Designing interfaces for children with motor impairments

An ethnographic approach

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***Abstract*— The purpose of this paper is to convey the results of a user-oriented interaction design process based upon an ethnographic study developed in a school for motor-impaired children. Being this school part of the Uruguayan instance of the One Laptop Per Child program, we focused the research in how the children interact with the laptops provided by the program. Participant observation, interviews and questionnaires allowed for the conception of a multimodal interaction framework aiming to improve accessibility and enhance the autonomy of the school's children. Within this work, a working prototype was developed, demonstrating the feasibility and usefulness of the proposed interaction schema. We expect this experience of conducting an ethnographic research to serve as a case study for user interface designers and human-computer interaction researchers interested in designing interaction for children in similar contexts.**

Keywords- accessibility to motor impaired children; assistive technology; ethnography in HCI, tangible interaction, multimodal interaction.

I. Introduction

Designing interfaces for users with impairments is a challenge, especially if those users are children. Both gathering information about their specific needs, and understanding how they interact with the environment, usually require the support of intermediaries, and extensive and intensive observation. However, due to the users' story, which is often complex, it is fundamental to involve them directly in human-computer interaction (HCI) research, design and evaluation [3].

As Lazar et al affirm it is artificial to think of 'users with disabilities' as if they would form part of a homogeneous group that could be addressed in a generic or single way [3].

It is simple to understand that designing interfaces for blind people is a completely different achievement to designing interfaces for individuals who suffer from, for example, Alzheimer's Disease. However, designing for individuals who share the same impairment group diagnosis represents an enormous challenge as well, for the symptoms could be multiple and unique for each case.

For example, individuals with Cerebral Palsy (CP) present different motor conditions: stiff muscles and weakness, spontaneous and uncontrolled movements, joint and bones deformities, etc. Even more, individuals with CP may present different postures, adding complexity to the interaction design process. Consequently, nonspecific solutions often fail to adequately address the needs of individuals under this condition [10].

Computing devices should be accessible by all people regardless of their abilities. However, individuals with physical, cognitive or perceptual impairments have difficulties to integrate themselves into the information society. For example, individuals with uncontrolled or spasmodic movements tend to experience difficulties in using computer keyboards or mouse devices. These accessibility problems impact on their personal life, diminishing their possibilities to express their potential, to achieve self-development, to gain autonomy, and, in the end, to self-realize themselves as human beings. The inability to use this technology can significantly limit employment, educational, and social opportunities [10]. Interaction design processes which take into consideration potentially impaired users, involving them in the process, can help to reverse this situation, turning these potential barriers into new opportunities [12].

This challenge is particularly relevant in Uruguay, where an ambitious plan to provide one laptop to every student attending primary public schools is being applied since 2006, as part of the One Laptop Per Child (*OLPC*) program, originally created by faculty members of the MIT Media Lab[1]. Uruguay was the first country worldwide that achieved the 'full deployment' status, extending the program to the totality of the public schools, including schools for impaired children [1]. Other countries participating in the plan are Argentina, Ghana, Peru, Rwanda and Sierra Leona [6].

Nevertheless, *OLPC* laptop ergonomics could prevent children with physical impairment from an effective access, especially because of the small keyboard and screen dimensions [2]. Despite assistive technology being under development by third-party institutions, it is significantly expensive for families with low socio-economic status and it

[1] More information about the OLPC program is available in the URL: http://laptop.org/.

[2] Our research team confirmed this issue, and then it was confirmed lately by an independent study [5].

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has not been massively distributed yet [5]. Considering that *OLPC* laptops come with an integrated webcam, a reasonably fast processor and a speaker, it is possible to develop multimodal interfaces to improve accessibility. Potentially, multimodal interfaces accommodate a broader range of users than traditional graphical user interfaces (GUIs) or unimodal interfaces, allowing for the inclusion of users of different ages, skill levels, cognitive styles, sensory impairments, and other temporary or permanent disabilities [7].

In order to explore the technical feasibility of incorporating a multimodal user interface to the *OLPC* laptop, we designed and developed a proof-of-concept prototype for children with motor impairments, which can be used in daily school activities. For the prototype conception, we prepared and conducted an interaction design-oriented ethnographic research. The principal reason for adopting this methodology was to obtain detailed and nuanced comprehension of the condition of the users, their environment, needs and potentials.

The purpose of this paper is to compile the results of this ethnographic study, which may serve as input for user interface designers and HCI researchers interested in designing interaction for children in similar contexts. Furthermore, the results from the study may provide opportunities for further research in improving children's learning possibilities.

II. Context

The field study was developed in the Uruguayan public school *Dr. Ricardo Caritat*, the only public school in Montevideo, the capital city of Uruguay, for children with motor impairments. The objective of the *Caritat* center is to partially or fully rehabilitate its students through different strategies, with the objective of taking their abilities to the highest potential and to help insert themselves into the society.

The educative level of the school comprehends kindergarten and primary level, following the national teaching program for regular schools.

Every day, 90 students with different types of motor impairments attend the center in the regular school time schedule, 6 receive support in a special time schedule and 6 attend regular schools but receive itinerant support from *Caritat*'s teachers. In total, 47 females and 55 males receive attention from the center. Although the school population is principally composed by children in their school ages, some of the students are teenagers, covering the age range of two to twenty years old.

Students arrive from different neighborhoods in Montevideo, some of which lay several kilometers distant from the center. Eighty percent of the students live in low socio-economic context, and the center provides a free of charge shuttle for transportation.

Caritat's staff is composed of the Director, ten teachers, two physiotherapists, one computer teacher, one psychologist, one social worker, one music therapist and nine assistants, among other employees. Teachers work the entire academic year with the same class group. However, the school policy disallows teachers to spend more than two years with the same group. This restriction is intended to prevent deterioration in the relationship between teachers and students' parents.

Uruguayan academic year starts in March and ends in December. Most of the students spend three hours a day in the center except for one group that spends six hours.

With regard to the student's diagnostics, 90% suffer from Cerebral Palsy, 8% from Spina Bifida, and 2% from other motor-related pathologies. Below, a general characterization of the students' motor impairments is provided, in order to understand the difficulties in carrying out a user interface design process in this particular context.

A. User's limitations

Cerebral Palsy (CP), Spina Bifida (SB) and Muscular Dystrophy (MD) fall into the category of Physical Impairments (PI). These pathologies can, but do not always, result in disabilities [10].

CP is a non-progressive condition that typically occurs during the fetus development [10]. Children's activity is restricted by CP during critical development stages, causing several disorders, including sensory, perceptive, communicative and cognitive disorders [5]. Most of individuals with CP present stiff muscles and weakness (*spastic* CP), and, to a lesser extent, spontaneous, slow and uncontrolled muscle movements, or abrupt and jerky movements (*choreoathetoid* CP); poor coordination, weakness and trembling, or difficulties to perform rapid or fine movements (*ataxic* CP); or a combination of both *choreoathetoid* and *ataxic* CP (*mixed* CP) [10].

SB is a congenital malformation of the neural tube in which one or more vertebral arches do not fuse properly during gestation. In consequence, the spinal cord remains without the protective bony encasement that normally surrounds it [5]. Paralysis, loss of sensitivity in lower extremities, constipation, and bladder malfunctions are some of the symptoms [5].

Finally, MD is a group of inherited muscle disorders that begins with muscle power weakness that spreads and becomes more severe [10].

In general, individuals with PI have vulnerable self-esteem, closely linked to their poor concept of self-worth [5] [10]. Educational approaches include activities to enhance children's self-esteem in their daily schoolwork, among other procedures to improve physical and communicative capabilities [5].

Interaction between individuals with PI and computers could require much or less effort, depending on the severity of the symptoms. Activities like pressing keys on a keyboard, pointing and clicking with a computer mouse, or activities requiring the mouse button to be held down while dragging the mouse, may be impossible for some users [10]. Other factors, like small screen sizes, may also diminish user productivity [10].

B. Disability in Uruguay

According to the latest National Survey for People with Disabilities report [2], in Uruguay the prevalence of disability

Figure 1. *OLPC XO* 1.

reaches 7.6% of the population. In absolute terms, 210400 Uruguayans have some kind of disability. Children, teenagers and young people represent the 17.9% of this population.

The percentage of population of impaired children aged 4-15 that assist the kindergarten, primary school and the first three years of secondary school (88%) is 7% lower than the percentage registered for population without impairments. Excluding the kindergarten, and including the age range necessary to complete secondary school (ages 6 – 18), the gap between impaired and non-impaired students increases 9% in favor of the latter.

A high percentage, 37.7%, of impaired individuals of 25 years old or more, either lack of education, or abandon education at lower stages, in contrast with a significantly lower percent relative to population of non-impaired individuals in the same age range (12.6%).

Only 32% of the population with impairments completes primary school. According to the report, this low value confirms that primary school is the first barrier for disabled people. Considering higher educational stages, the difference between impaired and non-impaired individuals who completes secondary school is 19% in favor of non-impaired people.

C. One computer per child

With the vision to promote the digital inclusion and reduce the digital divide, in December 2006, Uruguay launched *Plan Ceibal* [3], a local instance of the *OLPC* project, with the objective of providing every grade public school student and teacher in Uruguay with a laptop, named *XO*, connected to the Internet, free of charge.

[3] The acronym '*Ceibal*' stands for *Conectividad Educativa de Informática Básica para el Aprendizaje en Línea* (Basic Informatic Educative Connectivity for Online Learning). More information about *Plan Ceibal* is available in the URL: www.ceibal.edu.uy/.

The plan achieved the 'full deployment' status at primary schools (ages 6 – 11) in October 2009 and in 2010 it commenced with secondary schools (ages 12 – 17).

XO hardware features include: an *AMD Geode LX700* (433 Mhz) processor, 256 Mb of RAM, 640x480 30 FPS webcam, *WiFi*, keyboard, touchpad and a 7.5 inches (19.05 cm) *LCD dual-mode TFT display*.

III. METHODOLOGY

Ethnography in interaction design has been widely used in a great variety of software products [4]. The main difference between ethnography and requirements analysis is that the former is more suitable when the product concept has not yet been conceived, whereas requirement analysis is more suited for exploring a particular product concept [9].

For the purpose of our research, we commenced with an explorative interaction design process, which consisted mainly of ethnography based upon participant observation, structured interviews and questionnaires. Participants included children, teachers and the school director.

We focused on recognizing the participants' environment and identifying their needs. It is important here to settle the difference between our work as user interface designers performing an ethnographic study and traditional ethnographic research. In the latter, the focus is on understanding the subject in its context. On the other hand, user interface design is concerned with enabling design decisions that are rooted in a true understanding of the users' needs [8].

A. Preparation

As a preliminary step to the fieldwork, we interviewed a community psychologist with vast experience in working with children with CP and other motor disorders. The interview prepared us psychologically, to meet this sensitive reality, and technically, receiving practical information about the different types of symptoms exhibited by the children attending the *Caritat*'s center.

We received informed consent from the school Director and all aspects of the field study were monitored directly by the Director or the schoolteachers.

B. Methodology

Our research team was conformed by three observers taking notes independently, in order to triangulate the results properly. The data consisted of extensive field notes, audio and video recordings.

Visits started in November 2009 and extended until the school summer recess in December, i.e. the ending of the academic year, summarizing 25 hours in a time frame of one month. In that period, we dedicated 8 hours, once per week, to interview the Director, two teachers and two physiotherapists, and 17 hours, once or twice per week, to observe the children in their classrooms, 8 hours logging activities that required the use of their *XO's* and 9 hours registering other daily classroom activities that did not require the use of computers.

TABLE I. OBSERVED PATHOLOGIES

	CP	SB	MD
Group A	6	1	2
Group B	6	1	0

In total, we observed 16 children, 7 boys and 9 girls, divided in two classrooms, namely *Group A* and *Group B*. The selection of the groups was defined by the Director. *Group A* was conformed by nine children in the age range 8 – 12, six with CP, one with SB, and two with MD. *Group B* consisted of seven eight year old children, six with CP, and one with SB. Table I summarizes the observed pathologies.

Most of the children lived at least with one of their parents, except for one of them that lived in a state child caring institution[4].

After finishing the interviews and the observations, we returned to the school to discuss the scope of the first prototype with the Director and the teachers. Finally, in 2010 we ran the first prototype tests.

The process involved the following phases: preparation for the evaluation, execution of the field study, data analysis, prototype design, and prototype testing.

IV. RESULTS

The examined *XO*'s lacked of software specifically designed for users with PI. However, teachers managed to include these educative tools in their daily classroom activities.

During the observation period, participants worked with two of the *XO* factory-installed applications (in *XO* jargon, *activities*): *Tux Paint*, a drawing program, and *Speak*, a text-to-speech program. Fifteen children participated, eleven with CP[5], two with SB, and two with MD. We registered that most of the children had difficulties to find and use the different *Tux Paint*'s GUI controls, requiring assistance from the teachers. Even a simple action as drawing a line took them, when feasible, a great amount of time. We observed similar problems while using *Speak*: most of the participants were able to input their names only with assistance. In both cases, two children with CP failed to perform the task; one child was blind and the other suffered from severe paralysis. Table II details these observations.

TABLE II. CHILDREN'S PERFORMANCE WITH TWO *XO*'S ACTIVITIES

	Tux Paint			**Speak**		
	Without assistance	***With assistance***	***Failed***	***Without assistance***	***With assistance***	***Failed***
CP	1	8	2	1	8	2
SB	1	1	0	2	0	0
MD	1	1	0	2	0	0
Total	3	10	2	5	8	2

Figure 2. Accessibility switch that allows the user to move the mouse pointer.

Teachers attribute the difficulties in using *Tux Paint* to a combination of both the *XO*'s small screen size and the *Tux Paint*'s GUI design. According to the teachers, the screen layout of this activity is too compact and the controls are not enough different one from the other. In accordance with this, we could observe that children made considerable efforts to get close to the screen, in an attempt to see the GUI elements. With respect to the problems while accessing *Speak*, teachers affirm that the keyboard size is inappropriate for motor-impaired users. Beyond all these problems, the participants always responded with interest and excitement during the process.

To alleviate the problems arising from the small screen size, teachers tried to encourage the children to use a software magnifier tool included in the *XO* factory distribution. Nevertheless, teachers reported that it is particularly difficult for the children, especially the ones with CP, to handle the tool, an observation we were able to corroborate. Teachers speculated that the problem is derived mainly from a cognitive inability, attributed to the CP, to switch context between the magnified and the non-magnified area. Finally, the tool was dismissed.

A significant amount of the surveyed *XO*'s (44%) was not connected to any assistive peripherals. Three *XO* belonging to children with CP were aimed with assistive technology, including accessibility switches and other *ad-hoc* arrangements (see Fig. 2). Five children with CP and one child with SB had conventional mouse devices connected to their *XO's* (see Table III) in replacement of the integrated touchpad. In spite of the abrupt and jerky movements related to the paralysis, we

TABLE III. USE OF ASSISTIVE TECHNOLOGY

	With switch	With mouse	Without accessories
Group A	1	4	4
Group B	2	2	3
CP	3	5	4
SB	0	1	1
MD	0	0	2
Total	3	6	7

4 *Instituto del Niño y el Adolescente del Uruguay*, *INAU* (Uruguayan Institute of the Child and the Teenager)

5 The twelfth child with CP worked with a different application. Therefore, the child was not considered for this comparison.

observed that they managed to handle the mouse to carry out the tasks. Comparing the mouse and the touchpad efficiency, children using the mouse performed faster than children using the touchpad did. The lack of assistive peripherals was attributed to a combination of factors, including the children's low socio-economic context, the relatively immaturity of the program, which is still in its early stages and have not resolved some of the major problems yet, and the school's insufficient financial and human resources to acquire and introduce assistive technology.

We observed that the *XO* can potentially increase children's autonomy, something that was mentioned by the teachers and the Director during the interviews. One participant, a child with CP, was able to solve arithmetic problems, but unable to take a pencil and write the result of the operation in a notebook. The teachers knew about the participant's potential because the student was able to speak the result, with no less effort. Remarkably, by using the *XO* the child was able to write the result of arithmetic operations down.

One of the aims of *Plan Ceibal* is to engage the whole community in the project, giving the children the right to take the *XO* to their homes[6]. According to the Director, this right can potentially foster educative activities out of the scholar schedule, and communicate the children's progress to the families, especially families that cannot afford going to the institution.

A. The prototype

With the purpose of demonstrating the feasibility and the usefulness of enabling a multimodal interface for the *XO* [11] upon the mentioned context, a proof of concept prototype was developed.

The prototype recognizes different printed images that the user exhibits to the computer's webcam. Because the *XO*'s webcam is mounted on its monitor's frame, a periscope was created, in order to allow the user to put the images on the table.

The user then situates a printed image in the camera's field of view, triggering a predefined response from the software. For example, showing a print of an animal would trigger a reproduction of the animal sound and display a picture of the animal in the screen.

Analogously, the software can ask for an animal, either by saying its name, showing its image, or playing its characteristic sound, and the user has to find the corresponding printed image and show it to the computer.

This simple behavior can escalate to more refined interactions. For example, the user can present a set of instructions for the computer to execute (thus, programming the computer), or can touch (occlude) one image out of a set in order to select an item, give an answer, or move the mouse pointer.

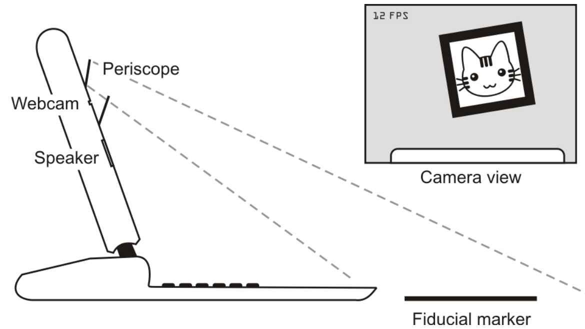

Figure 3. Scheme of the prototype, showing the *XO* with the camera and the speaker, the periscope, and one fiducial marker.

The software was programmed in *C++*, and the computer vision subsystem was implemented using *ARToolkitPlus*[7], a fiducial marker-based computer vision library.

V. CONCLUSION

We have successfully applied an ethnographic method based on participatory observation, in the study and the ulterior design of a multimodal interaction-based prototype for the computers of the *Plan Ceibal*. This prototype is to be put into effect in the only public school for motor-impaired children of Uruguay.

The ethnographic approach contributed in many fundamental aspect of the process, as follows:

It contributed to understand the particular characteristics of the participants, their needs, abilities, and limitations. We were able to observe their activities at the school, some of which involved the use of their *XO's*. These observations proved to be extremely useful in order to have an authentic perspective of their everyday life at the school, and how they use the *XO* and which type of interaction takes place.

Getting involved with the children and the school members during the design stage was decisive to conceive the prototype. It would have been extremely difficult, if not impossible, to synthesize the idea of the prototype without participating in this reality.

The applied ethnographic method strengthened the relationship between the research group and the institution authorities and members, opening the door for future research. We attribute this result to the chosen participatory approach.

We successfully tested the feasibility of building a simple computer vision-based application for the *XO*. This result opens new opportunities for introducing new interaction techniques that allow to avoid the classic keyboard/mouse/screen paradigm in the *Plan Ceibal*'s computers, without adding extra hardware.

Finally, it became clear that the *XO* massive dissemination provides an excellent opportunity for interaction designers,

[6] In spite of the fact that the program explicitly establishes that the children are the truly owners of the computers, and that they should not see the *XO* as belonging to a government institution, some schools discourage, or even forbids, them to take it to their homes. Some authorities argue that this unfortunate restriction is occasionally needed in order to protect the integrity of the computer from the children's often adverse home environment.

[7] More information about *ARToolkitPlus* is available in the URL: http://studierstube.icg.tu-graz.ac.at/handheld_ar/artoolkitplus.php.

software developers and HCI researchers to combine efforts for enabling accessibility and reducing the digital divide.

VI. FUTURE WORK

This work is part of an ongoing research within the *Computer Science Department* of the *Engineering School* of the *University of Uruguay*[8].

The immediate next steps are to improve the prototype performance, and to elaborate new ones based on the same multimodal interaction schema.

Having observed that there is a great demand for technological solutions to address the unique needs of each motor-impaired child, we conclude that it is essential to create a specific interaction design methodology, that would allow for streamlined design and production processes, while maximizing the products' usability and usefulness.

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