates the accessibility and non-discriminatory requirements for people with disabilities' access and use of transportation.

On December 26, 2007, Act 49/2007 was approved. It establishes the rules on infringements and penalties regarding issues of equal opportunity, non-discrimination and universal accessibility for persons with disabilities. This law has provided a tool for people with disabilities to defend themselves from any discriminatory action taken against them. Penalties for serious infringements can reach up to one million euros. None of the previous laws on disability included a penalty system, so they were habitually breached.

On March 17, 2006, the Spanish Royal Decree 314/2006 establishing the Technical Building Code was issued without technical regulations on accessibility, which had to await the issuance of the Royal Decree 505/2007 mandating the setting up of basic accessibility requirements in buildings. Such requirements were finally put in place in 2010 through Royal Decree 173/2010 of February 19. This latest decree amended the 2006 Technical Building Code on accessibility and non-discrimination of people with disabilities established by the Royal Decree 314/2006.

On December 13, 2006 the UN approved in New York the Convention for the Rights of Persons with Disabilities. On May 3, 2008 both the Convention as well as its Optional Protocol became effective in Spain, having been previously ratified, as reflected in the Spanish Official State Gazette of April 21, 2008 and April 22, 2008, respectively. This Convention has come to fill a void in the framework of international human rights legislation as no previous regulation had taken into account the special circumstances of

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people with disabilities. As such, it constituted an ultimate recognition in support of, and an essential step for the promotion of, their full integration in all areas of society.

It is important to highlight that the ultimate purpose of the UN Convention is to enumerate the rights of people with disabilities and to establish a specific code for their application. Consequently, its 50 articles specifically detail the rights of people with disabilities, which encompass, among others, civil and political rights, including accessibility, participation and inclusion, as well as the rights to education, health, employment and social protection. It should be noted that the Convention recognizes the need for a change in societal attitudes as a requisite for people disabilities to enjoy equal rights.

Standardization

In addition to legal provisions, there exist other tools to promote accessibility, prominently among them standardization and certification. Standardization and certification have been powerful promoters of concepts such as quality and environmental and labour risk prevention. This has been amply demonstrated by the success of ISO 9001, ISO 14001 or OHSAS 18001 standards. Standardization and Certification have also shown themselves to be important elements in harmonizing national and regional legal provisions.

AENOR, the Spanish Association for Standardization and Certification, has been working for years on the standardization of accessibility, propelled in part by social agents and in part by its principles. While this work has been on going for years, it has notably intensified during the last five years. Among the results of these efforts are the developments of UNE standards and the participation in European activities geared towards accessibility standardization.

Several UNE standards have been developed including:

- UNE 26316:1983. “Passenger cars. Driver-hand controls in passenger cars;”

- UNE 41500:2001 IN. "Accessibility in urban areas and buildings. General design criteria;"
- UNE 41501:2002. "Accessibility signage. Rules and usage;"
- UNE 41510:2001. "Accessibility in urban areas;"
- UNE 41512:2001. "Accessibility in beaches and their surroundings;"
- UNE 41520:2002. "Building accessibility. Horizontal inter-action components communication elements;"
- UNE 41522:2001. "Building accessibility. Access to buildings;"
- UNE 41523:2001. "Building accessibility. Access to bathroom facilities;"
- UNE 139801:1998 EX. "Computer applications for people with disabilities. Computer accessibility requirements. Hardware;"
- UNE 139802:1998 EX. "Computer applications for people with disabilities. Computer accessibility requirements. Software."

In 2001, the UNE 170.001 standard "Universal accessibility: criteria to facilitate accessibility to the physical environment," was published. It consists of two parts:

- Part 1. MGLC requirements (Mobility, Grasp, Localization and Communication);
- Part 2. Universal accessibility management system.

This new standard represents an entirely new approach to standardization processes from that followed until that point and introduces three new concepts:

- It adds MGLC requirements, which approach disability from the point of view of its effects rather than the kind of disability;
- It establishes an accessibility management system and, as a result, an ongoing improvement of accessibility within a built environment;
- It sets out a certifiable standard.

MGLC requirements. In part 1, UNE 170.001 standard reads: "This standard establishes the requirements to be met by a specific physical environment

(places, establishments, buildings and facilities) so that their users can overcome any accessibility limitations."

The requirements specified in this standard aim to "integrate the different needs of people in any kind of built environment so as to guarantee that such environments be used independently and in the same way by all people." The standard also defines MGLC requirements as "the set of requirements related to the actions of mobility, grasp, localization and communication to be satisfied in order to guarantee universal accessibility to all built environments."

The universal accessibility management system is based on the structure of the Quality Management System established by the UNE-EN ISO 9001 standard. Its definition follows an examination of the processes the user must follow to be able to enjoy a particular physical environment, on the basis of the MGLC requirements. Such system will allow determining the accessibility needs, which once satisfied will lead to an accessible environment.

The Universal Accessibility Management System is certifiable. As such, it can be evaluated by an established independent entity with competence in this area. The results of that evaluation would lead such entity to issue a certification of the system as meeting the UNE 170.001 standard requirements. (Fontanals, 2006).

Assessment of Accessibility in Spanish Municipalities

In order to verify whether current accessibility legislation is being enforced effectively, it is important to perform the necessary fieldwork to assess the actual state of both built environments and transportation systems.

It is also important to take into account the individual's capacities as well as needs in terms of its interaction with the physical environment (Tyler, 2011). To this end, one must consider the capacity model developed by the University College of London.

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In order to carry out the fieldwork systematically, it is necessary to develop an appropriate methodology that makes it possible to assess all the parameters and elements affecting accessibility conditions in built environments and transportation systems. It is also necessary to quantify them effectively. To this end, Fundación ONCE put in place in 2010 the Observatory for Universal Accessibility in Spanish Municipalities (Fundación ONCE, 2011). What follows describes the methodology as well as the results obtained in the above-mentioned study.

Methodology

The methodology used consisted of:

- Municipalities' selection: carried out through a stratified random sample. Six strata were identified based on the number of inhabitants. They are: less than 20,000; from 20,000 to 50,000; from 50,000 to 100,000; from 100,000 to 500,000; from 500,000 to one million; and more than a million. A total of 70 municipalities were evaluated.
- Limitations: the study has focused on urban planning, public buildings, public transportation systems and municipality websites.
- Items: measurable and quantifiable elements have been selected which are included in current legislation, establishing accessibility percentages in the evaluated municipalities.
- Evaluation: this methodology does not evaluate the degree of accessibility or inaccessibility of the studied elements. Instead, it measures the degree (in percentage) to which the current legislation is being enforced, and thus it deals with objective facts and not subjective assessments.
- Thoroughness: the accessibility assessment has been carried out with a great level of detail. One hundred seventeen indicators were reviewed and evaluated for urban layouts, 147 for buildings, and 68 for transportation systems.

- Specialization: architects specialized in accessibility gathered all data. The use of self-assessment, systems that can distort accuracy in the gathering of data, was avoided.
- Objectivity: in no case have the data been based on users' perceptions. All data are objective, as they are obtained on the basis of current legislation, and have been accounted for and registered every time a deficiency was observed.

In the 70 municipalities included in the study, evaluations were undertaken in 330 routes encompassing more than 254 km of streets, 354 public buildings, and 70 transportation units. One hundred forty in-depth interviews were carried out with municipal technicians and architects, as well as with local representatives of the disability rights movement.

Results

This article presents the principal results of the study undertaken by the Observatory for Universal Accessibility in Spanish Municipalities. They have been grouped according to the different areas of study, i.e., urban planning, public buildings, transportation systems, and websites.

Urban layouts

- Pavement: of the 254 km of street assessed, 1.7% was found to be deficient. These deficiencies are usually related to firmness, use of cobblestones, instability, etc.
- Loose parts, bumps, ditches, etc., which impede accessibility are due to deficient execution of public works, inadequate selection of construction elements (such as excessively wide grates) or both. These obstacles affect 0.7% of the evaluated urban layouts.
- Tree basins. Of all the assessed basins, 69.7% are not covered or inadequately covered.
- Occasional sidewalk slopes: 42.3% are caused by driveways to garages, 30.2% by curb cuts, 9.3% by access to building entrances, and 18.2% by other causes, such as road works, stairs, etc.

- Pedestrian crossings: 64.7% of the assessed crossings were affected by some deficiency and as a result could not be used properly by all people, and in 17.4% of cases, there were no crossings at all. Moreover, in 35.7% of cases, warning pavement was inexistent or incorrect; in 19.7% there were no curb cuts, and 15.7% lacked proper signposting.
- Traffic lights: 67.6% lacked acoustic signals, which impede blind or visually impaired individuals to be able to make it across streets safely and independently.
- Stairs: a very high percentage (90.6%) does not meet at least one of the basic design requirements. The most frequent flaws are the lack of accessible banisters or handrails (26.5%); absence of warning pavement both entering and exiting (26.5%); and lack of sidewalls, and uneven steps (16%).
- Ramps: 6.78% are not wide enough, which makes them very hard or even impossible to use; a ramp with a steepness or length above the limit established by law (1.7%) requires a greater effort and higher balance control on the part of the user, which not all of them can achieve. When handrails do not meet the appropriate design criteria (15.5%), they do not serve their purpose and thus become useless. The lack of sidewalls (32.8%) entails a dangerous level of falling risk.
- Bollards: 10% present design deficiencies in their shape, height or paint contrast with the surroundings.
- Dumpsters: 74.7% of the assessed dumpsters present design deficiencies.

Public buildings

- Access: of the 354 assessed public buildings, 42.6% do not have ground level access, and of those, 49.6% of them lack accessible walkways. The result is that a total of 21% of the buildings is not accessible.
- Stairs: 29.2% lack warning pavement; 89.5% have deficient handrails and banisters; 69.2% have de inadequate steps, and 66.2% have no sidewalls.

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- Ramps: design deficiencies include excessive steepness (27.7%) and inadequate length (31%); lack warning pavement (96.2%); and the absence of adequate banisters or handrails (85.4%).
- Signage: 66.1% of buildings lack directional signs; 95% have no Braille signs. In addition, of the total existent signs, 13.4% are not accessible.
- Information and communication: 89.9% of buildings lack specialized customer service staff with knowledge of sign language and 95.6% lack documents and brochures in Braille.
- Elevators: 18.5% of buildings with more than one floor have no elevators, and 12.5% of elevators have no buttons with acoustic/luminous detection, raised surface or Braille signs.
- Restrooms: 20% of public buildings lack accessible restrooms, and in 31.6% of buildings that do, they are not located at ground level.

Transportation

- Bus stops and approaching areas: while 89% are favourably located on sidewalks wider than 1.5 meters, negative factors were found, such as badly covered tree basins in 23.9% of the cases, or slippery pavement in 7.7%. In addition, there were no chromatic/podotactile warning strips in 94.1%.
- Bus stop shelters: 36.1% have no signage; 13.1% have no seats, and of those that do, 89.6% are inaccessible.
- Buses: 28.8% are not low-floor buses and 32.8% have no ramps. As for information systems, 79,7% lack audio devices and 56.7% have no visual devices.

Websites

The main accessibility issues relate to multimedia contents, applications such as Adobe Flash, and PDF files. The evaluated municipality websites have been rated at 6.5 in a scale of 1 of 10.

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Conclusions

- While legislation on the removal of barriers was approved in every Autonomous Community during the 1990's, it was only beginning in 2003 that the corresponding set of regulations was completed. It was the Equal Opportunity, Non-Discrimination and Universal Accessibility Law and its subsequent legislative elaboration, in particular its basic accessibility requirements, that have provided Spain with a legislative body that constitutes a model.
- By and large, current legislation is not being enforced. One of the main reasons has been the absence until virtually 2008 (December 26, 2007) of a law establishing rules on infringements and penalties regarding issues of equal opportunity, non-discrimination and universal accessibility. This time lapse resulted in a situation where people with disabilities were defenceless in the face of lack of enforcement of the existing Law.
- The previously existing accessibility legislation suffered a high level of dispersion until 2007, when the basic accessibility and non-discriminatory requirements for persons with disabilities were approved for four of the five fields established by the Equal Opportunity, Non-Discrimination and Universal Accessibility Law. In addition, and apart from this lack of homogeneity in national legislation, regional legislation has not been enforced systematically.
- Regional legislation on accessibility suffers from a high degree of obsolescence. The first area that calls for modernization is its terminology, which must evolve from the concept of "removal of barriers" to those of "Design for All" and "universal accessibility". In addition, many Autonomous Communities lack specific accessibility regulations regarding the information society as well as new technologies. This is behind the need to modernize and harmonize regional legislation on the basis of national legislation.
- A National Accessibility Plan was not approved until 2004. This document has provided the public administration and civil society with a strategic tool to make accessibility to environments, goods,

products and services a reality. Previously, there was no specific plan which would prompt all social agents to work jointly towards a shared objective.

- The conclusions of the fieldwork carried out as part of Observatory for Universal Accessibility in Spanish Municipalities confirm that, to this point, accessibility improvements have focused on the needs of people with limitations in their motor functional capabilities, in particular wheelchair users.
- The needs of blind and visually impaired people have recently begun to be addressed, but their progress has been slower than of actions affecting people with motor disabilities. As an example, while 80.3% of evaluated pedestrian crossings have flattened curbs, only 64.3% display a proper warning pavement. Another example is the very high percentage of traffic lights lacking acoustic signals.
- The needs of people with hearing disabilities and limited cognitive capabilities have seldom been addressed when accessibility improvements in physical environments have been carried out. This is reflected in the fact that 89.9% of public buildings lack specialized staff with knowledge of sign language.
- The actions carried out have not followed a strategic plan but have taken place on an ad hoc basis aimed at implementing partial solutions. This reflects the fact that accessibility issues have not been analyzed holistically, and, therefore, the solutions to the existing problems have not taken into account Design for All principles.
- A very high percentage of the evaluated urban and signage elements do not meet the necessary conditions for them to be used easily and safely by people with disabilities.
- While safety in elements such as banisters, handrails, sidewalls and tree basins are of utmost importance, flaws are widespread. In the case of the first three elements cited, more than 50% of the flaws were found inside buildings.
- As for transportation systems, the situation mirrors that of built environments: the accessibility improvements have been geared

mostly towards meeting the needs of people with motor functional limitations rather than those of people with sensory disabilities.

- As for websites, while their rating might seem acceptable, it should be pointed out that they are sometimes difficult to use, particularly for people with sensory disabilities.

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AN ACCESSIBLE INTERFACE FOR PROGRAMMING AN ASSISTIVE ROBOT

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***Abstract*:** In this paper, we present an accessible interface in the context of our work on bringing advanced robotics closer to everyday domestic users. This interface allows inexperienced users to be capable of programming an assistive robotic arm to perform a specific desired task in a household environment. The programming process is performed through the developed Web Browsable interface, within which a Task Creator Wizard plays an essential role. The robot's open architecture enables flexible multi-modal interaction. In addition to the touch buttons provided by the Web Browsable interface when presented on a touch screen, voice commands and the use of the Wii Remote™ controller for intuitive robotic movement have also been enabled. The Web Browsable interface has been designed to provide high accessibility while taking aesthetic details into account, in order to prevent distraction caused by boredom of the user.

Keywords: Assistive Robot, Graphical Interface, Usability, User-Centered Design.

Introduction

In our everyday lives, we are increasingly being surrounded by modern technologies. Advanced electronics are exponentially embedded in smartphones, tablet PCs, ebooks. Inexperienced people and even young

children are able to interact with touch screens or buttons, navigating through tabs, menus, and icons (Holzinger, 2003). This fact provides the reason for existence of end-user developments (EUD) (Burnett & Scaffidi, 2011). With all the possibilities for efficiency and improvement of EUD, some researchers have already begun to see the potential of web applications (Rode, Rosson, & Qui, 2006) and alternative controllers (Guo & Sharlin, 2008). Web interfaces can additionally provide several potential benefits, such as ubiquitous availability, and public access if desired.

All of these advances are also being progressively incorporated in the field of robotics, although perhaps at a slower pace. Robotics and automation are fields that are first commercially developed for industrial environments, with non-friendly interfaces, requiring technical training for personnel. However, recent works such as Baxter (Guizzo & Ackerman, 2012) are now taking the user-oriented point of view into account, aiming at simplifying industrial manipulator programming.

From the steady regime of production plants, robotics and automation technology can now be found in retail stores, and ultimately, in home environments. In their broadest scope, robotics and automation include everything from motorized shutters and vacuums to less common advanced robotic manipulators (Iocchi, Ruiz-del-Solar, & Van der Zant, 2012). Current worldwide research focuses on how to introduce dynamic and mobile elements to perform "household chores" and daily tasks that require complex manipulation and advanced reasoning skills. These technologies will begin to make our life easier only with the development of human-robot interfaces that provide comfort and satisfaction to the user (Kim, Oh, Choi, Jung, & Kim, 2011). In this paper, the authors propose the merger of robotics with technology that everyday users can be familiar with, such as web browsing, voice commanded control, and video-game controllers, and present proof-of-concept Open Source implementations and documentation with experimental results.

These developments have taken place using an assistive robotic arm, which is currently located in an assistive living kitchen test environment. The

following is a review of some of the assistive robotic arm's most important features and characteristics.

- Full on-board robot control and communications, with no need for an external control cabinet.
- Unlimited workspace through power supply climbing connectors.
- Light-weight symmetrical structure for climbing.
- Tool exchange system for grippers, utensils, sponge, etc.
- Portable and friendly interfaces adapted to different levels of user diversities and preferences.
- Open architecture for flexible component integration.

These last two features are the ones that have been mostly exploited by the authors in this paper, in order to extend the reach of their developments to the hands of everyday home domestic users.

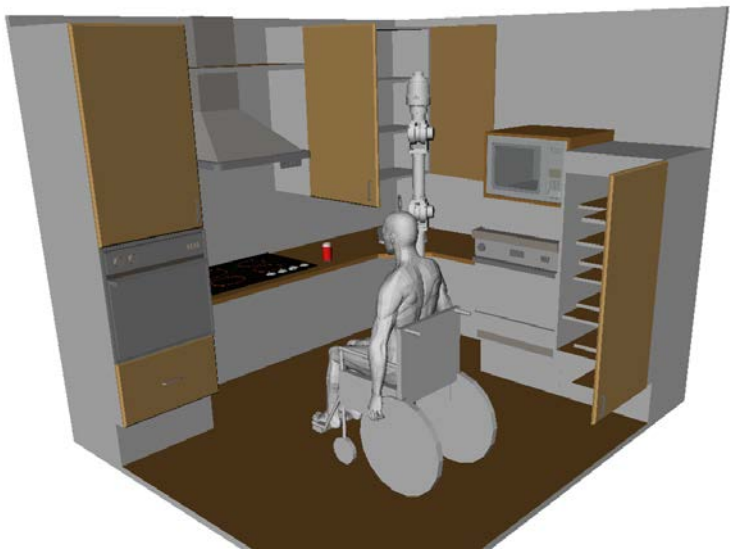
Methodology

To provide an accessible interface for a system as complex as an assistive robotic arm, an open architecture must be provided. We provide this open architecture through the use of the YARP robotics platform (Fitzpatrick, 2008), that enables multi-modal interaction by providing a flexible and robust implementation of the publisher/subscriber paradigm. This platform is lightweight enough for our embedded system, and provides multi-lingual and multi-platform support combined with easiness of use for a great range of possible developer profiles (Victores, 2010). The developed YARP modules are intended to a run within the Wireless Local Area Network (WLAN) of the robot, but the user is free to expose the interface connections for external assistants to collaborate, remotely interacting with the modules from a distant location.

A simulator environment is crucial for an initial training phase, to allow end users to practice with the assistive robotic arm before handling it in the real physical environment. The simulator used is OpenRAVE (Diankov, 2010), given that it is lightweight, modular, and exposes an application programmer

interface to its core libraries. The default environment it is set to load is the robot's assistive living kitchen test environment (Fig. 1). Robot sensors and cameras are also incorporated in the simulated 3D environment to provide a higher degree of realism and fidelity.

Figure 1. The simulator is set to load the robot's assistive kitchen model



One of the main objectives of our assistive robotic arm research and software development of the past years has been to provide integrated modes of Human-Robot Interaction (HRI) through devices with which users can already be previously acquainted with, therefore allowing them to immediately start discovering how to control the robot platform through the interface devices instead of using time learning how to use a new specific interface device. The robot system's open architecture methodology additionally allows the control interface devices to be used simultaneously. These device modules are all managed coherently by the system.

Touch Buttons

The robot's Web Browsable interface is intended for display on devices that support tactile interaction. It is composed by nine functional tabs (Home, Joint, Cartesian, Program, Speech, Assigner, Launcher, Video, and Docking). A persistent Connection Manager for establishing and terminating

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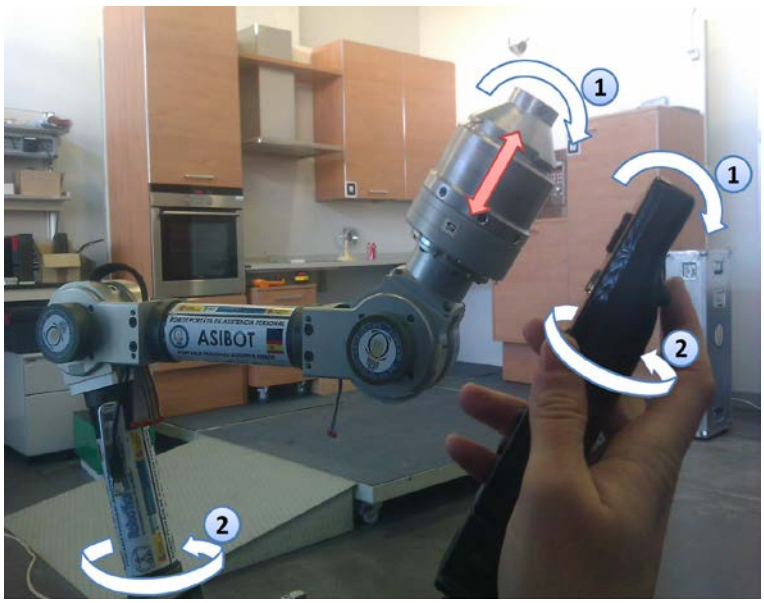
communications with the real robot and with the simulator is set to be rendered at the bottom left corner of the browser window. The client side scripts of the pages served have been optimized to minimize the amount of client-server interactions that take place.

Wii Remote controller integration

A Wii Remote Plus controller interface module has been developed as part of the robot's open architecture components for multi-modal interaction. The controller's A and B buttons control forward and backward movement functionalities respectively, while maintaining both buttons pressed allows plain reorientation. The robot tip aligns with the Wii-Remote controller pitch, and the robot's base roll is controlled with the controller roll (Fig. 2).

Figure 2. The Wii Remote orientation is tracked with a fixed linear velocity



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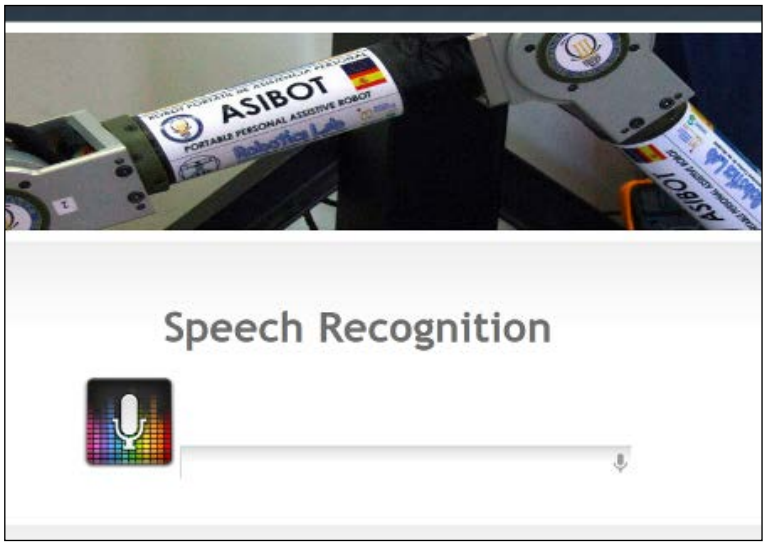
Automatic Speech Recognition

The robot's automatic speech recognition has been integrated into the Web Browsable interface as a selectable tab. The page served (Fig. 3) contains a speech recognition input field for recording and saving commands which can later be assigned to different tasks.

Figure 3. The robot modules provide speech recognition for HRI



The input field makes use of the x-webkit-speech attribute, linking the field to the Google Inc. implementation of the HTML5 Speech Input API (currently a W3C Editor's Draft (Sampath & Bringert, 2010)) by default. The Google Inc. implementation of the x-webkit-speech attribute uses Google's service cloud to perform the actual speech recognition, which returns a plain text string that the robot stores in its User Program Repository.

If the final system is not going to have access to a constant Internet connection, a local, but more limited, speech recognition mechanism may be used. This solution is based on PocketSphinx, part of the CMU Sphinx - Speech Recognition Toolkit (Huggins-Daines et al., 2006). This software is more accurate when a reduced dictionary (or 'corpus') of words is used. The corpus used is formed by common relevant words, including: color names, daily life activities (give, bring, wash, etc.), pronouns, and domestic objects (can, water, fridge, door, etc.). Once the corpus language model has been

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created, the use is the same as if it were using the Google service cloud alternative. This local method is very robust to pronunciation and external noise, but lacks flexibility because its results are limited to the words contained within the developed corpus.

Task Creator Wizard

The robot Web Browsable Task Creator Wizard has been developed to guide the user through the task creation process from within the robot Web Browsable interface. A robot task is composed by one or several custom or predefined programs that the user may invoke through the use of one or more of the open architecture's multi-modal interfaces. The Task Creator Wizard is initialized from within the Web Browsable interface homepage. It is set to display useful user guide information in the form of prompts and alerts. The use of the Wizard is, however, not mandatory. The user may instead choose to browse through the tabs manually to develop robot tasks.

First, once activated, the Wizard automatically redirects the user to the Joint space movement tab (Fig. 4). The tab is invoked so that a progress bar is displayed on the bottom right corner of the page. It indicates how advanced the user is in the task creation process, and allows the user to jump to each next step throughout the entire creative process.

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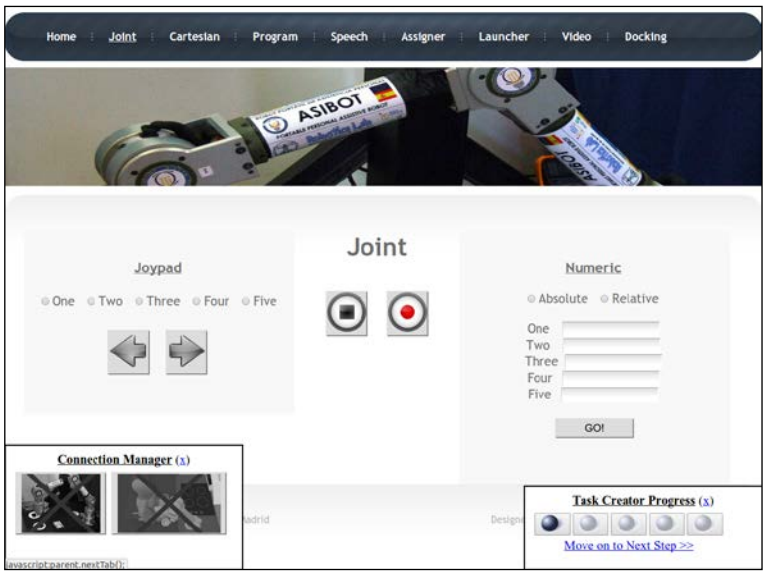
Figure 4. A progress bar guides the user throughout the whole creative process



As previously mentioned, the user can establish connections with the real and the simulated robot using the persistent Connection Manager situated at the bottom left of the interface. Once the connections are established, the user can move the selected robots in the Joint space using the correspondent tab buttons.

Additionally, the user can press the capture button (the round red Record icon situated at the center-right of the same Fig. 4) to open a prompt for saving the robot's tip point with a custom name. The robot's tip point position and orientation information that is stored is computed when the user clicks on the capture button, which may occur even if the robot is in movement. This behavior has also been implemented in the Cartesian space movement tab (Fig. 5), which is the next step the user is guided through.

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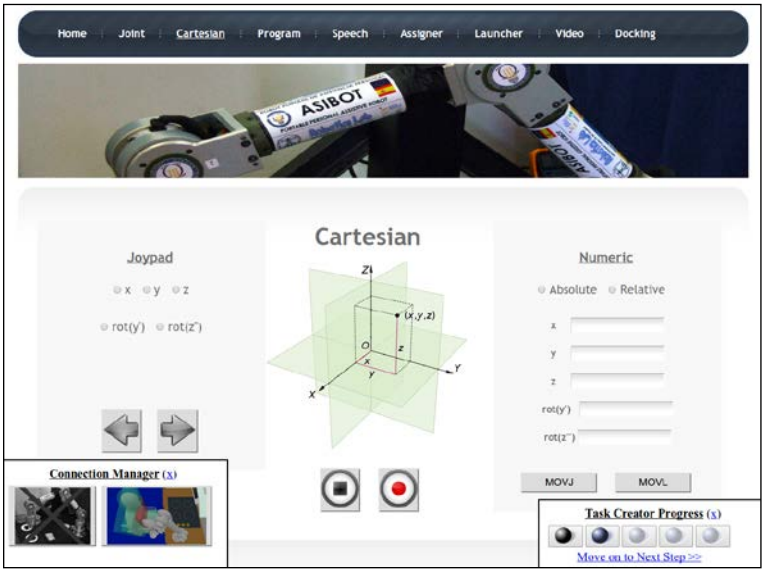
Figure 5. Points may be captured even when the robot is in movement



The capture button of either of these two tabs, namely the Joint space movement tab and the Cartesian Space movement tab, may additionally be used to capture points when the robot is moved by using the Wii Remote Plus controller interface. On the completion of this point capturing phase of the Task Creation process, the user is guided by the Wizard to the Program tab (see Fig. 6). Here, the user can create, edit, save and delete robot programs directly from within the Web Browsable interface.

The robot Web Browsable interface Program tab plays the role of an Integrated Development Environment (IDE) for developing robot user Python programs. The left side panel allows the user to create, explore and delete robot user Python programs. When the user decides to create a new program, the IDE returns a new file with a snippet of default source code. This source code is extracted from a template file which is set to load the basic resources for programming the robot (libraries, initialization routine calls). Additionally, some hint lines of code are added for connecting to a remote instance of the robot or simulation control module, performing a robot homing movement, waiting, and closing the module cleanly.

Figure 6. The robot Web Browsable interface Program Tab

The Program tab additionally provides a set of buttons with the captured point names, situated on the top part of its right side panel. Clicking on this type of button inserts two lines of code into the central program text area:

- A Point definition. The definition of the point that was captured and given the name that the button indicates.
- A Cartesian space movement command. The robot is commanded from its current position to the point indicated, following a straight line trajectory (a MOVL command).

A robot Python point is defined as a native Python list of doubles that indicate the position and orientation of the robot tip in absolute base coordinates. The MOVL member function calls may also be modified and transformed into MOVJ function calls. Movements due to MOVJ function calls are, generally speaking, faster but less precise (trajectory-wise) than those issued by MOVL commands. This is because MOVL commands involve the computation of a straight linear trajectory, whereas MOVJ commands involve trajectory interpolation at single joint level. This nomenclature is commonly found in the context of industrial robots, and the authors have particularly been inspired by the RAPID, an ABB proprietary programming language (ABB, 2005).

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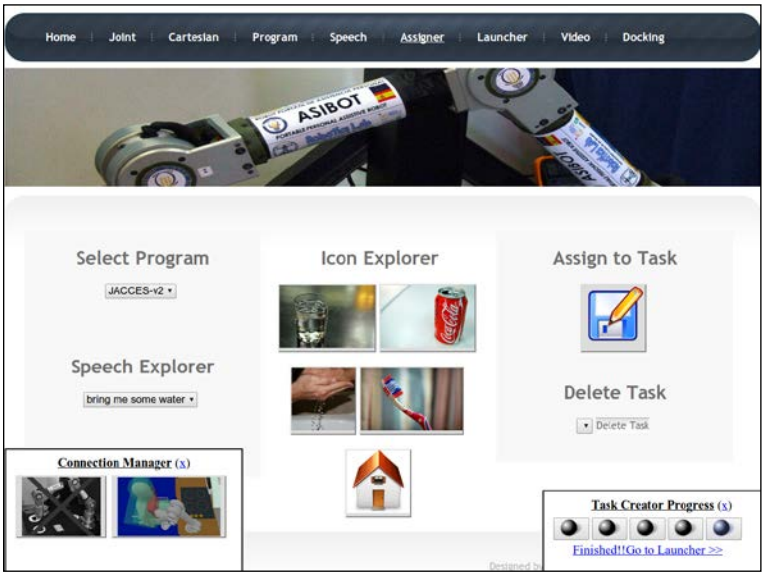
Once the user has finished programming, she or he will be prompted to save the program with a custom name by pressing the save button. The Wizard then guides the user to the Speech tab. In the Speech tab, the user records and saves words that will be assigned to programs in the Task Creator final step, the Assigner tab (seen in Fig. 7). The Assigner tab is composed by program, recorded word, and icon selectors to generate robot task files, which are minimalistic scripts that link these three elements.

The Task Creator Wizard leads the user to the robot Web Browsable interface Launcher tab once the assignment has been performed. The Launcher parses the task files and presents the selected icons zoomed as touch buttons on screen, waiting for user tactile interaction or voice commands to execute the tasks that the user has developed through the use of the multi-modal interfaces, with or without the use of the interface's Task Creator Wizard.

Figure 7. The robot Web Browsable interface Assigner Tab



Results

In order to perform a complete system assessment, we conducted two different tests: one with people that were previously inexperienced with robotics, and one with robotics-related people who were familiar with the

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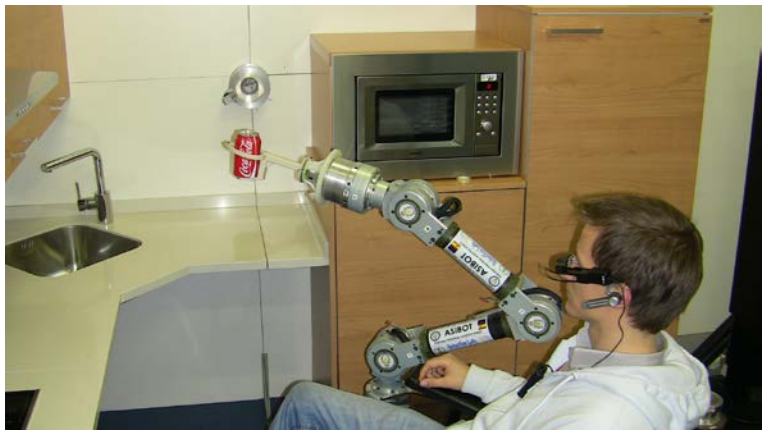
robot. The reason for this double-test was to include the not-so-common opinion of developers or technology-skilled users to the common analysis of inexperienced people. The comments and suggestions of technology-skilled users can be useful to assure an easy teaching process, as at a certain point they could actually become the people in charge of training disabled people in handling high-tech adapted devices.

In the first test, the ten healthy inexperienced users in robotics were invited to the robot assistive living kitchen environment and attended a five-day course for two hour sessions each day. At the end of the entire course, where they were explained how the system and the robot work, they were asked to use the developed interface presented for the creation of a common domestic task: grabbing a red can from a table. This is a task which we already knew that the robot was capable of performing (Fig. 8).

Figure 8. The robot "Grab a red can from a table" task achievement



To evaluate their experiences, we performed spoken interviews at the end of the five-day course. This type of feedback (instead of regulated tables or forms) was chosen because these non-experienced people found it easier to express their sensations by speaking naturally. They were all asked the same set of questions, about pros and cons, comfortability, complexity, and main drawbacks. The following is a summary of the answer received:

- From a domestic point of view, all of the users found the use of the proposed multi-modal interfaces (touch buttons, voice commands, and automatic speech recognition) very interesting and useful.
- Each of the users found a device that best fit their necessities to use the Web Browsable interface for comfortably interacting with the assistive robotic arm.
- All of the users were capable of generating several voice patterns that could be recognized by the Internet version of the automatic speech recognition system.
- Every user was able to make the robot grab the red can from the table successfully. From our professional experience, similar courses with industrial robots and controllers indicate a time closer to two weeks for performing a similar task.
- Two users evaluated the programming performed with the Wii Remote controller negatively. The reason was having to sustain the implemented "dead man"' buttons while moving the controller. They found it uncomfortable and counterintuitive.

In the second test, we asked ten robotics researchers to perform the same task, without the five-day course, and only a brief introduction to the system. To measure their satisfaction with the system, we provided them with standard SUS tests (System Usability Scale). The reason behind this difference in tests between robotics and non-robotics people is because, with the technological people, we were aiming toward system improvements beyond those that can be pointed out by inexperienced users. The following are the SUS results:

- The total average punctuation of the system was 70.5 ± 9.5 over 100 (where 100 is the best score).
- The best results were obtained in the statement: "I think that I would like to use this system frequently". Its numerical result was 4 ± 0.6 over 5 (where 5 is the best score).

- The worst results were obtained in the statement: “I think that I would need the support of a technical person to be able to use this system". Its numerical result was 2.6 ± 0.8 over 5 (where 5 is the worst score).

As a general overview, experiences were positive and the feedback received from robotics people indicates us where to improve the programming for a lighter and faster browsing interaction.

Conclusions

The presented interface has proved to be a feasible and useful way to program an assistive robot for common activities in a domestic environment. Its multi-modal tools and its commercial off-the-shelf device integration (e.g. Wii Remote controller) enable the possibility of interacting with robots in a different way, which may result more accessible for certain people with special necessities. We ensure accessibility for all kinds of people, taking into account the fact that industrial robots are known for their use of their own, expensive and complex, programming elements. The presented system may be accessed from any kind of device with Internet capabilities.

The Task Creator Wizard ensures a complete process of programming a complex action, without having any knowledge of programming. This is a major advance towards the domestic introduction of advanced robotics. Additionally, the use of visually relevant icons helps to easily recognize pre-recorded tasks. The feedback received from the users has helped us understand where to focus future research efforts. The presented system gets closer to the original aim of the assistive robotic arm, which is to aid disabled and elderly people.

Acknowledgments

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OVERVIEW OF THE AUDIO DESCRIPTION IN SPANISH DTT CHANNELS

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***Abstract*:** This paper presents a research of current practices in audio description broadcast in Spanish television channels. The results of this research show that in some television channels the audio description is broadcasted in 'receiver mix audio description' mode while in other channels the alternative used is 'broadcaster mix audio description' mode. In both cases, correct signalling and correct audio description coding is crucial so that digital television receivers can recognize audio description in the broadcast signal and reproduce it upon user request. The current practice of audio description broadcast in Spanish television channels only partially fulfils DVB standard. In addition, not all digital television receivers are able to reproduce appropriately the wide range of options defined in DVB to convey audio description in the television channels. The consequence for the users is less availability of audio description services than expected. Some of the problems detected for the activation of audio description in users' receivers can be solved by applying some enhancement to signalling information used by broadcasters in their DVB television channels. Finally, some recommendations for the users are included to present the key aspects for audio description activation in their digital television receivers.

Keywords: audio description, digital television, DTT, descriptor, audio stream, accessibility.

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Introduction

On 13 December 2006, the General Assembly of the United Nations adopted, ratified by more than 80 countries, the Convention on the Rights of Persons with Disabilities (CRPD) and an associated Optional Protocol (United Nations, 2006) (Kayess & French, 2008). Governments in many countries have taken initiatives to promote and regulate accessibility services to multimedia television contents. This is the case of Spain (Spanish Ministry of Industry, Tourism and Trade, 2006) (Spanish Government, 2010) , UK (Ofcom, 2012), France, Italy, Germany and other countries in Europe. Current regulations establish minimum levels of availability of accessible multimedia in digital terrestrial television (DTT) and also in the fast growing IPTV networks.

In Spain the recent approval of the General Communication Audiovisual Law, LGCA (Spanish Government, 2010), minimum levels of availability of accessible multimedia in digital terrestrial television have been established. Among all accessibility services regulated, the LGCA establishes the minimum threshold of programs with audio description for most Spanish television channels. The audio description provides a narrative of the visual elements of an audiovisual program to visually impaired people (Utray, Pereira, & Orero, 2009). Once completed the transitory period that finished last 31th December, 2013, the Law establishes minimum levels for audio description that become 10 hours per week in every public television channel, and 2 hours per week in every private channel.

The Law defines quantitative obligations as well as recommendations to the broadcasters to fulfil technical requirements according to applicable standards.

Once these regulations are established, the need to measure and qualify the actual contents of subtitling and audiodescription services arises from the involved actors. Television providers need to evaluate the real presence of accessibility services in their emissions, and users' organizations are also interested parties, but it is a duty for regulators to monitor what providers are really offering. When dealing with quantity measurements of subtitling

time in digital terrestrial television or IPTV networks, the MPEG-2 transport stream (ISO/IEC 13818-1, 2007) composition and content need to be explored in detail. Along with the technical quality and related signalling parameters, there are codes of best practices in the field of audio description that address issues such as: language use, quality of diction (intonation and interpretation), sound mix and adequacy in fulfilling needs of users (Orero, 2005). All these parameters require the intervention of domain experts in the evaluation process.

In Spain and in Europe, terrestrial digital television is broadcast according to the family of international standards for Digital Video Broadcasting (DVB) (ETSI EN 300 744 , 2009) (ETSI EN 300 468, 2009). The DVB signal relies on a MPEG-2 structure consisting of data streams (video, audio, data) and signalling streams and, of these, some carry the so called PSI (Program Specific Information) signalling tables (Program Association Table, Program Map Table, …) while other, in the case of DVB digital television (Reimers, 2006), are SI (Service Information) tables (Event Information Table, Service Description Table…). Audio description is carried as part of the television channel, as a private data elementary stream within the MPEG-2 streams.

Hence audio description offered by the television channels is regulated by the DVB standard family. DVB defines different ways in which broadcasters can embed audio description of television programs in their television channels.

On the other hand, DTT receivers and televisions with integrated DTT must fulfil the DVB standard´s requirements to ensure that audio description in the received DTT signal is presented to the users and played correctly. Correct signalling and audio description coding is crucial so that television decoders can recognize audio description in the broadcast signal and reproduce it upon user request.

The current practice of audio description broadcast in Spanish television channels only partially fulfils DVB standards (ETSI EN 300 468, 2009), (ISO/IEC 13818-1, 2007). In addition, not all the televisions are able to play correctly the wide range of options defined in DVB for the delivery of audio

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description in the television channels. The consequences to the users are less availability of audio description services than expected.

In the following sections, we present the result of the research done in the Spanish Centre of Subtitling and Audio Description (CESyA) during the monitoring of accessibility services in Spanish television channels, which has been done manually since 2006 and automatically since 2012. Automatic monitoring of the audio description presence in all nation-wide television channels is done systematically in CESyA since October 2013. Monitoring of subtitling and audiodescription is performed with SAVAT 2.0, CESyA´s own technology that allows performing automatic monitoring of accessibility in DVB television channels. Studies in the areas of communication sciences, audiovisual translation, linguistics and telecommunications engineering, conducted in collaboration with leading companies and international experts (Looms, 2010), have led to significant and high quality technological developments in Europe and particularly in Spain. SAVAT 2.0 is the contribution of Spanish government to the monitoring of digital terrestrial television, as part of the monitoring activities foreseen by United Nations in its convention (United Nations, 2006).

Next section provides an analysis of the different alternatives offered by the DVB standard family for broadcasting audio description in television channels; every broadcaster should deliver audio description according to one or these alternatives. Current practice in all public and private television channels is covered after that; the results presented are derived from the exhaustive research performed at CESyA covering audio description monitoring 24 hours/day over 26 television channels. All data presented here has been obtained in the period January 2014-May 2014. During these months, the overall audio description detected in the 26 DTT channels monitored adds up to 2201 hours; during this period, the total emission is 84048 hours for the 26 television channels.

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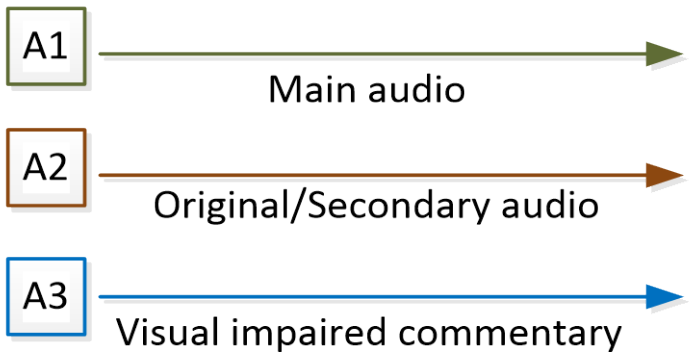
Audio description in digital television

Audio description in digital television (terrestrial, cable, satellite…) is included in the television channels as an option, selectable by users in reception. According to DVB, there are two ways to broadcast audio description for the visually impaired in a television channel:

- Audio stream dedicated entirely to the comments for visual impaired (unmixed audio description / receiver mix audio description): it is usually transmitted through the third audio stream of the television channel and requires the decoder to have the functions needed to mix both of the two audio streams involved: main audio stream and the audio stream that contains the audio description. It is schematically as is shown in Figure 1.

Figure 1. Flow of visual impaired commentary in an independent audio channel



- Audio channel with the comments for visual impaired mixed with the main audio of the program (mixed audio description / broadcaster mix audio description): it is usually broadcasted in the second audio stream of the television channel. In most broadcasters this audio stream is not only used to transmit audio description, but it is also used to transmit the original version of the television program or other types of audio (Figure 2). When there is no audio description or original version, the actual practice is broadcasting in the second

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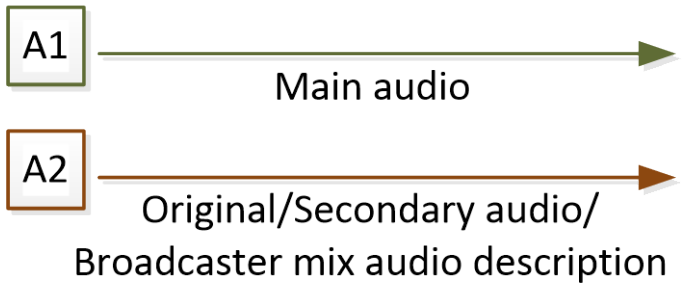
audio stream the same content transmitted through the main audio stream.

Figure 2. Audio stream carrying the program´s audio description mixed with main audio in the same channel



The two alternatives imply different choices in the protocol elements involved. The most relevant aspects regarding audio description are those affecting signalling carried in PMT and EIT tables, which are summarized in next chapter.

Nowadays, nearly all DVB DTT decoders and televisions with integrated DTT decoder are able to reproduce the secondary audio stream when audio description is mixed with the main audio of the program (Option 2). However, many DTT decoders are not fully DVB compliant and do not support receiver mix audio description mode (Option 1). In addition, some DTT decoders do not offer audio description related options in their On-Screen Display (OSD) menus.

This results in the inability of many users to reproduce audio description when receiver mix audio description is the option chosen by the broadcaster. Receiver mix audio description is the preferred option for many broadcasters for this service as it requires lower bandwidth.

Audio description signaling

Digital television is carried over MPEG-2 Transport Streams. The MPEG-2 (ISO/IEC 13818-1, 2007) structure consists of data streams (video, audio, data) and signalling streams and, of these, some are PSI signalling tables

(PMT, PAT, …) while other, in the case of Transport Streams carrying DVB digital television, are SI tables (EIT, SDT,…).

The applicable standards in this case are:

- ETSI EN 300 468 V 1.11.1 (ETSI EN 300 468, 2009)
- ISO 13818-1 (ISO/IEC 13818-1, 2007)
- ISO 639-2 (ISO 639-2, 2008)
- TS 101 154 V1.9.1 (ETSI TS 101 154, 2009)
- UNE 133300:2011 (UNE 133300, 2011)

When a television program includes audio description for the visual impaired users, this implies two types of data in the broadcast signal:

- Content information: The audio stream that carries audio description for the television channel.
- Signalling information: Transport Stream composition as defined in PSI tables and DVB program and service SI: EIT, SDT...

With regard to content information, Annex J (Signalling of Receiver-Mixed and Broadcast-Mixed Supplementary Audio) of DVB ETSI EN 300 468 defines two mechanisms for transmitting supplemental audio (audio description):

a) Receiver mix audio description.
b) Broadcaster mix audio description.

Signaling information describes the type of audio content and how it is conveyed in the MPEG-2 Transport Stream, together with other data of the television channel. Correct signalling comprises, in the case of audio description, information in two of the Transport Stream´s tables: PMT and EIT.

- The composition of each television channel is transmitted in its PMT; among the information specified for a given channel is the description of the audio streams associated to the television channel. Audio description carried in one of the audio streams of the television channel is therefore specified through DVB descriptors foreseen in

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(DVB), and shall be according to the option selected in emission. The descriptor used is the *ISO language descriptor* defined in ETSI EN 300 468.

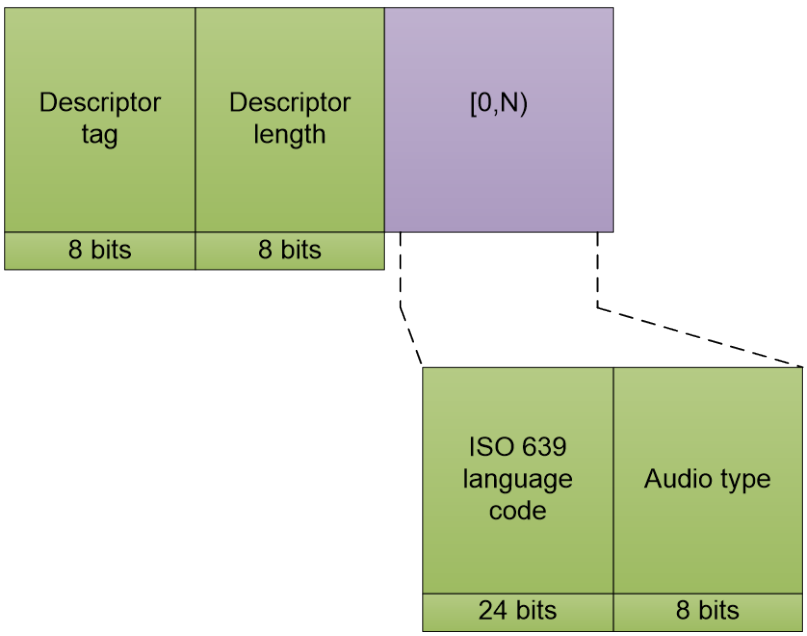
- The EIT carries the program schedule of all channels in the Transport Stream, including the indication of audio description availability and its type.

The correct signalling choices for receiver mix audio description and broadcaster mix audio description, both in the PMT and EIT tables, are described in next paragraphs.

Audio description signaling in PMT table

Signaling the presence of audio description to the digital television receiver starts by indicating in the PMT table the type of audio conveyed in each audio stream. This is done in the PMT table by means of the *ISO 639 language descriptor* (ISO/IEC, 2007), which indicates the language and type of audio associated with an audio stream. The structure and fields of the *ISO 639 language descriptor* are shown in Figure 3.

Figure 3. Structure of ISO 639 language descriptor.



- Descriptor_tag: "0x0A".

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- *Descriptor_length*: identifies the descriptor´s size
- *ISO_639_language_code*: identifies the language or languages of the audio stream with 3 characters. For those cases in which the flow uses different types of language or audio, depending on the program that is being emitted, it is allowed either to define multiple languages or to use a generic *language code.* Table 1 shows the most common values used in Spain:

Table 1. Language_code values

Language_code	Description
spa	Spanish
qaa	Reserved for original version
qad	Reserved
mul	Multiple languages
und	Undefined

- *Audio_type*: describes the type of audio associated with an audio stream. Table 2 shows the values allowed for this field.

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Table 2. Audio_type values.

Audio_type	Description
0x00	Undefined
0x01	Audio for the hearing impaired
0x02	Hearing impairment
0x03	Comment visual impairment
0x04 – 0xFF	Reserved

Among all possible combinations of fields *audio_type* and *language_code*, only a subset of them are valid in the case of audio description. Subsections J.2.2 y J.3.2 of Annex J of DVB ETSI EN 300 468 specify the values to be used in the two scenarios foreseen:

Receiver mix audio description:

- *ISO_639_language_code*: the value of this field, taking into account that the audio description will be in Spanish, should be "spa".
- *Audio_type*: for the case where the audio stream carries just the visual impairment comments, its value must be "0x03".

Broadcaster mix audio description:

- *ISO_639_language_code*: in this case, the encoding depends on the broadcast method chosen. There are two main possibilities:

  a) A single audio stream: when a single audio stream is used to broadcast alternatively audio description and original version depending of the program, there exist in its turn two signaling

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alternatives: 1) transmitting a single *ISO_639_language_code* within the *ISO_639_language_descriptor* containing one of these two values: "NAR" or "qad" (other allowed values defined in ISO 639-2 being "mul" and "und"), or 2) alternatively an *ISO_639_language_descriptor* could be sent with two *ISO_639_language_code*: one with value "qad" referring to audio description and another with the value "qaa" referring to original version.

b) Dedicated audio stream: when different streams are used for audio description, original version, secondary language, etc., a second *ISO_639_language_descriptor* will be introduced in the PMT for each audio stream; the respective fields *ISO_639_language_code* of those descriptors will be coded according to the standard ISO 639-2, namely, "spa" for Spanish, "cat" for Catalan, "qaa" for original version, "qad" for audio description…

- *Audio_type*: taking into account that former *ISO_639_language_code* field refers to different types of audio, the *audio_type* field has to carry the undefined audio value, and therefore "0x00" value shall be assigned.

In addition to this, the standard ETSI EN 300 468 offers the possibility to describe in greater detail in the PMT the content of the audio stream. For this purpose, the subsection J.4 of annex J specifies an additional descriptor. *Supplementary audio descriptor* allows the broadcaster to specify the type of audio description mix conveyed in the audio stream. The *Supplementary audio descriptor* belong to the *Extension descriptor* family, its structure being depicted in Figure 4:

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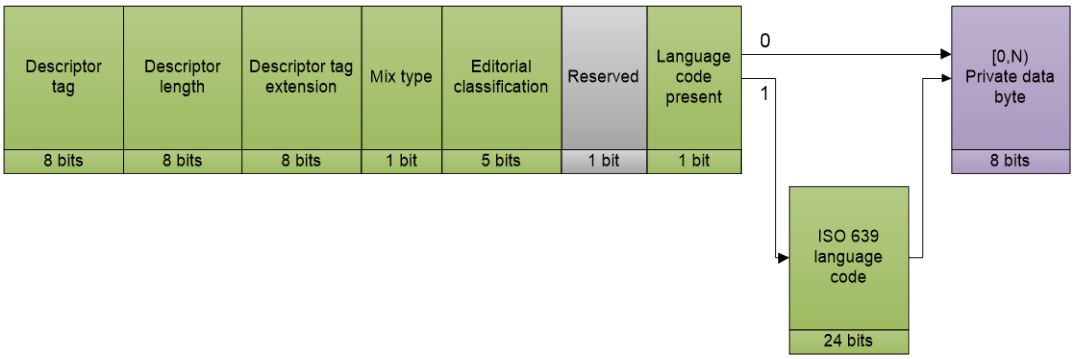
Figure 4. Structure of the Supplementary audio descriptor.



- Descriptor_tag: "0x7F". Identifies the *Extension descriptor* family.
- Descriptor_tag_extension: "0x06". Identifies the *Supplementary audio descriptor*.
- *Mix_type*: identifies the type of mix. Allowed values are shown in Table 3.

Table 3. Mix_type values.

Mix_type	Description
0x00	Supplementary stream
0x01	Complete and independent audio stream

- *Editorial_classification*: classifies the audio stream´s content. Allowed values are shown in Table 4.

Table 4. Editorial_classification values.

Audio_type	Description
00000	Main audio
00001	Audio description for the visually impaired
00010	Clean audio for the hearing impaired
00011	Spoken subtitles for the visually impaired
00100 a 10111	Reserved for future use
11000 a 1111	User defined

- *Language_code_present*: when the value of this field is set to one, it indicates that the following 3 bytes will indicate the audio´s language by the field *ISO_639_language_code*.
- *Private_data_byte*: the values in this field are reserved for private use.

None of the above described descriptors are independent. Subsection J.4 of ETSI EN 300 468 specifies the valid combinations of the fields of the descriptors *Supplementary audio descriptor* and *ISO 639 language descriptor* to signal the details of the audio stream carrying the audio description of the television channel. Table 5 summarizes the field´s combination and values allowed. Field *audio_type* belongs to the *ISO 639 language descriptor*, while the fields *mix_type* and *editorial_classification* belong to *Supplementary audio descriptor*.

Table 5. Audio descriptor´s possible combinations in PMT.

Audio	Audio type	Mix type	Editorial classification
Main	0x00	1	0
Audio description (mixed broadcast)	0x00 o 0x03	1	1
Audio description (mix in receptor)	0x03	0	1

These two descriptors, when used by broadcasters, provide the maximum information about all the audio streams associated with each television channel, and allow the digital terrestrial television receivers to present enhanced information to the users in the On Screen Display menus.

Audio description signalling in EIT table

On the other hand, the standard DVB ETSI EN 300 468 specifies the way to signal through the EIT table that a specific program in the television channel has audio description available. This information is relevant for the Electronic Program Guide (EPG) that digital terrestrial television receivers present to the users in their On Screen Display menus. OSDs are an additional source of information for the users in order to present all accessibility services available for each television channel.

For each program in the television channel, an entry in EIT table shall specify the content type of the streams associated to the channel while the program is on air. For instance, if a movie is broadcast with two languages, this must be taken into account and therefore show that the audio is multilanguage. Another example regarding video characteristics may be that

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if a movie has a panoramic format, it should be indicated as video format 16:9. All this information describing the content of each stream in the television channel is provided through the EIT´s *component descriptor*. The structure of this descriptor is as follows in Figure 5:

Figure 5. Structure of the Component descriptor.

Descriptor tag	Descriptor length	Reserved future use	Stream content	Component type	Component tag	ISO 639 language code	[0,N) Text char
8 bits	8 bits	4 bits	4 bits	8 bits	8 bits	24 bits	8 bits

- Descriptor_tag: "0x50".
- *Stream_content*: specifies the stream type. Table 6 shows the possible values that this field can take for audio description.

Component_type: specifies the type of content conveyed in the respective video, audio or data stream.

- Table 6 shows the possible values that this field can take for audio description.
- *Text_char*: contains a textual description of the stream component.

Table 6. Values of the field component descriptor for audio description.

Stream content	Component type	Description
0x02	**0x40**	Audio MPEG-1, audio description for visually impaired people
0x02	**0x47**	Audio MPEG-1, audio description mixed in reception
0x02	**0x48**	Audio MPEG-1, broadcast mixed audio description
0x06	**0x40**	Audio HE-AAC, audio description for visually impaired people
0x06	**0x44**	Audio HE-AAC V2, audio description for visually impaired people
0x06	**0x47**	Audio HE-AAC, audio description mixed in reception
0x06	**0x48**	Audio HE-AAC, broadcast mixed audio description
0x06	**0x49**	Audio HE-AAC, audio description mixed in reception
0x06	**0x4A**	Audio HE-AAC, broadcast mixed audio description

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As in the case of PMT, these values must be used to signal via the EIT table the availability of audio description for a television program in the channel. Taking into account what is specified by ETSI EN 300 468 (Table 6) and the limitations imposed in the Spanish market by the norm UNE 133300:2011, valid values for the *component descriptor* in EIT for audio description in Spain are the following:

- Receiver mix audio description:

  a) MPEG-1:

  - Stream_content: "0x02"
  - Component_type: "0x47"

  b) HE-AAC:

  - Stream_content: "0x06"
  - Component_type: "0x47"

- Broadcast mix audio description:

  a) MPEG-1:

  - Stream_content: "0x02"
  - Component_type: "0x48"

  b) HE-AAC:

  - Stream_content: "0x06"
  - Component_type: "0x48"

- Usual case:

  a) MPEG-1:

  - Stream_content: "0x02"
  - Component_type: "0x40"

  b) HE-AAC:

  - Stream_content: "0x06"
  - Component_type: "0x40"

  c) HE-AAC V2:

  - Stream_content: "0x06"
  - Component_type: "0x44"

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Current practice of audio description broadcast in Spanish television channels

Spanish television outlook in terms of audio description signaling is very varied. All channels are choosing to signal the audio description in one of the two methods that we have seen in figures 1 and 2, with some exceptions such as TV3 that add a fourth audio channel to broadcast the program´s audio in more than 2 languages.

Regarding PMT, the use made by broadcasters of the different options given by DVB to signal the streams is appropriate. They signal audio streams in a standardized way, depending on whether the audio description is mixed in emission or in reception. For this, they always use the descriptor *ISO 639 language descriptor* which was described above.

Moreover, it is noteworthy that in any case program audio description´s signaling is done using the EIT tables. Currently, any channel uses the *component_descriptor* (ETSI. Digital Video Broadcasting (DVB), 2009) to signal the accessible contents of channel's programs for people with visual impaired. However, this same descriptor is used to signal the type of audio or video. On the other hand, it is usually signal through descriptors in the table EIT the name, genre and even the minimum age to watch the program.

RTVE

Signaling

As shown in the table below, channel TDP has only one audio stream and therefore this channel does not broadcast audio description in any of its programs. On the other hand, channels La 1, Clan and La2 have three audio streams, while the second stream is used to send the program´s original audio ("qaa") the third audio stream is used for just broadcast the audio description content (mix in reception). Finally, channel 24h has a second audio stream in which they only broadcast the program´s original audio.

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Table 7. Audio streams language in RTVE

	First stream	Second stream	Third stream (AD)
TDP	spa	-	-
La 1	spa	qaa	spa
La 2	spa	qaa	spa
24h	spa	qaa	-
Clan	spa	qaa	spa

Optimal signaling

In case of channel 24h wants to broadcast audio description, they should change the value "qaa" of *ISO_639_language_code* in their second stream for either "NAR", "qad", "und" or "mul" as it has been shown before.

Table 8. Proposal of audio description broadcast in channel 24h

	First stream	Second stream
24h	spa	**NAR**, **qad**, **und** or **mul**

Statistical data

The statistical data obtained by analyzing the channels belonging to this media group during 2014 are shown in the following table.

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Table 9. RTVE audio description weekly hours

	AD weekly hours
TDP	0h
La 1	2,39h
La 2	1,40h
24h	0h
Clan	0h

In RTVE group, La1 and La2 are the only channels which broadcast audio description, and its emission is mainly based on movies, TV series and culture shows.

Atresmedia

Signaling

All channels in Atresmedia Group broadcast audio description in the same way, through the second audio channel giving to it a value of "und". This way of broadcast audio description is the appropriate because that audio stream is used to send the original language of the program and also to send audio description. Therefore, the indication is adequate.

Table 10. Audio streams language in Atresmedia Group

	First stream	Second stream	Third stream (AD)
Antena 3	spa	und	-
Neox	spa	und	-
Nova	spa	und	-
LaSexta	spa	und	-

Statistical data

All channels in Atresmedia group broadcast audio description, with the results shown in the following table during 2014.

Table 11. Atresmedia audio description weekly hours

	AD weekly hours
Antena 3	4,37h
Neox	9,21h
Nova	2,66h
LaSexta	4,45h

Among Atresmedia group is noteworthy NEOX, because in addition to having the highest level of weekly audio description, has programs with audio description almost every day while other channels just have isolated programs.

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Mediaset

Signaling

Within Mediaset Group all channels broadcast audio description in the same way, in their third channel with visual impaired commentary to mix with first audio stream in receiver.

Table 12. Audio streams language in Mediaset Group.

	First stream	Second stream	Third stream (AD)
Telecinco	spa	qaa	spa
FDF	spa	qaa	spa
Energy	spa	qaa	spa
Cuatro	spa	qaa	spa
Boing	spa	qaa	spa
Divinity	spa	qaa	spa

Statistical data

In Mediaset group, all channels have broadcasted audio description during 2014 as is shown in the following table.

Table 13. Mediaset audio description weekly hours

	AD weekly hours
Telecinco	1,40h
FDF	28,68h
Energy	3,20h
Cuatro	1,75h
Boing	2,09h
Divinity	2,06h

FDF is the channel in Spanish TV with the highest level of audio description and has daily programs which are always audio descripted. Almost all channels base their audio description programming on movies and series, highlighting Boing which is entirely devoted to children's programming.

Other television channels

Signaling

In this case we can see that there is a disparity in the methods used for managing audio streams. In the case of Paramount Channel in the same way as channel 24h, use the second audio stream to send original audio of programs. Furthermore, as we have seen in the case of channel TDP, channels Intereconomía and 13 TV only have one audio stream and therefore it is impossible to broadcast audio description. The channel Discovery Max has only two audio streams and the second one is used only for broadcast the original audio in English. Finally, Disney Channel like Mediaset group sends in third audio channel visual impaired commentary to mix with first audio stream in receiver.

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Table 14. Audio streams language in various communication groups.

.	First stream	Second stream	Third stream (AD)
Paramount Channel	spa	qaa	-
Intereconomía	spa	-	-
Discovery Max	spa	eng	-
Disney Channel	spa	eng	spa
13 TV	spa	-	-

Optimal signaling

As much in Paramount Channel as Discovery Max only use second audio stream to broadcast original audio language of TV show or movies. In case of these channels want to broadcast audio description, they should change their respective fields *ISO_639_language_code of second stream to* "NAR", "qad", "und" or "mul". Another option to broadcast audio description and not delete the original audio of second stream would be open a new third audio stream to send visual impaired commentary with value of field *ISO_639_language_code to "spa".*

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Table 15. Proposal of audio description broadcast in channel Discovery Max and Paramount Channel

	First stream	Second stream	Third stream (AD)
Paramount Channel	spa	**NAR**, **qad**, **und** or **mul**	**spa**
Discovery Max	spa	**NAR**, **qad**, **und** or **mul**	**spa**

Statistical data

During 2014, channels in this group have the levels of audio description per week shown in the following table:

Table 16. Other channels audio description weekly hours

	AD weekly hours
Paramount Channel	0,53h
Intereconomía	0h
Discovery Max	0,77h
Disney Channel	14,73h
13 TV	0h

Disney Channel stands out among these channels. It is entirely devoted to children's programming. Some of the programs always include audio description.

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Access for users

Activating audio description in a television channel is not always trivial and it can involve a serial of steps regarding the receivers or televisions the user has and the way television broadcasters broadcast their contents.

Currently in Spain, program´s audio description is done by broadcasters in two different ways as it has been shown in previous points: mixing in emission the original audio with the audio description or broadcasting only the audio description so that it is mixed with the original audio in the user´s receiver or television. Each one of these ways has a method to be activated in the receptor and therefore we will explain both of them separately.

When a television channel broadcasts an audio description mixing it directly in the emission, the user has the audio description service in his receiver through the channel´s second audio stream. Therefore, in this second audio stream it is available the original program´s audio mixed with audio description, without the receiver having to do any additional work. To activate audio description within this method, the user only has to change to the second audio stream, usually by a command button called DUAL or I-II, which is the same used to listen programs' original version when this option exists. In some receivers, the second audio stream is activated through the menu, which is accessible via one button in the remote control.

Alternatively, television broadcasters can broadcast audio description through an independent stream, which will be mixed with the program´s original audio in the user´s receiver when he activates the audio description in it. This mix is always dependent on the receiver, so it exist the possibility that the receiver lacks of the mixture option and therefore it cannot be done. This should be the first condition a user should check in his receiver before purchasing it, reviewing the user´s manual or by contacting the manufacturer.

Once it has been checked that the receiver allows making the mix, the way to activate it is very different depending on the type of receiver, the manufacturer, the menu´s organization in the user interface, etc. The

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simplest, although not the most common, is when the remote control has a button with the initials AD and in these cases, just by pressing a button the mixture is activated in the receiver and every time a program has audio description, it will be played automatically at the same time as the original audio is played. In other receivers, the users must activate the mix of audio description using the receiver´s setting audio options. For this, they must explore the receiver´s menus in order to search for the audio settings, looking for the option called "audio description" or similar. In this option, audio description has to be enabled along with the volume (optionally) which the user desire to listen audio description regarding the original audio. In some receivers, audio description activation options and volume settings are located in different menus. Therefore, it is important to check the user´s manual in order to configure properly the device

In most devices, once audio description is configured, this configuration remains permanently active. In this way, when a program is being broadcasted with audio description, the user will listen it in the device´s speakers.

As it can be seen, not all devices are prepared for the new methods used for broadcasting audio description, although most modern devices have incorporated the possibility of mixing streams in the receiver itself. If the user has a receiver that allows it, the user is responsible for properly configure it so that audio description can be received without any problem.

Conclusions

Audio description´s broadcasting in Spanish TV channels has begun to include an option, which was recently unused, that provides the mixture in reception. This method saves bandwidth and production costs to broadcasters, but it is not compatible with many of the currently installed devices in Spanish homes, despite being one of the provided options given by the standard DVB.

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Receivers and DTT televisions which are able to play an audio description stream mixing it with the program´s main audio have, in many cases, user interfaces with low usability, making it very difficult for many users to access audio description services and leads them to believe that audio description is not available when in fact it is truly being emitted.

The Spanish Center for subtitling and audio description gives recommendations and future working guidelines for answering this problem and they have been broken into two big groups:

- Recommendations for broadcasters:
    - Choose preferably the option of broadcasting audio description mixed in emission while most of users´ installed receivers and DTT televisions are not compatible with the mixture in reception option.
    - Once most of users´ installed receivers and DTT televisions are compatible with mix in reception, broadcasters should choose preferably this option which allows users not to worry activating the second audio stream to test if a program has or has not audio description contents.
    - Signal correctly audio description´s broadcast in the tables SI and PSI according to what it is established in the standards DVB and AENOR (Spanish Association for Standardisation and Certification).
- Recommendations for manufacturers:
    - Full audio description functionality support as defined in standard DVB, taking care of all descriptors and information elements defined by the protocol and implementing the functionality for each one of them.
    - Incorporation in the remote control of buttons for direct access to audio description for receivers, DTT televisions and in the future, Smart TVs and HbbTV (Hybrid Broadcast Broadband TV) receivers in order to guarantee an easy access for visually impaired people.

- Improve the settings menu and audio description activation usability.
- Show in the OSD menus the availability of audio description in TV programs, in response to the signalling information received in the tables SI and PSI.
- Display the availability of audio description when it is available in TV channels in any of its modalities (mix in reception, mixed broadcast) using acoustic signs which will be activated with channel switching and other user´s relevant actions.

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DESIGN AND EVALUATION OF AN INTERGENERATIONAL GAMING PLATFORM FOR COGNITIVE STIMULATION

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***Abstract*:** Cognitive stimulation therapies based on games are commonly used nowadays in care centers for people suffering from Alzheimer's or other cognitive diseases. Although users usually like the proposed games, they are not motivated enough to play willingly on a regular basis. This work presents a novel game platform for cognitive stimulation that introduces the factor of intergenerational interaction in order to increase user's motivation towards playing. This work tries to involve patient's relatives in the gaming experience by including the use of social networks. The presented gaming platform has been designed, implemented and evaluated with real patients, proving its technical feasibility and usability. Evaluation results and practitioners' experience show that the gaming platform will be more suitable for patients suffering from a mild level of cognitive disease.

Keywords: intergenerational games, cognitive disease, usability.

Introduction

During last years, the use of non-pharmacological therapies for the treatment of cognitive diseases, such as Alzheimer's, has increased as its therapeutic validity has been proven (Orrell, Spector, Thorgrimsen, &

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Woods, 2005). These kinds of therapies are known as cognitive stimulation therapies and they are often based on games (Whitlock, McLaughlin, & Allaire, 2012). Practitioners often use these kinds of games in stimulation sessions with their patients, playing either with real cards or using new interaction systems that have recently emerged (interactive TV, multi-touch screens or tablets). Nevertheless, their main problem is that users are not motivated enough to play regularly.

Non-pharmacological therapies have also been evolved introducing concepts of social interaction. The main concept is that interacting with other people in their same situation will help patients with the development of their therapies. Moreover, intergenerational interaction (social interaction between people from different age groups) can be beneficial for them and also for their families, as the family environment usually takes part in it (A Guide to Intergenerational Practice, 2011).

This work presents a system that combines the benefits of game-based cognitive stimulation therapies with intergenerational therapies, using information and communication technologies. The proposed gaming platform allows people with cognitive diseases and their relatives to interact and play cognitive stimulation games by using social networks as a means of communication. As these two groups of users do not have the same characteristics, patients suffering from a cognitive disease will interact with a simple device (a tablet) while the other group of users will be able to integrate the gaming platform in their preferred social network. Results show that the use of a simple multiplayer game increases user's motivation to play and maximizes the benefits of the game as a cognitive stimulation therapy.

This gaming platform has been developed under the COGNIGEN project, which has been partially funded by the Institute for the Elderly and Social Services (IMSERSO), within the National Plan for Scientific Research, Development and Technological Innovation 2008-2011, exp. 222/2011.

Cognitive stimulation systems using information technologies

Most care centers for people suffering from any type of cognitive disease offer some platforms for cognitive stimulation nowadays. Some of the most popular platforms for this kind of therapies are Gradior or Feskits. They are commercial platforms which offer different games for cognitive stimulation that will be run on a computer. During the last few years, research in Spain and Europe has been focused on the development of cognitive stimulation platforms for being run on simpler devices in order to improve usability: interactive TV (García et al., 2011) or interactive tables ("Elder Games" European project).

In addition to improving usability by defining special gaming platforms, another research topic is related to intergenerational games (Theng, Chua & Pham, 2012; "LEAGE" European project; Khoo et al., 2006). All these works obtained positive results regarding user's motivation for the games. Nevertheless, as targeted users of these platforms were people who did not suffer from any cognitive disease, the validity of these games as a cognitive stimulation therapy was not studied.

Besides intergenerational interaction, social interaction is important for older people and their use of social networks has been studied. Some works have proven that the reason why older people do not use social networks is not the lack of technical knowledge, but the lack of interest (Sundar, Oeldorf-Hirsch, Nussbaum & Behr, 2011). The last annual report of social networks in Spain (2013) shows that Facebook is the user's favorite social network: it is used by the 96% of the social network users during an average time of 5,18 hours a month. Taking these data into account, the existing social networks have to be considered in order to bring them closer to older people.

System description

A game platform was designed and a prototype of a game was developed in order to have a functional system, which supported various user profiles and

devices. Every design aspect has taken into account the special needs of the users of the game platform. This design was addressed with the collaboration of practitioners from the National Reference Centre for Alzheimer and dementia care (CRE Alzheimer).

Components

Two types of clients have been developed for being used in two different types of devices. The tablet client is run in a Tablet PC and the social network client is run on a computer using a web browser. Both applications have the same functionalities, their main differences being the user interaction method: a touchscreen (for the tablet client) and a mouse and/or keyboard (for the social network client). Some social networks (Facebook, Tuenti and Google+) were evaluated for the implementation of the social network client. Finally, Facebook was chosen for the development of the prototype as it provided an Android SDK for mobile and web applications.

A server application was also developed for the communications management. This server application is used as a connection element between clients in order to synchronize the game state between players. The server is in charge of creating and transmitting the games to the clients as well as storing the data that the practitioners need in order to monitor the patients.

There are three types of user profiles considered in this work: patients with some kind of cognitive disease (the main group of users this work is aimed for), relatives (patients can use the platform to play with their relatives) and practitioners (they can use the game platform with their patients in the therapy sessions).

Main functionalities

The designed game platform can support any number of games, but only one kind of game was developed in this work as a proof of concept. Practitioners proposed the implementation of a memory game, which consists of finding

pairs of matching cards by turning them over. This game was suggested because the professionals used this game in therapies with paper cards and having it in an electronic format was interesting for them.

Both the tablet and the social network client allow a complete gaming experience. The main functionalities are briefly described below:

- Identification: the user has to log into the system with his Facebook user credentials. Once the login process is completed, an initial personalized screen will appear showing the user's profile image and a personalized welcome message with his name.
- Game mode selection: the user can choose to play in multiplayer or individual mode.
- Opponent selection: When a user selects the multiplayer mode, all Facebook contacts that are online at that moment will be shown. By selecting one of them, an invitation to play will be sent to that user.
- Invitation reception: When a user has been sent an invitation, he will receive a notification of this fact, showing the person that invited him and allowing its acceptation or rejection.
- Game: A game for finding matching pairs of cards is implemented.

Considerations on usability

This work tries to maximize the system's usability as the final users of the game platform have special needs. Two main aspects have been considered: personalization and user interface.

Personalization

The game platform has to adapt its content to the user profile, as the abilities of the potential users of the gaming platform could be very different. For this reason some parameters that affect the game difficulty can be personalized for each user:

- Game board size: the number of cards that appear on the game board is the main factor that determines the game difficulty. The game platform has been designed to use a variable game board size, supporting a range from 8 to 16 cards.
- Stimulus exposure time: in this context, the stimulus exposure time is defined as the time during which the non-paired cards are visible until they are hidden again. The longer the exposure time, the easier it will be to remember the location of each card.
- Game mode: the game platform will allow users to play against another user or on an individual mode. Nevertheless, for certain users, the multiplayer version of the game could be very difficult, so this game mode can be disabled for them.

The aforementioned parameters can be personalized individually for each user. As the practitioners know the abilities of each patient, they are responsible for editing these parameters before the patient uses the game platform for the first time. These parameters are also dynamic, so practitioners can change any parameter any time, for increasing or decreasing the game difficulty.

User interface

During the design of the game platform, the main objective was to achieve a user interface as usable as possible. Therefore, both usability guidelines and opinions from healthcare professionals were taken into account to select some design principles that have been applied to every screen the user has to interact with ("Buenas prácticas de accesibilidad en videojuegos", 2012; Ijsselsteijn, Nap, de Kort & Poels, 2007).

Distractions are very common in this kind of users so simplicity and consistency were very important restrictions to maintain users focused on the parts that contain the information or that he has to interact with. Moreover, the application has been designed to use big screen elements that provide a large area of interaction, as the main user input is tactile. The use

of big interaction elements also addresses some possible usage problems related to age (finger rigidity and deterioration of movement coordination).

Color combination had to be also considered in order to create enough contrast between the different elements and specially for improving text legibility. In addition, the application has to inform the user about its state so he knows at every moment if an action is required. To do this, both audio and textual feedback is used.

Figure 1 shows four different screens that are part of the application and follow the usability restrictions identified. Each of the screens implements one of the main functionalities of the platform: identification (top-left), opponent selection (top-right), invitation reception (bottom-left) and game (bottom-right).

Figure 1. User interface

Evaluation

An evaluation process for determining the usability of the gaming platform, and especially the tablet client, was carried out using direct observation techniques and questionnaires. Users were provided with tablets of two different sizes (10 and 7 inches).

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Participant description and evaluation set-up

Twelve participants took part in the evaluation process of the gaming platform. They were patients from the National Reference Centre for Alzheimer and dementia care who had been diagnosed with some type of dementia. They were in stages 3, 4 and 5 of the Global Deterioration Scale (GDS), being stage 4 the most common of them. Only two of them suffered from a mild level of a cognitive disease, whereas the cognitive disease level of the other ten people was medium. Participants' age ranged between 55 and 90, with a mean of 79 and a mode of 86.

User tests were conducted at the National Reference Centre for Alzheimer and dementia care at Salamanca making use of a Gesell dome (two contiguous rooms with a one-way mirror between them). The patients used one of the rooms to do the test while a group of researchers and practitioners observed the tests in the other room.

Evaluation procedure

Each patient who took part in the system evaluation had to use the system for 15 to 20 minutes. The number of games they played was variable as it depended on some factors such as user skills using the tablet or his ability for remembering the hidden cards. Practitioners had previously configured the parameters that affect the game difficulty for each user. They decided that only the mild level patients could play with the 16-card version of the game. The other patients used the 8-card version. Patients were always accompanied by a practitioner who helped them in everything they needed. The practitioner guided patients through the test following the procedure described in the following paragraphs.

The practitioner started the test by showing the user how to use the tablet. After that, the practitioner explained the objective of the game and how to play. Then, the user started playing in the individual mode with the 10-inch tablet. After a certain number of games, some users were given the 7-inch tablet to continue playing, being then questioned by the practitioners about their preferences.

Taking into account the game performance shown by users in the individual mode, the practitioners proposed certain users to play some games in the multiplayer mode. Their opponent could be another patient (who was in the same room) or another practitioner (who was in a different room).

Figure 2. Evaluation procedure

Test results

The mean playing time on each type of device was analyzed in order to determine the differences between the 10-inch and 7-inch tablets: 2:33 minutes for the 10-inch tablet and 1:52 minutes for the 7-inch tablet. The Student's t-test was applied (using the independent two-sample t-test for unequal sample sizes and unequal variances) and it proved that there were no significant differences between the tablets (t statistic = 2,001 – critical t value = 2,131 – P (T ≤ t) for a two-tailed test = 0,063).

Table 1.Game duration comparison.

User ID	Average playing time in individual mode (minutes)	Average playing time in multiplayer mode (minutes)
User 5	03:03	03:15
User 3	02:56	04:31
User 12	01:52	05:03

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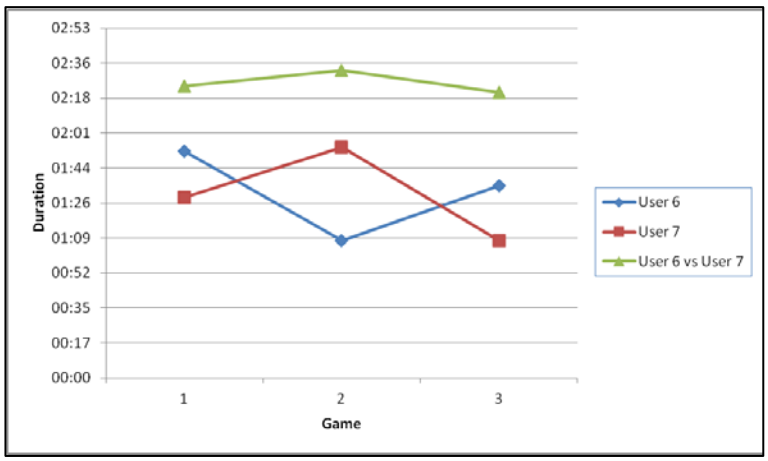
The gaming time for multiplayer games differs from the gaming time for individual games. Multiplayer games between a patient and a practitioner (Table 1) or between two patients (Figure 3) shows that the time spent in a multiplayer game is higher than the time spent in the individual mode. This is due to the fact that in the multiplayer version of the game the user needs to remember the cards for a longer time, which increases its difficulty.

Figure 3. Game duration comparison.



Practitioner's impressions

When the user sessions ended, evaluation questionnaires were sent to each practitioner that took part in the experiment. Some affirmations were written on the questionnaires and the practitioners had to answer if they agreed with the affirmations. Practitioners had to write their answers in a range from 1 to 5, where 1 meant that they "strongly disagree" and 5 meant that they "strongly agree". These affirmations were meant to get their opinions about the patients' use of the gaming platform.

Four practitioners filled out the questionnaire. They considered that the application interface is easy to use and they think that the best option for the patients would be the 10-inch tablet. Nevertheless, during the tests, the users showed no preferences between the devices. Practitioners were also asked about the validity of the gaming platform as a complement to other existing therapies. The 90-percentile shows that they strongly agree on this affirmation and also that playing against another person increases the

patient's interest on using the gaming platform. However, practitioners are not sure about users' understanding of the multiplayer concepts: 90-percentile shows a scoring of 4 out of 5.

The questionnaire had a set of affirmations regarding the patient's use of the platform describing four scenarios that took two factors into account: game mode and help needed. In addition, they had to distinguish between patients with a mild or a medium level of cognitive disease. Table 2 and Table 3 show the results for this set of questions.

For patients with a mild level of cognitive disease, practitioners strongly agree that they will be able to play both in the individual and multiplayer mode if they have the practitioner's help. If they do not have any help, practitioners think that they will be able to play in the individual mode (90-percentile is 4 out of 5) whereas the 90-percentile for multiplayer games is 3.7 out of 5.

Table 2. Practitioners' answers regarding patients with a mild degree of cognitive disease.

Question	Range	Mode	90 percentile
Patients are able to use the tablet to play in the individual mode, with a practitioner's help.	5	5	5
Patients are able to use the tablet to play against another person, with a practitioner's help.	4-5	4 and 5	5
Patients are able to use the tablet to play in the individual mode, without any help.	3-4	3 and 4	4
Patients are able to use the tablet to play against another person, without any help.	2-4	3	3.7

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Table 3. Practitioners' answers regarding patients with a medium degree of cognitive disease.

Question	Range	Mode	90 percentile
Patients are able to use the tablet to play in the individual mode, with a practitioner's help.	3-4	3 and 4	4
Patients are able to use the tablet to play against another person, with a practitioner's help.	3-4	3 and 4	4
Patients are able to use the tablet to play in the individual mode, without any help.	1-2	1 and 2	2
Patients are able to use the tablet to play against another person, without any help.	1-2	1 and 2	2

If patients have a medium level of cognitive disease, practitioners' answers show some differences. While for the simplest scenario practitioners agreed unanimously that users with a mild level of cognitive disease will be able to use the system, the 90-percentile in this case lows to 4 out of 5. The same values are obtained for playing against another person if they can get help. On the other hand, practitioners do not think that patients will be able to play without help: values from 1 to 2 out of 5 were obtained, being 2 the 90-percentile, which clearly shows that they disagreed on these affirmations.

Discussion

Twelve potential users of the platform did the gaming platform evaluation. Although there were not enough users to get formal conclusions for its validity as a cognitive therapy, some valid results about the usability of the system were obtained.

Direct observation of the evaluation procedure revealed that users seemed comfortable using the tablet and they understood how to interact with it. They used 10-inch and 7-inch tablets, not showing any preferences for one or another. In addition, figures confirmed that tablet size did not affect the gaming time. Patient's attitude towards the game was positive and they seemed to be motivated in the multiplayer mode, as they liked to continue

playing to be the winner. Figures indicated that games in the multiplayer mode lasted longer than the individual ones: as they had to wait for the opponent's movement, they tended to forget the cards location more easily so they needed more movements to find the matching cards.

Patients suffering both a mild and a medium level of cognitive disease took part in the evaluation process. All of them were able to play with the tablet, but the practitioners had to give more indications to the group of patients that had a medium level of disease. Using these tests and their experience, the practitioners filled out a usability questionnaire. The main conclusion that can be obtained from this questionnaire is that users with a mild level of cognitive disease will be the more suitable user group for the gaming platform, as practitioners think that this kind of patients will be able to use both game modes without help. On the other hand, help will be a decisive factor for the other group of patients, as they only will be able to play if someone helps them.

Conclusions and future work

This work presents the definition of a new cognitive stimulation therapy, based on the concepts of serious games, multiuser interaction and intergenerational interaction. As a result, a gaming platform with these features has been designed, implemented and evaluated. This gaming platform allows users to play a memory game individually or against other people using a tablet (meant to be used by patients with cognitive disease) or a browser on a computer (meant to be used by relatives or practitioners who play against the patients). The design process focused on usability in order to adapt the application to the special needs of potential users. All of these features turn the gaming platform into a novel system.

A group of patients suffering from several types of cognitive disease, such as Alzheimer's, and a group of practitioners have evaluated the gaming platform. Technical feasibility of the system has been proven and positive results regarding user's acceptance have been obtained after these tests.

Taking into consideration the evaluation results, patients with a mild level of cognitive disease will be able to use the gaming platform on their own, whereas patients with a medium level of cognitive disease will need some kind of assistance. Results also showed that the multiplayer game option increased user's motivation: they wanted to continue playing and they were also more concentrated on the game.

A more detailed evaluation of the system from the therapeutic point of view is needed in order to guarantee its validity as a cognitive stimulation therapy. This evaluation will have to be carried out for a longer time and focusing on the patients with a mild level of cognitive disease. Patient's relatives should also take part in this evaluation process, so the intergenerational and multiplayer benefits regarding user's motivation could be studied.

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VIRTUAL REALITY IN REHABILITATION: WII™ AS AN OCCUPATIONAL THERAPY TOOL IN PATIENTS WITH SPINAL CORD INJURIES

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Abstract: The use of virtual reality has gained importance in the rehabilitation sector over the last few years. The Wii™ console complements traditional treatment by exercising the motor skills in a motivating context, which is important in long-term interventions, such as spinal cord injury.

Objectives: to describe our work with the Wii™ console and the different support products used in occupational therapy at the Fundación del Lesionado Medular, and to discuss advantages and disadvantages.

Method: 63 patients with spinal cord injury (of whom 46 with quadriplegia and 17 with paraplegia), treated over the period of one year in weekly 30-minute sessions.

Results: motor-skill improvements, more involvement of the patients in the treatment.

Conclusion: the features of the console and the support products created by our department make the Wii™ accessible to patients, increase their motivation and enrich the treatment.

Keywords: Spinal cord injury, Nintendo Wii™, rehabilitation, Occupational

Therapy.

Introduction

Recently there has been a rising interest in the use of virtual reality to the rehabilitation process (Holden, 2005). The Wii ™ console, together with other new technologies, provides a complement to conventional treatment in the form of activities which are accessible and motivating to patients, while enabling the practice of functional movements (Gil- Gómez, Lloréns, Alacañiz, & Colomer, 2011; Cameirao, Bermúdez, & Verschure, 2008).

The Nintendo Wii ™ is a console that detects three-dimensional movements of the user by means of an infrared remote control and a sensor bar. This makes for intuitive and easy use, as it is with this control that the desired movements are executed.

The Occupational Therapy Department of the *Fundación del Lesionado Medular* has developed a skill-training program by means of the aforementioned games console. This new tool makes possible the work on different motor skills in a highly motivating context, which is important in cases of spinal cord injury as they involve long periods of rehabilitation and physical maintenance which can be arduous.

The advantages of using the Wii™ in rehabilitation include:

- Ease of use
- Accessibility
- High motivation
- Visual and auditory feedback
- Low cost
- Great variety of games
- Economy of space

Although the obtained results with this training program do not constitute scientific evidence in a strict sense, there are several studies on the application

of the Wii ™ as a therapeutic tool. Research by Laver, George, Thomas, Deutsch and Crotty (2011) states that virtual reality and interactive video games can be more effective in improving upper-extremity function and daily life activities, compared to conventional therapy. Different researches (Saposnik et al, 2010; Mouawad, Doust, Max & McNulty, 2011; Celinder, Peoples, 2012; Hurkmans, Ribbers; Streur-Kranenburg, Stam, & Van den Berg-Emons, 2011) mention the potential benefits in the rehabilitation of stroke patients and also the increased motivation resulting from introducing WiiSports® in occupational therapy treatment programs. Other studies (Hurkmans, Ribbers, Steur-Kranenburg, Stam,& Van den Berg-Emons, 2011; Hsu et al, 2011) conclude that tennis and boxing games of WiiSports® can be useful in increasing activity levels and promoting healthy lifestyles in patients with neurological damage. In addition, other studies about the Wii™ console mention the benefits of these games on elderly people in terms of strength, cardiovascular capacity, balance and coordination (Baker, Atlantis, & Fiatarone Singh, 2007).

As regards the support products, there is also evidence of more effective correction of the head position in severely disabled patients by using the Wii control (Shih, Shih, & Shih, 2011).

Objectives

- To describe how the Wii™ was employed as a working tool in the Occupational Therapy Department of the *Fundación del Lesionado Medular.*
- To describe objectives and administration of console-based treatment in cases of spinal cord injury.
- To present different ways of adaptation in order to facilitate its use.
- To discuss advantages and disadvantages of interventions with Wii™.

Methodology

Wii™ training has been used in our occupational therapy department for a year. It was used on 63 patients with the following diagnoses:

- 46 patients with quadriplegia; their injury levels ranging from C4 to C7 (ASIA A, B, C and D)
- 17 patients with paraplegia; their injury levels ranging from D2 to L2 (ASIA A, B, C and D).

All the patients were evaluated on daily life activities, using a version of the SCIM (Spinal Cord Injury Measure) scale; in addition, those with upper-extremity impairment underwent testing of key muscles, upper-extremity goniometric measurement and functional grip strength evaluation. Based on this, certain objectives were established which would constitute the basis for the training program, if they coincided with the skills that can be trained with the console.

The contraindications are just relative, since, according to the manufacturer's instructions, there is no health hazard in using the console. However, several considered factors resulted in patients being excluded from the console-based treatment:

- Cardiorespiratory impairment, which may prevent normal participation in the game, as it may be the cause of dizziness, inability to speak during the activity, etc.
- Low tolerance to frustration.
- Acute musculoskeletal injury: tendinitis, fracture, etc.
- Cognitive or behavioral disorders which may cause the patient to fall.

The objectives that can be targeted with the Wii™ are: range of movement in the upper limbs, coordination, dexterity, speed of movement, exercise tolerance, balance, posture control, visual-motor integration and weight transfer.

In order to reach these objectives, the following games were chosen: *Wii Sports*®, *Wii Sports Resort*®, *Zumba*® and *Just Dance 2*®. In addition, a level of difficulty was selected and a specific type of work was chosen from the following:

adaptations and support products to make it accessible, a change in the patient position (sitting or standing), unstable bases, additional weights, etc…

The sessions are held weekly and last for 30 minutes; they can be done individually or in pairs. Games based on dancing and training can be done in groups, with only one or two people obtaining scores. The training program is always carried out with the assistance of at least one occupational therapist that makes sure the activity is being developed on an appropriate way.

In addition, a questionnaire was held in order to know the opinion of the participants about what physical abilities they consider were working on with this Wii training program. They were asked to mark the most appropriate of them in relation to their rehabilitation routine with the Wii console. Balance, mobility of arms, mobility of trunk were considered to be the principal physical abilities trained by the participants.

Table 1. Physical abilities worked on with Wii console according to the participants.

PHYSICAL ABILITY	BALANCE	STRESS RESISTANCE	MOBILITY OF ARMS	MOBILITY OF NECK	MOBILITY OF TRUNK	STRENGTH	OTHER
Nº PARTICIPANTS (TOTAL OF 53)	40	22	41	16	34	14	10

Development

Characteristics of the Wii™ console

The Wii™ is a console with multiple possible uses, given that besides its own characteristics, there are several ways it can be used with patients. It works by means of a sensor bar that detects the movements of the control through infrared rays.

- Control: the main control, known as *Wii Remote*, has certain characteristics that adapts to the skills of a patient with upper extremity impairment –it is wireless, it is held by gripping with the palm, does not

require constant manipulation of buttons or a joystick and has a non-slip sleeve. In addition, its vibration during play functions as a proprioceptive stimulus.

- It has an in-built sensor that measures movement in any direction and at any speed (Cameirao, Bermúdez, & Verchure, 2008).
- There are other control accessories for specific games, such as the *Nunchuck* or the *Balance Board*.
- *Mii* character: an avatar can be created for each user, with a wide range of physical features to choose from. Thus, each patient has their own character, which accumulates the score of each game. This gets them more involved during the activity.

Wii™ Console games

Our Occupational Therapy Department has been working with *Wii Sports*®, *Wii Sports Resort*®, *Zumba*® and *Just Dance2*®, in order to train different skills, as shown in Table 1.

The games *Wii Sports*® and *Wii Sports Resort*® are simulations of different sports: bowling, tennis, golf, baseball, boxing, swordplay, wakeboarding, frisbee, archery, table tennis, power cruising, canoeing, cycling and air sports. There are different levels of difficulty, the level for each game depending on the player's choice or on the accumulated score. The patient must perform the movements just as he/she would do in real life and the *Mii* character moves with the player's movements, so there is immediate feedback. With most of the games, it is possible for two or more players to compete. The games are not very long (maximum 5 minutes) and a break can be taken at any point in the game.

The games *Zumba*® and *Just Dance 2*® consist in performing choreographies by imitating the movements of the character on the screen. In *Zumba*®, information is recorded about the rhythm and energy expenditure: an energy sensor checks in real time if the person should move "more energetically". If the character looks red, the rhythm is not right, while green means "correct rhythm". Besides, it is possible to compete with other patients, in which case a score is obtained at the

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end of the choreography. There is also the option to select a single song, lasting about five minutes, or a series of them with increasing and decreasing intensities, lasting twenty minutes.

In *Just Dance 2*®, it is possible to check the accumulated score on the screen as the choreography goes on. Feedback is given on how correctly the movements were performed. Each song lasts about four minutes.

Table 2. Skills that are exercised in Wii™ games training.

SKILL	Range of movement	Posture control	Exercise tolerance	Speed of movement	Coordination	Motor control	Visual-motor integration	Weight transfer while standing, bimanual activity.
Bowling	X	X			X	X		
Golf		X			X	X		X
Boxing		X	X	X		X	X	X
Tennis	X	X	X	X	X	X	X	
Baseball	X			X	X	X	X	
Frisbee	X	X				X		
Table Tennis	X	X	X	X	X	X	X	
Air sports	X	X				X		
Wakeboarding	X	X			X	X		
Canoeing	X	X	X	X		X		
Cycling	X	X	X	X		X		X
Basketball	X				X	X		
Power Cruising	X	X				X		
Swordplay	X	X	X	X		X	X	X
Zumba	X	X	X	X	X	X	X	X
Just Dance 2	X	X	X	X	X	X	X	X

Working Method

Each treatment is personalized. Working position, length of training program and level of difficulty are established after considering individual's characteristics, evaluation and initial objectives.

- Sitting position: the patient can stay in his/her wheelchair if he/she has insufficient trunk control, or if the only purpose is to work on the upper extremities or the neck. However, activity can be done in the long sitting position, especially when working on posture control and trunk balance. This can be done on a mat, on a stretcher without armrests, on a chair or in a more unstable type of sitting position, using objects such as a ball or a proprioceptive cushion.
- Standing position: certain games, such as golf, frisbee or dancing are interesting when it is necessary to work on lower-extremity weight transfer, righting reactions and posture and movement control.

Adaptations

Accessibility of the Wii™ is relative, since several adaptations can be done in order that as many users as possible can benefit from the treatment activities. Here is a discussion of different ways to make video console training more accessible to patients.

- Glove or bandage: recommended for those who cannot sustain their grip. It consists in bandaging or tying the control to the patient's hand, so that he/she does not need to apply strength to the grip.
- Helmet: it is used on people with severely impaired upper extremities, when the purpose is to work on their neck –or even trunk– mobility. The control is placed on the helmet, which allows the patient to participate in games such as Wakeboarding or Air Sports.
- *WiiWheel*: By means of the steering wheel, a Wii™ accessory, it is possible to work on pronosupination with patients who have no grip strength whatsoever and hardly any shoulder mobility. The steering wheel is placed on a surface (preferably made of non-slippery

material), so that the patient only needs to keep it perpendicular to his/her body, thus performing the required pronosupination movements. This type of movement is not exclusive to the driving games; it can be performed, for example, as an adaptation in the Wakeboarding game.

- Blocking of buttons: in certain games, the patient has to press a button to perform a particular action, which can be a problem. In some cases, adhesive elastic can be used to hold down the button.

Results

The results obtained at our Occupational Therapy Department suggest that there are benefits in using the Wii™ as part of the rehabilitation process:

- Increased motivation towards the activity. As the objective is pursued through games, the activity is more entertaining. Besides, the fact that patients can compete with each other can result in greater tolerance to frustration.
- Greater adherence to treatment. Seeing results in the form of scores and moving on to higher levels of difficulty, the patient receives positive feedback and learns new self-improvement strategies.
- Physical benefits: As the patients work with functional movements and obtain immediate feedback, the activities are more intuitive and easier to integrate into normal movement.
    - Speed of movement. In games such as Table Tennis, the rival keeps the pace that corresponds to the level, forcing the patient to keep up with it in his/her movements.
    - Range of movement and muscular strength in upper extremities. As can be seen on tables 2 and 3, with the games used in the training program, several upper-limb movements are worked on, with the additional advantage that the movements include all planes of space, which is more functional.

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- Visual/motor integration. Games such as Table Tennis, Bowling, Baseball or Swordplay require movements performed at a specific time determined by a visual stimulus.
- Exercise tolerance. Because of the variety of games and their short duration, resistance can be adapted to each patient, who can do a single game or a series of games/choreographies.
- Posture control: working in different positions allows the patient to work on his/her balance. He/she continually needs to adjust his/her righting reactions.
- Motor control. The patterns of movement used in the console are functional.

- Suggesting daily life activities for leisure. As a result of the intervention, and the creation of specific adaptations and support products for the console, a new possibility is offered for patients' leisure activities, even for those with very high levels of injury.

Table 3. Main movements worked on with the Wii games.

MOVEMENT	Abdominal flexion and shoulder	Flexion/Extension of the elbow	Pronosupination	Flexion/Extension of the wrist	Trunk rotations	Neck
Bowling	X	X				
Tennis	X					
Table Tennis			X	X		
Golf	X				X	
Wakeboarding			X	X	X	X
Zumba, Just Dance 2	X	X			X	
Cycling		X				
Swordplay	X	X				

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The main advantage of this type of virtual reality technology is that it offers a new form of rehabilitation and exercise for functional movement, in a product that is accessible and affordable to the majority of the population.

Furthermore, the satisfaction questionnaire filled by all participants show that motivation is one of the most important reasons for which they got involved in the program.

Although participants consider that their attendance has not increased since this Wii training program started, the majority of them think that it is a useful tool to be used in rehabilitation. It seems to be that motivation is the real challenge of this program as participants express that they consider that physical abilities are working same with Wii training than with other occupational therapy treatments as shown in table 4.

Table 4. Questionnaire analysis. Wii training

Questions	ALMOST NOTHING	LESS	SAME	MORE	A LOT MORE
Are you more motivated to come to your occupational therapy treatment since the beginning of your Wii training?	0	0	14	22	17
Do you think that you are working better on these physical abilities with your Wii training than with other occupational therapy treatments?	1	1	19	19	13
Do you think your attendance to your treatment has improved since the beginning of your Wii training?	1	0	37	11	4
Do you think the Wii training is a useful tool for rehabilitation?	1	0	5	20	27

Discussion

As the Wii™ console was designed for leisure and it was not anticipated that it would be used by people with physical disabilities, we encountered several problems during the rehabilitation process. First, it is not possible to obtain other objective measurements apart from the score. It would be interesting if more detailed data could be collected about each patient; since this would show the progress they made and would make it possible to compare data. Furthermore, it is not always possible to grade difficulty. Ideally, it should be possible to adapt games to each type of injury, so the level of difficulty can be adapted to the patient's skills. The same problem exists with the pace of the games. If both the pace and difficulty were adaptable, the games would be adapted according to the established objectives for each individual patient.

Another problem is that, when some patients see their scores going down, or compare themselves to other player's performance their feedback can be negative.

As regards adaptations, it would be useful if there were some games in which only one joint could be used, as opposed to a combination of several of them. It would also be useful if there were more games that do not require pressing buttons; since such requirement has limited the number of people that could do the proposed Wii™ activities.

In addition, the sample size for this type of research should be greater. Thus, more studies are needed to confirm both the benefits in terms of motor skills and the increased motivation and adherence to treatment.

Conclusion

Wii™ is a useful tool for the intervention process in the rehabilitation of patients with neurological impairment, such as survivors of spinal cord injury. Its characteristics, in combination with the adaptations created by occupational therapists, make it accessible to patients with severe

impairment to the upper extremity. The value that the Wii™ has as a working tool in rehabilitation is given by the professional, who knows the most appropriate way to approach the game so that the desired objectives are achieved for each patient. This results in greater adherence to the treatment on the patient's part and opens the road to a new line of research on this technology.

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Appendices

Appendix 1. Questionnaire filled in by participants in Wii training program at Fundación del Lesionado Medular

ISSUE	QUESTIONS	ALMOST NOTHING	LESS	SAME	MORE	A LOT MORE
1	Are you more motivated to come to your occupational therapy treatment since the beginning of your Wii training?					
2	Do you think that you are working better on these physical abilities with your Wii training than with other occupational therapy treatments?					
3	Do you think your attendance to your treatment has improved since the beginning of your Wii training?					
4	Do you think the Wii training is a useful tool for rehabilitation?					

ISSUE	QUESTIONS	BALANCE	STRESS RESISTANCE	MOBILITY OF ARMS	MOBILITY OF NECK	MOBILITY OF TRUNK	STRENGTH	OTHER
5	Which physical abilities, from your point of view, are you working on with your Wii training?							

1. Could you explain the usefulness of this treatment from your point of view?

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AN INNOVATIVE SOLUTION BASED ON HUMAN-COMPUTER INTERACTION TO SUPPORT COGNITIVE REHABILITATION

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Abstract: This contribution focuses its objective in describing the design and implementation of an innovative system to provide cognitive rehabilitation. People who will take advantage of this platform suffer from a post-stroke disease called Apraxia and Action Disorganisation Syndrome (AADS). The platform has been integrated at Universidad Politécnica de Madrid and tries to reduce the stay in hospital or rehabilitation center by supporting self-rehabilitation at home. So, the system acts as an intelligent machine that guides patients while executing Activities of Daily Living (ADL),

such as preparing a simple tea, by informing them about the errors committed and possible actions to correct them. A short introduction to other works related to stroke, patients to work with, how the system works and how it is implemented are provided in the document. Finally, some relevant information from experiment made with healthy people for technical validation is also shown.

Keywords: Activities of Daily Living, CogWatch, stroke, cognitive rehabilitation, healthcare.

Introduction

One third of the stroke sufferers experience long-term physical and/or cognitive disabilities, and stroke is considered to be the most common cause for severe disability and even death. Following a stroke incident, a significant proportion of patients can suffer from Apraxia and/or Action Disorganisation Syndrome (AADS) which, among other symptoms, is demonstrated by the impairment of cognitive abilities to carry out Activities of Daily Living (ADL) (Hermsdörfer, 2003; Goldenberg, 1998; Liepmann, 1908).

Most common rehabilitation systems are focused on treating physiological aspects of stroke, such as limb movement (Freeman, 2012), and are based on robot or virtual environment platforms which are expensive and not effective for a home base environment (Amirabdollahian, 2001; Kahn, 2001; Krebs, 2003; Shor, 2001). Furthermore, they are space dependent, requiring the patient to function within their working space rather than adapting to patient's natural environment.

To date, most common rehabilitation systems that are based on Information and Communication Technologies (ICT) focus on treating physiological symptoms of stroke (e.g. muscle weakness) (Galiana, 2012; Kesner, 2011; Mao, 2010; Ueda, 2010). These systems are inappropriate for rehabilitation of the cognitive basis of AADS. Moreover, these systems tend to be expensive

and so impractical for home installations. As a consequence, this affects the continuity of therapy and weakens its impact.

This paper presents a different solution whose contribution is part of a European project called CogWatch (http://www.cogwatch.eu/). The aim is to provide a rehabilitation system based on highly instrumented common objects and tools, wearable and ambient devices that are part of patients' everyday environment and can be used to monitor behavior and progress as well as re-train them to carry out ADL through persistent multimodal feedback at home.

The document is divided into several sections. Section II presents a brief description of AADS patients and the effects of stroke. Once the main features of these patients are described, the physical description of the platform and how the system works are presented in section III and section IV in order to detail an experiment carried out to assess the solution adopted in section V. Finally, in section VI, a conclusion and brief summary of the general results are presented.

Apraxia and action disorganisation syndrome

Apraxia is a cognitive impairment affecting the ability to make purposeful skilled actions with objects or to use communicative gestures which is not attributable to motor weakness or sensory impairment. It is commonly associated with lesions due to stroke in the left parietal region of the cerebral cortex. Action Disorganisation Syndrome is a cognitive impairment affecting the performance of sequential action. Lesions of frontal lobe of the cerebral cortex resulting from stroke can produce ADS.

Together, Apraxia and Action Disorganisation Syndrome (AADS) can lead to marked impairment in ADL task performance (Hanna-Pladdy, 2003).

Single case studies are informative for developing approaches to rehabilitation that are closely related to the needs of specific patients. However, group studies are important to test the generalizability of findings

from single case studies and they have also been used to examine whether apraxia rehabilitation is effective.

Patients were randomly assigned to apraxia or control (aphasia) treatment. Apraxia training was based on progression from more to fewer cues. For instance, transitive gesture training involved progression through spoon, picture of spoon, verbal command. Intransitive gesture and meaningless gestures were also trained. Approximately 15 items in each condition were trained 3 times per week for up to 35 sessions. Before and after each treatment, patients underwent neuropsychological testing and caregiver evaluation of patient's ADL independence in personal hygiene, feeding and dressing. Apraxia treatment specifically reduced apraxia and improved ADL function. Control (aphasia) treatment improved patients' language and intelligence performance but had no effect on apraxia and ADL.

The group study, demonstrating the benefits of apraxia training, suggests the need for further rehabilitation research to determine which cues lead to what gains in which patients so that interventions can be targeted more effectively.

However, a barrier to such aim is the intensive nature of AADS therapy, requiring constant supervision by trained staff to monitor the patient's actions for errors and to provide the cueing. Given limited therapist resources, AADS patients generally receive relatively little practice in such tasks.

System overview

As mentioned above, the goal of the system is to help the patient to perform ADL tasks independently. The first impression that this may cause to the reader is that the goal is extremely ambitious, the possible tasks that the patient can take and the ways for doing them are unlimited. For this reason, four different activities are selected to split the effort in general cases of some of the most representatives that the patient has to face daily.

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These chosen activities are: (a) preparing a hot drink, (b) preparing a snack, (c) grooming and (d) dressing.

For each activity one task is chosen. This task is divided into component sub-tasks along the lines of Cooper (2000). The idea of segmenting the tasks is useful for several reasons. The first reason is that it allows performing one task in different ways, defined by the different order of execution of the sub-tasks. It makes the system suitable to adapt easily to other tasks of the same activity, i.e., when every sub-task for preparing a tea is defined, most of them can be used for defining how to prepare a coffee. Finally, it can provide a diagnosis of what particular ones are difficult for each patient.

Following these guidelines, the platform developed is based on standard electronic gadgets that can be easily installed and avoid drastic changes in the house layout.

Figure 6 and Figure 7 show the concept idealization of the platform located in different scenarios.

Figure 6. Kitchen scenario. Source: Javier Rojo.

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Figure 7. Bathroom scenario. Source: Javier Rojo.

The patient will always have the possibility to get in contact with the clinician through the platform. Meanwhile, the clinician will dispose in his/her house or rehabilitation centre of dedicated software to supervise the rehabilitation sessions, send messages, personalize the interface to generate statistics, etc.

Overall architecture

Once the bases for the utilization and installation are settle down, now it is time to focus on the technical description of the platform.

Figure 8 shows a general technical overview of the system architecture. The system is composed by two main subsystems, a Client sub-system (CCS) and a Server sub-system (SS).

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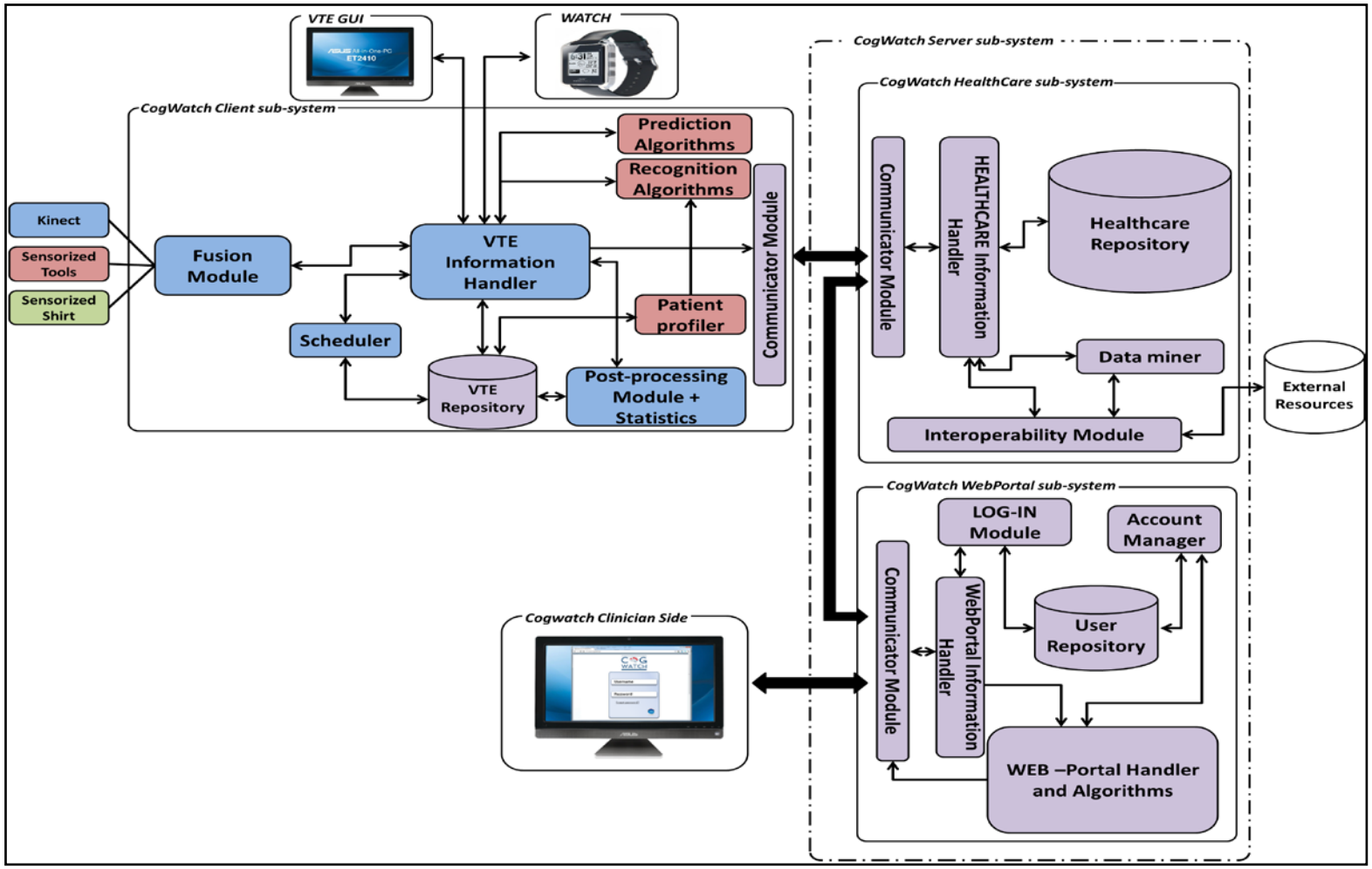
Figure 8. Main architecture of the system.Source: José M. Cogollor, Matteo Pastorino, Javier Rojo and Alessio Fioravanti.



Client sub-system (CCS)

The CCS, which will be located at the patients' house, is used for data acquisition and patient graphical user interface, during the rehabilitation sessions. It manages the patient data and presents the related rehabilitation sessions outcomes to the healthcare personnel.

Regarding the hardware components, a group of devices is used to capture and analyze the behavior and activity performance of the patients. These devices are divided into two categories: monitoring and feedback purposes.

First of all, the monitoring devices include vision-based systems and instrumented objects to be used during the tasks performance. Their main objectives are:

- Microsoft Kinect™: responsible for acquiring information from patient hands, movement and general video of the execution of the task.
- Sensorized objects: equipped with accelerometers and force sensitive resistors to capture their interaction with patient and collect the related data for future movement recognition (kettle, cup, etc.).

Meanwhile, feedback devices are composed by a smart wireless access wristwatch and a PC monitor which provide the following functionalities:

- Smart watch. This device vibrates in case of error, in order to make the patient aware of his/her mistake.
- PC monitor. It is known as VTE (Virtual Task Execution) monitor and it turns out to be an All-In-One computer whose main features are to provide to patients with the corresponding cues and possible risks for correction of the errors committed; it also collect the data coming from the patient rehabilitation session in a database.

On the other hand, taking into account the software modules, the main functions of the sub-modules of CCS are focused on: (a) handling the data, (b) storing relevant information in the database, (c) recognizing actions and errors committed by the patient by processing inputs from the sensorized objects and Kinect™ and (d) communicating with clinician application.

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Server sub-system (SS)

The SS is composed by the HealthCare sub-system (HS) and the Web Portal sub-system (WS). The HS is the module installed in the rehabilitation center or hospital to be in charge of receiving and storing the data of the rehabilitation sessions. It is also designed to manage data coming from external resources different from rehabilitation session.

More in detail, the HS is responsible for: (a) communication with CCS side, (b) storage of personal information about the patient and (c) guaranteeing interoperability among existing and external devices in the healthcare center.

The WS is in charge of showing the rehabilitation sessions' data and statistics of patients to the healthcare personnel. The module installed in an external and unique server, based on a web-based portal, is accessible only by the healthcare and the administration personnel.

The WS main sub-modules are in charge of: (a) management of the user account, (b) security in the login access and (c) information management between all the sub-modules.

Graphical interfaces

The system provides to both, patient and clinician, simple and attractive interfaces, in order to let the users interacting easily with it.

Considering the interface provided to the patient, this is showed in the VTE monitor and its purpose is to provide cues in sense of images, videos and messages (text and verbal) that make the patients aware of the error committed and try to tell them how to correct the action not executed or executed in a wrong way.

Figure 9 shows the appearance of the first window of patient interface, used to select the task to be performed.

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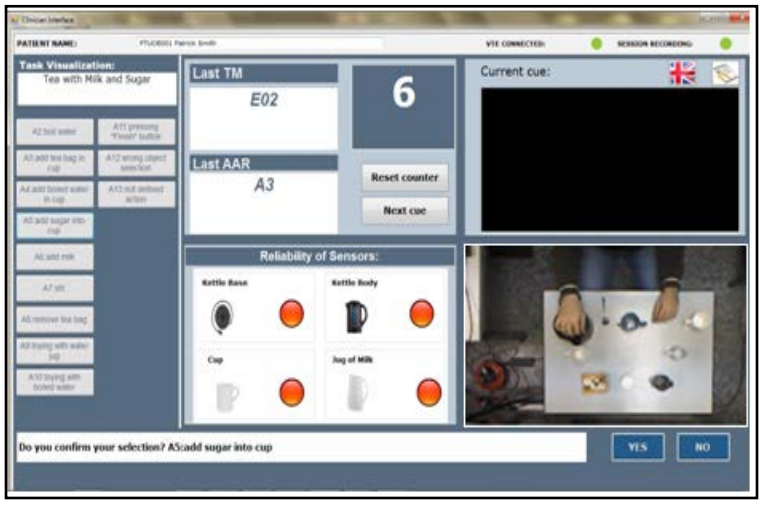
Figure 9. Patient interface on the VTE monitor. Source: Matteo Pastorino, Javier Rojo, Alessio Fioravanti and José M. Cogollor.

Finally, the professional interface allows the clinician to check and control the performance of both, the system and patient, during the follow-up.

It is installed in a common computer and composed of several features, which make the clinician supervise the system and act when required. (Figure 10)

Figure 10. Professional interface on the clinician laptop. Source: Matteo Pastorino, Alessio Fioravanti, Javier Rojo and José M. Cogollor.



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Experiment and validation

Once the architecture and components of the system have been shown, now it is time to test them and assess the suitability for being used at home during the execution of ADL.

For this purpose, the platform has been installed in the kitchen of a specific Living Lab (Figure 11) to be used, initially, by healthy people for technical validation.

Figure 11. Real kitchen used for validation. Source: Living Lab, ETSIT-UPM, Avda. Complutense 30, Madrid, Spain.

A simple task was considered to be executed and simulate how a real patient would interact with the system. In this case, the task was focused on the preparation of a hot drink, in particular a tea, with four different versions: (a) simple tea, (b) tea with sugar, (c) tea with milk and (d) tea with sugar and milk.

For the preparation of the tea, a task tree (Figure 12) is considered, to collect all the necessary steps that the user must execute for the correct completion of the task.

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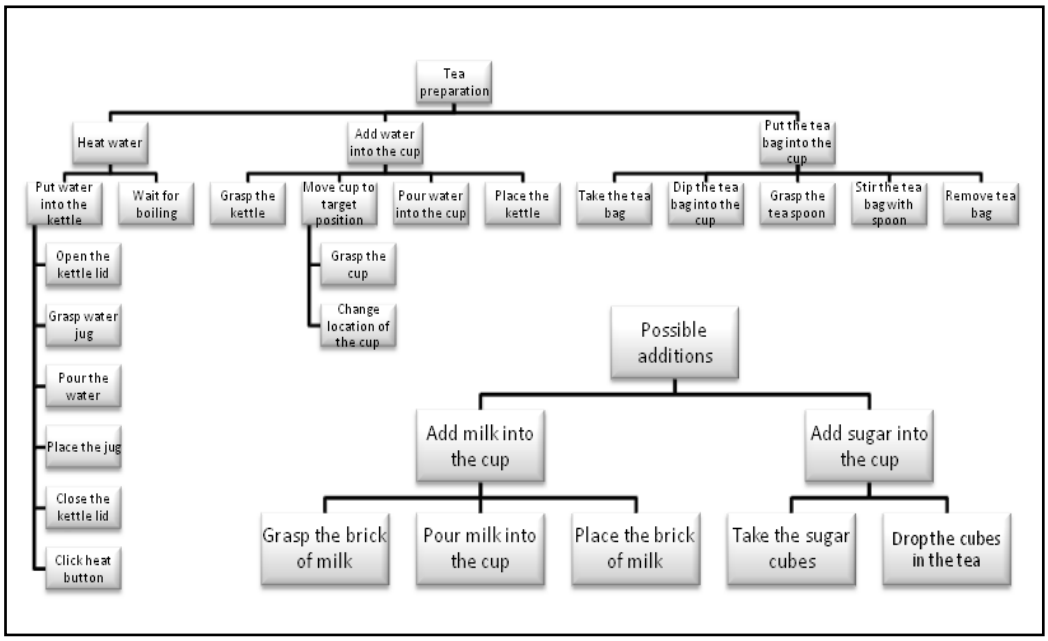
Figure 12. Task tree for tea preparation. Source: Alan Wing.



The task tree helps to locale the steps patient has already performed in case an error occurs.

The errors are classified as: (a) addition, when adding an extra component not required; (b) omission, when forgetting to perform a step; (c) perseveration, when repeating a step or sub-task; (d) anticipation, when performing a step earlier; (e) perplexity, when presenting a delay in the performance of an action and (f) toying, when moving an object randomly.

Table 17 shows few examples of the errors committed by patients, intentionally for validation, with the corresponding cue provided.

Table 17. Feedback provided for each error committed. Source: Alan Wing and Joachim Hermsdörfer.

Error	**Cue for feedback**
Add sugar into the cup when not needed.	Final message to abort the system.
Forget to add water to the kettle.	Image>>Video>>Final message to abort the

Error	Cue for feedback
	system.
Add excessive water to the kettle.	Vibration>>Text/verbal message>>Final message to abort the system.
Drink tea without adding a tea bag.	Image>>Video>>Final message to abort the system.
A noticeable pause in placing the tea bag into the cup.	Image>>Video>>Final message to abort the system.
Touching the water jug repeatedly without using it.	Final message to abort the system.

As seen in the previous table, there are mainly three groups the errors were grouped into:

The first group is composed by those errors whose feedback provided was only a final text or verbal message in the monitor to indicate the error and abort the system because the error could be dangerous for the user and/or the task cannot be completed.

The second group is composed by those less dangerous errors which feedback is divided into three stages: (a) firstly, a simple image of the correct action was shown to the user; (b) in case the patient does not execute the subtask, a more explicit cue, represented by a real video, is played and (c) finally, if pause in movement continued, a final message is provided, informing about the error, and abort the system, letting the user to be relax and to try to perform again the task later.

The third and final group was composed by those errors which feedback was also divided into three stages, but different from the mentioned above: (a)

firstly, a vibration from the watch is provided to the user; (b) if the user is not aware of the error, then a simple text or verbal message from the monitor is shown and (c) finally, if pause in movement continued, another final message is provided informing about the error and aborting the system letting the user relax and try it again later.

As said before, healthy people, not involved in the project, carried out the experiment testing the performance of the system.

Personally, they found the platform quite effective, attractive and useful. In addition, ergonomics and comfort are achieved for future patients due to the fact that the wearable device is a simple and commercial watch that can be purchased on Internet. The rest of the devices, such as VTE monitor or Kinect™, can be placed easily at home as a common TV or security camera, respectively.

Regarding technical aspects, only few relevant issues have been observed, mainly related to unexpected disconnection of the sensors placed in the sensorized objects and punctual repetition of the same cue, due to communication issues between both interfaces (clinician and patient). However, these aspects will be early improved, as the platform is just on a first prototype version of the whole system, continuously in development.

Conclusion

This contribution has presented an innovative and totally different platform, which will provide a personalized, long-term and continuous cognitive rehabilitation for stroke patients with Apraxia and Action Disorganisation Syndrome (AADS).

The patients interact with mainly two groups of devices: for monitoring and for feedback which are in charge of monitoring the execution of the task and movements of the patient and providing feedback to make the patient aware of the errors committed, respectively.

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In order to assess the implementation of the platform for its use at home, the system has been used during the execution of a simple task, such as preparing a tea. The results obtained from the performance show that it is quite easy to use, attractive and very useful for its objective.

It is relevant to mention that, up to date, the system is being used both by healthy people and real patients, following the work plan of the project.

As future work, the features of two of the main devices involved, watch and objects, will be extended for future versions of the platform. For instance, a new version of the watch will be analyzed to acquire relevant data from the internal accelerometer in order to have redundant information from the wrist movement of the patient. Meanwhile, objects will be redesigned to have an improved wireless communication and a better autonomy of the batteries.

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TOWARDS PAYMENT SYSTEMS FOR ALL: ACCESSIBLE POS

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Abstract

The project presented here is a first step towards building a more accessible world through Payment Systems and a successful implementation of a User Centered Design. By means of a beep-system, a Point of Sale (POS) payment device informs the user of those transaction steps that require his/her attention at the moment of payment, such as when:

- The card has been successfully read.
- The Personal Identification Number (PIN) must be entered.
- The transaction has been successfully processed.
- The transaction has not been completed due to an error.

The proposed solution increases the personal autonomy and security of blind people when paying at a merchant.

Keywords: payment systems, accessibility, POS.

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Introduction

According to the World Health Organization [1] 1000 M people suffer some type of disability -15% of the population-. In Spain, more than 3,85 M people (8.5% of the population) have some disability [2]. While the disparity in numbers may be due to different survey sample and disability criteria, both reports show that a very significant group of people have disabilities worldwide. It is not quite the same to suffer an impairment than being disabled by it. It will depend on the activity the person wants to perform and the available resources. For example, 10.8% of survey participants would like to go shopping but are unable to do so due to their disabilities [2]. Not all impairments will have the same impact during a purchase process. Buying a train ticket may not be possible if the vending machine is too high to be operated by a person in a wheelchair, thus there are specific guidelines to ensure access [3]. A blind person may not be able to operate the same vending machine if it does not provide an alternative to the visual information.

Accessibility is an issue of equal rights [4], but it is also a profitable one, since accessible services tend to be easier to use for all customers, especially online services, increasing visits and purchases [5].

Difficulties in Payment Systems for blind users

In the project described here the focus given is on the visual impairment, which total some 285 million people worldwide [6], and it was carried out with the collaboration of the main association of blind people in Spain (ONCE). There are close to 75,000 ONCE [7] members, all potential users of payment cards, and the partially blind population is much greater, although it is not quantified. In addition, 1000 to 2000 of them also own businesses that require card payments [7]. Some of them have smartphones, a trend that continues to grow.

The most pressing user challenges in Payment Systems are the following scenarios:

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- When **purchasing tickets and travel passes**, despite the terminals being already quite accessible, the moment of payment is still rather complicated. When paying, the user has no way of knowing if the card fails to communicate an error, if it asks for a pin or whether the pin is incorrect. At present, many users use a trial-error method: that is to say, when a reasonable time elapses they introduce the pin, and if the receipt is finally obtained, it is assumed that the operation has been successful. There are many other products and services using such unattended terminals. However, for blind users, buying transport tickets is particularly important for their self-independence [8].

An international consortium has deployed in 2013 accessible, usable and personalised services in real-life settings: 24 TVMs of Hoeft & Wessel in Paderborn (Germany) [9].

- When **purchasing in shops**, users rely on the seller to enter the correct amount and hand the POS over to the user to enter the pin when required. It is possible to enter the correct pin by identifying number 5 via a tactile dot in relief. Nonetheless, verifying the amount is not possible. Neither can they be sure that the PIN is not visible if entered during another phase of the operation (for instance, when entering the amount) [8]. In general terms, traditional POS devices use a tiny LCD display to show the user instructions, and the amount that they will be charged, which are difficult to read even by people with a moderate vision impairment [10].

In the case of touch POS it is even more complex since they have no tactile references. [8] As an example, a class action lawsuit has been filed in march 2014 against Apple because visually impaired customers cannot operate the company's touchscreen iPod POS without assistance, with added security concerns regarding PIN introduction, which takes place in a traditional pinpad. This is a violation of the American with Disabilities Act (ADA), which calls for retail outlets to provide a POS system independently accessible by a blind customer [11].

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- There is also the case of many blind people who manage their own businesses, but cannot **charge with a card** since they are unable to follow the entire operation process [8].

A new solution has been developed recently by pairing a Bluetooth keyboard with an iPad and installing an accessibility app. The solution talks back to the user to indicate what is being done with an order [12]. Functionality includes adding items and discounts to an order as well as credit card payment, being useful for both business owner and customer [13].

- The **use of ATMs** faces several challenges: such as, knowing whether it is operating or not, identifying the desired operation or where to press. Basically, the same thing applies here as with the POS terminals, once inserting the card is accomplished, knowing exactly when to enter the PIN or that everything is correct, etc. At present, users memorize sequences of the most common operations, but when the bank changes the ATM software menu, the sequence is no longer valid. In the same way, audio jacks available in many ATMs are not being used by the financial institutions' applications, and the trend towards touchscreens to the detriment of keyboards and buttons, also makes access much more difficult [8]. Despite clear recommendations such as ADAAG [14], it is difficult to implement in a mass market. American banks have faced class action lawsuits grounded on ADA's [4] accessibility guidelines. However, the consortium APSIS4All has supported the launch of 1000 accessible ATMs of "la Caixa" in Barcelona and Madrid (Spain) [12].
- Finally, when the **card is inserted incorrectly** the terminal prevents full access, this also occurs when an ATM is out of service. Hence, the reason for the error is unknown. A method is needed to ensure that the card is inserted in the right direction, so that if it does not enter it is because the device is out of service. Some financial institutions resolve this problem with a notch on the side of the card that indicates the right direction, but this solution is neither standardized nor mandatory [8].

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Methods

A leading Payment Systems' company in Spain has set-up a plan to sensitize with the needs of all their users, including those with disabilities, beginning with blind users. From this Payment Systems' company perspective, the challenge to meet the needs of blind users is solely limited by the technical and economic viability, as well as the regulations. The company followed Tusler's best practices for implementing accessibility within the industry [5]:

- create an implementation plan
- create clear documentation of accessibility features for developers
- integrate accessibility into the existing company practices

In order to address the above issues, the company designed an "Accessible payment plan", whose first priority was improving POS experience. They have carried out a thorough analysis of the Point of Sale (POS) usage requirements and looked for accessibility solutions that are technically viable, while meeting current regulations. Moreover, not only do they improve the quality of life of this particular group, but also make them more accessible to the rest of the population, especially those with partial blindness.

This paper describes the solution proposed by a Payment Systems company to bring greater independence and security to blind users during POS payments. This solution is the definition of the technical specifications that include a beep code (described below) which will gradually be deployed throughout the company's certified POS park.

The most common payment process requires, first entering the amount, then inserting the card and finally the PIN. Should the transaction be approved, a receipt is issued at the end.

Methodology

The underlying work philosophy is to create standard products or services, which are accessible, with no special design, as stated by the Universal

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Design principles [15]. The Accessible Payment Plan schedules first the essential barriers to accessibility and plans for incremental improvements as recommended by WHO [16].

> "To succeed, accessibility initiatives need to take into account affordability, availability of technology, knowledge, cultural differences, and the level of development. Solutions that work in technologically sophisticated environments may be ineffective in low-resource settings. The best strategy for achieving accessibility is usually incremental improvement. Initial efforts should focus on removing basic environmental barriers." [16]

When evaluating the different solutions, priority was given to reaching the largest amount of population possible in the most efficient way, which means paying attention to the availability of technology (types of POS managed by the company). Thus, although using a talking system was considered, only a small percentage of POS deployed could handle it. It was agreed with the experts that for the solution to be useful, it had to be as universal as possible.

A human-centred design approach was followed [17] as part of the user centered methodology since it was considered essential to collaborate with the target user population due to their specific needs. The approach taken was Rubins' [18]:

1. Early focus on users and tasks
2. Empirical Measurement and testing of product usage
    a. Focus on ease of learning and ease of use
    b. Testing of prototypes with actual users
3. Iterative Design

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Technical Validation.

A preliminary meeting with ONCE technical experts allowed to assess the pain points of the interaction with the device in addition to brainstorm viable solutions. During a second session a demo version of the solution was presented and validated by the experts. Finally, a session with users was organized to validate the solution by means of open discussion and testing.

After analysing the difficulties and the current legislation, three POS leading manufacturers were asked to perform demo versions incorporating a beep code indicating the correct reading of the card, PIN code request and error occurrence.

The sounds in the three demos were as follows:

- A beep every time a card is correctly read
- Three high pitched beeps to request pin introduction. If the pin is incorrect, there will be the same three beeps
- One low-pitched beep: operation accepted.
- Two high-pitched beeps: operation denied.

ONCE's technical team evaluated this first version and recommended that all correct or accepted action beeps, use high-pitched tones and leave the bass tones for incorrect actions (i.e.: denied operations), which seems more intuitive to the user.

Thus, the new sounds are as follows:

- A beep every time a card is correctly read
- Three high pitched beeps to request pin introduction.
    - If the pin is correct, 1 single high pitched beep.
    - If the pin is incorrect, there will be the same three request beeps. After a third failed attempt, the transaction is denied.
- One high pitched beep: operation accepted.
- Two low pitched beeps: operation denied.

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It is important to bear in mind that when defining the appropriate tones for each step of the transaction process, there are international standard regulations that must be met. For example, due to VISA regulations it is not possible to use the same frequency and tone they establish for their own functions [8].

It is also necessary to point out that the resulting audio coming from each of the prototypes mainly depends on the type of hardware employed. Therefore, no beeping sound is alike even though the specification is the same. However, according to ONCE's experts this is not a difficulty or a problem.

For users with reduced vision, it was recommended to use the brightness of the screen as recommended in the norm UNE 170002 (2009) [19].

User validation

Once implemented ONCE's recommendations, an evaluation test took place at ONCE's Regional office in Madrid to evaluate the solution.

Out of the 9 participants appointed, two had partial blindness and 7 were blind (Nielsen recommends recruiting at least 5 participants for usability evaluation studies [20]. There were two retired persons (>65), one trainee student (<30) and the remaining were active workers. The group consisted of five women and four men. All of them own one or more payment cards and all but one have used them to pay for goods in a retail store.

The session lasted 2 hours and started with an introduction of all parties and the goal of the session. Then, in a first exchange of experiences the two most common situations were clearly identified:

- Users who avoided using POS and tried to make payments in cash.
- Users who used the POS at a considerable risk, such as not being able to identify the keyboard easily to type numbers and having to, in most cases, ask the cashier to type the OK for them to accept the insertion of the PIN.

Everyone (users and experts) agreed that the touch POS is impossible to use. Subsequently, various tests were conducted using two different devices with the following scenarios:

- Valid PIN card and operation completed successfully.
- Invalid PIN.
- Valid PIN and rejected operation.
- Correct operation without PIN request.

During the tests several discussions arose about the convenience of alerts (beeps), the structure and the reasons behind every decision as well as the regulatory restrictions.

Results

Specifications: Guiding the user with interface tones during a card transaction with a POS

Following user evaluation, a new and final set of POS specification was defined.

Operational description

The purpose of this section is to describe the beep system guidelines that allow the POS to guide the user through the different steps of a card transaction.

The POS must comply with the following previous requirements:

- The POS must be capable of producing audible tones.
- The volume of the tones produced by the terminal must be set at an appropriate hearing level so that it may be clearly heard by the user.
- The set of tones produced by the POS are used to show the user the progress of the transaction. Different beeps in the terminal are employed to indicate whether the result of the process is successful or not, and to indicate when data must be entered in the POS.

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- The three different beep tones must be clearly distinguishable from each other and any other sounds used in the POS.
- Functionality must be compliant with all international standards and requirements formerly defined by the financial institutions and the card transaction payment schemes.

Defined below are the tones to be incorporated in the terminal's transaction operating process:

- Card correctly read tone: a single beep at a frequency of approximately 1500 Hz, sinusoidal waveform and approximately 500 ms duration.
- Correct process tone: a single beep at a frequency of approximately 2000 Hz, sinusoidal waveform and:
    - If the PIN is correctly entered in the POS, a long tone with a duration of about 500 ms.
    - If the transaction is accepted, a short tone with a duration of approximately 200 ms.
- Tone for correct POS data input (PIN entry): the PIN entry tone will be a triple beep at a frequency of approximately 2000 Hz, sinusoidal waveform and duration of approximately 200 ms. The gap between the three beeps will be approximately 200ms.
- Alert tone: a double beep at a frequency of about 750 Hz, sinusoidal waveform and duration of approximately 200 ms. The gap between the two beeps will be approximately 200 ms.
- Keystroke tone: the frequency and length of the sound has not been specified yet but should be clearly distinguishable from the other tones defined here for the transaction process, and must be indistinctly the same tone for all keys regardless of the key(s) pressed.
- Tone to alert the user that the card has been forgotten in the reader: the frequency and duration of this alert has not been stipulated but must be distinctly different from the other tones defined here for the transaction process.

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In order to make each step of the transaction process completely clear to the user, the POS must only use the beeps and tones described above and avoid any background sound during the transaction.

It should also be noted that during the transaction the terminal will always generate only these tones and no other than those specified.

Discussion

There are some limitations in the results, such as the lack of quantitative data from the user testing session. The goal of the project was to develop an accessible solution the most efficient way and, while opinions were collected, performance data was not recorded. Due to the great dependence on others at the time of payment, with the lack of autonomy and security risks involved, the time required to perform a task was not analyzed.

The solution itself is limited since the test was conducted in a quiet room, but most payment takes place in a noisy environment making it more difficult to hear the device beeps. However, the specifications listed here are a simple way of increasing autonomy and security for blind people in card payments. They have been tested and agreed upon with users as part of a user-centered design approach, and they will be put into place by the main POS providers in Spain. They should be known and applied in a standardized manner, and therefore must be conveyed beyond the Payment Systems company's operating environment.

Conclusions

After the accessible POS tests, users expressed the following conclusions:

- This system would provide greater security and autonomy to end-users.
- That the beep sequence requesting the PIN again, in case of it being invalid, is a crucial feature.

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- Users who are now reluctant to use these terminals would be willing to use them.

The experience shows the successful implementation of user-centered methodologies: the Payment Systems' company has developed in collaboration with ONCE new specifications that facilitate the use of POS for blind people. From this moment on, manufacturers incorporate an acoustic system in the final products they develop while meeting with the Payment Systems' company POS functional specifications. As of September 2014, the number of POS which include the new specifications in their operating systems is over 320.000, which is above 50% of the total of POS managed by the company across the country [21].

Currently, their goal is to promote these developments and contribute to their standardization, even beyond national borders, improving accessibility to the payment system devices that the company manages. The choice of a solution that can be implemented in very old devices makes it possible to replicate by other payment processors around the world.

Further work

As part of the commitment to the user a new area of User Experience was created in may 2014, with the purpose of allocating the necessary resources to ensure the usability and accessibility of their products and services as well as improving the overall user experience. The corporate UX policy informs the goals and good practices in UX throughout the company, starting with user-centered design methodology and integrating accessibility and usability requirements within development methodologies. It is far less expensive and more efficient to design an accessible product than to adapt one that is not. They have also developed a corporate manual that includes, not only new designs adapted to new mobile devices, but also usability and accessibility criteria to ensure that every new product is accessible from the outset.

The company is currently addressing the needs of blind users to accept card payments by means of a mobile POS, available for iOS and Android (Windows

Phone is under way). In the initial stage of the application design, ONCE's technical team was called to learn the functionality and advice on accessibility issues. When developing the first version, ONCE team analysed it and their findings were adopted in the following version. Next steps involve user testing to further fine tune accessibility issues and make it fully functional for blind users.

Another priority project is to address the accessibility of unattended terminals, to facilitate the purchase of Metro and train tickets. The company intends to make online payment accessible to all. The first step was to analyse the accessibility state of the company's payment platform, which is used by some of the most important banks in Spain. The company has also launched a digital wallet in February 2014, and is now focused on improving the user experience for all.

While they try to respond in a first stage to the needs of blind users, such as unattended terminal payments or the possibility of charging independently, they are also considering addressing the needs of users with other profiles in future stages. Along these lines, the Payment Systems' company aims to be an accessibility reference within the Payment Systems market.

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