Fundación ONCE

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH
Accessibility Chair

JACCES

JOURNAL OF ACCESSIBILITY AND DESIGN FOR ALL

www.jacces.org

VOLUME 6 - Nº2 (2016)

DOI: 10.17411/jacces.v6i2

Journal of Accessibility and Design for All

Office

Accessibility Chair

Universitat Politècnica de Catalunya · Barcelona Tech

Av. Víctor Balaguer, 1. 08800 Barcelona.

Telf. +34 93 896 78 31

jacces@catac.upc.edu

Twitter: @Journal_JACCES LinkedIn: JACCES page

www.jacces.org

ISSN: 2013-7087

EDITOR'S LETTER

This second issue of 2016 includes three articles related to Engineering, and Society and Economics. Related research faces challenges such as understanding the physiological mechanisms of prosthetic vision, with the purpose of restoring vision to the blind through the development of a visual neuroprosthesis. In this direction, the first article presents an in vivo electrophysiological investigations on new stimulation paradigms that can potentially lead to improved visual perception. This paper describes a multi-viewpoint architecture of an experimental setup for the study of electrically evoked potentials in a retinal neuroprosthesis.

The challenge faced by the second study presented is to ensure that voters with disabilities could vote independently. The focus of this research is to examine the viability and usability of a particular voting system, Interactive Voice Response (IVR), as an accessible voting platform for visually impaired voters.

Latest challenge addresses difficulties faced by people with disability when accessing to Massive Open Online Courses (MOOCs). This revolutionary computer and mobile-based educational scenario allow students to learn at their own time, place and pace, improving, consequently, their level of employability and social inclusion. The third paper describes the need for designing an information model and related specifications to support a new strategy for delivering accessible MOOC. This approach takes into account preferences and context of use, resulting in as user profile's design based on standard metadata schemas regarding the achievement of accessibility from content to user preferences.

Daniel Guasch Murillo

Accessibility Chair Director UPC-BarcelonaTech

Chief Editor

Jesús Hernández Galán

Universal Accessibility Director-Fundación ONCE

Chief Editor

Editorial

Articles

Journal of Accessibility and Design for All

(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

A 4+1 ARCHITECTURE FOR IN VIVO ELECTROPHYSIOLOGY VISUAL PROSTHESIS

Alejandro Barriga-Rivera[1], Calvin D. Eiber[1], Paul B. Matteucci[1], Spencer C. Chen[1], John W. Morley[1, 2, 3], Nigel H. Lovell[1], Gregg J. Suaning[1]

[1]Graduate School of Biomedical Engineering, University of New South Wales, Sydney, Australia

[2]School of Medical Science, University of New South Wales, Sydney, Australia

[2]School of Medicine, University of Western Sydney, Sydney, Australia

[1]a.barrigarivera@unsw.edu.au, [2]calvin.eiber@sydney.edu.au, [3]pmatteucci@gmail.com, [4]spencer.chen@utexas.edu, [5]j.morley@uws.edu.au, [6]n.lovell@unsw.edu.au, [7]g.suaning@unsw.edu.au

Received: 2016-03-04| Accepted: 2016-09-17| Published: 2016-11-30

Abstract: Researchers around the globe are working towards restoring vision to the blind through the development of a visual neuroprosthesis. Overcoming physical, technical and biological limitations represents one of the main challenges for the scientific community and will eventually benefit the wellbeing of the recipients of these devices. Thus, understanding the physiological mechanisms of prosthetic vision plays a key role. In this context, in vivo electrophysiological studies are aiming to shed light on new stimulation paradigms that can potentially lead to improved visual perception. This paper describes a multi-viewpoint architecture of an experimental setup for the investigation of electrically evoked potentials in a retinal neuroprosthesis.

Keywords: visual prosthesis; electrophysiology; bionic eye; preclinical

Introduction

Electrical stimulation of excitable tissue has been used to treat a broad variety of health conditions including hearing loss (Snyder, Middlebrooks, & Bonham, 2008), Parkinson's disease (Limousin et al., 1998) or fecal incontinence (Rosen, Urbarz, Holzer, Novi, & Schiessel, 2001) among others.

(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

In particular, lessons learned from the success in cochlear implants are driving the development of visual prostheses. These devices represent a hope for the visually impaired community with nearly 40 million people profoundly blind worldwide (Pascolini & Mariotti, 2011). First attempts to electrically elicit visual perception in humans date from the 18th century (Shepherd, Shivdasani, Nayagam, Williams, & Blamey, 2013). However, the first clinical experiment was conducted by Brindley and Lewing in 1968 (Brindley & Lewin, 1968). In this study electrical stimulation of the visual cortex produced the perception of bright spots of light (phosphenes). Since then, different strategies to restore functional vision by electrical stimulation have primarily targeted cortical and retinal neurons (Habib, Cameron, Suaning, Lovell, & Morley, 2013; Suaning, Lovell, & Lehmann, 2014).

Retinal approaches aim to activate surviving retinal ganglion cells (RGCs) which are viable in pathologies such as retinitis pigmentosa or macular degeneration (Habib et al., 2013). However, the development of these devices is facing engineering, physical and biological challenges that reduce the spatial and temporal resolutions that can be delivered through electrical stimulation of the visual system (Eiber, Lovell, & Suaning, 2013). Current steering in the suprachoroidal space is being investigated as a technique to increase the performance of retinal neurostimulators by creating virtual electrodes (Dumm, Fallon, Williams, & Shivdasani, 2014) or reducing activation thresholds (Matteucci et al., 2013). These sorts of studies, both in vivo and in vitro, require complex experimental setups for which the scientific literature does not provide sufficient information. The aim of this contribution is therefore to present a laboratory setup for in vivo experimentation in retinal neurostimulation. The structure of the paper is inspired by the 4+1 architectural model described by Kruchten (Kruchten, 1995). A logical view depicts a general approach from a user's point of view addressing the main requirements of the system. A physical view presents the devices and hardware architectures required as well as the interconnection between them. The development view provides a description of the software systems, components and units from a programmer's perspective. The process view describes concurrency and

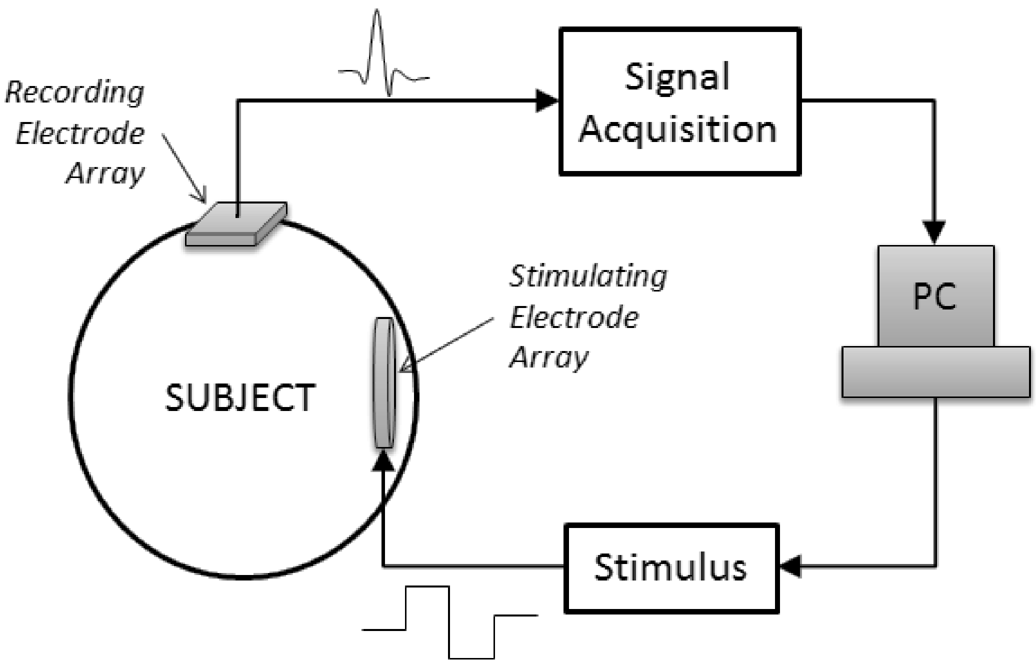
(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

communications between software elements. And last but not least, an example of the system application is presented as the scenario.

Logical View

Electrically evoked potentials (EEPs) following retinal neurostimulation are electrical responses elicited in the visual cortex. An electrode array is implanted close to the retina (epiretinal, subretinal or suprachoroidal) to create electric fields able to activate the RGCs (Shepherd et al., 2013). Then, a cascade of action potentials propagates through the optic nerve eventually activating the neurons of the visual cortex. A second electrode array is placed on the primary visual cortex to record the EEPs produced after stimulus delivery, as shown in figure 1. A personal computer (PC) is used to control both the retinal neurostimulator and the signal acquisition system and serves as an interface for the researcher.

Figure 1. Description of the logical view of the experimental setup. A personal computer controls the retinal neurostimulator and stores biosignals acquired from the subject. A stimulating electrode array is implanted close to the retina whereas the recording array is located on the visual cortex.

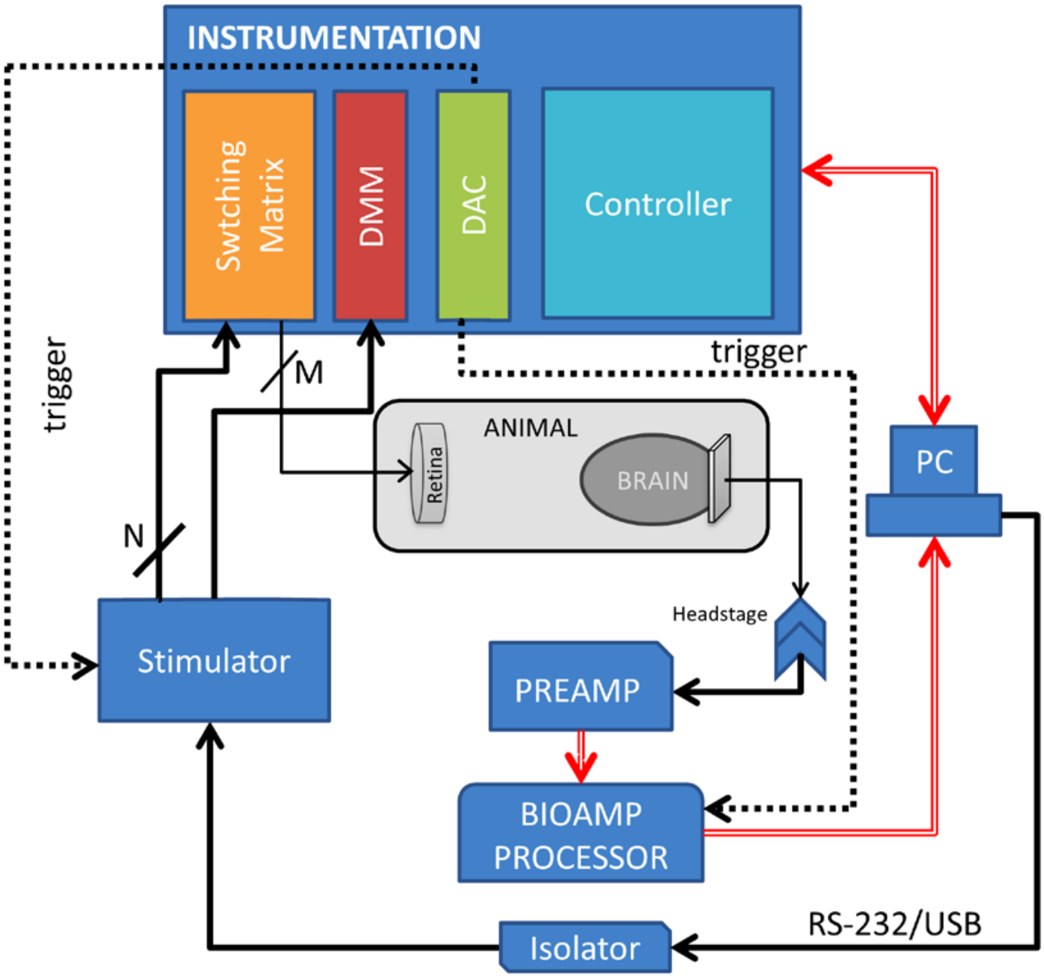


A neural stimulator consisting of a number of independent current sources connected to the stimulating electrode array allows the delivery of a repertoire of different stimulus configurations (Wong et al., 2007). The

(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

waveform parameters are programmed on the neural stimulator through the PC. On the other hand, signals acquired from the visual cortex require the second electrode array to be interfaced to a sophisticated signal acquisition system. These signals are typically low in amplitude and therefore there is a need for using a headstage amplifier, that is, an ultralow-noise amplifier that acts as an impedance adaptor between the excitable tissue and the amplifier (Fambrini, Barreto, & Saito, 2014). Data recorded during the experiment will be stored in the PC for off-line analysis.

Figure 2. Block diagram that illustrates the connections between the physical subsystems of the experimental setup. A personal computer controls a bioamp processor and the instrumentation platform through an optical connection (red arrows), and the stimulator by an electrically isolated USB connection. The bioamp processor is connected to the preamplifier using fibre optics and interfaces to the recording array using a headstage. The stimulator is connected to a switch matrix, and a digital multimeter records the waveforms at the stimulator site. The output of the switch matrix is connected to the stimulating array located at the retina.



(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

Physical View

Both the stimulating and the recording subsystems are controlled and synchronized by the PC. This computer is optically connected to a modular instrumentation platform that generates the stimulus trigger signal, provides extra switching capabilities and digitizes the stimulus waveform to assess the impedance of the electrode-tissue interface. The PC is also optically connected to a BioAmp processor and through isolated USB to the neurostimulator. Figure 2 presents a block diagram showing the interconnections between the different hardware subsystems.

Instrumentation platform

A National Instruments PCI eXtensions for Instrumentation (NI PXI, National Instruments Corporation, Texas, USA) provides an instrumentation platform to further the capabilities of the retinal neurostimulator.

- Chassis (NI PXI-1000B): general purpose PXI chassis with capacity for up to eight instruments.

- Controller (NI PXI-8336): this module provides control over the whole system by implementing a PCI-to-PCI bridge through an optical connection. This is a transparent link that provides electrical isolation between the PC and the PXI system. It consists of two parts, a PCI card installed on the personal computer which is to be used to control the PXI and a module connected to the main PXI chassis.

- Digital multi-meter (NI PXI-4071): high-performance digital multi-meter (DMM) able to measure voltage from ±10 nV to 1000 V, current from ±1 pA to 3 A at sampling rates up to 1.8MS/s. This device is used to record the waveforms and to estimate the impedance of the electrode-tissue interface.

- Digital-Analog Converter (NI PXI-6259): this module has four 16-bit resolution analog outputs used to generate the trigger signal for recording of the stimulus waveforms.

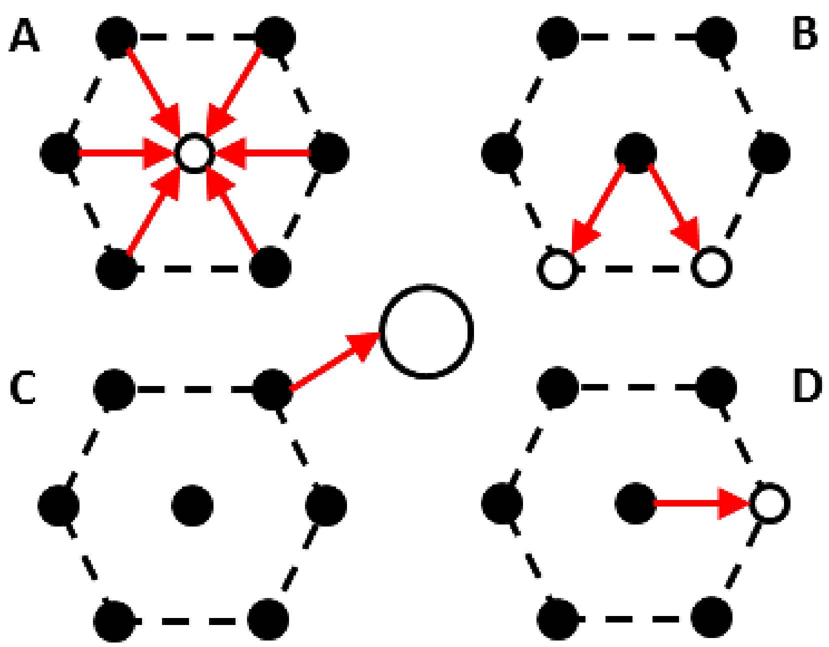
(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

- Switch matrix (NI PXI-2532): this device provides 512 cross points that allows combining different current sources from the retinal neurostimulator to achieve more complex stimulus configurations.

Retinal neurostimulator

A 98-channel neurostimulator able to activate up to 14 electrodes simultaneously was designed at the authors' laboratory (Jung et al., 2013). The system consists of 14 pairs of current sources/sinks that operate together to provide charge balance. Each pair can be switched to any of seven electrodes arranged in a hexagonal pattern to provide monopolar, bipolar, tripolar and hexapolar configurations as shown in the example of figure 3.

Figure 3. Example illustrating different return configurations based on a hexagonal pattern. Red arrows represent the flow of electric current and hollow electrodes indicate they have been configured as the electrical return path. Hexagon A, B, C and D illustrate hexapolar, tripolar, monopolar and bipolar return configurations respectively.



The neurostimulator is designed as an application-specific integrated circuit (ASIC) that is controlled by an ATxmega128A3U (Atmel, San Jose, California, USA) microcontroller using a serial peripheral interface (SPI) bus. The microcontroller can be programmed from the PC using RS-232 over USB.

(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

Signal acquisition subsystem

Three elements constitute the signal conditioning and acquisition subsystem: high-impedance headstages, a multichannel preamplifier and a bioamp processor. The following devices are manufactured by Tucker Davis Technology (Tucker Davis Technology, Florida, USA).

- Headstage (NN32AC/NN64AC): both 32-channel and 64-channel high impedance headstages are used as a recording interface. These devices provide a unity gain with an input impedance of 1014 □.
- Multichannel preamplifier (PZ5-128): a 128-channel digitizer records synchronized potentials from the brain. To provide electrical isolation, the preamplifier is battery powered and communicates with the processor system using a fiber optic connection. It provides a sampling rate up to 50 kHz.
- Bioamp Processor (RZ2-8): it is a signal processor comprising eight ultrafast digital signal processors that can be programmed for fast data acquisition and real-time processing.

Stimulating electrode arrays

Retinal stimulating electrode arrays are fabricated at the authors' laboratory by laser micromachining of platinum foil positioned on a polydimethylsiloxane substrate and mechanically strengthened with a layer of polyethylene terephthalate (Dodds, Schuettler, Guenther, Lovell, & Suaning, 2011; Matteucci et al., 2013). The electrode openings are cut using the same laser micromachining technique. The exposed surface of each of the electrodes is roughened using a picosecond laser as described by Green and coworkers (Green et al., 2014). This technique extends longevity and increases the electrochemical surface area of the electrodes improving charge transfer.

Recording electrode arrays

Cortical surface electrodes can be used to map the activity of the primary visual cortex. These electrodes are fabricated following the procedure

(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

previously described for the stimulating electrode arrays. These electrodes can record evoked potentials. However, intracortical multi-electrode arrays are able to capture the electrical activity of single neuron and local field potentials and therefore are more pertinent to electrophysiological research. Although the system allows for both kinds of electrode arrays, results from surface electrodes are presented.

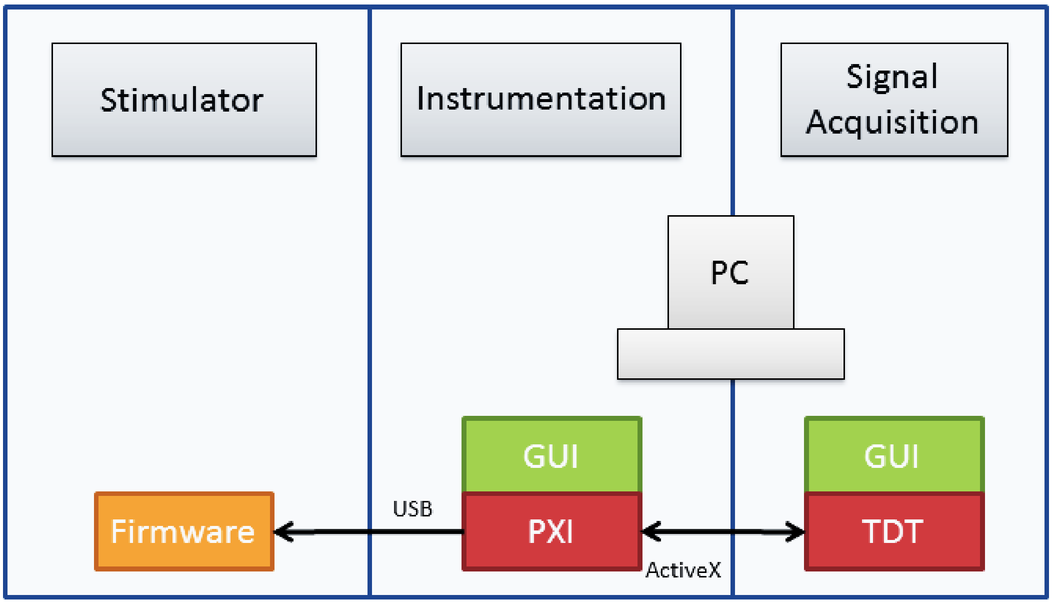
Development View

Three main software components were developed in this experimental setup to control the retinal neurostimulator, the instrumentation platform and the signal acquisition subsystem as shown in Fig. 4.

A firmware subsystem was developed in C language to provide the ASIC chip with further capabilities. A PXI software subsystem, also written in C, initializes the instrumentation platform and provides the user with a friendly interface to program the stimulator with the stimuli to be delivered. A TDT software subsystem is implemented using Real-time Processor Visual Design Studio (RPvdsEx), a visual programming language that defines control objects to generate the circuits in the processor system. Communication between the PXI and the TDT software subsystems relies on ActiveX controls, a framework to exchange information between software applications, whereas communication between the stimulator and the PXI software uses a proprietary high level protocol over RS232.

(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

Figure 4. Overview of the software architecture. Three main software subsystems can be identified and related to hardware subsystems: firmware, PCI eXtensions for instrumentation (PXI) software, and Tucker Davis Technology TDT software. The firmware runs on the retinal neurostimulator, whereas the PXI and the TDT subsystems are executed on the personal computer to control the instrumentation platform and the signal acquisition system respectively.

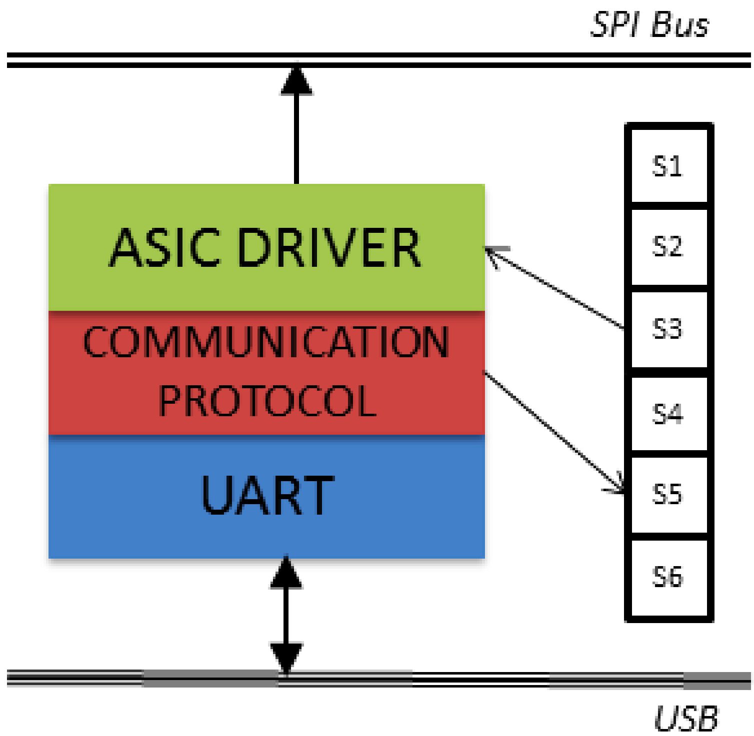


Neurostimulator firmware

The software driving the stimulator can be described as following a layer model in which each layer is implemented in a separate C file, as in figure 5. Serial communications are carried out using a universal asynchronous receiver/transmitter (UART) unit. On top of this layer, a proprietary communication protocol enables programming the stimulus configuration in the microcontroller. Each stimulus is defined in terms of a structure of parameters that determine the current amplitude, phase and inter-phase times, symmetry of the pulse, number of stimuli per train and the return configuration. A list of stimuli is stored in memory such that the PC can indicate which stimulus is the next to be delivered after reception of the trigger signal. Finally, the upper layer translates the stimulus into a series of microinstructions which are sent through the SPI bus to the ASIC chip. This software subsystem was developed in C and compiled using Win AVR GCC compiler.

(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

Figure 5. Layer model of the firmware subsystem. Communication relies on USB using a UART interface. A proprietary protocol defines a series of data frames to program the stimuli to be delivered. The upper layer deals with the ASIC to deliver the chosen stimulus through a serial peripheral interface.



PXI software

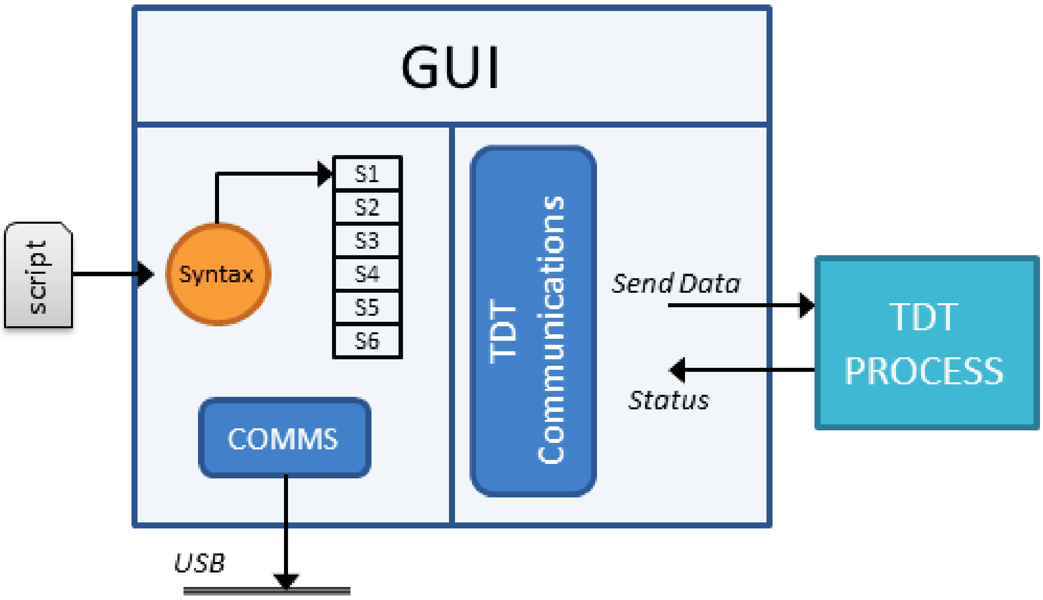
This software subsystem provides the primary graphical user interface (GUI). The main function initializes all the instruments and launches the GUI. The architecture of this subsystem can better be described as a modular architecture in which each module is implemented in a separate C file. On the one hand, a simulator module provides data structures for storing the set of stimuli to be programmed in the neurostimulator. These stimuli can be programmed using the GUI or through a script that is read by this module. In addition, the stimulator module implements the other end of the communication protocol between the neurostimulator and the PC. On the other hand, the TDT module of the PXI software is in charge of sending stimulus information to the TDT subsystem to be stored along with the biosignals as illustrated in figure 6.

Additionally, the GUI allows the researcher to access the switch matrix to combine the stimulating channels in a fashion such that different stimulation

(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

strategies can be investigated. Note that this software subsystem was developed in C and compiled under Windows 7 (Microsoft, Redmond, Washington, USA) using LabWindows/CVI (National Instruments Corporation, Texas, USA).

Figure 6. Diagram illustrating the modules that integrate the PXI software. A GUI represents the upper layer and the interface with the end user. Stimuli can be described in a file. Two different modules implement communications with the stimulator and with the TDT subsystems.

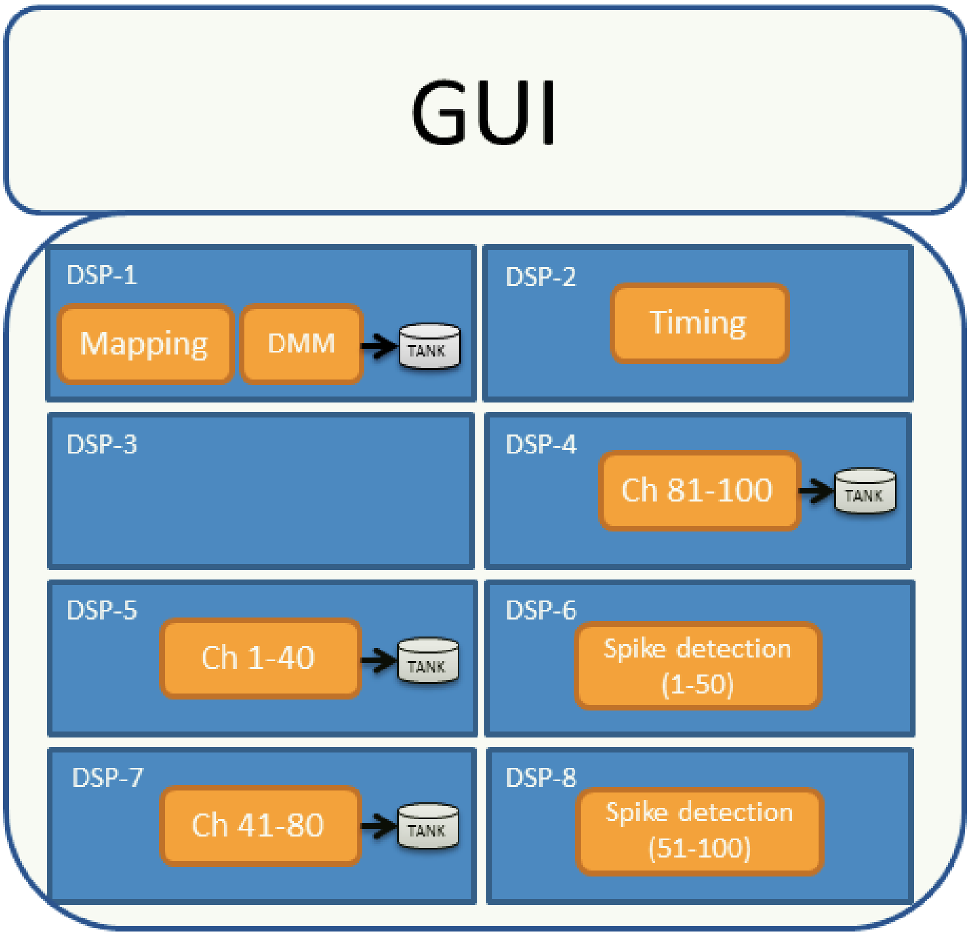


TDT software

The BioAmp processor provides powerful real-time signal processing capabilities. Low-level programming is normally required to optimize the performance of these kinds of devices. RPvdsEx is a tool developed by the Tucker Davis Technology that facilitates the development of applications by means of a graphical design interface. This is a visual programming language that simplifies the complexity of assembly code giving control over each digital signal processor (DSP).

(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

Figure 7. Task assignment per DSP. The figure illustrates which task was assigned to each processor. DSP-1 is in charge of mapping the recording array and streaming data from analog input. DSP-2 handles timing. DSP-4, DSP-5 and DSP-7 store data in the appropriate tank. Finally, DSP-6 and DSP-8 provide real-time spike detection.



The TDT software creates a data tank which is a collection of files stored in the hard drive of the PC to where signals are streamed. Access to this information can be performed off-line. Two main conceptual layers can be identified in this subsystem. First of all, there is a GUI that allows visualization of acquired and processed signals. This interface provides control over the circuits as well. The second layer, as illustrated in figure 7, represents the tasks performed by each DSP. Five main tasks can be identified:

- Channel mapping: this is a table that switches channels in the recorded data stream to match the pinout of each recording electrode array.
- DMM: records the waveforms registered by the instrumentation platform.

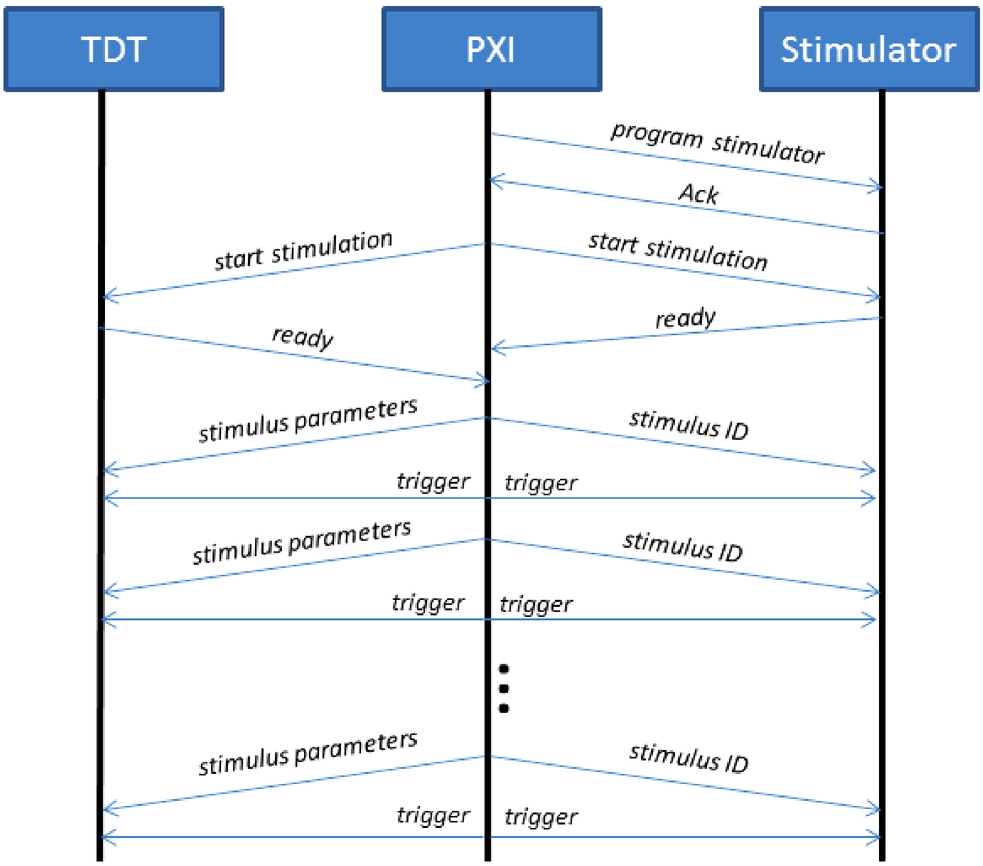
(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

- Timing: timing and control signals including the addition of timestamps to identify the onset of segments of interest within the recordings known as epochs.
- Channel streaming: stores the corresponding channel waveforms in the data tank.
- Spike detection: applies a cascade of filters to detect spikes in real time during the recording.

Process view

First of all, the user defines the list of stimuli to be delivered by writing a file with the parameters of each stimulus or using the GUI of the PXI subsystem to build the file.

Figure 8. Message-passing diagram illustrating the sequence of events occurring in different subsystems. After programming the simulator, the PXI subsystem indicates that stimulation is about to start. Then, it sends the stimulus identifier and the parameters of the stimulus followed by the trigger signal. This sequence is repeated until the end of the experiment.



(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

Next, the user sets the number of repetitions for each stimulus and the inter-stimulus time. In general, the arrival of stimuli is modeled as a Poisson process with an inter-stimulus time distributed uniformly around the average value within a given interval. Afterwards, the process starts and the PXI software sends the list of parameters to the stimulator as defined by the user.

Once the device is programmed, the PXI communicates to both ends that stimulation is ready to start. After receiving acknowledgement from both ends, the PXI software sends, on the one hand, the stimulus identifier to be delivered to the stimulator, and the parameters corresponding to that stimulus to the TDT subsystem, as shown in figure 8. Then, the PXI software triggers the stimulus delivery and repeats this operation accordingly until the experiment ends or the user stops the process.

Scenario

This section presents briefly an experiment conducted at the University of New South Wales, Australia, using the setup previously described in this contribution. This section illustrates an example of the application of the system previously described. This research was approved by the UNSW Animal Care & Ethics Committee in compliance with the Australian code for care and use of animals for scientific purposes. This study adheres to the ARVO Statement for the Use of Animals in Ophthalmic and Vision Research.

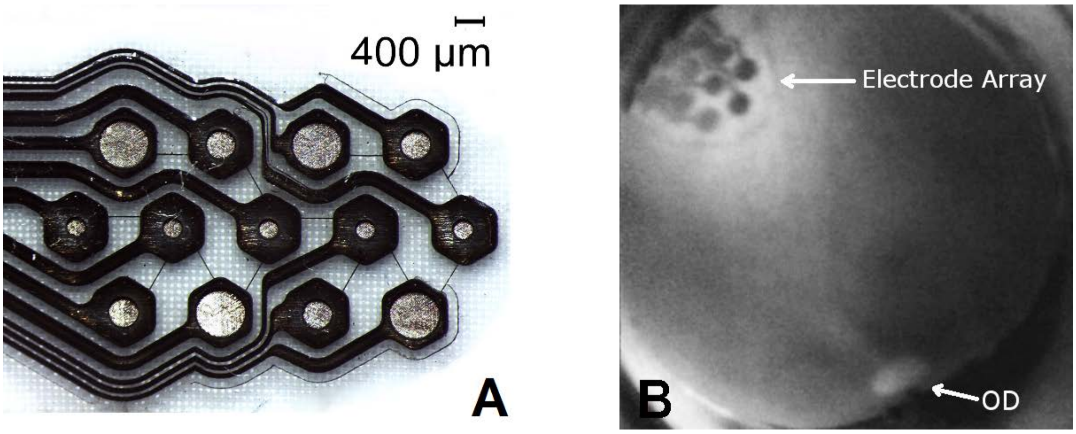
Animal preparation

In this study two normally sighted adult wethers were included. An intramuscular injection (12 $mg \cdot kg^{-1}$) of Zoletil 100 (Virbac, Australia) was used to induce anaesthesia, which was maintained afterwards by inhalation of isofluorane (1.5-3% in 2 $l \cdot min^{-1}$ O_2). Dexamethasone (1.5 $mg \cdot kg^{-1}$) was injected intramuscularly to reduce inflammation and fluid loss was replaced by intravenous infusion of Hartman's solution. During the experiment, oxygen saturation, heart rate, blood pressure, and core temperature were continuously monitored.

(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

A 13-electrode array arranged as two overlapping hexagons with electrode diameters between 0.4 and 1.0 mm was implanted in the suprachoroidal space of the right eye through an incision opened 10 mm posterior to the limbus. The stimulating electrode array was manufactured in the authors' laboratory following the methodology described by Schuettler and coworkers (Schuettler, Stiess, King, & Suaning, 2005) and is illustrated in figure 9A. The surfaces of the electrodes were laser-patterned to increase charge injection limits (Green et al., 2014).

Figure 9. Panel A: stimulating electrode array consisting of 13 platinum electrodes with opening diameters of 400, 600 and 1000μm. Panel B: Infra-red fundus imaging showing the optic disc (OD) and the location of the stimulating electrode array.



An area of the visual cortex was exposed through a craniotomy contralateral to the implanted site centered 20 mm rostral and 10 mm lateral to the lambdoid suture (Suaning, Lovell, & Kerdraon, 2001). Correct placement of the array was assessed via infra-red (940 nm) fundus imaging as illustrated in figure 9B using an in-house-built system.

Two different surface electrode arrays were used to record EEPs through the dura: a 7-electrode array from the author's lab and a 16-electrode array (IMTEK, University of Freiburg, Germany). Biphasic constant-current pulses with return set to a distant monopolar return were delivered. Charge injection was balanced and at all times remained below 210 $\mu C \cdot cm^{-2}$ in each phase. All pulses had a phase duration of 500 μs and interphase interval of 10 μs. Inter-stimulus time was randomized between 0.75 and 1.25 s. All data were analyzed off-line using scripts written in Matlab 2013b (The MathWorks,

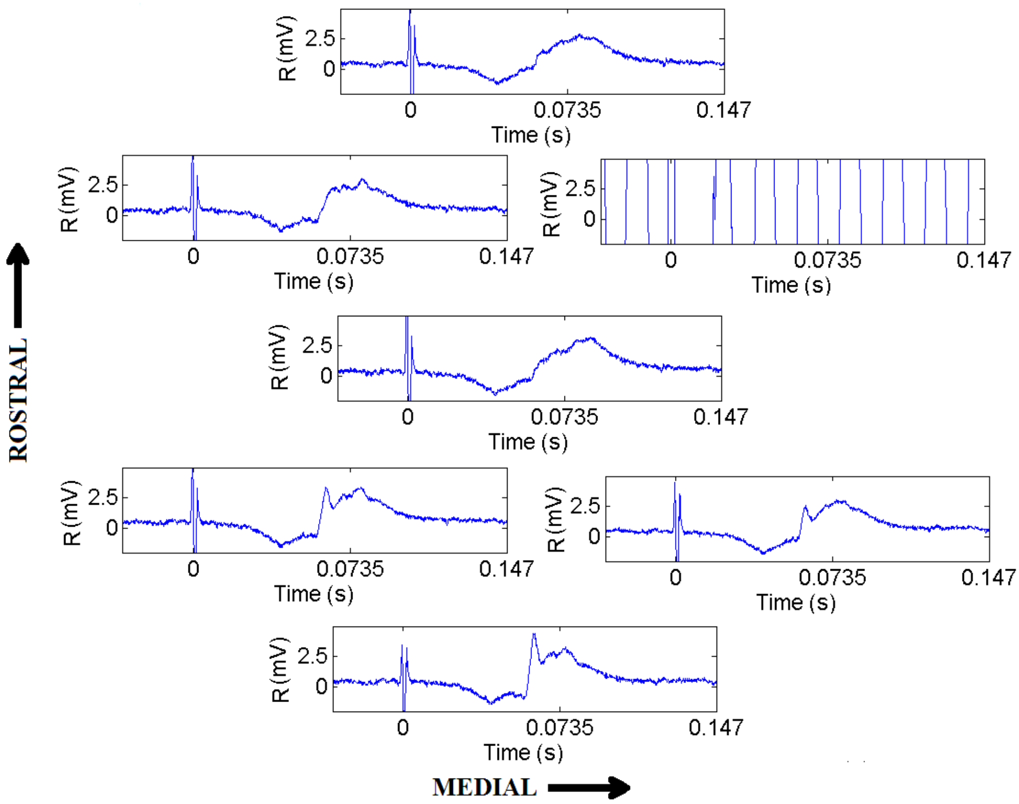
(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

Massachusetts, USA) to calculate the ensemble averaging of 25 repeats. Note that the stimulus waveforms were chosen as in previous publications in cat models (Matteucci et al., 2013) and similar to those used in humans during clinical trials (Stronks, Barry, & Dagnelie, 2013).

Results

EEPs were successfully elicited and recorded by electrically stimulating the eye of an ovine model. Figure 11 shows an example of the EEP obtained using a 7-electrode array arranged in a hexagonal pattern. One can observe the stimulation artifact occurring at t=0. Note that the most rostro-medial channel was faulty.

Figure 10. Electrically evoked potentials recorded using a 7-electrode array arranged in a hexagonal format. Stimulation artifact can be observed at t=0. The most rostro-medial channel was faulty.

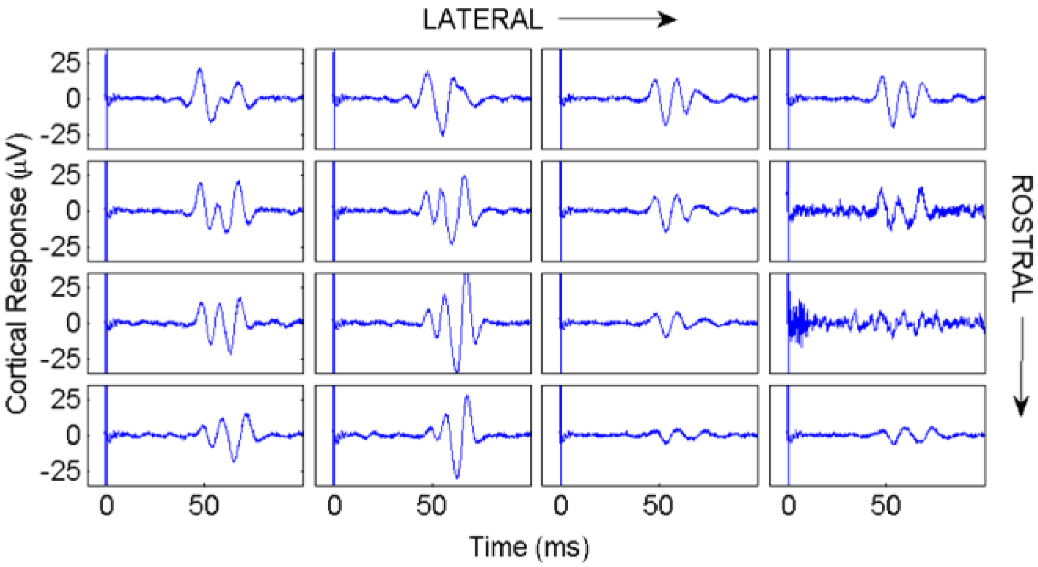


On the other hand, figure 12 shows an example of an EEP recorded with the 16-electrode array after applying a band-pass filter to remove low frequency components. In both cases, the latency between the onset of the stimulus and the peak of the response was approximately 66 ms. Stronks et al. (2013)

(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

reported EEP in humans with latencies to first peak between 40 and 80 ms, similar to that presented in this work.

Figure 11. Band-pass electrically evoked potentials recorded with a 16-electrode array. Stimulus artifact was recorded at t=0 in all channels with two channels with poor coupling to the cortex observable on the lateral side.



Discussion and conclusion

The study of the electrophysiology underpinning retinal neurostimulation is a growing area of research with an important number of publications in the last few years (Eiber et al., 2013). As visual prostheses continue to develop, further understanding of current steering strategies is required to improve the performance of retinal implants (Dumm et al., 2014; Matteucci et al., 2013). This paper presents a comprehensive architectural description of an experimental setup for the investigation of visual prosthesis with the aim to facilitate other researchers to further the knowledge in this area. This four-view model does not cover low-level aspects of the design. Nevertheless, it provides sufficient information for other researchers to replicate a similar implementation. Future neural stimulators should include further switching capabilities and instruments to monitor the electrode-tissue interfaces. This would simplify the current setup and improve its usability.

(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

Electrophysiological recordings may be impacted by a number of noise sources including electrical (such us equipment, main power line or lifts) and biological (breathing, cardiac activity or blood flow among others). Because the stimulus will create a strong artifact, it is recommended that some filtering of the neural signals be applied off-line after artifact removal. Additionally, some researchers may consider the use of Faraday cages to minimize interferences from other devices.

Results obtained from supradural recordings are comparable to those found in the scientific literature (Barriga-Rivera et al., 2015; Stronks et al., 2013; Suaning et al., 2001). This experiment shows evidence on the feasibility of retinal neurostimulation in an ovine model. The amplitude of the EEP varied in different cortical locations: higher amplitudes showed higher correlation with the retinal site where stimuli were delivered. The experimental setup described in this paper can be used to investigate the benefits derived from field shaping strategies in retinal stimulation (Dumm et al., 2014; Matteucci et al., 2013) and allows combining multiple current sources to achieve more complex current distribution patterns. It can also be used to investigate other forms of neural stimulation including high-frequency stimulation. Penetrating electrode arrays allow recording multiunit spiking activity in the visual cortex. Multi-shank probes could be used to record neural activity from lower visual centers such as the lateral geniculate nucleus or the superior colliculus. This has been used to assess the efficacy of different stimulation paradigms, particularly through the reduction of activation thresholds and the increase in visual acuity. Similar methodologies can be used to investigate other fields in neurosciences including cochlear stimulation (Fallon, Shepherd, & Irvine, 2014) or pain perception (Houzé, Bradley, Magnin, & Garcia-Larrea, 2013) among others.

Acknowledgement

This research was supported by the National Health and Medical Research Council (RG1063046), Australia. The authors would like to acknowledge Tom Kulaga for helping with the electronics and control of the stimulator, Dr. Barry Gow for the assistance with fundus imaging and Veronica Tatarinoff for

(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

the assistance with the in vivo preparation.

References

[1] Barriga-Rivera, A., Eiber C.D., Doods C.W.D., D., Fung A., Tatarinoff V., Lovel N.H. & Suaning, GJ. (2015). Electrically Evoked Potentials in an Ovine Model for the Evaluation of Visual Prosthesis Efficacy. Proceedings of the 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC).

[2] Brindley, G. S., & Lewin, W. (1968). The sensations produced by electrical stimulation of the visual cortex. The Journal of Physiology, 196(2), 479-493.

[3] Dodds, C., Schuettler, M., Guenther, T., Lovell, N., & Suaning, G. (2011). Advancements in electrode design and laser techniques for fabricating micro-electrode arrays as part of a retinal prosthesis. Proceedings of the 33rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC).

[4] Dumm, G., Fallon, J. B., Williams, C. E., & Shivdasani, M. N. (2014). Virtual Electrodes by Current Steering in Retinal Prostheses. Investigative Ophthalmology & Visual Science, 55(12), 8077-8085.

[5] Eiber, C. D., Lovell, N. H., & Suaning, G. J. (2013). Attaining higher resolution visual prosthetics: a review of the factors and limitations. Journal of Neural Engineering, 10(1), 011002.

[6] Fallon, J. B., Shepherd, R. K., & Irvine, D. R. (2014). Effects of chronic cochlear electrical stimulation after an extended period of profound deafness on primary auditory cortex organization in cats. European Journal of Neuroscience, 39(5), 811-820.

[7] Fambrini, F., Barreto, M. A., & Saito, J. H. (2014). Low noise microelectrode array signal headstage pre-amplifier for in-vitro neuron culture. Proceedings of the 27th International Symposium of the IEEE Computer-Based Medical Systems (CBMS).

[8] Green, R., Matteucci, P., Dodds, C., et al. (2014). Laser patterning of platinum electrodes for safe neurostimulation. Journal of Neural Engineering, 11(5), 056017.

[9] Habib, A. G., Cameron, M. A., Suaning, G. J., Lovell, N. H., & Morley, J. W. (2013). Spatially restricted electrical activation of retinal ganglion cells

(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

in the rabbit retina by hexapolar electrode return configuration. Journal of Neural Engineering, 10(3), 036013.

[10] Houzé, B., Bradley, C., Magnin, M., & Garcia-Larrea, L. (2013). Changes in sensory hand representation and pain thresholds induced by motor cortex stimulation in humans. Cerebral Cortex, 23(11), 2667-2676.

[11] Jung, L. H., Shany, N., Emperle, A., Lehmann, T., Byrnes-Preston, P., Lovell, N. H., & Suaning, G. J. (2013). Design of Safe Two-Wire Interface-Driven Chip-Scale Neurostimulator for Visual Prosthesis. IEEE Journal of Solid-State Circuits, 48(9), 2217-2229.

[12] Kruchten, P. B. (1995). The 4+ 1 view model of architecture. IEEE Software, 12(6), 42-50.

[13] Limousin, P., Krack, P., Pollak, P., Benazzouz, A., Ardouin, C., Hoffmann, D., & Benabid, A.-L. (1998). Electrical stimulation of the subthalamic nucleus in advanced Parkinson's disease. New England Journal of Medicine, 339(16), 1105-1111.

[14] Matteucci, P. B., Chen, S. C., Tsai, D., et al. (2013). Current steering in retinal stimulation via a quasimonopolar stimulation paradigm. Investigative Ophthalmology & Visual Science, 54(6), 4307-4320.

[15] Pascolini, D., & Mariotti, S. P. (2011). Global estimates of visual impairment: 2010. British Journal of Ophthalmology, bjophthalmol-2011-300539.

[16] Rosen, H. R., Urbarz, C., Holzer, B., Novi, G., & Schiessel, R. (2001). Sacral nerve stimulation as a treatment for fecal incontinence. Gastroenterology, 121(3), 536-541.

[17] Schuettler, M., Stiess, S., King, B., & Suaning, G. (2005). Fabrication of implantable microelectrode arrays by laser cutting of silicone rubber and platinum foil. Journal of Neural Engineering, 2(1), S121.

[18] Shepherd, R. K., Shivdasani, M. N., Nayagam, D. A., Williams, C. E., & Blamey, P. J. (2013). Visual prostheses for the blind. Trends in Biotechnology, 31(10), 562-571.

[19] Snyder, R. L., Middlebrooks, J. C., & Bonham, B. H. (2008). Cochlear implant electrode configuration effects on activation threshold and tonotopic selectivity. Hearing Research, 235(1), 23-38.

(CC) JACCES, 2016 - 6(2): 81-101. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.108

[20] Stronks, H. C., Barry, M. P., & Dagnelie, G. (2013). Electrically elicited visual evoked potentials in Argus II retinal implant wearers. Investigative Ophthalmology & Visual Science, 54(6), 3891.

[21] Suaning, G., Lovell, N., & Lehmann, T. (2014). Neuromodulation of the retina from the suprachoroidal space: The Phoenix 99 implant. Proceedings of the 2014 IEEE Biomedical Circuits and Systems Conference (BioCAS).

[22] Suaning, G. J., Lovell, N. H., & Kerdraon, Y. A. (2001). Physiological response in ovis aries resulting from electrical stimuli delivered by an implantable vision prosthesis. Paper presented at the Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC).

[23] Wong, Y. T., Dommel, N., Preston, P., Hallum, L. E., Lehmann, T., Lovell, N. H., & Suaning, G. J. (2007). Retinal neurostimulator for a multifocal vision prosthesis. IEEE Transactions on Neural Systems and Rehabilitation Engineering, 15(3), 425-434.

Journal of Accessibility and Design for All

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

VOTE-BY-PHONE: AN INVESTIGATION OF A USABLE AND ACCESSIBLE IVR VOTING SYSTEM

Danae Holmes[1], Philip Kortum[2]

[1,2]Department of Psychology, Rice University, United States of America

[1]danae.holmes@gmail.com, [2]pkortum@rice.edu

Received: 2016-04-05| Accepted: 2016-11-05| Published: 2016-11-30

***Abstract*:** One of the main goals of the Help America Vote Act (HAVA) was to ensure that voters with disabilities could vote independently. However, the current state of most voting methods does not allow for independent voting for everyone. In response to this issue, we tested a remote IVR voting system developed by Holmes and Kortum (2013), with an added audio speed adjustment feature and synthetic voice to increase usability and accessibility, especially for visually impaired voters (Piner, 2011). The focus of this research was to examine the viability and usability of the IVR voting system as an accessible voting platform for visually impaired voters. The system was tested by users with and without visual impairments, and usability was measured using the three ISO 9241-11 usability metrics (ISO 9241-11, 1998) of efficiency (time to complete a ballot), effectiveness (accuracy), and satisfaction (subjective usability). Results indicate that the IVR voting system could be a viable voting alternative to other established voting methods, with similar performance among sighted and visually impaired users.

Keywords: voting, accessible, usability, IVR, universal design.

Introduction

The Help America Vote Act (HAVA) and the Voting Accessibility for the Elderly and Handicapped Act were enacted to help preserve the rights to vote privately and independently and to access polling locations for those with disabilities (United States Government, 47th Congress, 2002; United States Government, 98th Congress, 1984). Even with these acts in place, voters with disabilities continue to have lower voter turnout rates than those without disabilities (Schur, 2013). Amongst those with disabilities, voter

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

turnout is lowest for those with visual, motor, or cognitive impairments (Schur, 2013). These low turnout rates are likely due to the increased likelihood of facing obstacles in the voting process, including travel to and navigation within a polling location, and reading or seeing the ballot (Schur, 2013). These obstacles affect at least 35 million American citizens with disabilities and therefore must be addressed in order to help preserve their right to vote (Houtenville, Brucker, & Lauer, 2014).

In light of these issues, this paper evaluates a novel remote voting system with a purely auditory interface that could help alleviate some of the difficulties in voting for the disabled, especially the visually impaired. The study used an interactive voice response (IVR) system that was designed to be highly usable and accessible, particularly for visually impaired or blind voters (Holmes & Kortum, 2013). While vote-by-phone systems have been investigated before, they have not been tested for usability, which could be a large component of successful implementation (Burg, Kantonides & Russell, 2009; Mazurick & Melanson, 2004). The goal of the assessment was to evaluate this system for its viability as a voting method and its usability for both visually impaired and sighted users.

Background

As of 2008, 73% of polling locations had one or more obstacles that could impede access to voting areas for those with disabilities (United States Government Accountability Office, 2009). Though nearly all polling locations have accessible voting machines, 23% of voting stations with accessible voting systems offered less privacy than non-accessible voting stations (United States Government Accountability Office, 2009).

According to Schur (2013), traveling to a polling location is another challenge for those with disabilities. This obstacle can be avoided by utilizing remote voting methods, but the current remote voting standard in the US still presents problems for the disabled. Voting by mail is the primary way citizens can cast their ballot without traveling to a polling place (Ellis, Navarro, Morales, Gratschew, & Braun, 2007). With this method, ballots can be lost in the mail and either not received on time or at all (Ellis, Navarro,

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

Morales, Gratschew, & Braun, 2007). Perhaps more importantly, mail-in ballots are usually paper ballots, where voters must mark their selections on physical ballot. This type of ballot can create a barrier for voters with visual disabilities, as these voters may have difficulty reading or even seeing the paper ballot. Overcoming this difficulty often requires the voter to trust someone to help them complete the ballot, negating their private and independent vote. Even if the ballot were to be requested with larger, more easily readable text, that also has the potential to lead to reduced privacy when voting (Norden, Creelan, Munoz, & Quesenbery, 2006) since it allows other in the room to more easily see how the voter is marking the ballot. Voters with cognitive impairments may not be able to fully understand complex instructions written on the ballot and voters with fine motor impairments could have trouble physically filling out the ballot (Tokaji & Colker, 2007).

Interactive Voice Response Systems

IVR systems allow interaction between users and computers via DTMF (touch-tone) inputs (Brandt, 2008). IVR systems have generally garnered a negative reputation due to the unsatisfying experiences many people have with the systems, with most of this dissatisfaction stemming from poor interface design (Brandt, 2008). However, by closely following the recommendations and research found in the current literature, it is possible to create a highly usable IVR interface that can increase the efficiency and perceived usability of these systems (Killam & Autry, 2000; Schumacher, Hardzinski, & Schwartz, 1995).

IVR systems can provide accessible interfaces for a broad range of physical disabilities (Brandt, 2008). Telephones can be purchased to match many different levels of physical ability, by using simple design elements, such as larger buttons for visual and fine motor impairments. Also, the purely audio interface of IVR systems is considered ideal for those with visual impairments (Laskowski, Autry, Cugini, Killam, & Yen, 2004). Norden, Creelan, Munoz, and Quesenbery (2006) noted that Vote-by-Phone systems show their greatest strength as accessible interfaces because they could allow voters to complete a ballot remotely. Voters could cast their ballots at home using

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

their own telephones configured with any accessible features needed. Voters would also not be required to travel to polling locations, which, as noted earlier, can be a difficult task for many disabled voters having to arrange for transportation to polling locations (Norden, Creelan, Munoz, & Quesenbery, 2006).

Over 97% of US households have DTMF (touch-tone) telephones, which is the primary interface for IVR systems (US Census Bureau, 2011). Because telephone access is ubiquitous and low cost telephones are readily available, the use of telephone-based IVR voting systems would not require the deployment of additional equipment to voters and would be cost effective to implement at polling locations.

Another advantage of IVR system interfaces is that they can be easily ported to other voting methods or technologies that use “prompt and response” interfaces (Brandt, 2008). This means that building a voting interface for the telephone and a graphical computer interface, for example, will be relatively cost effective since they share much of the same interaction structure. Further, because of the simplified nature of most IVR interactions, it is possible that other technologies may see performance improvements if a successful IVR system interaction design is implemented.

IVR systems have been successfully implemented for voting in both the laboratory and in the field in actual election settings. Holmes and Kortum (2013) demonstrated that an IVR voting system performed comparably to other voting methods and was considered subjectively usable by participants. A form of voting by phone was implemented in New Hampshire and Vermont elections. This instantiation of a vote-by-phone system did not permit remote voting, but instead allowed voters to use telephones at the polling locations to cast their ballot (Norden, Creelan, Munoz, & Quesenbery, 2006). Though the benefits to voting remotely were not available to the voters, the advantages of having a non-visual interface still remained for those with visual impairments, allowing for private and independent voting.

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

Study 1 - Testing the IVR System with the General Voting Population

Holmes and Kortum (2013) developed and tested an IVR voting system to assess its usability and determine its general viability as a voting medium. This system was fitted with a user adjustable audio speed feature to increase its accessibility specifically for blind voters according to recommendations put forth by to Piner (2011), Asakawa, Takagi, Ino, & Ifukube (2003), and Theofanos & Redish (2003). Although the system was shown to be usable and to perform comparably to other voting methods, the sample population, comprised solely of college undergraduates, limited the generalizability of the results.

In this study, we addressed the sample limitation in Holmes and Kortum (2013) by testing the system with the general voting population. The goal of this study was to further evaluate the general usability of the accessible IVR voting system and its viability to as a voting system with the general voting population. We also examined the utilization of the speech-rate accessibility feature to determine whether it would prove useful to sighted individuals and if it positively impacted overall usability.

Method

Participants

135 subjects (65 females and 70 males) were recruited from the general Houston population. The participants had normal or corrected to normal hearing, and ranged in age from 19-65 years, with an average age of 36.54 (SD = 12.82). Subjects were compensated $25 for their participation.

Design

The study was a mixed design with one within-subjects variable and one between-subjects variable. The within-subjects variable was ballot type. Subjects voted on both the IVR voting system and a standard paper bubble ballot where a vote is made by filling in a small circle, or “bubble”, next to a candidate in a race or choice on a proposition. The between-subjects

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

variable was the 2-level information condition, which determined how subjects voted. Subjects were randomly placed in either a directed-voting condition or an undirected-voting condition. Participants in the directed condition were given a sheet of paper, called a slate, that instructed them how to vote in each race and proposition. Those participants who were placed in the undirected condition were given a voter's guide, similar to the League of Women Voters' guide, which details the political stance of all candidates as well as arguments for and against each proposition on the ballot. Participants in the undirected condition were allowed to vote freely. After casting their votes, participants in the undirected voting condition were given an exit interview, which assessed their voting intent for each race and proposition on the ballot.

The three measures of usability (efficiency, effectiveness, and satisfaction) as defined by the International Organizations for Standardizations recommendation ISO 9241-11 (ISO, 1998) served as the dependent variables. Efficiency reflected how long subjects took to complete a ballot.

Effectiveness captures how accurately participants made their intended selections on the interface, and was measured by error rate. In the undirected condition, errors were determined by comparing subjects' selections on the two ballots, IVR and bubble, with their answers on the exit interview. Selections that matched on two out of the three methods were considered to reflect the subjects' actual voting intent. Selections that deviated from two matching selections were considered an error on the method with the differing selection. For example, there are two major political parties in the US, the Republican Party, and the Democratic Party. If a participant selected the Republican Party candidate in the Presidential race for both the IVR voting system and the exit interview, but voted for the Democratic Party candidate on the bubble ballot, then this would count as an error on the bubble ballot. In the directed condition, selections deviating from the slate were counted as errors. Error rate was calculated by taking the total number of errors on a ballot and dividing it by the total number of possible errors on the ballot.

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

The System Usability Scale (SUS) was used to assess the subjective usability of the system, representing the satisfaction metric. It is a ten item, Likert scale survey scored from 0 (poor) – 100 (excellent) (Brooke, 1996). It has been demonstrated to be an effective measure across a wide range of interface types (Bangor, Kortum & Miller, 2008), making it ideal for use in this study of different voting technologies.

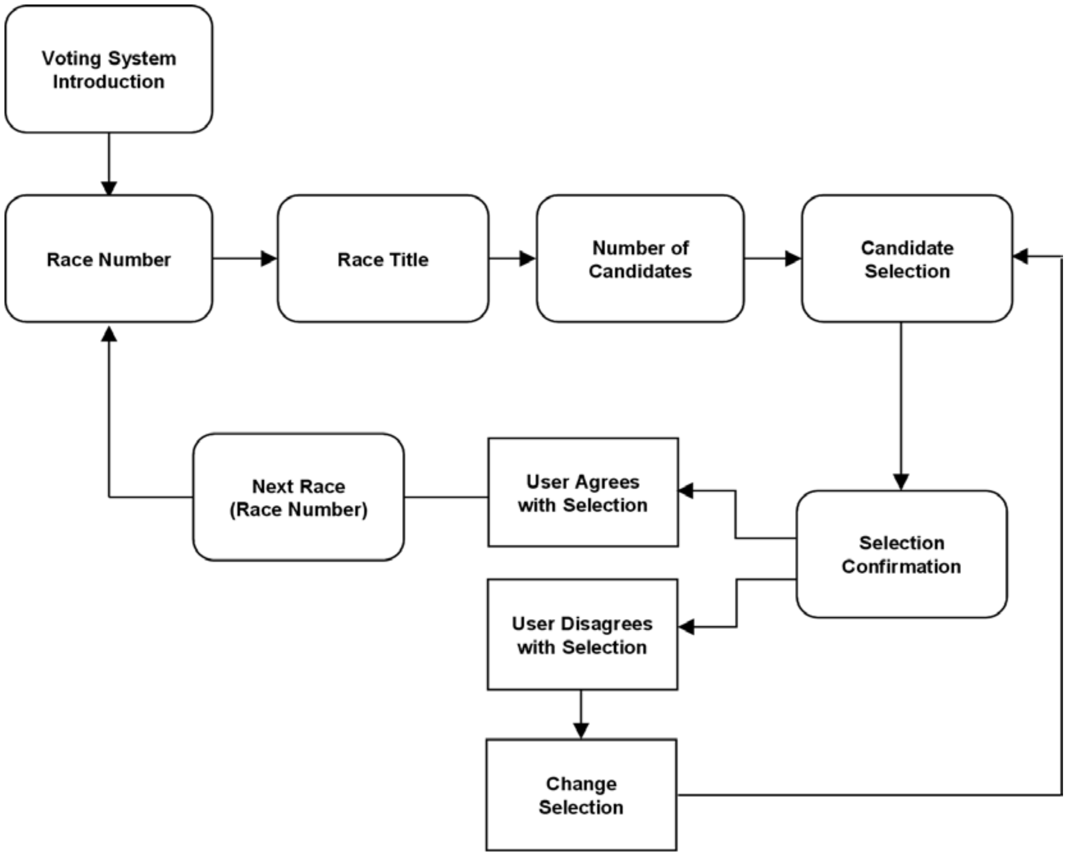
Materials

The IVR voting system was a serial representation of the ballot used in studies by Everett et al., 2008, Byrne et al., 2007, Everett et al., 2006, and Greene et al., 2006. The paper bubble ballot used the same ballot as well. The ballot contained 21 races at the national, state, county, and non-partisan (without political affiliation) level and 6 propositions from various state or county ballots.

The IVR employed a male synthetic voice, as recommended by Piner (2011). The system provided general instruction on the use of the IVR, and then presented each of the races in turn. The IVR utilized an in-line confirmation method, rather than an end of ballot review. After making a selection, the voter was asked to confirm the selection. If they were satisfied with the selection, the system moved on to the next race. If they were not satisfied with the selection, the system returned to the list of candidates for the current race to allow the user to make another selection. Figure 1 shows the basic operational flow of the IVR.

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

Figure 1. Basic flow of the IVR interaction



The IVR system also employed a speed adjustment system that allowed users to change the rate of speech without distortion. The feature was configured to allow users to slow or speed the system audio in 10% increments to a maximum of +/- 50% at any time throughout the voting process. To control this feature, users pressed "7" to slow the audio and "9" to speed the audio in accordance with Schumacher et al.'s (2000) usable IVR design guidelines. Those guidelines suggested that the IVR should have directional metaphors consistent with the common stereotypes and keypad layout.

A section 508 (Rehabilitation Act of 1973, 1973) compliant telephone was used to complete the ballot on the IVR voting system. The system logged ballot completion times, user responses, and audio speed adjustment usage.

Procedure

Subjects placed in the undirected condition were given a voter's guide, modeled on the League of Women Voter's guide, which contained information about every candidate and proposition. Participants could

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

decide whether or not they wished to use the guide to make their voting selections. Participants in the directed condition were randomly given a voting slate that contained either a majority of Democratic or Republican candidates. The ordering of the voting methods was counterbalanced. Immediately after voting with a particular method (paper or IVR) participants rated their satisfaction using the System Usability Scale survey.

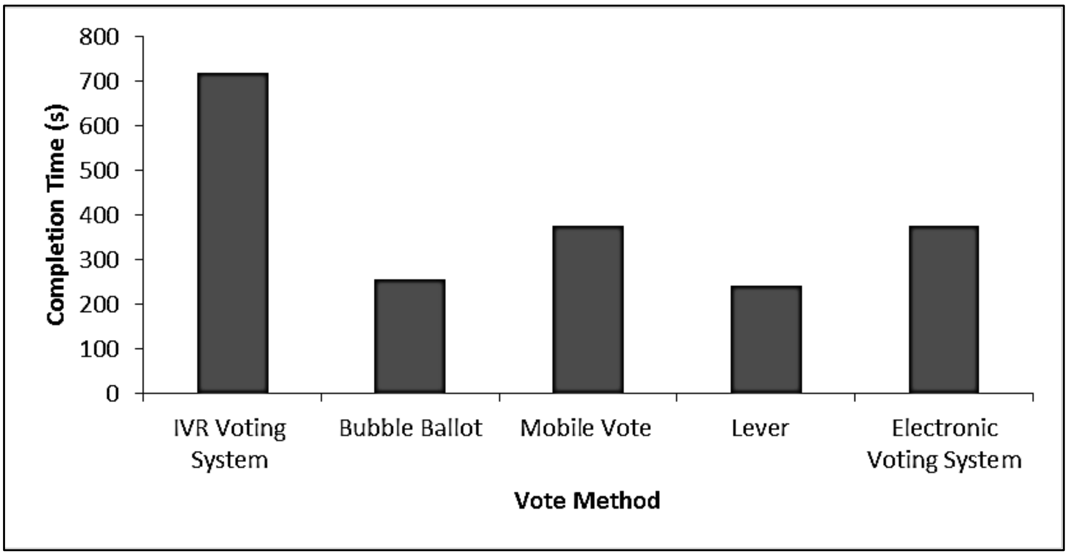
Results

The usability metrics collected on IVR voting performance were evaluated and directly compared with those of the paper bubble ballot. We also compared IVR performance with performance measures collected in usability studies of other voting technologies that used the same ballot as this study to better understand how the IVR system fares against other common voting methods. These additional technologies included lever machines, prototypical electronic voting systems and an experimental application that allows people to vote on their smartphone as studied in Everett et al., 2008, Byrne et al., 2007, Everett et al., 2006, and Greene et al., 2006.

Efficiency**.** The average ballot completion time across the information conditions for the IVR voting system was 719.90 seconds (*SD* = 251.28), which is approximately 12 minutes. This time was noticeably longer than that of the bubble ballot and times of other voting methods from previous studies (data collected from Everett et al., 2008, Campbell, B., et al., 2010, and Greene et al., 2006) as seen in Figure 2.

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

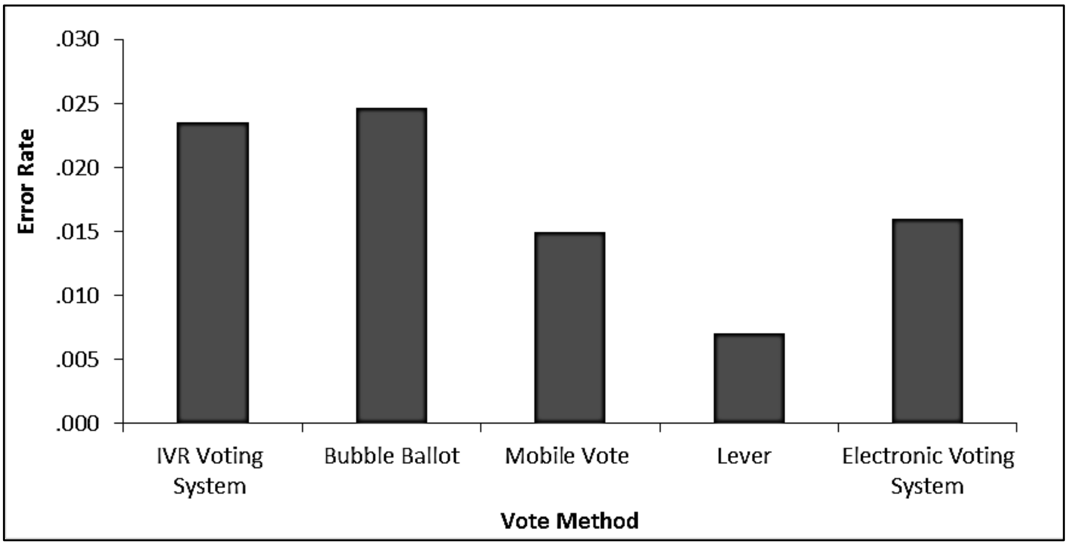
Figure 2. Total ballot completion time comparison of the IVR voting system with various voting methods.



Effectiveness**.** Six subjects were removed from this analysis due to their error rates being above 15% on both the IVR voting system and the bubble ballot, indicating a lack of understanding or non-compliance of the experimental task (Byrne, Greene, & Everett, 2007). The IVR voting system's error rate was .023 (SD = .054), while the bubble ballot's error rate was .025 (SD = .067). There was no evidence supporting a difference between the error rates of the two voting methods, $F(1, 128) = .03$, $p = .86$, $MSE < .01$. Figure 3 displays a comparison of the IVR voting system and bubble ballot error rates to error rates from other voting methods (Everett et al., 2008; Campbell, et al., 2010; Greene et al., 2006).

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

Figure 3. Comparison of error rates between the IVR voting system and other voting methods.



Error was also examined on a by ballot basis (see Table 1), meaning that a ballot either contains one or more errors or does not. Approximately 25.6% of ballots contained at least one error on the IVR. About 21.7% of bubble ballots contained one or more errors.

Table 1. Frequency of ballots with and without errors

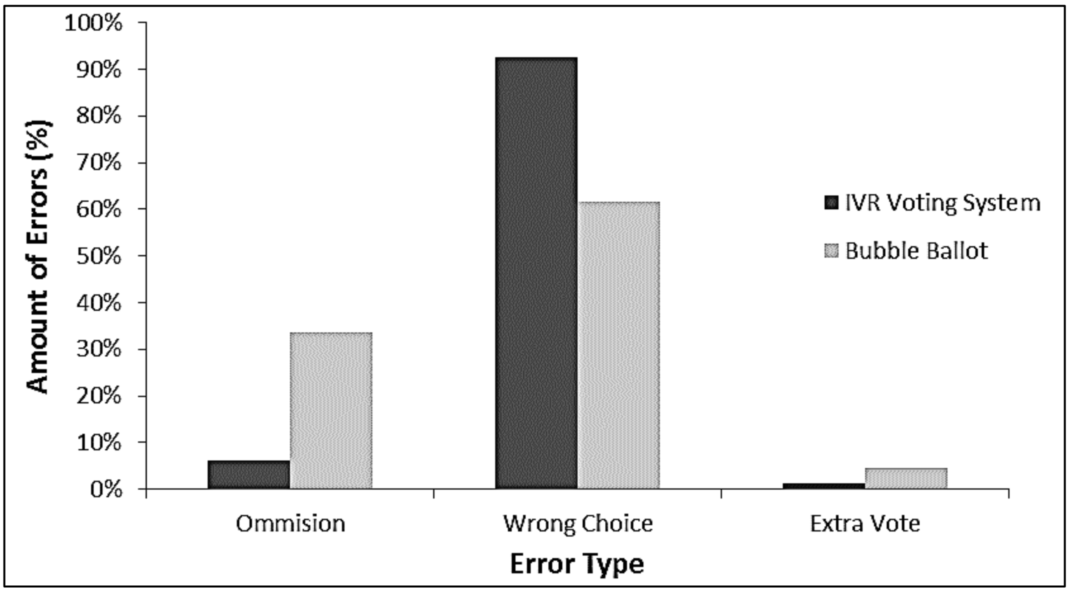
	No Errors	Errors
IVR Voting System	33	96
Bubble Ballot	28	101

There were three types of errors that subjects made during the experiment. Omission errors occur when there is no selection made when the intent was to make a selection. Wrong choice errors occur when the selection made is not the one that was intended. Lastly, extra vote errors occur when a selection is made when the intent was not to make a selection in a race.

The bubble ballot elicited the most omission and extra vote errors, while the IVR voting system produced the highest count of wrong choice errors. The percentage of each type of error committed for the IVR voting system and bubble ballot is shown in Figure 4.

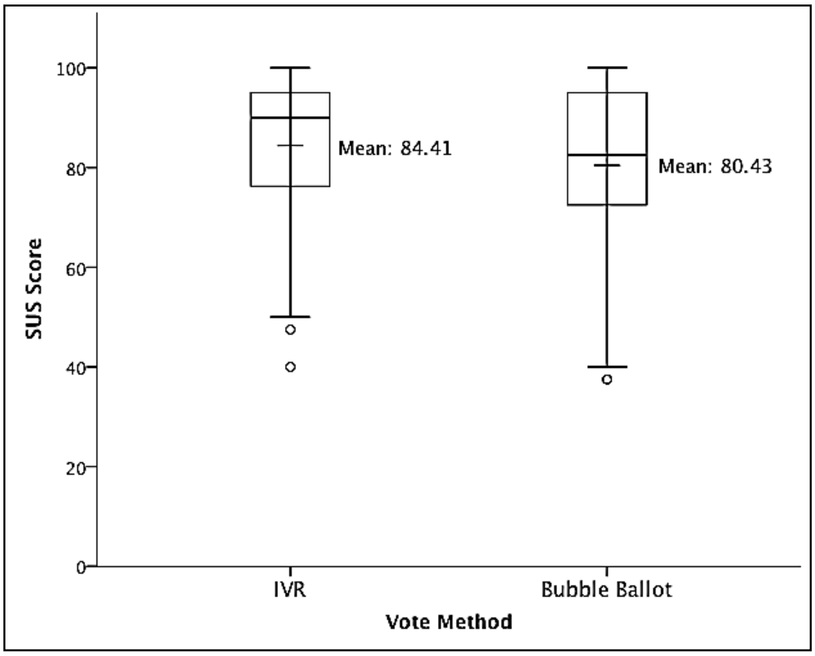
(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

Figure 4. Number of each type of error committed within the IVR voting system and bubble ballot.



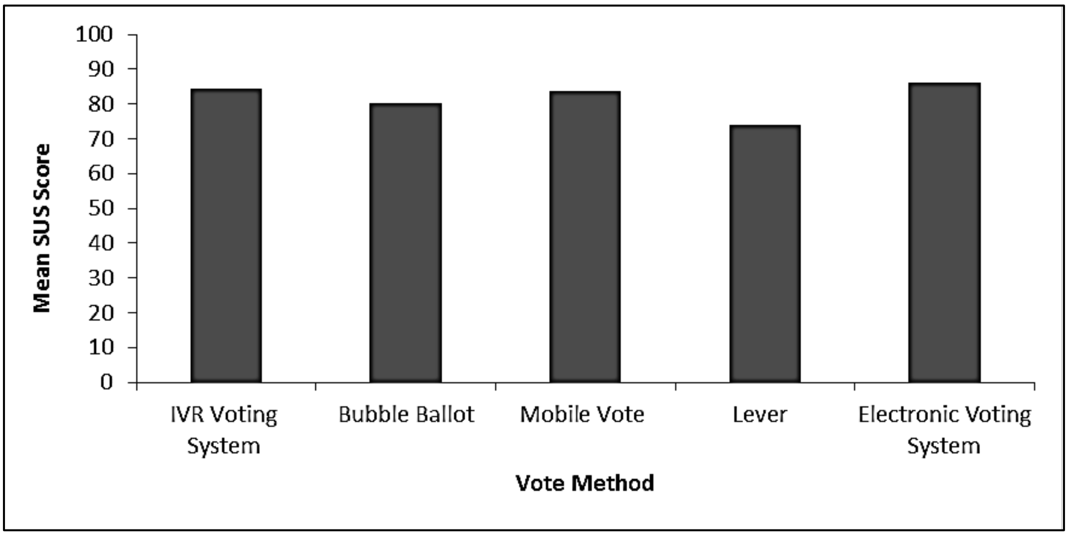
Satisfaction**.** The IVR voting system received an average SUS score of 84.41 (*SD* = 14.48), while the bubble ballot scored approximately 4 points lower at 80.43 (SD = 16.15). The two scores were reliably different (see *Figure 5*), $F(1, 134) = 5.12$, $p = .03$, $MSE = 208.97$. Figure 6 depicts a comparison of SUS scores of the IVR voting system with other voting methods from previous studies by Everett et al., 2008, Campbell, et al., 2010, and Greene et al., 2006.

Figure 5. Boxplot comparing SUS scores for the IVR voting system and bubble ballot.



(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

Figure 6. Comparison of SUS scores between the IVR voting system and other voting methods.



Audio Speed Adjustment Usage. Approximately 37% of subjects utilized the speed adjustment feature. When the audio speed adjustment feature was used, average ballot completion time was 607.06 (SD = 213.43) seconds compared to the non-use average of 786.28 seconds (SD = 249.22).

Study 2 - Testing the IVR system with the Visually Impaired Voting Population

The second study extended the results from study 1 by testing the IVR voting system with users from the general population who were legally blind. The performance of visually impaired and sighted users in their use of the system was then compared. This analysis is important since the system is intended to equally support both sighted and visually impaired users in their vote casting efforts.

Participants

19 (11 females, 8 males) legally blind subjects were recruited from the general Houston population. These participants reported normal or corrected to normal hearing, and had an average age of 43.47 years (SD = 15.81). Participants were compensated with a $25 e-gift card for their participation.

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

Design

The same design as Study 1 was used, with the exception of the information and ballot type conditions. Because the participants were visually impaired, we only used the directed condition and did not have them complete a bubble ballot. The voting slate was verbally administered to subjects prior to voting, and the experimenter collected satisfaction data from the SUS using a verbal protocol as well. A participant's visual status (sighted or legally blind) was the between-subjects variable used when comparing sighted and visually impaired subjects. To allow for direct comparison between sighted and visually impaired subjects, only data from the 67 subjects in the directed condition in Study 1 were used.

Materials

The same materials in Study 1 were utilized, with the exception the use of a Section 508 compliant telephone. Subjects used their personal telephones to complete the study since the study was conducted remotely.

Procedure

A modified version of the procedure from Study 1 was used in order to accommodate testing with visually impaired subjects. Participants were asked to call into the laboratory at a specified appointment time from any touch-tone telephone to participate. Subjects were given a simplified verbal slate, instructing them to vote for all Democrats, skipping races that did not have a Democratic candidate and non-partisan races, and to vote "no" on all propositions.

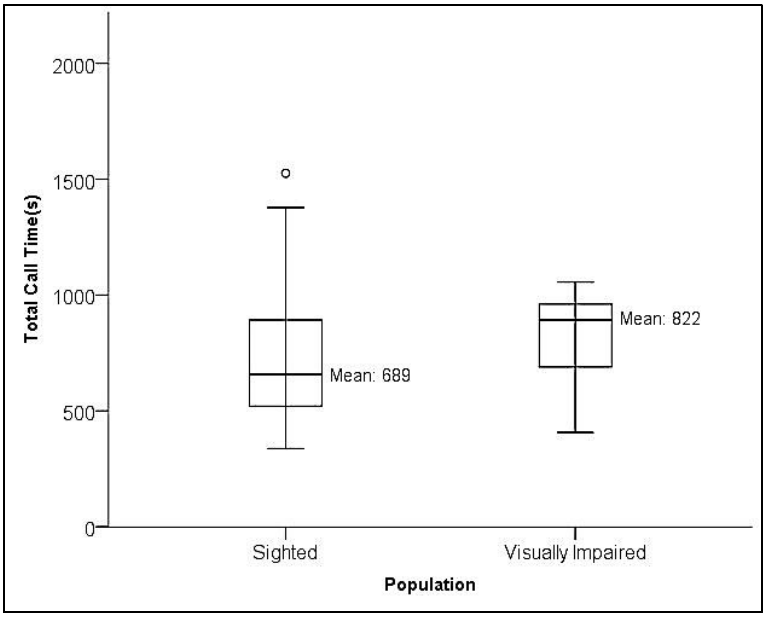
Results

Efficiency. The average ballot completion time for visually impaired users was 822.16 seconds (SD = 201.83), which is approximately 14 minutes. Average voting time for sighted users was 689.00 seconds (*SD* = 206.10), or approximately 11 minutes and 30 seconds. The total ballot completion times were significantly different, $F(1, 84) = 6.23$, $p = .01$, $MSE = 42{,}104.08$.

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

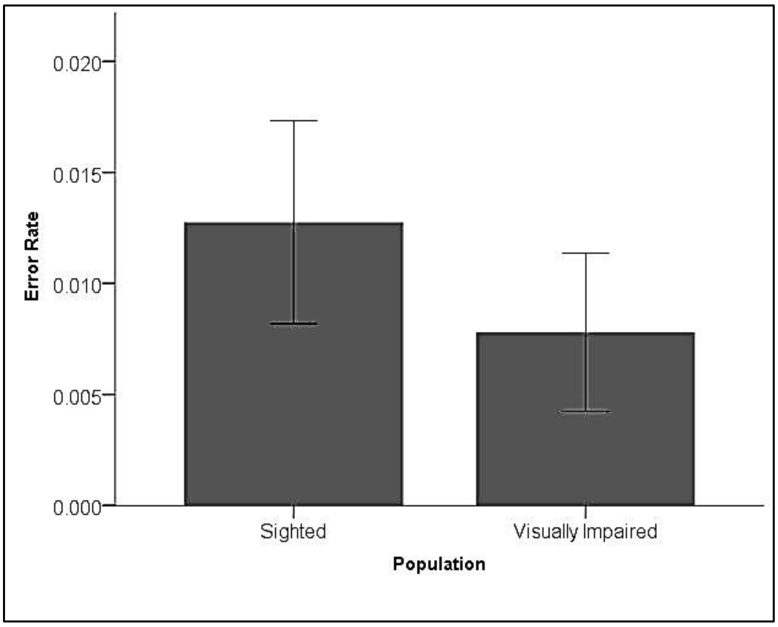
Figure 7 compares the total ballot completion time of sighted and visually impaired subjects.

Figure 7. Comparison of total ballot completion time between populations.



Effectiveness**.** The error rate of visually impaired subjects was .008 (SD = .016), while sighted subjects' error rate was .013 (SD = .036). No evidence supported a difference between the error rates of the two populations, $F(1, 78) = .34$, $p = .56$, $MSE = .76$. Figure 8 compares the error rates of sighted and visually impaired users on the IVR voting system.

Figure 8. Error rates of sighted and visually impaired users on the IVR voting system. Error bars represent +/-1 standard error.



(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

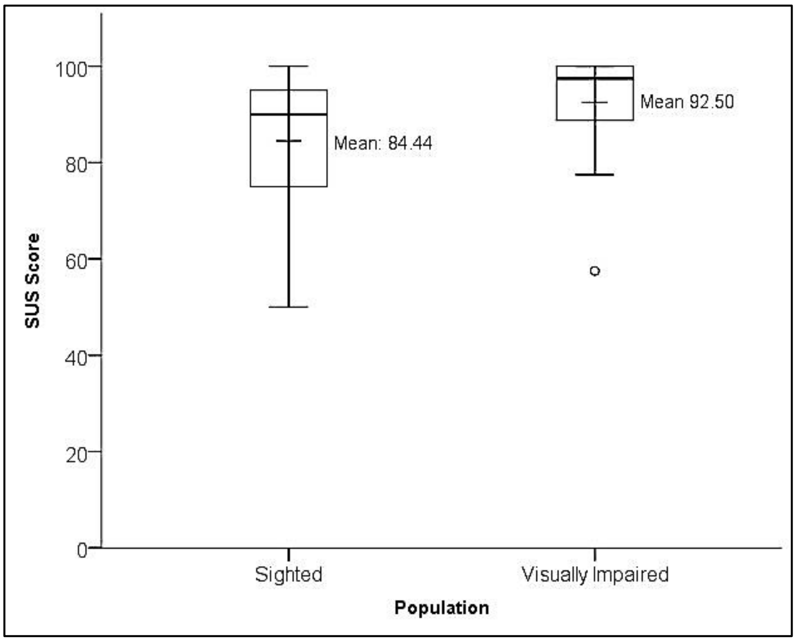
The by ballot error rate for the system was measured (see Table 2) for the visually impaired participants. Approximately 21% of ballots contained at least one error, equating to four ballots out of 19 containing errors. This number appears to compare well with by ballot error rate (25.6%) of sighted participants. Three ballots contained undervote errors, meaning no selection was made on races that required one. One ballot contained a wrong choice error, where a selection that did not coincide with the slate was made.

Table 2. Frequency of ballots with and without errors on the IVR voting system between populations

	No Errors	Errors
Sighted	33	96
Visually Impaired	4	15

Satisfaction**.** The average SUS scores from visually impaired subjects was 92.50 (*SD* = 10.74) and 84.44 (*SD* = 14.14) for sighted subjects. A Welch corrected ANOVA revealed that the SUS scores were reliably different, $F(1, 37.58) = 7.18$, $p = .01$, $MSE = 181.82$. Figure 9 depicts a comparison of SUS scores between the two populations.

Figure 9. Average SUS scores for sighted and visually impaired users.



(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

Audio Speed Adjustment Usage. Approximately 26% of visually impaired subjects utilized the speed adjustment feature. Those who used the feature had an average ballot completion time of 684.73 (SD = 294.58) seconds, while those who did not complete their ballot in an average of 871.25 seconds (SD = 140.87).

Discussion

Efficiency. The IVR voting system is slower, in terms of ballot completion, than other voting methods. This is an expected result because of the serial nature of the interface; voters must listen to every candidate and every race if they are to complete the ballot fully, and visual scanning short-cuts cannot be utilized. Both sighted and unsighted users showed longer completion times, suggesting that the presence of a visual impairment was not the issue, but rather the exhaustive presentation of the information.

One large contributor to the lower efficiency of the IVR was that the IVR interface had a different form of review than the other forms of voting described here. In most voting methods, voters mark their entire ballot and then perform a check of those selections at the end of the voting process, immediately prior to casting the ballot. This type of vote reviewing significantly complicates the interface for an IVR system, because it would require that a user be able to navigate back and forth to a race to change or modify a selection if it was deemed incorrect during the review. In order to eliminate this significant interface complexity, the IVR system utilized an in-line review process. Immediately following the selection of a candidate, and acknowledgement of that selection, the IVR would ask the user to verify that selection. This verification took the form of a prompt that stated “In the race for the Senate, you voted for John Smith. If this is correct, press 1. If this is not correct, press 2”. If a user made a mistake, pressing 2 would take them back to that race for the correction. The review prompt would be played again and, if the user was satisfied with their vote, they would move to the next race. This means that users were forced to review every single race by having it read back to them. This is in contrast to the typical skimming behavior exhibited by users during the review of their ballots.

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

Paper ballots are often cast with little review at all (Herrnson et al., 2006), since there is not a formal review step in the process.

Even on electronic voting machines, where a voter is presented with a formal review screen that summarizes all of the selected votes and asks the user for confirmation, voters typically spend very little time (most spend less than 20 seconds) (Everett, 2006) on the review screen.

In the IVR, if the average review prompt is about 10 seconds in duration, this adds 270 seconds to the overall time across the 27 races. If we were to remove this forced review time from the analysis, IVR completion time would be much more similar to other voting systems.

Even though we can account for this extra time, the fact remains that IVR voting took longer than other forms of voting. However, this disadvantage may be counteracted with the fact that the IVR voting system does not necessarily require voters to travel to a voting location and wait in line to vote, which could translate into significant time savings for voters. Since visually impaired users took approximately 2.5 minutes longer to complete a ballot on the system than sighted users, the benefit of not incurring the previously discussed barriers of travel and ability to vote independently may outweigh the decreased efficiency for visually impaired voters (Schur, 2013).

The IVR system did employ a modified version of a standard feature that is common in commercially deployed IVR system: barge through. Barge through allows a user to make a selection at any time during the prompt presentation. This feature allows a user to make their selection immediately upon hearing it, thus reducing errors due to memory load. The IVR deployed here used a modified form of barge thorough, which forced the user to hear the race number and position (e.g. “Race 3 of 21”, You are voting for the US Senator”), but allowed them to make their selection any time after that. If they selected a candidate before all of the candidates had been read, the prompt would terminate, and the voter would be taken to the confirmation message. We measured the full run time for each race without barge through, called system time, to help determine the usage of the barge through feature. Use of this feature was significant as all races, for both

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

sighted and visually impaired users, were on average faster than system time. The use of the feature reduced the average ballot completion time by 34.0% for sighted users and 24.9% for visually impaired users. This feature was the only reason the ballot could have been completed in faster than system time, therefore is solely responsible for increasing efficiency in the system. It is an integral attribute to the system as it positively affects usability.

Effectiveness. There was no evidence supporting a difference between the error rates for ballot type and population. Due to that result, we could assume that the IVR voting system could perform well in the aspect of accuracy as a voting medium for both sighted and visually impaired users. It is worth noting that the error rates for both the bubble ballot and IVR voting system for sighted users seemed elevated compared to other voting methods, though statistical support of a difference could not be established due to lack of data from the previous studies for comparison. Increased error rates observed in this study for both the IVR and bubble ballot as compared to error rates for the two methods in past studies could be due to sample differences since both methods showed an increase. Regardless, the error rates for both methods are still considered to be very low.

Satisfaction. The IVR voting system had a higher average SUS score than the bubble ballot, suggesting that the IVR is more subjectively usable than the bubble ballot. It was also rated higher by visually impaired users than sighted users. Though the SUS scores for the bubble ballot and IVR voting system (blind and sighted participants) varied, they could all be considered 'Excellent' according to the adjective rating scale for the SUS (Bangor, Kortum, & Miller, 2009). This was a favorable outcome because it helps support the proposed viability and usability of the IVR voting system as a voting method for both sighted and visually impaired users. Despite of the longer voting times, the IVR voting system was still assessed to be on par with other voting methods in terms of subjective usability, furthering its stance as a universal voting medium for both sighted and visually impaired users.

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

Audio Speed Adjustment Usage. About 37% of sighted subjects and 26% of visually impaired subjects utilized the audio speed adjustment feature. The feature was implemented specifically to support visually impaired users, as they often have experience with increased rate text presentation through their extensive use of screen reading technology on the personal computer. The fact that a third of the sighted users took advantage of the feature suggests that, like closed captioning on televisions, this feature has relevance as an interface feature across the population. The IVR is uniquely suited to provide a universally accessible voting interface as there is no separate accessible mode like you would find with some electronic voting systems in use today. Essentially, everyone who would use the IVR voting system could benefit from its accessible features.

Finally, it is important to note that this study only addressed the usability of the IVR voting system. Other issues, most notably security, were not intended to be evaluated in this study. If the IVR were to be used in a polling location, security concerns would be minimal. However, one of the stated strengths of the system is the ability of the IVR to be used virtually anywhere, which brings about additional security issues, including potential loss of privacy from interception of the voting session and coercion of the voter since the voter is not within the controlled environment of a secure polling station. These security issues would need to be addressed before the IVR voting system could be used in an in a real election, particularly if voters were allowed to vote remotely.

Conclusions

The study strongly suggests that IVR voting platforms could be a potential option to help increase the ability of visually impaired users to participate in elections with the same privacy and self-reliance as other voters. At a minimum, this study has provided the first step in determining how the IVR stands as a remote and accessible voting system. Further research with larger numbers of visually impaired users, could help us better understand the performance of these systems in voting environments, and could have implications in the realm of voting accessibility.

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

Acknowledgements

This work was supported in part by the National Science Foundation (NSF) under Grant CNS-1049723. We would like to thank Daniel O'Sullivan, Founder and CEO of Gyst, for providing the audio speed adjustment feature for the IVR voting system and those who participated in this study.

References

[1] Asakawa, C., Takagi, H., & Ino, S., Ifukube, T. (2003). Maximum listening speeds for the blind. Proceedings of the 2004 International Conference on Auditory Display. Boston, MA.

[2] Bangor, A., Kortum, P., & Miller, J. (2008). An empirical evaluation of the system usability scale. International Journal of Human–Computer Interaction, 24(6), 574-594.

[3] Bangor, A., Kortum, P., & Miller, J. (2009). Determining what individual SUS scores mean: Adding an adjective rating scale. Journal of usability studies,4(3), 114-123.

[4] Brandt, J. (2008). Interactive voice response interfaces. In P. Kortum (Ed.), HCI beyond the GUI: Design for haptic, speech, olfactory, and other nontraditional interfaces (pp. 229-266). Burlington, MA: Morgan Kaufman Publishers.

[5] Brooke, J. (1996) SUS: A "quick and dirty" usability scale. In P. W. Jordan, B. Thomas, B. A. Weerdmeester & A. L. McClelland (Eds.) Usability Evaluation in Industry. London: Taylor and Francis.

[6] Burg, F., Kantonides, J., & Russell, L. (2009). U.S. Patent No. 7,522,715. Washington, DC: U.S. Patent and Trademark Office.

[7] Byrne, M. D., Greene, K. K., & Everett, S. P. (2007). Usability of voting systems: Baseline data for paper, punch cards, and lever machines. In Human Factors in Computing Systems: Proceedings of CHI 2007, (pp.171-180). New York: ACM.

[8] Campbell, B., Tossell, C., Kortum, P., & Byrne (2010). Voting on a Smartphone: Evaluating the Usability of an Optimized Voting System for Handheld Mobile Devices. (Unpublished manuscript). Rice University, Houston, TX.

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

[24] Ellis, A., Navarro, C., Morales, I., Gratschew, M., & Braun, N. (2007). Voting from abroad: The international IDEA handbook. Stockholm, Sweden: International IDEA.Everett, S. P. (2007). The usability of electronic voting machines and how votes can be changed without detection (Doctoral dissertation, Rice University).

[25] Everett, S. P., Byrne, M. D., & Greene, K. K. (2006). Measuring the usability of paper ballots: Efficiency, effectiveness, and satisfaction. In Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting. Santa Monica, CA: Human Factors and Ergonomics Society.

[26] Everett, S. P., Greene, K. K., Byrne, M. D., Wallach, D. S., Derr, K., Sandler, D., & Torous, T. (2008). Electronic voting machines versus traditional methods: Improved preference, similar performance. Human Factors in Computing Systems: Proceedings of CHI 2008 (pp. 883-892). New York: ACM.

[27] Greene, K. K., Byrne, M. D., & Everett, S. P. (2006). A comparison of usability between voting methods. In Proceedings of the 2006 USENIX/ACCURATE Electronic Voting Technology Workshop. Vancouver, BC.

[28] Herrnson, P. S., Niemi, R. G., Hanmer, M. J., Bederson, B. B., Conrad, F. G., & Traugott, M. (2006). The Importance of Usability Testing of Voting Systems. EVT, 6, 3-3.

[29] Holmes, D. & Kortum, P. (2013). Vote-By-Phone: Usability evaluation of an IVR voting system. Proceedings of the Human Factors and Ergonomics Society, Santa Monica, CA: Human Factors and Ergonomics Society

[30] Houtenville, A. J., Brucker, D. L., & Lauer, E. A. (2014). Annual compendium of disability: 2014. University of New Hampshire, Institute on Disability, Durham, NH. Retrieved November 2015, from Annual Disability Statistics Compendium: http://www.disabilitycompendium.org/docs/default-source/2014-compendium/2014_compendium.pdf?sfvrsn=4

[31] ISO 9241-11 (1998). Ergonomic requirements for office work with visual display terminals (VDTs) – Part 11: Guidance on usability (ISO 9241-11(E)). Geneva, Switzerland: International Organization for Standardization.

[32] Killam, B., & Autry, M. (2000). Human factors guidelines for interactive voice response systems. IEA 2000 Congress Proceedings, 1, pp. 391-394.

(CC) JACCES, 2016 - 6(2): 102-124. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i2.115

[33] Laskowski, S. J., Autry, M., Cugini, J., Killam, W., & Yen, J. (2004). Improving the usability and accessibility of voting systems and products. NIST Special Publication, 500-256.

[34] Mazurick, M., & Melanson, D. A. (2004). US Patent No. 20,040,248,552. Washington, DC: U.S. Patent and Trademark Office.

[35] Norden, L., Creelan, J., Munoz, A., & Quesenbery, W. (2006). The machinery of democracy: Voting system security, accessibility, usability, and cost. New York: The Brennan Center for Justice. Retrieved from https://www.brennancenter.org/publication/machinery-democracy

[36] Piner, G. (2011). A usability and real world perspective on accessible voting. Master's Thesis, Rice University, Houston, TX.

[37] Rehabilitation Act of 1973 (1973), 29 U.S.C. § 701 (1973).

[38] Schumacher, R., Hardzinski, M., & Schwartz, A. (1995). Increasing the usability of interactive voice response systems: Research and guidelines for phone-based interfaces. Human Factors and Ergonomics Society, 27(2), 251-264.

[39] Schur, L. (2013). Reducing obstacles to voting for people with disabilities. Retrieved January 2016, from The Presidential Commission on Election Administration: https://www.supportthevoter.gov/files/2013/08/Disability-and-Voting-White-Paper-for-Presidential-Commission-Schur.docx_.pdf

[40] Theofanos, M. F., & Redish, J. J. (2003). Bridging the gap: Between accessibility and usability. Interactions, 10(6), 36-51.

[41] Tokaji, D., & Colker, R. (2007). Absentee voting by people with disabilities: Promoting access and integrity. McGeorge Law Review, 38, 1015-1061.

[42] United States Government Accountability Office. (2009). Voters with disabilities: More polling places had no potential impediments than in 2000, but challenges remain. Washington, DC: United States Government Accountability Office.

[43] United States Government, 47th Congress. (2002). Help America Vote Act of 2002. Public Law 47-252. Washington, D.C.

[44] United States Government, 98th Congress. (1984). Voting Accessibility for the Elderly and Handicapped Act. Public Law 98-435. Washington, D.C.

Journal of Accessibility and Design for All

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

A PRELIMINARY STUDY FOR DEVELOPING ACCESSIBLE MOOC SERVICES

Francisco Iniesto[1], Covadonga Rodrigo[2]

[1]Institute of Educational Technology, the Open University, Milton Keynes, UK

[2]Department of Languages and Computer Systems, School of Computer Science, Universidad Nacional de Educación a Distancia (UNED), Madrid, Spain

ORCID: [1]*0000-0003-3946-3056,* [2]*0000-0001-8135-3163*

[1]francisco.iniesto@open.ac.uk, [2]covadonga@lsi.uned.es

Received: 2016-04-21 | Accepted: 2016-11-05 | Published: 2016-11-30

***Abstract*:** The flexibility of the MOOC service allows students to learn at their own time, place and pace, enhancing continuous communication and interaction among all participants in knowledge and community building. This model especially benefits people with disabilities, which can improve therefore their level of employability and social inclusion, reaching a better quality of life. Unfortunately the access to MOOC platforms present severe barriers: there is a lack of accessibility on the learning resources, the communicating tools and personalized user interfaces. All these issues add extra difficulties such as the need to develop specific digital or even social skills for students with functional diversity. In this context, MOOCs are leading a revolutionary computer and mobile-based scenario along with social technologies that will emerge new kinds of learning applications that enhance communication and collaboration processes. For that reason, this paper describes the need for designing an information model and related specifications to support a new strategy for delivering accessible MOOC courses to learners with special needs, in terms of their preferences and context of use based on a particular application profile. This user profile's design is based on standard metadata schemas, data that provides information about other data, regarding the achievement of accessibility from content to user preferences.

Keywords: MOOC, accessibility, employability, standards, metadata, social inclusion.

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

Introduction

Massive Open Online Courses (MOOCs) have made open education available to the public domain by offering a free window to the same courseware that students might experience at university and colleges. Higher Education institutions are shifting from closed educational platforms to new open learning environments, demonstrating that the evolution of open education on the internet is enabling thousands of people around the world to follow different educational initiatives. A basic characteristic of MOOC courses, independently of its type, is the high degree of interactivity that facilitates and reinforces the bidirectional communication between the students and the mediators. In MOOC courses the figure of the teacher changes, being less prominent in the traditional conception than it is in classroom training or even traditional eLearning. In open courses the role of the tutor is updated, more close to the idea of pedagogical mediation, playing the role of a content curator, a mediator, counsellor, or facilitator of the learning processes. Therefore, the academic figures inside the MOOCs act more like community managers. As the learning is not faculty-centered but student-centered, it requires a greater commitment from the student side into self-learning, deep research aptitude, and analysis, reflexive capacity along with a high component of personal autonomy.

Downes (2012; 2013) clearly differentiates between basic types of MOOC: cMOOCs and xMOOCs. The cMOOC (connectivist) are based on the principle of forming learning communities with very active users who contribute to re-factorizing the content and building knowledge collaboratively. Siemens (2012), one of the fathers of connectivism, bases his theory, in which learning takes place within a community of users, in which the students can use different digital platforms organized as personal learning environments that allows them to create blogs, wikis, tweets and share this knowledge by means of social networks to form new communities and build knowledge. Siemens insists that this type of course emphasizes creativity, personal autonomy and social learning in the community. While xMOOCs (extended) are based on already existing university courses and reflect a more traditional training focus (Morrison, 2013) in the transmission of information

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

by means of presentations recorded on video and in the carrying out of brief assigned exercises which are evaluated automatically by the platform itself. Thus the evaluation may be carried out through multi-choice examinations/tests or even peer-to-peer review. The methodology proposes that the huge thematic blocks should be divided into bite-sized pieces of learning, which are much easier to digest. Given that it is the student who must develop his/her own knowledge networks, it becomes compulsory for the student to become an active participant when looking for and creating appropriate learning content and being always able to learn something new. The teachers, consequently, instead of reducing their creative capacity to merely transmitting the knowledge, give each student the possibility of becoming co-creators of their own learning through being active participants in the process (Zapata-Ros, 2013).

However, the pedagogical and visual design of MOOCs, their information architecture, usability and interaction design could be having a negative impact on student engagement, retention and completion rates as it has been previously analyzed in adult learning (Tyler-Smith, 2006). The recent addition to this new open and online learning called MOOC, the creation of new educational forms (both from the instructional and technological point of view) can be used to refactor education delivery, also renewing inclusive education that can reach all citizens. Social inclusion can only be reached by embedding inclusive strategies, the importance of targeting and including vulnerable groups in MOOCs, such as people with disabilities is emphasized.

Information and communications technology (ICT) offers great possibilities for people with visual, auditory and mobility disabilities to improve their well-being, promoting their training and therefore their potential for entering the workforce (Pallisera & Bonjoch, 2007; Vila, Pallisera & Fullan, 2007). There are numerous studies looking in depth into both the ease of and difficulties in accessing and using the different types of technology that they come up against, thus giving rise to significant limitations while using ICT (Koon & De la Vega, 2000) and the appearance of the concept of digital divide (Cullen, 2001). The difficulties especially focused on the use of computers and the Internet, rather than the user's devices, which usually

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

are already adapted or personalized via its operating system tools and functionalities.

Integrating accessibility standards actively, through metadata (Neville, Cooper, Heath, Rothbergeine & Treviranus, 2005; Green, Jones, Pearson, & Gkatzidou, 2013), into both MOOCs courses and platforms would make them more accessible. Metadata standards could then be incorporated in two separate fields by:

- Incorporating preferences and context information into user's profile definition.
- Adding metadata information to wrap up the educational resources.

The research presented in this article offers major opportunities of modelling user profiles with accessibility metadata standards being able to map the access to educational resources that best suit user’s preferences. The main objective of this work is to design a system for recommending MOOCs, being the ranked list of courses adapted to the user needs in order to achieve new professional competences and closed to the learner’s preferences.

The structure of the paper is as follows: first, a case study of accessibility in MOOCs is explained, then the different standards that applied are presented, followed by a brief design model for the recommender system and the metadata that would be necessary to integrate. Finally, main conclusions are established.

Accessibility issues in MOOCS

MOOC platforms are web based eLearning engines that provide mechanisms for scheduling academic curriculum, allowing synchronous and asynchronous communication between instructors and students and delivering various modes of assessment.

Most modern LCMS environments claim to achieve good levels of accessibility compliance (Martin et al., 2007), also MOOC platforms. In terms of interface

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

elements, logging in, logging out, navigating in courses and content, MOOC environments have like other LCMS multi layered structures across which users with special needs must be able to navigate by using WAI-ARIA specifications (2014). Managing content in MOOC platforms can include some easy tasks such as editing the names of items, deleting items or setting the sequence of items, but not all of the approaches are necessarily intuitive or quick to use. Old versions of LCMS management functionalities were more accessible in their intrinsic conception: simple drop-down lists or numbered field values being attached to each module or content item within a module and so on. Nowadays MOOC platforms have evolved to more media rich, graphically interactive web applications that greatly increase the interface complexity (Rodrigo & Iniesto, 2015).

Unfortunately, accessibility issues have been reported for years in regular LMS, and the same happens for MOOC platforms. Sanchez-Gordon and Luján-Mora (2013) made a review of five Coursera courses and authors found web accessibility problems in five courses, both regarding the content and navigating into the Coursera platform, limiting access to elderly students. Moreover, Al-mouh, Al-khalifa, and Al-khalifa (2014) did the evaluation of ten Coursera courses on different topics (technology, design, humanities, physics, etc.) aimed to be used by blind or partially sighted people, and none of the courses reached the minimum level of accessibility. Bohnsack and Puhl (2014) proceeded with the evaluation of the accessibility of five MOOC platforms (Udacity, Coursera, edX, OpenCourseWorld, and Iversity) for blind users, the experiment had to be stopped at the point at which an accessibility problem prevented the user from continuing without help. All platforms (except edX) had fatal accessibility problems in the initial stages of the interaction. Finally expert accessibility evaluations were carried out on UNED COMA, UAb iMOOC, COLMENIA and Miriada X platforms, all scored low results, indicating that there is scope for improvement in their accessibility (Iniesto, Rodrigo & Moreira Teixeira, 2014; Iniesto & Rodrigo, 2014a).

It is also important to consider that eLearning materials are often used with a specific technology which can make them less available to people who

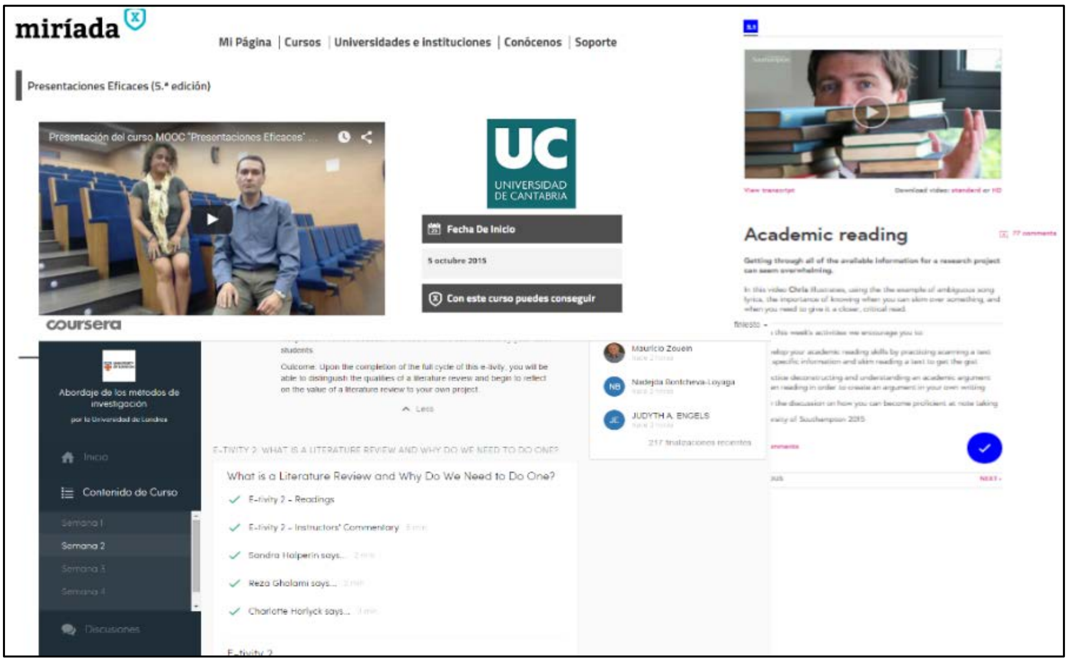
(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

have limited access capabilities or who are using nonstandard computer equipment. Problems regarding accessing the eLearning platform and also great difficulties for user interaction with learning resources have been reported (Iglesias, Moreno, Martínez & Calvo, 2011). Typically, eLearning environments have a variety of interactive components which do not always share a consistency of interface logic or managing interactive elements, such as posting in a forum, making up elements in tests or timed quizzes, embedded videos or a variety of document formats (Figure 1).

Probably one significant issue is precisely the real openness of the content (Jansen & Schuwer, 2015). Many MOOC providers nowadays allow login with Google, Facebook and other open ID providers, which currently have no metadata for users' abilities (Mirri, Salomoni & Prandi, 2011). An effective "open" eLearning environment should take into account each learner's abilities, learning goals, where learning takes place, and which specific devices the learner uses letting user's access the content directly.

Figure 1. Different MOOCs examples

Source: Prepared by the authors from Miriada X, Coursera, and Futurelearn.



In this context, it is strategic to describe learner's preferences and user's special needs by means of a specific profile. How the profile information interacts with the eLearning platform interface and the objects containers

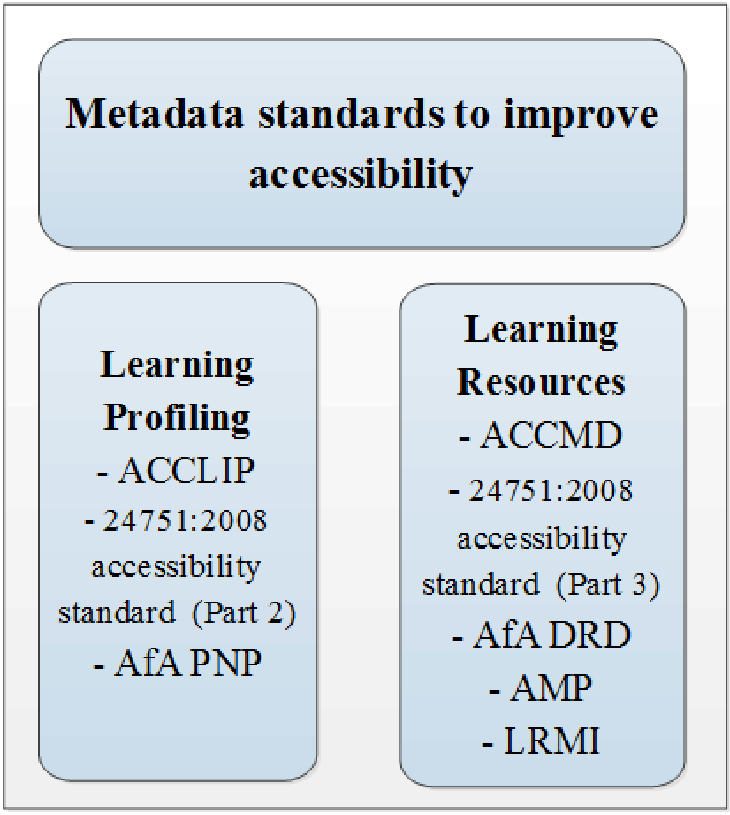
(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

can impact upon the learning experience of users with different capabilities, as it was reflected in the EU4ALL project (European Unified Approach for Accessible Lifelong Learning, 2010). With all these standards, learners can specify which kind of adapted and\or alternative resource they prefer or need. For instance, text may be preferred over visual resources, or audio might be preferred over text or images, etc. For creators of educational content, at the most basic level a standard metadata framework for learning resources means increased interoperability.

Therefore, the strategy presented here relays upon integrating some metadata application profiles, based on standard metadata schemas both for user profiling enrichment and also adding accessibility characteristics to MOOC learning content (as shown in figure 2).

Figure 2. Metadata standards to improve accessibility

Source: Prepared by the authors.



(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

Learning profiling standards

Some standards have been defined to profile learner preferences and needs that will help the user to personalize devices and services for students with disabilities. Groups that have been really active in this work are IMS Global Learning Consortium and ISO.

IMS Learner Information Profile (IMS LIP) and IMS Learner Information Package Accessibility for LIP (ACCLIP).

The IMS Global Learning Consortium has developed a specification that attempts to address learner profiling, the IMS Learner Information Profile (IMS LIP, 2001), devoted to describe general learner characteristics, by defining a set of packages that can be used to import data into and extract data from an IMS compliant Learner Information server.

The IMS Learner Information Package Accessibility for LIP (ACCLIP, 2003) is that subset of IMS LIP which lets learners specify accessibility preferences and accommodations in terms of visual, aural or device. This profile provides a means of describing how learners interact with an eLearning environment, by focusing on accessibility requirements, therefore the user's set of preferences can be exploited according to the different contexts of use of the eLearning environment, customizing the visualization of the learning contents, selecting the preferred input or output device, etc. In 2009, a new version of ACCLIP was released, called "Access-For-All Personal Needs and Preferences for Digital Delivery".

Accessibility user preferences in the IMS standards can be grouped as follows:

- **Display information**: this set describes the user preferences to have information displayed or presented. For example, it is possible to define preferences related to text (fonts and colors), video (resolution), mouse (pointer, motion), etc.
- **Control information**: this set defines the user preferences to control the device: keyboard (virtual), zoom preferences, voice recognition.

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

- **Content information**: this set defines the user preferences to visualize learning content.

- **Privacy and data protection information**: each ACCLIP element has meta-data sub-elements related to this information. The privacy and the data integrity is considered very important, since the exchanged information can be closely related to the user's disabilities.

ISO/IEC 24751:2008 accessibility standard (Part 2)

While the IMS standard is focused on defining content characteristics, ISO specifies the senses through which content is accessed. The second part of the ISO/IEC 24751:2008 accessibility standards (Information technology–Individualized adaptability and accessibility in eLearning, education, and training–Part 2: "Access for all" personal needs and preferences for digital delivery, 2008) is devoted to describing the learners' Personal Needs and Preferences (ISO PNP).

IMS Access for All (AfA) Personal Needs and Preferences (PNP) 3.0

According to the standards, learners can explicitly declare only one alternative access mode for each form of learning resource and it does not allow a change: for example, a blind user might prefer audio description but if such alternatives are absent, he/she cannot choose a text description instead. Therefore a new standard IMS Access for All (AfA) Personal Needs and Preferences (PNP, 2012) 3.0 has recently been developed, aiming to solve this type of problems and letting the learner specify multiple adaptation requests for each existing Access Mode. Still, IMS AfA PNP has some restrictions while choosing the size or quality of video and audio resources.

For instance, it is not possible to request a lower version of a video clip or audio file to be adapted to the user's device. Therefore, a specific quality profile for learning resources would be desirable as well as clarification rules to better describe the list of alternative recommendations.

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

Learning resources standards

At the time of using the Internet as a mean of communication to publish multimedia content in audio-visual format, it is necessary to take different aspects into account:

- **Technological**: the user agents that must make possible access the information, the technology to develop and edit the resources, authoring tools to facilitate the production of accessible materials or the adaptation of those already produced.
- **Adapted Devices**: when a user accesses a resource available on the Internet, it can be accessed directly or a device would have to be used specifically: screen reader, specialized mouse, virtual keyboard, magnifying glass, etc.
- **Existing Inclusive Methodologies and Educational Standards**: here the XML markup languages have to be mentioned, together with the use of metadata that provides the adaptability of the content according to the user profile.

IMS Access-For-All Metadata (ACCMD)

In order to improve the accessibility of eLearning content, the Access-For-All Metadata (ACCMD) specification was developed by IMS in 2004. It describes learning content by identifying which types of resource are available in a Learning Object, which can be used to present the same content to a given learner, but by means of different media. Metadata can then be used to describe the types and the relationships between an original resource and its available adapted formats. Interpreting user profiles for choosing the appropriate content, ACCMD metadata can be exploited to describe textual alternatives that are available for images, audio descriptions for videos, transcripts or captioning for audio tracks, visual alternatives for text, and a variety of other potential alternative formats matching user’s preferences. Based on ACCMD, these appropriate alternative media resources can be retrieved and presented to the user. A visually-impaired learner, for instance, viewing a video that had entered an ACCLIP profile previously, will

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

automatically receive that video with audio descriptions, while a hearing-impaired learner will receive the same video but with captioning included in the presentation.

ACCMD and ACCLIP have been incorporated at the ISO/IEC Standard 24751 "Individualized Adaptability and Accessibility in e-Learning, Education and Training".

ISO/IEC 24751:2008 accessibility standard (Part 3).

Furthermore, the third part of the ISO/IEC 24751:2008 accessibility standards (Information technology–Individualized adaptability and accessibility in eLearning, Education and training–Part 3: "Access-for-all" digital resource description, 2009) is devoted to describing the resources which make up an eLearning content (ISO DRD), with an approach which is similar to the IMS ACCMD, both standards having the same aim: providing information on alternatives to original resources. Then, any resource presented in an e-learning content can be identified as having an original form and one or more adapted forms, depending on its media type.

*IMS Access for All (AfA) Digital Resource Description (DRD) 3.**0***

A limitation to these standards arises whenever eLearning content authors want to provide alternatives both to the whole original content and to each single part that makes up the entire resource (images included in a document, formatted texts, etc.).

According to these standards, it is neither possible to declare those pieces of formatted text as original resources if they are not in separated files, nor can a subset of adapted resources be declared as an alternative to a single resource. For example, a sequence of audio files cannot be identified as a single auditory resource, a video with sign language cannot be defined as an alternative to it, and a sequence of images cannot be declared as an alternative to a video.

The IMS Access for All (AfA) Digital Resource Description (DRD) 3.0 aims to solve these problems by radically changing the point of view: now it is possible to declare one or more access modes for each resource, define

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

existing accessible adaptations and whether they come from the specific original resource.

IMS Accessibility Metadata Project

The Accessibility Metadata Project (AMP, 2014) is a metadata subset that emerged with the idea to define a set of accessibility metadata to enable the search and discovery of Web resources that would suit user's needs and preferences. It tries to find a solution to the lack of properties to identify the accessible nature of resources being useful to define semantics that describes resources in ways that will facilitate their discovery by suitability.

Is a subset of the standard IMS Access for All Digital Resource Description focused in matching of the characteristics of resources where they might not be suitable for all types of users.

The Accessibility Metadata Project has developed a common metadata framework for describing or “tagging” the accessibility attributes and alternatives on the web, with the contribution of Benetech Corporation, IMS Global's Access for All and the Learning Resource Metadata Initiative (LRMI) groups and funding from the Gates Foundation. Once a critical mass of content has been tagged to a universal framework, it becomes much easier to parse and filter that content, opening up tremendous possibilities for search and delivery, as well as easily discovery of other accessible adaptations. The Accessibility Metadata Project is the byproduct of LRMI initiative and the accessibility working group within IMS Global, called Access for All that has been working on a framework for specifying both digital resource information and personal preferences. This accessibility metadata project brought a subset of the most important attributes of Access for All into a proposal for broad adoption within the schema.org framework, called A11Y Metadata proposal, with the hope that this will enable rapid adoption. Incorporated into Schema.org can become the de facto standard for tagging accessibility information for educational resources and other content on the web.

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

Learning Resource Metadata Initiative ***(LRMI)***

Learning Resource Metadata Initiative (LRMI) is an initiative promoted by the Association of Educational Publishers (AEP) and Creative Commons that has worked to facilitate to publish, discover, and deliver educational resources on the web, having developed a common metadata framework for describing learning resources. It is focused to benefit: search engines so they can return richer results, educators and learners to discover learning materials pertinent to their immediate learning situation.

Aside from improved search, the LRMI also has the potential to:

- Facilitate personalized learning—the right content at the right time
- Decrease production costs through industry standardization
- Address demands of states for standardized description of learning resources.

LRMI, which has been adopted into schema.org, had considered accessibility metadata as part of their charter, increasing the scope of their effort to be even more ambitious.

Adaptive model for delivering accessible MOOC services

The objective of a model for delivering accessible MOOC services is supported by the functional diversity scenario illustrated by Rodriguez-Ascaso and Boticario (2015), in the development of accessible services a reference is the previously mentioned EU4ALL project to be used ideally in any eLearning platform (Boticario et al., 2012), in modelling MOOCs for accessibility purposes Sanchez-Gordon and Luján-Mora (2015) propose a three-layer architecture to extend the MOOCs platform Open edX to enhance course content accessibility for users with disabilities. Finally Salomoni, Mirri, Ferretti and Roccetti (2007) strongly encourage the use of accessibility standards to profile learners in their practical approach.

Adaptive model architecture

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

The model of educational services we propose is useful for people with special needs to find MOOCs courses whose platforms and content are as accessible as possible taking into account users' disabilities. The recommender system has to establish a relationship within the level of accessibility required and take into account the assistive technologies more commonly used by the user, having the following characteristics:

- The ability to help these vulnerable users to find the MOOCs courses that are more accessible regarding their disability.
- Requires accessibility analysis of both: the MOOC platform and the educational content.
- Offers personalization of the app: GUI adaptation to each assistive technology.
- Adjustment of the rated list of recommended MOOCs that best fit accessibility requirements.

The system will have the following distinguishable parts where we have focused the work (Figure 3):

- Enriched user profile. User's device personalization: the preferences or needed assistive technologies and the technical needs regarding user's functional diversity.
- Accessible MOOCs. Accessibility evaluation on MOOC platforms and their educational resources, offering an automated recommendation list adapted to the user's functional diversity to be used in the user's profile.

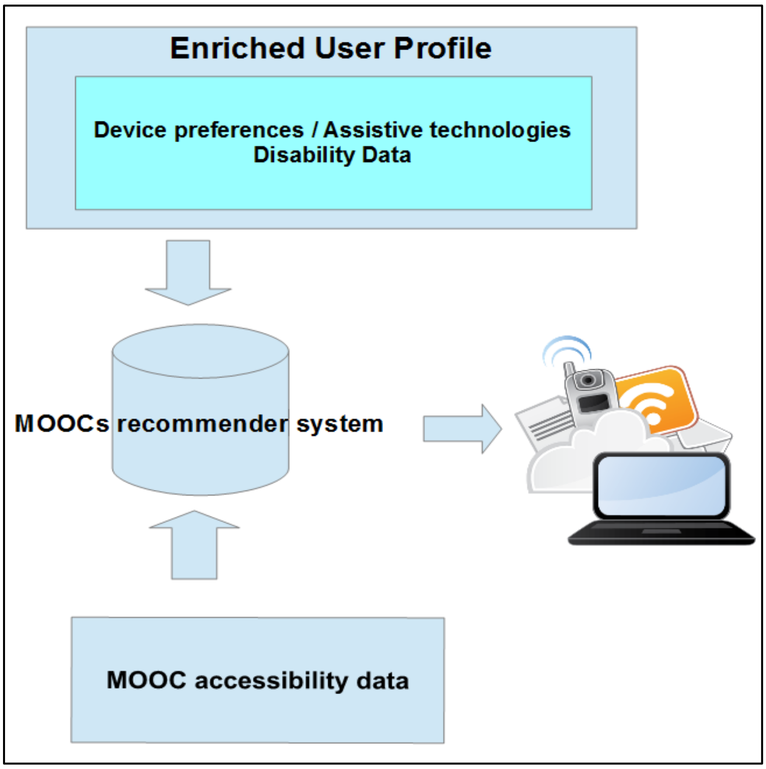
In the Development of an accessibility evaluation of MOOC platforms and courses to achieve a map of accessible MOOCs versus functional diversities, we have taken into account the level of accessibility involving, therefore, an assessment of the web content of MOOCs courses and the educational resources by themselves. Automatic tools and user experience are used for this task of accessibility assessment so we can get a holistic evaluation methodology. This methodology has previously been explained and tested in

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

published works by the authors (Iniesto et al., 2014; Iniesto & Rodrigo, 2014a; Iniesto & Rodrigo, 2014b).

Figure 3. MOOCs recommender system characteristics.

Source: Prepared by the authors.



- Evaluation through automatic accessibility tools:
    - WCAG Accessibility Validation
    - Disability Simulators
- Usability and User Experience (UX)
    - Testing Tools
- User evaluation
    - Educational content evaluation.

Enriched user profile

To define and model the user profile we focus on the most recent and most comprehensive IMS standards relatives to Access for All (AfA) and its aspects

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

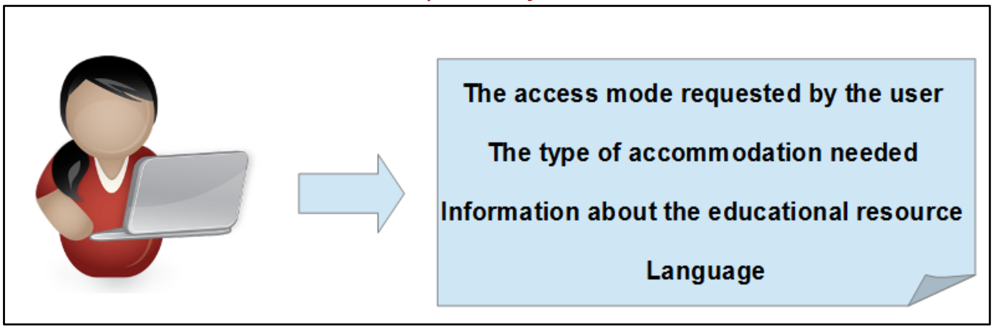
PNP and DRD, as it has been done for example in the METALL project, because they allow us to define collections rather than a single value for each case (multiplicity) (Centelles Velilla, Vázquez Guzmán, Ribera & Pérez Pineda, 2014).

This is a preliminary study, in the future may be interesting to introduce other standards such as AMP or LRMI that could complement the functionality offered in this first selection. Below are detailed the selected metadata to model the learning and educational profiling, the criteria has been to select those that define the access mode requested by the user, the type of accommodation needed, those which deal with information about the educational resource and finally those related to language. The selection takes into account the approach used in the design of the recommender system (Figure 4).

- **Access Mode**. Access mode the user seeks either an adapted or an original resource as a replacement for a different access mode.
- **Accommodation type**. Nature or genre of the adaptation required as a replacement for a specific access mode.
- **Educational resources**. A preference for a resource that is simplified or enriched relative to another resource that presents the same intellectual content.
- **Language**. Language of the intellectual content of the resource or the interface.

Figure 4. Learning and educational profiling

Source: Prepared by the authors.

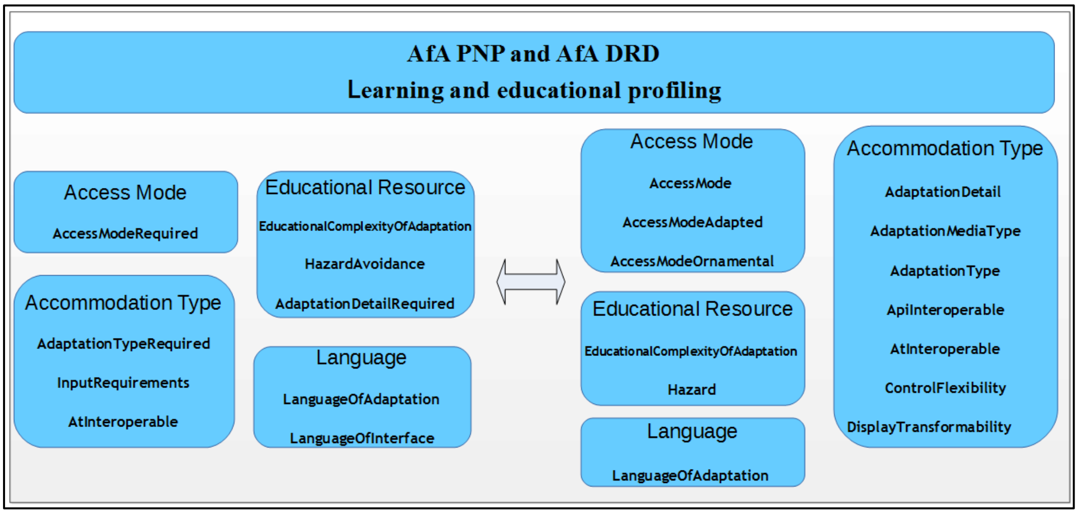


(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

We have chosen nine from twelve elements that have to do with the educational aspects of the profile and thirteen from nineteen elements relating to the educational aspects of the resource as shown in figure 5, the detailed metadata description can be reviewed in the appendix.

Figure 5. Access for All (AfA PNP and DRD) user profile and preferences

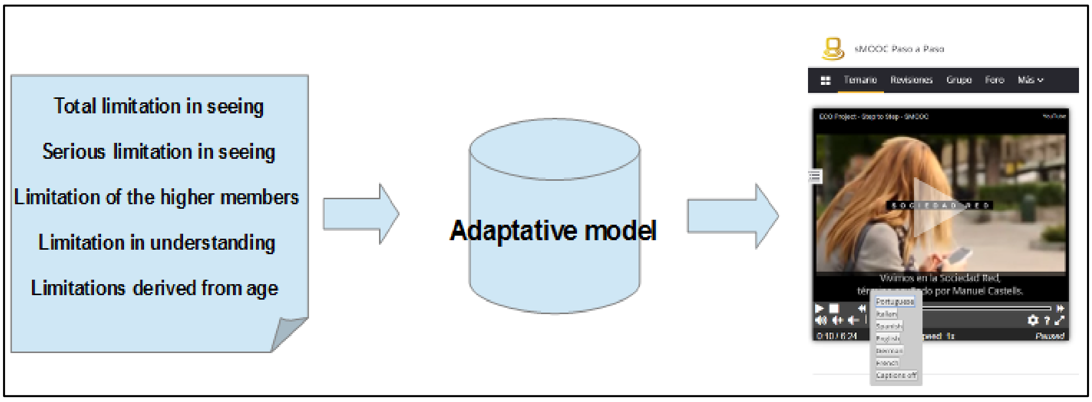
Source: Prepared by the authors.



Depending on the limitation the user might have, providing the information from the user and the resource the system can select the proper adaptation required (Figure 6).

Figure 6. Adapting the resources depending on user's limitation

Source: Prepared by the authors, image from ECO eLearning project.



(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

Conclusions

How eLearning systems are designed, how their interfaces function, how communication is handled, how assessments take place and what form the learning content takes, all impact on the accessibility of these systems by students with disabilities. In MOOCs, the learning activities used had been originally designed neither for specific MOOC platforms nor for a specific learning scenario. Therefore, educational resources that are being delivered present some problems for certain target groups, such as people with special needs. As a result, the level of usability and accessibility of these resources is often lower than desired. This is a clear setback if they are to be used at a greater scale for inclusive learning.

MOOC platforms should be compliant with accessibility standards, not only related to the Web interface, it is important in an eLearning environment like MOOCs take into account learner's abilities and learning goals. It is necessary to describe learner's preferences and needs by means of a profile and how this profile interacts with the eLearning platform interface and the learning resources. Access for All (AfA) in its aspects PNP and DRD standards offer the possibility to learners so they can specify which kind of adapted and/or alternative resource they prefer or need. We should not forget that most of these standards are devoted to technical accessibility aspects of learning materials while less attention is given to the cognitive and didactical issues (Catarci, De Giovanni, Gabrielli, Kimani & Mirabella, 2008).

In designing the recommender system the following steps are to refine the user profile modelling to finally be crossed with a vector of accessibility features from the different MOOC courses, therefore continuing to develop a holistic approach.

Acknowledgments

We would like to thank the Research Chair on "Technology and Accessibility" UNED - Fundación Vodafone España as well as the Global OER Graduate Network (GO-GN) for their support. Francisco's work is supported by a

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

Leverhulme Trust Doctoral Scholarship in Open World Learning based in the Centre for Research in Education and Educational Technology (CREET) at The Open University UK.

References

[45] Al-Mouh N. A., Al-Khalifa A. S., & Al-Khalifa H. S. (2014). A first look into MOOCs accessibility: The case of coursera. Lecture Notes in Computer Science (including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 8547 LNCS (PART 1), 145–152. http://doi.org/10.1007/978-3-319-08596-8_22

[46] Bohnsack, M., & Puhl, S. (2014). Accessibility of MOOCs. Computers Helping People with Special Needs, 141–144. http://doi.org/10.1007/978-3-319-08596-8_21

[47] Boticario, J. G., Rodriguez-Ascaso, A., Santos, O. C., Raffenne, E., Montandon, L., Roldán, D., & Buendía, F. (2012). Accessible Lifelong Learning at Higher Education: Outcomes and Lessons Learned at two Different Pilot Sites in the EU4ALL Project. JUCS - Journal of Universal Computer Science, 18(1), 62–85. http://doi.org/10.3217/jucs-018-01-0062

[48] Catarci, T., De Giovanni, L., Gabrielli, S., Kimani, S., & Mirabella, V. (2008). Scaffolding the design of accessible eLearning content: a user-centered approach and cognitive perspective. Cognitive Processing, 9(3), 209-216.

[49] Centelles Velilla, M., Vázquez Guzmán, C., Ribera, M., & Pérez Pineda, I. (2014). Asignación de metadatos de accesibilidad a vídeos docentes, INNOVADOC (Documents d'Innovació Docent) Retrieved from http://diposit.ub.edu/dspace/handle/2445/60425

[50] Cullen, R. (2001). Addressing the digital divide. Online information review, 25(5), 311-320.

[51] Downes, S. (2012). Connectivism and Connective Knowledge: essays on meaning and learning networks. National Research Council Canada, Retrieved from: http://www.downes.ca/files/books/Connective_Knowledge-19May2012.pdf

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

[52] Downes, S. (2013). What the “x”in “xMOOC”stands for. Retrieved from: https://plus.google.com/+StephenDownes/posts/LEwaKxL2MaM

[53] EU4ALL (2010). Retrieved from: https://adenu.ia.uned.es/web/es/projects/eu4all

[54] Green, S., Jones, R., Pearson, E., & Gkatzidou, S. (2013). Accessibility and adaptability of learning objects: responding to metadata, learning patterns and profiles of needs and preferences. ALT-J, 14(1), 117-129.

[55] Jansen, D., & Schuwer, R. (2015). Institutional MOOC strategies in Europe. Status report based on a mapping survey conducted in October - December 2014 EADTU, ISBN 978-90-79730-15-5. Retrieved from: http://eadtu.eu/documents/Publications/OEenM/Institutional_MOOC_strategies_in_Europe.pdf

[56] Iglesias, A., Moreno, L., Martínez, P., & Calvo, R. (2014). Evaluating the accessibility of three open-source learning content management systems: A comparative study. Computer Applications in Engineering Education, 22(2), 320–328. http://doi.org/10.1002/cae.20557

[57] IMS AccessForAll Metadata. Information Model. (2004). Retrieved from: http://www.imsglobal.org/accessibility/accmdv1p0/imsaccmd_infov1p0.html

[58] IMS Global Access For All (AfA) Digital Resource Description (DRD) Specification Information Model. (2012). Retrieved from: https://www.imsglobal.org/accessibility/accdrdv2p0/html/ISO_ACCDRDv2p0_InfoModelv1.html

[59] IMS Global Access For All (AfA) Personal Needs & Preferences (PNP) Specification Information Model. Version 3.0 Specification (2012). Retrieved from: http://www.imsglobal.org/accessibility/afav3p0pd/AfA3p0_PNPinfoModel_v1p0pd.html

[60] IMS Global's Accessibility Metadata Project. (2014). Retrieved from: http://a11ymetadata.imsglobal.org/

[61] IMS Learner Information Package Accessibility for LIP Information Model (2003). Retrieved from: http://www.imsglobal.org/accessibility/acclipv1p0/imsacclip_infov1p0.html

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

[62] IMS Learner Information Package Specification (2001). Retrieved from: http://www.imsglobal.org/profiles/index.html

[63] Information technology -- Individualized adaptability and accessibility in e-learning, education and training -- Part 2: "Access for all" personal needs and preferences for digital delivery. (2008). Retrieved from: http://www.iso.org/iso/catalogue_detail?csnumber=43603

[64] Iniesto, F., Rodrigo, C., & Moreira Teixeira, A. (2014). Accessibility analysis in MOOC platforms. A case study: UNED COMA and UAb iMOOC. In V Congreso Internacional sobre Calidad y Accesibilidad de la Formación Virtual (CAFVIR 2014) 545–550. Retrieved from: http://oro.open.ac.uk/45192/

[65] Iniesto, F.; & Rodrigo, C., Accessibility assessment of MOOC platforms in Spanish: UNED COMA, COLMENIA and Miriada X. (2014). Computers in Education (SIIE), 2014 International Symposium on vol., no., pp.169, 172, 12-14
doi: http://dx.doi.org/10.1109/SIIE.2014.7017724

[66] Iniesto, F., & Rodrigo, C. (2014). Pautas para la evaluación de la accesibilidad en las plataformas MOOC. In VI Congreso Internacional sobre Aplicación de Tecnologías de la Información y Comunicaciones Avanzadas (ATICA2014) 57–64. Retrieved from: http://oro.open.ac.uk/45191/

[67] ISO/IEC e-learning standard will help match user needs with the right resources (2009). Retrieved from: http://www.iso.org/iso/home/news_index/news_archive/news.htm?refid=Ref1217

[68] Koon, R., & De la Vega, M. E. (2000). El impacto tecnológico en las personas con discapacidad. In II Congreso Iberoamericano de Informática Educativa Especial, Córdoba.

[69] Learning Resource Metadata Initiative (2014). Retrieved from: http://lrmi.dublincore.net/

[70] Martin, L., Gutiérrez y Restrepo, E., Barrera, C., Rodríguez Ascaso, A., Santos, O. C., & Boticario, J. G. (2007). Usability and Accessibility Evaluations Along the eLearning Cycle. Web Information Systems Engineering – WISE 2007 Workshops, 453–458. http://doi.org/10.1007/978-3-540-77010-7_44

[71] Metadata-enabled Tools for Assistive Living and Learning (METALL). Retrieved from: https://access.ecs.soton.ac.uk/projects/metall

[72] Mirri, S., Salomoni, P., & Prandi, C. (2011). Augment browsing and standard profiling for enhancing web accessibility. In Proceedings of the International Cross-Disciplinary Conference on Web Accessibility (p. 5). ACM.

[73] Morrison, D. (2013). The ultimate student guide to xMOOCs and CMOOCs. MOOC News and Reviews. Retrieved from: http://moocnewsandreviews.com/ultimate-guide-to-xmoocs-and-cmoocso

[74] Neville, L., Cooper, M., Heath, A., Rothbergeine, M., & Treviranus, J. (2005). Learner-centred Accessibility for Interoperable Web-based Educational Systems. In: International World Wide Web Conference (WWW2005), 10-14 May 2005, Chiba, Japan.

[75] Pallisera, M., & Bonjoch, M. (2007). ¿Y después del trabajo, qué?: más allá de la integración laboral de las personas con discapacidad. Revista de Educación, (342), 329–348. Revista acreditada por la FECYT

[76] Rodrigo C., & Iniesto F. (2015). Holistic vision for creating accessible services based on MOOCs. Open Education Global Conference. 22-24 April 2015. Banff, Alberta, Canada. Retrieved from http://conference.oeconsortium.org/2015/wp-content/uploads/2015/02/oeglobal2015_submission_49.pdf

[77] Rodríguez-Ascaso, A., & Boticario, J. G. (2015). Accesibilidad y MOOC: Hacia una perspectiva integral. RIED. Revista Iberoamericana de Educación a Distancia, 18 (2), 61-85. doi: http://dx.doi.org/10.5944/ried.18.2.13670

[78] Salomoni, P., Mirri, S., Ferretti, S., & Roccetti, M. (2007). Profiling learners with special needs for custom e-learning experiences, a closed case?. In Proceedings of the 2007 international cross-disciplinary conference on Web accessibility (W4A) (pp. 84-92). ACM.

[79] Sanchez-Gordon, S., & Luján-Mora, S. (2013). Web accessibility of MOOCs for elderly students. 2013 12th International Conference on Information Technology Based Higher Education and Training, ITHET 2013, 1–6. http://doi.org/10.1109/ITHET.2013.6671024

[80] Sanchez-gordon, S., & Luján-mora, S. (2015). Adaptive Content Presentation Extension for Open edX Enhancing MOOCs Accessibility for

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

Users with Disabilities. The Eighth International Conference on Advances in Computer-Human Interactions Adaptive, (c), 181–183.

[81] Siemens, G. (2012). MOOCs are really a platform. ELearnspace, Retrieved from: http://www.elearnspace.org/blog/2012/07/25/moocs-are-really-a-platform.

[82] Tyler-Smith, K. (2006). Early attrition among first time eLearners: A review of factors that contribute to drop-out, withdrawal and non-completion rates of adult learners undertaking eLearning programmes. Journal of Online Learning and Teaching, 2(2), 73–85.

[83] Vilà, M., Pallisera, M., & Fullana, J. (2007). Work integration of people with disabilities in the regular labour market: What can we do to improve these processes? Journal of Intellectual and Developmental Disability, 32(1), 10–18.

[84] WAI-ARIA. (2014). Retrieved from: https://www.w3.org/WAI/intro/aria

[85] Zapata-Ros, M. (2013). MOOCs, una visión crítica y una alternativa complementaria: La individualización del aprendizaje y de la ayuda pedagógica. Campus Virtuales | Revista Cientifica de Tecnología Educativa, 2(1), 20–38. Retrieved from http://www.revistacampusvirtuales.es/index.php/es/revistaes/numerosanteriores/29-voliinum1/67-voliinum1-art2

Appendix. Detailed metadata

Metadata related with educational aspects of the profile:

- **AccessModeRequired**, access mode the user seeks either an adapted or an original resource as a replacement for a different access mode, it is allowed using the attribute "existingAccessMode" that defines the existing access, for example "visual" and by "adaptationRequest" attribute indicating the access mode the user prefers, for example " textual".
- **AdaptationTypeRequired**, nature or genre of the adaptation required as a replacement for a specific access mode, has the same attributes to allow access being equally "visual" the example to an access mode

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

and an adaptation type that the user prefers could be for example "audio description".

- **AtInteroperable**, denotes that the user does not require assistive technologies support, in compliance with WCAG 2.0.
- **EducationalComplexityOfAdaptation**, a preference for a resource that is simplified or enriched relative to another resource that presents the same intellectual content.
- **HazardAvoidance**, resources having such a characteristic should not be delivered to a user with this preference, for example "flashing visuals".
- **InputRequirements**, single input system that is sufficient to control a resource, for example if we want resources that are fully usable with a keyboard.
- **LanguageOfAdaptation**, preference for the language of the adaptation for the educacional resources.
- **LanguageOfInterface**, preference for the language of the user interface.
- **AdaptationDetailRequired**, detail of one or more required adaptation types, it also contains "existingAccessMode”, could be "auditory”, and allows using "adaptationRequest" to express the alternative desired if exist, for example "verbatim".

Metadata relating to the educational aspects of the resource:

- **AccessMode** access mode through which the intellectual content of a described resource or adaptation is communicated, for example "visually".
- **AccessModeAdapted**, access mode of the intellectual content of the resource that is being adapted, for example "visual".

(CC) JACCES, 2016 - 6(2): 125-149. ISSN: 2013-7087 DOI: 10.17411/jacces.v6i1.117

- **AccessModeOrnamental**, ornamental content of the described resource or adaptation is communicated
- **AdaptationDetail**, fine detail of one or more adaptation type values, for example if the object is recorded with human voice instead of synthesized speech.
- **AdaptationMediaType**, identifies the media type of the described resource.
- **AdaptationType**, nature or genre of the adaptation, for example "alternative Text"
- **ApiInteroperable**, indicates that the resource is compatible with the referenced accessibility API, for example "ARIAv1".
- **AtInteroperable**, the resource is compatible with assistive technologies, in compliance with WCAG 2.0.
- **ControlFlexibility**, identifies a single input method that is sufficient to control the described resource, could be as an example fully usable with keyboard control.
- **DisplayTransformability**, identifies a characteristic of display of the described resource that can be programmatically modified, if it permits its font size to be adjusted on user request can be an example.
- **EducationalComplexityOfAdaptation**, identifies if the resource is simplified or enriched relative to another resource that presents the same intellectual content.
- **Hazard**, a characteristic of the described resource that must not be delivered to some users, for example "flashing".
- **LanguageOfAdaptation**, language of the intellectual content of the resource.

JACCES

ISSN: 2013-7087

www.jacces.org

Twitter: @Journal_JACCES LinkedIn: JACCES page