UNIVERSAL
LEARNING
DESIGN

International conference
Linz, 13–15 July 2016

Proceedings of the Conference Universal Learning Design, Linz 2016

Masaryk University

Teiresiás, Support Centre for Students with Special Needs

Brno 2016

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How to cite this book (ISO 690)

Proceedings of the Conference Universal Learning Design, Linz 2016. Brno: Masaryk University, 2016. ISBN 978-80-210-8295-3 (Proceedings of the Conference Universal Learning Design, vol. 5. ISSN 1805-3947.)

How to cite an article from this book (ISO 690)

The Name of the Author(s). Title of the Paper. In *Proceedings of the Conference Universal Learning Design, Linz 2016*. Brno: Masaryk University, 2016. p. xx–yy. ISBN 978-80-210-8295-3 (Proceedings of the Conference Universal Learning Design, vol. 5. ISSN 1805-3947.)

ISBN 978-80-210-8295-3
ISBN 978-80-210-8296-0 (online : pdf)
ISSN 1805-3947

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Preface

Five years ago, the Teiresias Centre (Support Centre for Students with Special Needs) at Masaryk University started a tradition of international meetings for professionals with practical experience of applying universal accessibility design in tertiary education. The first Universal Learning Design conference was held at Masaryk University in Brno, Czech Republic, on 8–11 February 2011.

Now, in 2016, the Proceedings of the 5th ULD conference – organized as a track of the 15th International Conference on Computers Helping People with Special Needs in Linz on 13–15 July 2016 – is being delivered to you. The proceedings cover varied topics as well as target groups and thus reflect the real situation present at tertiary education of students with special needs; at the same time a few papers transcend the primary focus of the conference and examine topics connected with early childhood pupils.

All submissions have been peer-reviewed: each paper has been evaluated by at least three professionals, all of them either from Masaryk University or members of the ICCHP Conference Programme Committee (listed below).

We wish to thank all those who contributed to the preparation of the proceedings as well as the ULD track, and believe the experience and good practices shared in the present volume can contribute to further development of a universally accessible environment.

June 2016 ULD track organizers

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SenseMath – Blind Students Making Sense of Math

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Abstract

In the last ten years none of the blind students at the schools of Royal Dutch Visio [short Visio] did finals in mathematics. In 2013 mathematics became a compulsory subject in the finals for secondary school. Therefore Visio wanted to make mathematics more fun and accessible for blind students, using modern technology and devices.

A mathematics book consists of text and pictures. Because of the quality of current reader apps, that allow you to read, comment, share and more, Visio decided to fully focus on the graphic content primarily looking at graphs. To create an accessible graph it should be possible to examine it with both sound and touch. Because haptic feedback technology was not yet adequate for touching a graph on a tablet, 3D-printing is used in the design developed by Visio. Together with students Visio explored the possibilities of listening to the musical translation of a graph. Listening to the 3D-sounds of the graph shows a steep learning curve; more information of the graph is noticed in less time. Besides listening to the 3D-musical translation, spoken information (f.e. the name of the line) is given by touching a line of the graph. The spoken information and 3D-sounds together with a 3D-printed graph were presented in a demonstration model at the Dutch Design Week. Because this demonstration received many promising responses Visio decided to further develop this technology in a digital multi-sensible math book, called SenseMath.

With SenseMath Visio gives blind students the opportunity to an accessible and independent way of exploring and analyzing graphs.

1 The goal

Mathematics is one of the most important subjects at school. It provides general knowledge and an analytical way of thinking. These skills are becoming even more essential in education of the 21st century[1].

The graphical information and level of abstraction in mathematics makes it inaccessible and difficult to comprehend for blind students. The current highly visual and dynamic teaching material makes is even less accessible. The assistive technology is outdated and limited available and do therefore not fit the needs of blind students and the current teaching methods. With the current material blind student rely on the support of others (peers, parents and teachers) and are not able to work independently.

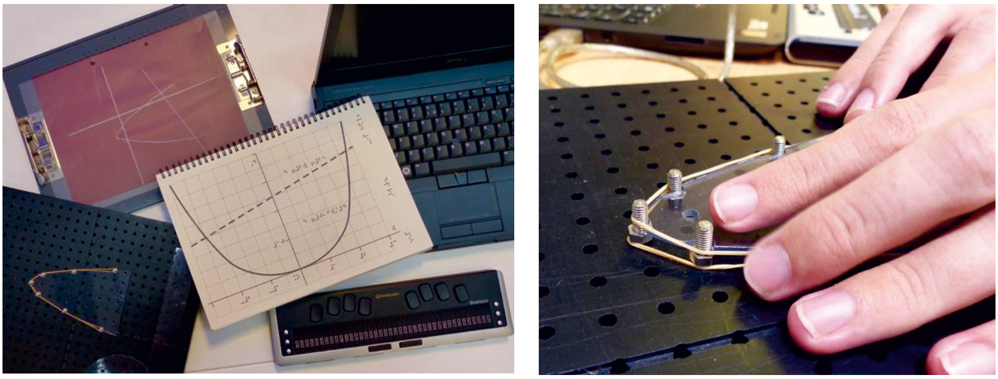
The objective of Visio was to make mathematics accessible and enjoyable for blind students. The aim is to make it possible for a blind student to independently produce, real-time material, to explore, analyze and solve a mathematical problem. The solution should be low in costs and in line with the current (and future) technology and learning methods.

1 www.onsonderwijs2032.nl/advies and OECD, review study OECD Dutch curriculum: onderwijs2032

2 A textbook

Textbooks for mathematics consist of text and pictures that can vary from images, geometry and graphs. The text is additional to the assignments or theoretical feedback. The ideal textbook makes it possible to read, make notes, share, navigate and search within the text. Visio developed a list of requirements that the should be fulfilled by the ideal digital textbook; an e-reader with lots of additional features, like making notes, highlighting and sharing options. Many e-reader apps fulfill some but now all of the requirements.

It was not feasible for Visio to develop a reader meeting all the requirements. Not only the lack of expertise but also the speed of development within the market would prevent Visio from completing a reader of good quality. The greatest challenge in making math accessible lies in the graphical parts of the mathematical book, therefore Visio decided to develop a way of making this part accessible to blind students.



[Fig. 1] Current mathematical material

2.1 Graphical information

A textbook for mathematics consists of an abundance of graphical information. Many figures can be explained verbally with exception of graphs. A graph is a way of visualizing raw data so that it is easier to understand. The aim of the Visio is to make these graphs accessible to blind students. It is assumed that blind students use similar methods in learning material as non-sighted students. The blind student is also part of regular school system and should be given the same information to a task as the non-sighted student.

3 Senses

A brainstorm session to investigate the important aspects in visualizing a graph was organized with blind students, assistive technology experts and math teachers. The main conclusion was: “Stimulating more senses will enhance understanding sciences courses”. Other aspects that were deemed important were the possibility to adjust the view of the graph to your own wishes and to switch between a general overview and a more detailed version of the graph. Visio decided to develop an app that displays graphs in both an auditory and tactile way to make teaching and learning mathematics understandable and fun. Visio named this project “SenseMath”.

3.1 *Starting points*

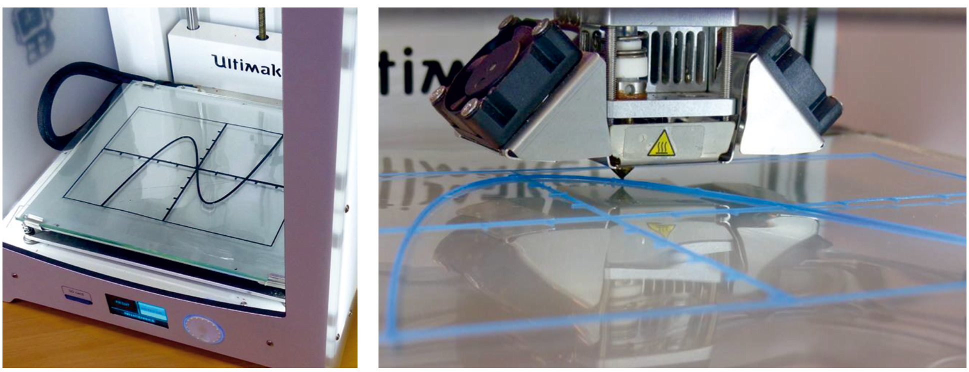
SenseMath has to be suitable for students who rely on braille and are in either secondary school or university. The application has to be suitable for a tablet. Upon completion of this challenge to make graphs accessible for blind students, the knowledge gained could be used to extent to other science subjects and another target population.

3.2 *Haptic feedback*

The many possibilities of haptic feedback on a tablet were researched by Dennis Willemsen, MSc[2] (master assignment Industrial Design Engineering at the Delft university of technology). A broad variety of haptic feedback techniques was researched including friction, force feedback and vibration. Five different prototypes were tested by subjects wearing a blindfold. Followig these tests swell paper graphs were deemed the best way to feel as much detail in as little time possible. The major challenge using haptic feedback is the feeling of direction which is essential to visualize the form of a graph. Because haptic feedback lacks this sense of direction, Visio decided to use 3D printing as a means to visualize graphs.

3.3 *Print to feel*

3D printing is a reasonably new technology that is changing the world. As a 3D-print (or 2,5-D print) has the same characteristics as swell paper, although sharper and in more detail, this technique could be the resolution for SenseMath. Visio is currently analyzing materials, dimensions (e.g. thickness and shape) and the way of printing. To make 3D-printing accessible to students it has to be done with a single tap in the application which is one of the challenges Visio is now working on.



[Fig. 2] 3D-printed graph

2 *Designing haptic graphics for mathematics: towards accessible math education for blind students* by Dennis Willemsen

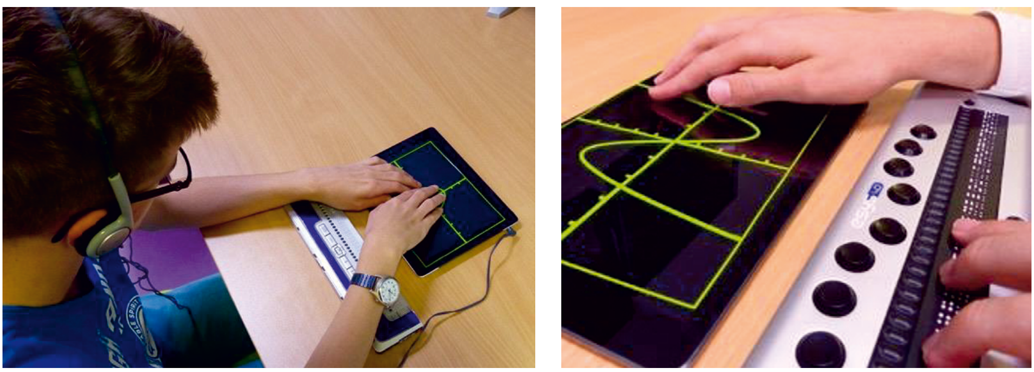
3.4 Musical translation

Software exists to make graphs audible in which a computerized sound will elaborate the graph. However, musical sounds, like piano or bass are easier to listen to. A composer created an audio translation mechanism, turning graphs in musical sounds, with a 3D component in it. With a 3D sound it's possible not only to represent the form of the graph but also the positions and place in the coordinate system. The sound puts the listener 'in' the graph origin (0,0). A group of blind students worked together with the composer to develop these sounds. Every form of a graph (e.g. parabola, dot) represents another musical instrument. Tests show that within a few seconds blind students can imagine a graph in both numbers, shapes and positions.

Hearing graphVisio developed a prototype, that shows the basics of SenseMath. A 3D-printed graph is placed on a tablet, the print will then interact with the 3D-audio and auditory information of the graph. Combining the 3D-print and the 3D-sound in the application gives a multi sensational way of exploring a graph. This demo was tested by students and presented at the Dutch Design Week. Because the reactions on the demo were promising Visio decided to further develop this prototype and eventually realise SenseMath.

3.5 SenseMath

The final desired product is a fully accessible application on a tablet (with a screenreader and a refreshable braille display). After entering the data for a graph in the application a graph is plotted. The student using the application determines the appearance of the graph (e.g. the number of lines and the appearance of axes). Depending on this appearance a musical translation will be made using 3D-sound. With a single tap, the tactile graph is printed on a 3D-printer. When placing the print on the tablet and touching the printed lines, auditory information about the graph is giving. With SenseMath, math makes sense.



[Fig. 3] Students exploring SenseMath

4 Future plans

SenseMath will give the opportunity to make an audio and/or tactile display of a graph in an accessible, simple and independent way. It creates teaching material matching the individual learning methods and needs of a student. It provides the teacher freedom and flexibility in teaching. Visio will further develop SenseMath. Making math accessible is only the beginning. SenseMath will unlock the possibility to make more science subjects accessible for both blind and visual impaired students.

Framework for Young Researchers in the Area of Participation through Technology and Media

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Keywords: UNCRPD, Technology, Accessibility, Research, University Education

Abstract

The implementation of UNCRPD is a societal process which needs to be supported by many players. The School of Rehabilitation Science at TU Dortmund University has set up project studies in order to prepare students for research and project work in this field. This paper describes the background and structure of these project studies and reports examples and experiences from the area disability and media.

1 Introduction

The *UN Convention On The Rights Of Persons With Disabilities* [1] has put a new perspective and reinforced emphasis on the full and equal enjoyment of all human rights and fundamental freedoms by all persons with disabilities. The use of available technologies is both a central precondition and tool towards the goals of the convention and the implementation of inclusion and participation. Technology is addressed in three ways: assistive technology, accessibility and universal design. It requests the use of traditional rehabilitation technology, but also new media and new technology. Research in the area of technology for inclusion and participation is needed and has to contribute to this development towards the UN goals. It is important to attract young researchers from different disciplines to this field. "C4C – Code for a Cause" [2] is one example for an international framework, the "Future Conference" of Aktion Mensch [3] an example for a national activity. In this paper the framework of "Project Studies" – PS of TU Dortmund University is introduced, which is run by the School of Rehabilitation Science in the last year of BA studies. It provides a framework for young researchers at the edge of their first academic degree to dive into research and prepare for further professional activities.

2 Background and Structure of Project Studies (PS)

2.1 TU Dortmund University and School of Rehabilitation Science

The School of Rehabilitation Science is part of TU Dortmund University: "*Since its founding 47 years ago, TU Dortmund University has developed a special profile, encompassing 16 faculties ranging from science and engineering to social sciences and culture studies. The university currently has circa 33,550 students and 6,200 staff members, including 300 professors. The curriculum is comprised of around 80 programs of study, both traditional and innovative, some even unique to this university. A broad teacher training program is* *also offered for all school types. The various scientific disciplines share a common university spirit in which interdisciplinarity, communication and cooperation are not only taught, but lived and experienced. This interaction creates an environment conducive to technological innovation and fosters advances in methods and knowledge.*"[1]

"*The Faculty of Rehabilitation Sciences contains 17 teaching and research areas, each of which has a specialist research focus in the field of rehabilitation. This makes it one of the largest teaching and research institutions of Rehabilitation Sciences in Europe. Currently, 80 members of staff offer programs of study at all levels to approximately 1,900 students.*"[2]

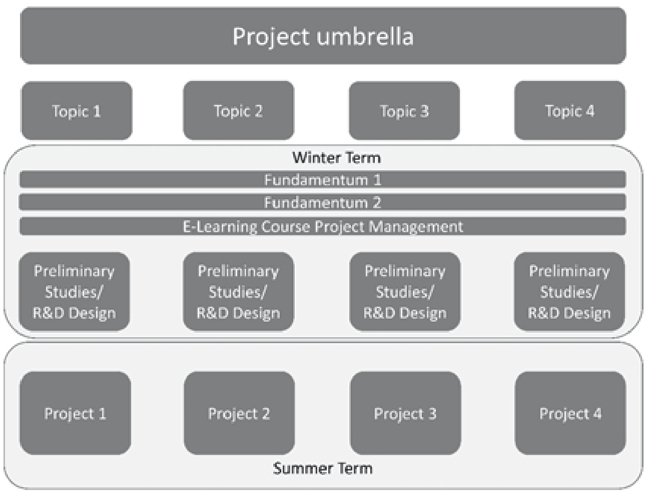
The research of the School of Rehabilitation Sciences is organised in three research clusters:

1. Inclusive Education and schools (IBIS)
2. Inclusive labour
3. Technology for Inclusion and Participation (TIP)

The School of Rehabilitation Sciences currently runs three Bachelor courses and three Master courses: Two consecutive Bachelor and Master courses preparing for a profession in teaching and one Bachelor and one Masters course which focus on the field of social rehabilitation.[3] PS is part of the study program of the 3rd year of the Bachelor in the field of social rehabilitation with 130–150 students in each year.

2.2 PS structure

PS is organized in 3–4 thematic umbrellas with 3–4 projects each. Each project is proposed and guided by one member of faculty and supported by a student tutor. For each project 8–12 students form a project group for one year. The PS starts with an introductory phase run by the PS office.



[Fig. 1] PS-Structure of one project umbrella

1 http://www.tu-dortmund.de/uni/International/University/index.html

2 https://www.fk-reha.tu-dortmund.de/fk13/en/Faculty/index.html

3 https://www.fk-reha.tu-dortmund.de/fk13/de/Studium_und_Lehre/index.html

In the winter term students have to study an e-learning course on project management and two introductory courses ("Fundamentum") related to their respective thematic project umbrella. In parallel they start their research with literature review, making contact to relevant institutions, and preliminary investigations to pave the ground for their research project. This phase is closed in January with a presentation of findings and the research design for the remaining term. At this point the students have five months left for conducting the research. The PS is closed by a final examination and a project market where the results and findings are presented to other students, cooperation partners and the public. The project market is the first step for students of the next year to get in touch with PS.

3 Examples of PS projects

3.1 Project overview

The range of project subjects reflects the diverse research interests of the School of Rehabilitation Science. However, all projects are referring to UNCRPD and its important principles. Full and equal participation in all aspects of society and inclusion are targets and concepts used in the research. Many of the projects create partnership with external institutions, organizations, and campaigns. The following list gives an introduction to the thematic umbrellas and project subjects:

- Disability and Media/ Participation through Media:
  - Supporting the Participation in the "digital society" – Public Internet Access points in Dortmund (two projects with different focus)
  - People with disabilities in social networks
  - Peer-support and use of media
  - AAC – concept of advisory services
  - AAC – networking
  - Children's movie festival
  - Get Online Week 2015
  - Barriers: found, notified and removed
  - Get Online Week 2016
  - Reh@pp-Quality – Participation through quality of apps in Rehab
- Inclusion/ Participation
  - Implementation quality of inclusion of pupils with support in social and emotional development taking into account the social environment and the perspective of teaching staff – A qualitative study at to schools in Dortmund
  - How can school inclusion succeed? Evaluation of the implementation at the Maischützenschule Bochum
  - Vocational inclusion – between reality and utopia, case studies to overcome barriers
  - Inclusive vocational education – (not) a subject for vocational schools

  - Transition from special school to vocational training
  - History of the disability movement (Germany)
  - National report on participation
  - Action plan "Inclusive Castrop-Rauxel"
- Diagnosis and support in early childhood
  - Interdisciplinary networking and educational partnership
  - Practice of early diagnosis in day-care centres
  - Stepping Stones Triple P – investigation on siblings of children with disabilities
- Arts and Abilities – aesthetic production, representation, disability and inclusion
  - Inclusive dancing
  - Music and ability – inclusive multicultural practise between participation and performance
  - Moved – "you think black and white?" Art creates coloured diversity
- Participation in education and cultural life, recreation, leisure and sports
  - Dance- Moving- Culture –Design of diversity at a cultural leisure site
  - Participation options and access in and through sports
  - Adult education in the context of severe and multiple disability
  - Windspiel on the move – inclusive dance and movement theatre on tour

3.2 Project examples – media and technology – in brief

In the following project examples are presented who relate to the umbrella themes media and technology.

3.2.1 Supporting the Participation in the "digital society" – Public Internet Access points in Dortmund 1/2.

The digital divide between wealthy and highly educated people and vulnerable groups still remains. Public Internet Access Points (PIAPs) are locations which have the potential to help to close the gap. However, they need to be accessible, provide accessible computers and appropriate support. Two projects deal with aspects of PIAPs. The first group delivers an analysis of PIAPs in Dortmund based on expert interviews and questionnaires [4]. This builds the basis for a policy recommendation which is transferred to the project partner "Disability Policy Network Dortmund".

The second group looks at options to support older people through PIAPs. The investigation shows that the first barrier is high unawareness of the target group about PIAPs and the offer for older people. Hence, the project collects data about PIAPs in Dortmund and creates a brochure with qualified information about PIAPS and older people.[4]

3.2.2 People with disabilities in social networks.

The project focuses on the empowerment of people with learning problems in social net-

4 https://www.fk-reha.tu-dortmund.de/fk13/de/Studium_und_Lehre/Studiengaenge/Bachelor_Rehabilitationspaedagogik_11/Projektstudium/PDF_1_2.pdf

works. In a first step Facebook is selected as the social network for the project. An analysis of activities, issues, and problems understanding and using Facebook® is carried out in cooperation with user experts form the Pixel Lab in Duesseldorf. The project provides an online training resource about Facebook with explanations in easy2read and screenshot videos[5]. A little mascot called Theo is used to guide the users (Figure 2). The online resource is evaluated with users who have not been involved in the process and have not been Facebook users before.

[Fig. 2] Banner of the Toolbox Website

3.2.3 Peer-support and use of media.

The project deals with peer support processes using the web. An analysis of existing resources is provided. The project decides to focus on available resources and collect and qualify information about such services. It develops a set of criteria in order to standardize the description. The platform is designed in a way that users can provide input to the database following the criteria structure.

3.2.4 AAC – concept of advisory services.

Many people working in sheltered environments or living in supported housing arrangements need support in communication. Unfortunately, not everywhere structured and reliable advisory services are established. The project analyses the situations in selected institutions in Dortmund. The group cooperates with Bethel.regional and AWO Dortmund. It develops a concept and proposal for the implementation of reliable structures and recommendations for concrete actions towards an appropriate service of AAC assistance.

3.2.5 Barriers: found, notified and removed.

Web accessibility can be achieved by using the WAI guidelines of W3C. National legislation has enforced this set of rules in many countries. Nevertheless, large parts of the Web content remains very inaccessible. Initiatives like "fix the web"[6] or "Meldestelle für Webbarrieren"[7] provide opportunities for people facing problems to strategically address the providers of content with respect to access barriers.

The project cooperates with the German user organization BAG Selbsthilfe[8] who runs the "Meldestelle für Webbarrieren". The project analyses the procedure to report an issue

5 http://www.fb-toolbox.de/

6 http://www.fixtheweb.net/

7 http://barrieren-melden.de/

8 http://www.bag-selbsthilfe.de/

or barrier. Expert interviews build the basis for recommendations to improve the service. The project creates three videos to support the awareness about info barriers and publicity of the "Meldestelle".[9]

[Fig. 3] Banner and Comic of the Meldestelle

3.2.6 Reh@pp-Quality – Participation through quality of apps in Rehab

Today we extensively use small aides based on smart phones and tablets, called apps. Many applications can be downloaded for free or little money from online stores. Besides gaming, communication and organization other domains like sports and health are booming. Many apps are of high relevance also for people with disabilities and older people. They have the potential to support at reasonable costs, without stigmatizing as well as support participation and inclusion. However, the market is sometimes confusing and there is little information about the quality of an app. The project deals with the questions, what quality means in this context and how quality related measures can be used to improve the situation. It develops and structures criteria of quality and provides information for different target groups ranging from end users to app developers.

4 Conclusions and perspectives

Implementation of UNCRPD is obviously a process with many facets. It is a societal process and takes time and resources. Legislation, standards, good practice, negotiations, priorities, advances and setbacks can be observed. Accessibility, assistive technology and universal design are of high relevance in this context. It is important to educate people, create awareness and support for a full implementation. At the University we have started to prepare students of rehabilitation science for targeted research related to UNCRPD. The experiences from the three years show the validity of this educational format: the students are highly motivated and make important progress during the year; the research results provide extra value to the field and the partners. Unfortunately, not all results are sustainable, because the students graduate and leave the university soon after the project. Therefore, the cooperation with external partners in rehabilitation, society, and science is an important element, which we will develop further. The ongoing restructuring of the Bachelor study programme will relate the PS more closely to the research clusters of the School of Rehabilitation. In addition we plan to investigate options for international collaboration with other Universities as well as other organizations.

9 https://www.youtube.com/channel/UCrCOKNySIo9dP-ZuyKjdHwQ

References

[1] United Nations. *Convention On The Rights Of Persons With Disabilities* [online]. 2006. [cit. 23-01-2016]. Available in URL <http://www.un.org/disabilities/convention/conventionfull.shtml>.

[2] *Code for a Cause*. [cit. 23-01-2016]. Available in URL <http://icchp.org/c4c-16>.

[3] Aktion Mensch. *Inklusion 2025 – Der Zukunftskongress der Aktion Mensch*. [cit. 23-01-2016]. Available in URL <https://www.aktion-mensch.de/zukunftskongress/dokumentation.php>.

[4] Pelka, Bastian, et al. Interneterfahrungsorte in Dortmund. Eine niedrigschwellige Unterstützungsform zur Teilhabe an der digitalen Gesellschaft [online]. *Beiträge aus der Forschung.* Band 189. SFS TU Dortmund, 2014. ISSN: 0937-7379. [cit. 23-1-2016]. Available in URL <https://www.fk-reha.tu-dortmund.de/fk13/de/Studium_und_Lehre/Studiengaenge/Bachelor_Rehabilitationspaedagogik_11/Projektstudium/Interneterfahrungsorte_Projekt-1_1.pdf>.

A Multilingual Interactive Workspace for Helping the Visually Impaired Learn and Practice Algebra

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Keywords: Accessibility, Algebra, Visually impaired

Abstract

In this paper a multilingual interactive workspace is implemented for helping visually impaired students learn and practice algebra. This interactive workspace aims at enhancing the abilities of students in manipulating algebraic expressions. Read-terms, Write expression, and Text-Tools are examples of techniques that the workspace implements. These techniques are executed by hot access keys with audio feedback that allow the user not only to navigate and edit the algebraic expression, but also to access its elements, find the solution and save it. Experiments were conducted on visually impaired upper elementary school students in Lebanon. The language of instruction was Arabic so the experiments used the Arabic language for both training and practicing Math. The results show that compared to traditional tools (Braille writers) used in doing Math, using the system implemented in this paper students were able to perform 20% to 40% faster and with less mistakes. In addition, visually impaired students trained on the implemented system are now able to do math exercises independently.

1 Introduction

The number of elementary and upper elementary school visually impaired students is significant. There are approximately 124 million people who are visually impaired and 37 million people who are totally blind. For example, as of 2011, 12.5% of primary school students in the Arab world suffer from severe weakness of sight [1]. Moreover, 50 students out of 10 thousand are blind [1]. To meet the educational needs of this growing sector of the population, the right tools, strategies, and technologies should be developed to help overcome this disability and enable students who have limited vision to learn normally like all other students.

In this paper, an interactive workspace is presented to help visually impaired students learn and practice math. It allows the visually impaired students to manipulate any expression independently. It implements all basic Math topics covered in upper elementary and middle school curricula. The workspace is language independent with the current implementation supporting Arabic and English. The system reads MathML formatted documents prepared by teachers using any editor which supports MathML. Every MathML structure in the document is then transformed by the system into a MathML object. Students are able to manipulate expressions with the aid of hot access keys and audio feedback. This allows the system to implement text to speech with support for any language. The system gives the visually impaired student the ability to use it in two different modes. The learning mode and the regular mode. In learning mode, the user is allowed to navigate and manipulate the expressions. If the user does any mistake, the system will provide guiding hints so that the user can solve the problem correctly. In regular mode, the system will allow the user to navigate and manipulate expressions without offering any hints even if the user makes mistakes. The system saves all steps of solving, in both modes, as MathML structures so that they can be eventually reviewed by the teacher using off the shelf Math editors supporting MathML. Moreover, the system has a scratch area feature which enables the visually impaired student to do side calculations whenever needed. The student will be able to easily navigate between the main area and the scratch area.

Unit level tests were conducted with actual visually impaired students in a renowned Deaf and Blind students care institute in Lebanon. Extensive updates were done to the workspace based on feedback from the visually impaired students. It was noticed during the experiments that students were very excited and interested in using the workspace and preferred it over the traditional tools (e.g. Braille writers) to which they were accustomed. The experiments were done using three levels of exercises, Easy, Moderate and Difficult. It was noticed that when the students used the implemented system, they were faster than when they used traditional tools (e.g. Braille Writers). The more difficult the level of the exercise the better the performance of the visually impaired student using the implemented system compared to traditional tools. It was also observed that students using the implemented system did less mistakes than when they used traditional tools. This lead to an increase in the satisfaction and confidence of the students both in themselves and the system.

2 Prior Research

The field of mathematics accessibility for the visually impaired has been dominated by static approaches since its inception. Recently, with technological advances, dynamic approaches are replacing static approaches since they are better serving the visually impaired. Static approaches use Braille to render mathematics while Dynamic approaches use mainly audio in rendering [2].

In [3] a new framework was proposed to facilitate doing and manipulating mathematical algebraic content in a way that is convenient, accessible, and usable for students with visual impairments. This approach relies on parsing MathML source code to capture any mathematical content on a web page. Non-visual accessibility of this MathML content is supported by audio feedback through the MathPlayer plug-in and hot access keys. In [4] another framework was proposed to facilitate math practice and learning for visually impaired students. This framework was designed to be independent of MathPlayer. It also enabled instantiation of systems to allow visually impaired students to manipulate expressions spanning multiple dimensions (horizontal and vertical). For example, an instantiation helped visually impaired students manipulate matrices by navigating horizontally, vertically and diagonally through a specific matrix [5].

In [6] a multimodal interface is presented to facilitate the editing, comprehension and resolution of algebraic equations using visual, speech and Braille output modalities. This interface helps students with their classroom activities such as dictation, solving exercises and exams. In [7] an intelligent tutoring math platform is presented to enable visually impaired students to learn mathematics using speech and (hot keys) buttons. In [8], the framework described in [3] was used for tutoring visually impaired students in mathematics manipulation using the MathPlayer plug-in as an audio interface.

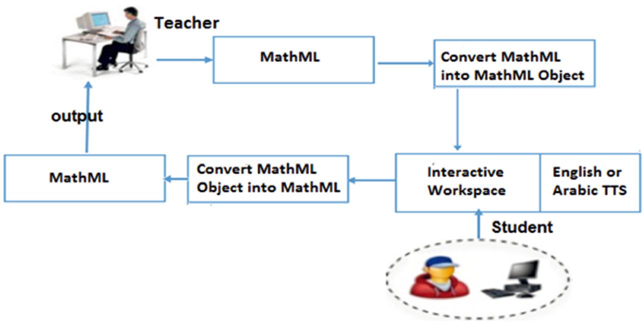
The workspace consists of two parts, the basic part which supports simple operations and the advanced part which supports advanced operations. The student needs to first choose the level, and then do the exercises in that level.

3 Application Idea

In this paper, an interactive workspace is described which enables visually impaired students in upper elementary and middle school levels to use their computers to independently learn algebraic skills while solving algebraic expressions. This workspace is an instantiation of the framework presented in [4]. The workspace is language independent and as such can be used by all visually impaired students regardless of their education language. In its current implementation, the system supports both English and Arabic languages.

As shown in Figure 1, the framework envisions two types of users, the teacher and the visually impaired student. The teacher prepares the lesson/exam using any mathematical creating/editing tool that generates algebraic expressions encoded in MathML (e.g. Wiris [9]). The MathML code is then parsed to generate a MathML object for each algebraic expression. A MathML object is a binary expression tree that encodes all the information in the algebraic expression in a form which allows easy access and update. The visually impaired student can easily navigate and manipulate algebraic expressions via hot access keys and Text-to-Speech (TTS) feedback. The interactive workspace generates MathML objects for all intermediate results produced by the visually impaired student. Those MathML objects can also be manipulated by the student and can be converted into MathML. Converting a MathML object serves to generate reports to be reviewed by the teacher using a MathML supporting editor.
The core concept of the framework is an interactive English/Arabic algebra workspace which enables visually impaired students to use hot access keys and a TTS system to learn and do Math. Students are able to manipulate algebraic expressions in accessible consecutive steps which lead them to a final answer. Each intermediate result in each step is stored so that by the end of the expression evaluation, all these steps can be sent as a complete step-by-step answer for the initial algebraic expression. The system consists of two workspaces. The primary workspace in which the visually impaired student solves Mathematical exercises. In addition, a temporary workspace is provided which mimics the scratch paper viewing students use. In the temporary workspace, the visually impaired student is able to navigate through an algebraic expression and solve sub-expressions then copy the result back into the primary workspace. This is most useful in operations such as long numbers addition, subtraction, multiplication or long divisions. The workspace can be used in two modes, learning mode or regular mode. In learning

mode students are given hints in order to assist them in solving an expression. Those hints are automatically generated whenever a student commits an error during the manipulation of an expression. In regular mode the student is not given any hints even if they commit errors.



[Fig. 1] Framework for learning and practicing Algebra

The novelty of this workspace compared to other existing systems is that the workspace presented in this paper is intended to create educational systems. It allows visually impaired students to be as independent as sighted students. Other systems are more tutoring systems than they are educational. Furthermore, the workspace presented in this paper can support both its user categories to be sighted or visually impaired. Students as well as teachers can use the system regardless of their degree of visual impairment. Another difference is that most of the existing systems use the MathPlayer plug-in. This makes them not able to support languages which are not supported by the plug-in. The workspace described in this paper transforms MathML content into objects. Then the objects are used along with existing TTS to support the language of choice of the visually impaired user. Objects enable the instantiation of multi-lingual systems which can accommodate visually impaired users regardless of their language. Another difference is that the whole work of the students is saved. All the steps in solving Math expression are converted into MathML content. This allows the student to review their solution as well as the teacher to be able to look at all the different steps to pinpoint the deficiencies in the student understanding in case of an erroneous answer. As already explained in section II, in [8] the workspace consists of two parts: basic and advanced. The students need to choose the level then do the exercises in that level. In the framework presented in this paper, the student sub-expressions can be manipulated in the temporary workspace and then updated in the original expression in the primary workspace. The student experiences exercises of different levels of difficulty without having to specify the level a priori. This allows the visually impaired student to learn and practice Math similar to sighted students in a better way compared to other existing systems.

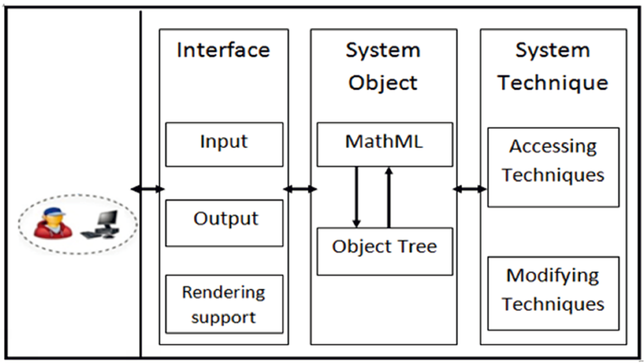
4 Methodology

Syllabi of algebra courses from upper elementary and middle school curricula, as well as the core curriculum were reviewed to collect the set of all Math operations. The following topics were identified: Power, Prime numbers, Adding and subtracting numbers, dividing and multiplying numbers, square root, solving algebraic expressions by taking into consideration the order of operations, inequality systems, and equations with single unknowns. Each topic was then broken into several subtopics. For example the topic "algebraic expression" was broken into the following subtopics: "applying arithmetic operations on algebraic expressions", "simplifying similar terms", and "finding the value of an algebraic expression." Each subtopic, in turn, was further broken into basic operations. The basic operations identified for the topic "algebraic expression" were adding/subtracting of numbers, multiplying/dividing numbers, adding/subtracting terms, multiplying/dividing terms, comparing numbers, calculating the square root, and manipulating powers. Each basic operation was then broken down into tasks. The following tasks were identified for the operation "Simplifying the similar terms": Read algebraic expression term by term, determine the boundaries for unknowns, combine similar terms, write the result on a new line, determine that all boundaries are simplified, and write the final mathematical expression. Tasks were then filtered based on whether or not they needed visual abilities. From the tasks listed above only the fifth (determine that all boundaries are simplified) does not need a visual ability. The tasks requiring visual abilities were then analyzed to determine the exact required visual abilities. The following is a list of all visual abilities identified: access the digit of a number, access a term in the expression or equation or inequality, access the similar terms in the expression or equation or inequality, find the size of the expression, return to a bookmark, write a fraction or number or power, write an inequality or equation or algebraic expression, transfer a term in equation or inequality from side to side, simplify a term in an expression, reduce the consecutive positive/negative signs, substitute the unknown with a given value

5 System Description

The system consists of three main modules: Interface, System Object, and System Technique as shown in Figure 2. Interface is the Input/output module which handles the interaction between the computer and the users. In the input module, a teacher edits the assignments to be solved by the student, designs and edits the lessons to be studied by the student, and grades the assignments. A student solves the questions using several techniques such as write expression, and saves the solution. The input module mainly uses hot keys. The user knows about the hot keys from training and can always refresh his/her memory by invoking the help menu. The output module renders the effects of the user's manipulations by using audio feedback for the visually impaired user or visual feedback for the sighted user. The output module is based on a Text To Speech (TTS) technique which keeps the users updated about their current situation. In addition, the feedback and hint features provide the users with the effect of their actions. In the current implementation of the system, Arabic and English are the languages supported by the TTS system. The system can currently switch between Arabic and English.

The object module converts MathML code into MathML objects, MathML objects into MathML code, and stores the objects of the system and its data. Converting MathML code into MathML objects allows the user to easily access, update, delete and navigate expressions and operations and perform Math. Converting MathML objects into MathML code allows the user to add his/her particular solution and save it. The system techniques module is a set of techniques or system operations which help the user to perform the algebraic operations supported by the system. The techniques are classified into two categories, accessing techniques and modifying techniques. Accessing techniques allow the end user to access and manipulate an expression or any of its elements. Modifying techniques allow the user to create or modify an expression.



[Fig. 2] The general architecture of the proposed system

Table 1 presents the implemented techniques and their descriptions as well as the visual abilities that are supported by each technique.

[Table 1] Implemented Techniques

Techniques	Description	Visual abilities
Read-Digit	After pressing enter on certain number this technique allows the user to navigate the number digit by digit using left /right arrow keys	T1, T3
Get-View	This technique allows the user to know the number of terms, and the type of operation which exists in an expression	T2, T4
Read-Term	After selecting an expression this technique allows the user to navigate it term by term using the left/right keys	T2, T3, T11
Bookmark	Highlight certain selected term	T5
Sub-expression	This technique allows the user to select a term by using the bookmark technique, and then modify the expression.	T5, T9
Select-Write option	To select a writing option (number, fraction, power) using enter and arrow key	T6

Write term	This technique allows the user to write a term.	T6
Write expression	This technique allows the user to write an expression.	T7, T11
Text-Tools	Select, Copy, Paste, Delete for term or expression	T8, T9, T11
Select Sign	Highlight the sign	T10
Check sign	This technique allows the user to write the sign after checking the select sign.	T10

The current system supports the following algebraic operations: addition with carry, subtraction with borrow, multiplication with more than one digit, long division, solving algebraic expression involving the above operations including nested operations and operator precedence, and solving equations in one unknown.

6 Experimental Results

The system has been tested on a group of visually impaired students from the upper elementary school level in Lebanon. Training the students took a considerable time; however, once they were familiar with the system, the performance of the students was much better. The performance of the students improved considerably compared to the performance when they were using traditional tools (e.g. Braille writers). The time for a student to perform a task using the system was considerably shorter than the time taken using traditional tools. When given the choice all students participating in the study preferred to use this system over the traditional tools they used to use.

Three experiments were done using three levels: easy, moderate, and difficult. The time was calculated in both regular mode and learning mode for both the implemented workspace and the traditional tools. In regular mode the students solve the problem without any help or feedback. While in learning mode, the student gets hints for each error step. Using traditional tools, the student needs a dedicated teacher to track his/her mistakes and provide hints. While in the implemented workspace, audio feedback is used to give hints whenever the system detects a mistake done by the student. Students participating in the experiments underwent three hours per week training for two months on the implemented workspace. A total of six upper elementary students participated in the experiments. Two participants used braille writers, and rest used CCTV. In each level the visually impaired students used the workspace and the traditional tool to solve two exercises. Table 2 shows the average time taken by the student to solve mathematical expressions.

[Table 2] Average Time for Solving Mathematical Expressions

		Implemented Workspace		Traditional Tools	
		Regular Mode	Learning Mode	Regular Mode	Learning Mode
		Average Time to solve mathematical expression			
Easy level	Ex.1	3	2.33	3.83	2.5
	Ex.2	2.16	2.4	2.83	3
Moderate level	Ex.1	6.5	4.5	7.66	7.5
	Ex.2	6.5	3.83	9.16	6.33
Difficult level	Ex.1	7.83	6.33	9.16	8.66
	Ex.2	9.16	6.5	10	9.16

The exercises consist of addition, subtraction, multiplication and division of large numbers. In multiplication and division of large numbers, students needed to use a scratch area to do the operation step by step. Students using Braille writers were not able to use a scratch area. This is why, the school did not give them exercises to multiply and divide large numbers. In contrast, students using the implemented workspace were able to use the scratch area feature of the workspace in order to do side calculations. In regular mode, no students committed any mistakes while solving the exercises in the easy level. However the number of mistakes started to increase whenever the students moved to a higher level of difficulty. In learning mode, all students were able to eventually solve all exercises correctly using the suggested hints. Using the implemented workspace, the time it took the students to use the hints in order to solve all exercises correctly was around 40% less than using traditional tools with a dedicated teacher giving the student hints.

In table 2, the average times for solving each exercise in both regular and learning modes and using the implemented workspace as well as traditional tools are reported. In regular mode as well as in learning mode, it took less time on the average for students to solve exercises using the implemented workspace. In general also, the difference between the times of the implemented workspace and the traditional tools gets larger as we move into more difficult levels. In both implemented workspace and traditional tools the times for regular mode are larger than the times for learning mode (except in traditional tools used to solve Ex. 1 in Moderate level). This means that the hints given by the teachers as well as those given by the system are helping the student achieve his/her goal more efficiently.

As the results, the significant effect of the workspace observed in the Moderate and Difficult levels. The students can easily edit the expressions in the workspace than in the traditional tool. The strategy of think loud helps the student to decrease the time in solving the mathematical expressions.

Observing the visually impaired students work through the exercises using both the traditional tools as well as the implemented system, several observations were made. The implemented workspace has significant effect in Moderate and Difficult exercises. In some cases, the implemented workspace enabled the students to learn and practice operations they were, otherwise, incapable of performing using traditional tools. The feature of scratch space mimics the "think loud" strategy and has been very helpful to students in attempting and being able to solve complicated mathematical expressions. This feature also is believed to be a main contributor to decreasing the time to solve a mathematical expression. The scratch area feature helped students keep numbers and letters they need later in an area and then recall them later when they are needed. Traditional tools forced the visually impaired student to rely on their memory and therefore were not effective when the number of items to remember is large or when the time of remembering the item is too long. Another good feature in the implemented workspace was the ability to erase any erroneous step and go back to the previous result.

7 Conclusion and Future Work

Visually impaired students need an easily interactive environment to learn mathematics. In this paper a framework for an interactive workspace was described which was designed for helping visually impaired students to practice the fundamentals of algebra. The topics of Algebra which should be supported were collected from curricula of well-known elementary schools as well as the core curriculum of a Lebanese school for Deaf and Blind Children. All topics were then analyzed and broken into subtopics. Each subtopic was then further broken into basic algebraic operations. Furthermore, each basic operation was broken into tasks which the student should perform in order to complete the basic operation. Finally the tasks were analyzed to identify which ones required visual ability. The tasks requiring visual abilities were targeted to be implemented. A workspace was implemented based on the framework to teach Lebanese students in upper elementary the topic of Algebra. After being trained on the system, the students performed much better using the system compared to their performance using the more conventional Braille writers. Students using the implemented workspace were able to solve exercises faster and with a higher rate of correct answers compared to traditional systems.

Currently, work is being done on augmenting the system with more operations such as fractions, powers and square roots so that it becomes useful for middle school students who are visually impaired. The next step would be to develop the workspace to cover all topics for all grades. Next, it would be great if the workspace would be able to support university students in such Math courses like discrete structures and data structures. Visually impaired students who used the workspace have expressed their interest in developing a mobile-friendly version which they would be able to download to their smart phones.

References

[1] DAESN Association. في دراسة حديثة لمنظمة الصحة العالمية. In *A recent study of the World health organization*. 2011. Last accessed January 30, 2016. Available from: http://daesn.org/tags/189555/posts#http://daesn.org/posts/271573.

[2] Pontelli, E., Gupta, G., Karshmer, A. Mathematics, Accessibility. In *Universal Access, Handbook*. CRC Press, Boca Raton, 2009.

[3] Alajarmeh, N.; Pontelli, E.; Son, T. From "Reading" Math to "Doing" Math: A New Direction in Non-visual Math Accessibility. In Stephanidis, C. (ed.) *HCII* 2011 and *UAHCI* 2011. Part IV. LNCS, vol. 6768, p. 501–510. Springer, Heidelberg, 2011.

[4] ElKabani, Islam; Zantout, Rached. A Framework for Helping the Visually Impaired Learn and Practice Math. *5th International Conference on Information and Communication Technology and Accessibility.* Marrakech, Morocco, December 21–23, 2015.

[5] AlMasri, Bassam; ElKabbani, Islam; Zantout, Rached. An Interactive Workspace for helping the Visually Impaired in Learning Linear Algebra. *14th International Conference on Computers Helping People with Special Needs – ICCHP 2014.* Universite Paris 8-St. Denis, Paris, France, July 9–11, 2014.

[6] Fajardo-Flores, S.; Archambault, D. A Non-visual Electronic Workspace for Learning Algebra, In K. Miesenberger et al. (Eds.): *LNCS 7382*, Part I, 2014. p. 158–165.

[7] Brzoza, P.; Maćkowski, M. Multimodal Interface for Working with Algebra: Interaction between the Sighted and the Non Sighted. In K. Miesenberger et al. (Eds.): *LNCS 8547*, Part I, 2014. p. 606–613.

[8] Alajarmeh, N.; Pontelli, E.; Burgert, T. A Multi-Layer Universally Designed Workspace for Tracking Students Skills and Mastery Transition in Mathematics Manipulation in Inclusive Education. *Frontiers in Education Conference (FIE)*, 22–25 October 2014, Madrid, Spain, 2014.

[9] *Wiris Editor*. Available from: http://www.wiris.com/en/editor.

A Learning System for Environmental Sounds on Tablets: Toward a Teaching Resource for Deaf and Hard of Hearing Children

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Keywords: Environmental Sound, Learning Application, Deaf and Hard of Hearing Children, Context Understanding

1 Introduction

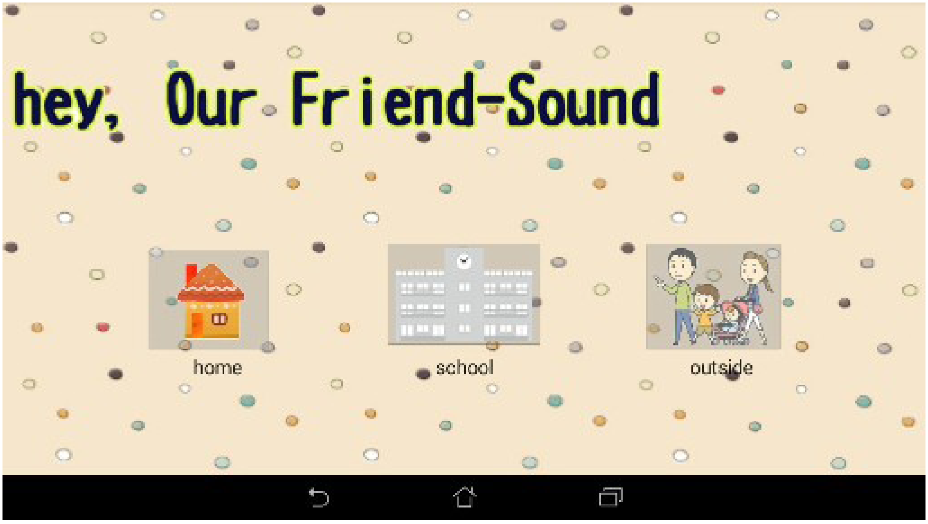
The special education in learning sound for deaf and hard of hearing (DHH) elementary school students has concentrated on speech recognition. In our everyday life, however, we listen to sounds other than speech, such as music and environmental sounds (ES). There are some teachers or volunteers who have a passion to teach DHH kids the joy of music.

However, though ES are considered as an effcient data source for recognizing human, nature, and social activities hence play more important roles in perceiving the surrounding circumstances and deciding actions responding to the situations, the understanding of ES has tended to be completely a matter for individual DHH kids. Liu et al. reported a low correlation between linguistic sounds and ES recognition because the training of ES has been less emphasized [1].

As a DHH person or teachers of DHH college students, we know that DHH people often misunderstand some ES, which is consistent with the results of a survey we conducted on 70 college students with hearing loss. Misperceiving some ES might lead to serious danger. Thus, we developed a self-learning system of ES for elementary school children, named "Mawari no Oto-kun" (Our Friend Sound). The system is aimed at teaching the "contexts" of the sounds, such as what kind of action is required after hearing some sounds or what causes the sounds, as well as improving recognition of sounds by listening. For children to voluntarily learn the ES and their contexts by listening to them, the system is made as an android application on a tablet with an intimate user interface. In this paper, we describe the system and analyze its use by an experiment.

2 Related Works

There are some reports on the ES training. Sharo [2] carried a training of ES to cochlear implanted (CI) children and found the improvement in recognizing ES. ES was used as one of the training material types by Loebach's [3]. Since the main purposes of the both training were to find out the effect of the training itself as a step of experiments, their training gave the intimate interface or fun to use of a training system less consideration. Also the subjects of their training were CI children. Though our system has also the purpose of train the recognition of ES, one of the focuses is to make DHH children either with CI or hearing aids spontaneously play the system with joy. Besides, our system tries to promote understanding the context accompanying ES.



[Fig. 1] Main screen

In order to train ES recognition, researchers need comprehensive, high quality, accessible database of ES [4], [5]. Since ES around the human are related to everyday life activities, the ES database was designed to include the contextual, semantic, and behavioral information [4]. As will be described in the next section, we chose the kind of ES to be used in the system from the result of questionnaire to DHH college students.

3 System

The system provides a set of sounds that small children may encounter in everyday life in three situations:

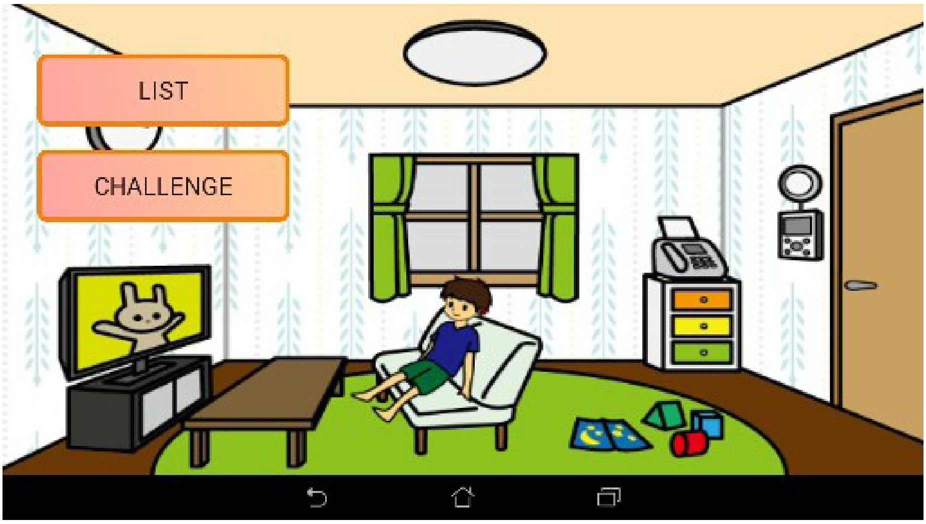
1. at school,
2. at home (a living room), and
3. outside.

Figure 1 shows the main screen of the application.

The set of sounds used in the system was chosen after showing DHH college students a list of ES and then asking them which sounds were important to know. Also, we added some sounds not included in the list but that students thought were important. Altogether the system includes 21 kinds of sounds.

For each sound, we prepared three descriptions of context – two of which were appropriate while one was inappropriate. For example, for the sound of chopping up vegetables, the three descriptions of context are a) What can I eat for dinner?, b)Mom uses a knife, and c) The faster the chopping, the tastier the dish, where c) is not suitable.

A user starts by selecting the scene from the three situations in Figure 1. For example, if a user chooses home in Figure 1, the user is asked to select either List or Challenge as in Figure 2. In Challenge, the user answers the type of sound after listening to it. After answering the quiz correctly, the user is asked to learn the context of the sound. In List, the user skips the quiz but just listens to the sound, and directly proceeds to the context understanding. The system runs on Android version 4.4 and above.



[Fig. 2] Choose the type of sound to listen to

4 Experiment

We conducted experiments with nine elementary school students with hearing loss altogether. Five are in mainstreaming education, while four are at a special school for DHH. The purpose of the experiment is to find out how DHH students use the application and what sounds and contexts they understand and misunderstand. We explained the application, handed a tablet to each student, let them practice the system for a short time, and asked them to use it freely for ten to fifteen minutes.

5 Results

We analyzed log data of using the application. We call a user's listening to a sound in Challenge or List and learning its context a "session". The nine students tried 136 sessions. They used Challenge for 71 sessions and List for 65. The duration of a session was from 12 to 102 seconds. The average duration was 30.5 seconds. All of the 21 kinds of sounds were at least once heard in the whole sessions.

Three students liked to play Challenge while others mainly listened to sounds in the List. Some students in the former group moved hands expressing signs accompanying the sound. Some in the latter group repeatedly selected sounds in the same category. Though there were fewer misunderstandings of the sounds when subjects played Challenge than we had expected, six of the nine students misunderstood sounds. There were two students who misunderstood the sound of the storm for that of running cars.

Moreover, only one student completely answered the context-understanding questions correctly. Some of the students could not correctly answer the context questions for the sounds which they might listen to them often in everyday life, such as an ambulance and a washing machine churning.

The results of the post questionnaire were as follows:

- "Do you think your understanding of ES was improved by using the system?" Eight kids answered "Yes".
- "Did you find ES that you wanted to understand in the system?" The number of answers of "Yes, there were many", "So so", and "No" were all three respectively.
- "Do you think the system was useful?" Nine kids answered "Yes".
- "Do you like to use the system after this?" Nine kids answered "Yes".

6 Discussion

We observed in the experiment that sound learning with a tablet let students voluntarily learn by their own tablet-operation and multimedia response. Thus, the tablet application could be a solution when teachers for DHH students lack time to teach environmental sounds to DHH students. Learning the context was not provided in similar past education material. Since some students chose the incorrect context, in which we imagine they act in accordance with their misperceptions, this application is helpful in not only understanding sounds themselves but also the accompanying situation or action when the sound is heard.

A future challenge will be to generalize the sound and context understanding by DHH students by having them repeatedly use the application with specic sounds.

Reference

[1] Liu, S.-Y.; Liu, T.-C.; Teng, Y.-L.; Lee, L.-A.; Lai, T.-J.; Wu, C.-M. Environmental Sounds Recognition in Children with Cochlear Implants. *PLoS ONE*. 2013. 8(6), p. e66100. DOI 10.1371/journal.pone.0066100.

[2] Sharo, V.; Sheft, S.; Kuvadia, S.; Gygi, B. Environmental sound training in cochlear implant users. *Journal of speech, language, and hearing research*. 2015. 58(2), p. 509–19.

[3] Loebach, J. L.; Pisoni, D. B. Perceptual learning of spectrally degraded speech and environmental sounds. *The Journal of the Acoustical Society of America*. 2008. 123(2), p. 1126–1139.

[4] Gygi, B.; Sharo, V. Development of the Database for Environmental Sound Research and Application (DESRA): Design, Functionality, and Retrieval Considerations. In *EURASIP J. Audio, Speech and Music Processing*. 2010. Available in URL <http://dblp.uni-trier.de/rec/bib/journals/ejasmp/GygiS10>.

[5] Zhang, K.; Maekawa, T. Gamification based Participatory Environmental Sound Collection Framework for Human Activity Recognition. 2013-HCI-155(2), 1–8, 2013-10-29 (IPSJ SIGHI).

A Complete Environment for Deaf Learner Support in the Context of Mainstream Education

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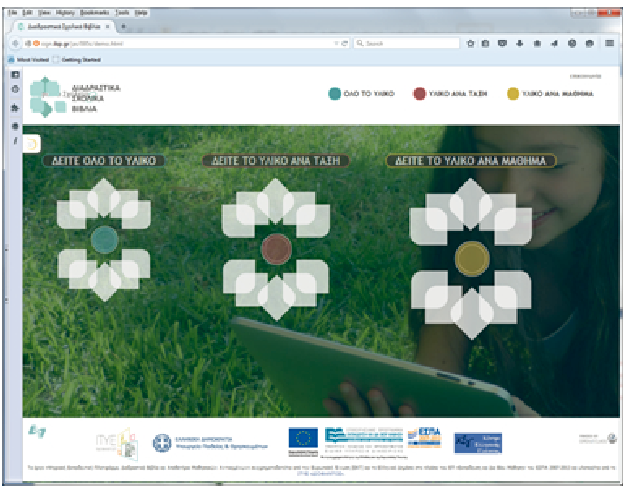
Keywords: accessibility, deaf education, learning, GSL, signing avatar, multimedia resources

1 Introduction

Accessibility of electronic content by Deaf WWW users is directly connected with the possibility to acquire information that can be presented in a comprehensible way in their native SL and also with the availability of ways to create new electronic content, comment on or modify and reuse existing "text" [1]. Sign Language (SL) authoring tools, in general, belong to rising technologies that are still subject to basic research and thus not widely available to end users. However, when such tools, along with tools that improve accessibility by Deaf users of written material [2], are integrated in platforms providing educational content that addresses basic curriculum needs of mainstream education, they increase considerably the participation of deaf individuals in classroom activities and they enhance the educational process. This is because, on the one hand, it is widely recognized that most Deaf individuals face reading difficulties, and on the other hand, the composition of synthetic sign phrases may facilitate communication over the Internet [3], [4], and it can also be decisive for the inclusion of Deaf participants in group work, allowing direct participation and dynamic linguistic message composition, similarly to what hearing individuals do when writing.



[Fig. 1] The platform's homepage; clicking on the signing hands graph at the bottom left corner initializes the integrated SL accessibility toolkit

In the sections that follow we present how a set of tools which enable content accessibility as well as student-student and student-teacher interaction via sign language have been integrated at the official educational content platform of the Greek Ministry of Education for the primary and secondary education levels (Fig.1).

2 Integrated tools: specifications

2.1 Functional specifications

The integrated tools entail:

1. A bilingual dictionary for the language pair Modern Greek (MG) – Greek Sign Language (GSL), linked with the textbooks uploaded in the platform, that enables unknown word search by:
   - double clicking on the encountered unknown words while reading
   - typing the search item in a search box
   - providing search input by means of a virtual fingerspelling keyboard.
2. A dynamic sign phrase synthesis tool [3], which allows composition of signed content on the fly, according to the platform users' communication needs and makes use of a signing avatar to represent the instantly created content.
3. A virtual fingerspelling keyboard of the Greek alphabet characters and the digits 0–9 that enables search and representation of proper names and various number formations via the set of handshapes corresponding to alphabet characters and digits, thus, facilitating accessibility and learning of primarily named entities in all subject areas in the curriculum – from History and Geography to Biology and Mathematics.
4. To further facilitate presentation and reuse of SL content, a link to the multilingual SL resources of the Dicta-Sign FP7 project is also available[1].

2.2 General characteristics

In the user interface, the initialization of the integrated services is done through the use of help buttons of appropriate shape and size, while colour code conventions and pop-up windows for information or interaction purposes have been employed so as to ensure that the services are friendly to deaf and hard of hearing users. Moreover, video tooltips are available in GSL in the form of help menus in all stages of use within the Deaf accessibility mode.

The integrated services are initialized by the user and are provided as Add-Ons while browsing through the "Photodentro" (Φωτόδεντρο) and "Digital Educational Content" (ΨΕΠ) educational platforms, while the bilingual lexicon can also be used as a means of educational content accessibility (by double clicking on any word).

2.3 Technical specification

The integrated tools are run through a web browser with the help of java applets, while

1 http://www.sign-lang.uni-hamburg.de/dicta-sign/portal/

currently Mozilla Firefox, Chrome and Internet Explorer are supported. Operating systems supported are Microsoft Windows (XP or above) as well as Mac OS X with Safari browser.

3 Bilingual Dictionary: Modern Greek-GSL

While browsing through any digital educational text uploaded on the supported educational websites, the deaf or hard of hearing user may seek explanation in GSL for any word present in the text. The unknown word is being selected and is then checked against the system's lexicon of signs by any of the methods described in 2.1 above, while the use of the search box may also exploit a "copy-paste" procedure to enter a specific query (Fig. 2). The unknown word is been sought in the database of correspondences between written lemmas of Modern Greek and the respective GSL sign, and if found, the user is provided with information regarding the video lemma representation in GSL, examples of use and related synonyms linked to each sense or expressions linked to each lemma.

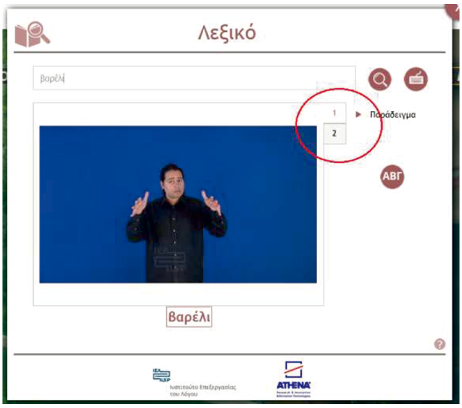
The task to be executed, however, is by no means trivial, since in many cases the morphological form of a word in a text differs considerably from the form associated with a headword in a common dictionary, especially in languages with very rich morphology like MG. Thus, the successful execution of a given query demands an initial processing step of morphological decomposition of the selected word prior to its correct association with the corresponding lemma entry in the bilingual dictionary.

[Fig. 2] Presentation in GSL of unknown lexical content from educational material as a result of double clicking on the unknown item while reading

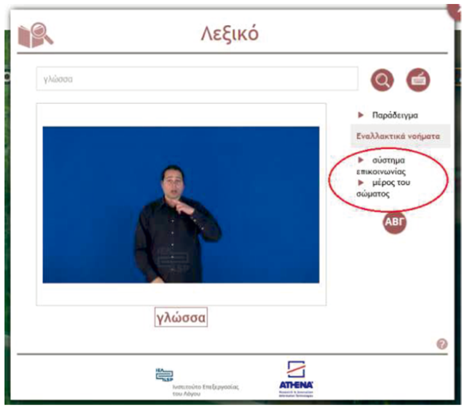
Hence the search procedure entails morphological queries for any given input word while it also takes into account any grammatical/semantic differentiation among lemmas in order to filter the search results as e.g. in the case of stress position in word sets («θόλος» [th'olos] – «θολός» [thol'os]) or semantic differences between two morphologically different types of the same word (e.g. «αφαιρώ» [afer'o] – «αφηρημένος» [afirim'enos]).

The dictionary that supports the accessibility of text material currently entails approximately 10,000 bilingual entries (MG-GSL).

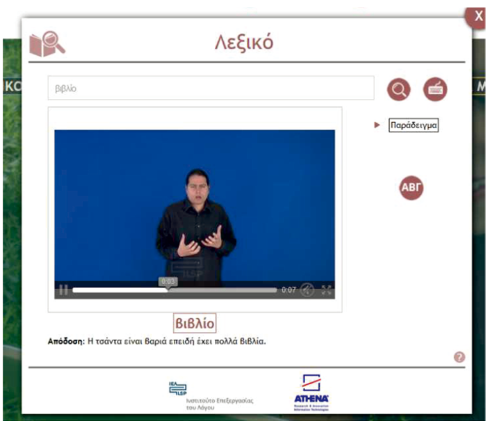
When the use of the dictionary is selected as a standalone platform tool, the user may also employ the alphabetically ordered search option. In all cases, the information provided incorporates presentation of the different senses and/or GSL synonym signs with which a MG lexical equivalent may be associated, as well as examples of use for each sense and/or sign available as well as related expressions for each lemma (Fig. 3a, 3b, 3c, 3d).



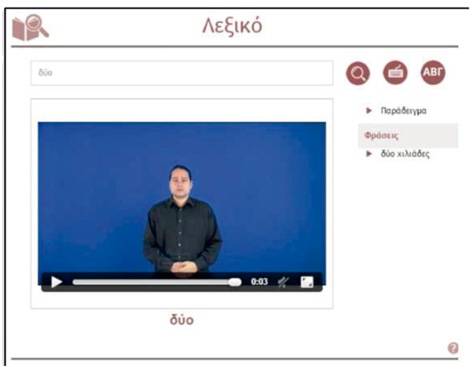
[Fig. 3a] The search result provides two synonyms in GSL.



[Fig. 3b] The search result indicates two senses related with the search string.



[Fig. 3c] Example of use in GSL and Modern Greek.



[Fig. 3d] The search indicates the existence of a related expression.

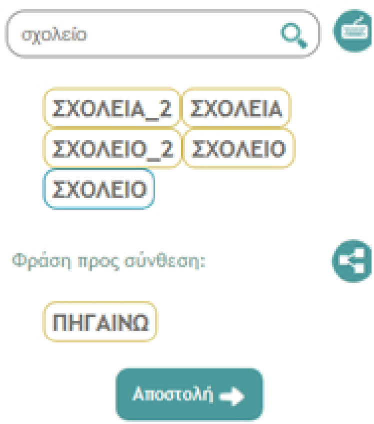
4 Dynamic Sign Synthesis Tool

Sign phrase representation is being performed via a virtual signer through the use of a java applet which runs in the web browser. The user selects the components of the phrase to be synthesized among the available lexical items that are appropriately coded for synthesis (namely, that contain information not visible to the user yet important for synthetic representation). The user interface is designed so as to allow for different word orderings of the phrase to be synthesized, while the signing phrase may consist of up to four components.

Composition of new synthetic sign phrases results by selecting the desired phrase components from a list of available, appropriately annotated lexical items [5], [6]. The HamNoSys notation system has been used for the phonological annotation of sign lemmas, along with features for the non-manual activity present in sign formation, while the UEA avatar engine [7] has been used to perform signing.

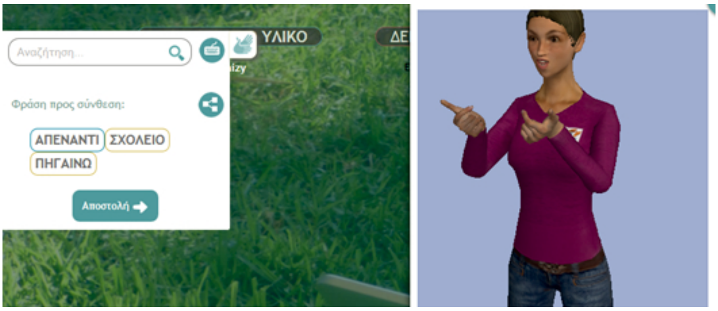
End users interact with the system via a simple search-and-match interface to compose their desired phrases (Fig. 4a). Phrase components are marked by different colour frames that indicate which items in the phrase are signed and which are fingerspelled. The user selects the desired element by clicking on it and the respective GSL gloss is then included in the sign stream/phrase to be performed by the avatar (Fig. 4b). In case a word is not present in the synthesis lexicon, the user is provided with the option to fingerspell it.

During the selection of the components of the phrase to be synthesized, the search results may provide options to choose among as in the case of possible GSL synonyms (e.g. for the lemma "school" (= σχολείο) there are coded synonyms in GSL [ΣΧΟΛΕΙΟ] and [ΣΧΟΛΕΙΟ_2] in Fig. 4a) or other "close" types to the desired lemma (e.g. plural formation for each GSL synonym [ΣΧΟΛΕΙΑ] and [ΣΧΟΛΕΙΑ_2] in Fig. 4a).



[Fig. 4a] The sign phrase synthesis box and the signing avatar used for SL content presentation

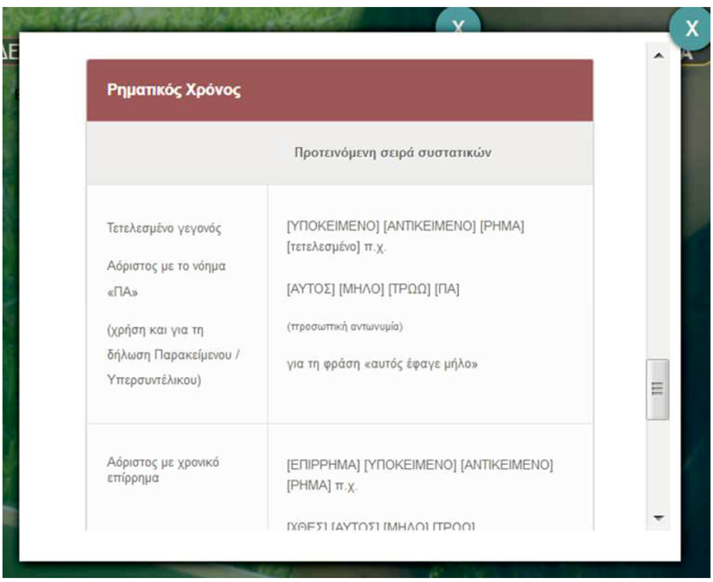
A drag-and-drop facility, first demonstrated in the Dicta-Sign sign-Wiki [8], allows ordering of phrase components so as to create grammatical structures in GSL. Verifying user choices is important at any stage of this process, so that users can be certain about the content they are creating. When the structuring of the newly built signed phrase is completed, this phrase is performed by a signing avatar for final verification.



[Fig. 4b] The sign phrase synthesis box and the signing avatar used for SL content presentation

Most importantly, the sign synthesis tool may also be used by SL illiterate individuals. Thus, a template based GSL grammar guide is incorporated in the sign synthesis environment to help non-signers compose grammatically correct GSL utterances (Fig. 5).The GSL grammar guide presents in tabular word order information as well as grammar/ syntax elements of the basic structures in GSL and language-specific characteristics for the formation of phrases for each phenomenon.

Beyond the obvious utility of the sign synthesis environment for the creation of SL educational/test material and the opportunity of deaf students to make queries or respond in their native language [9], since the platform is used by teachers and students across the country, it has been important to enable communication in all directions in the mainstream school environment also providing non-signers with the option to compose messages in GSL in order to communicate with their Deaf schoolmates or students.

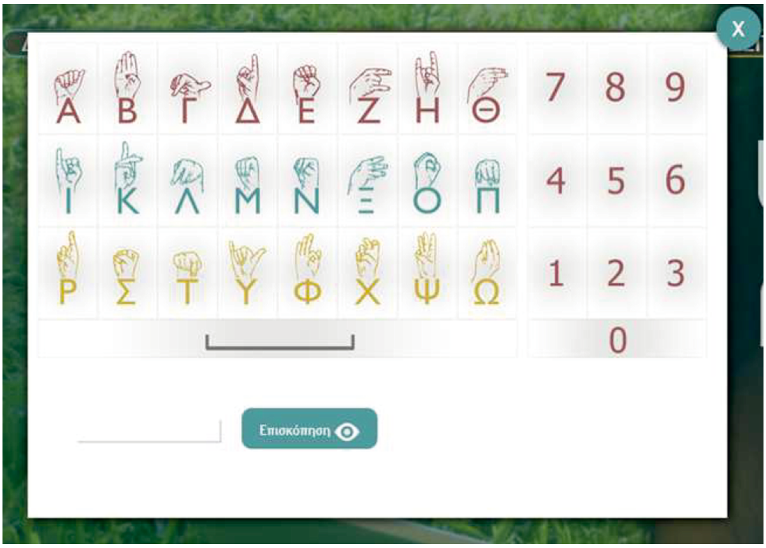


[Fig. 5] Template based GSL grammar guide

5 Virtual Fingerspelling Keyboard

The fingerspelling keyboard comprises a set of virtual keys that correspond to the fingerspelling alphabet of GSL. Each key depicts the handshape that corresponds to each letter of the alphabet, whereas the digits 0–9 are also included. Hence the user can select a sequence of preferred handshapes that correspond to the desired alphanumeric string, while on the screen he/she can visually inspect the selected sequence being fingerspelled in GSL.

The tool can either run as an external service (Fig. 6) or be interconnected with the lexicon and the dynamic sign synthesis tool as a string input mode of data (i.e. lemmas). Such tools allow for fingerspelling of proper names and can generally support deaf users while inserting data of the type names, numbers etc in web forms. The user interface provides help in GSL in the form of a video tooltip.



[Fig. 6] Fingerspelling keyboard

6 Conclusion

The emerging technology of sign synthesis opens new perspectives with respect to the participation of Deaf learners in Internet-based school activities. It also creates a completely new profile of student-instructor interaction. Initial trials of the entire suite of accessibility solutions proposed here verified their positive acceptance by end users in Deaf school environment. However, much remains to be done both as regards technology enhancement and language resources creation. Especially in respect to resources, the creation of terminology lists for all curriculum items is a critical parameter towards real inclusion and the enhancement of equal opportunities in education.

Acknowledgement
The research leading to these results has received funding from the POLYTROPON project (KRIPIS-GSRT, MIS:448306). Part of the technologies and resources developed within the project have been implemented in deaf accessibility aids of the platform developed in P61, MIS: 298759.

References

[1] Efthimiou, Eleni; Dimou, Athanasia-Lida; Fotinea, Stavroula-Evita; Goulas, Theodore; Pissaris, Michalis. SiS-builder: A Tool to Support Sign Synthesis. In *Proc. of the Second International Conference on the Use of New Technologies for Inclusive Learning*, p. 26–36. York, UK. 2014.

[2] Fotinea, Stavroula-Evita, Efthimiou, Eleni. Tools for Deaf accessibility to an eGOV environment. In *K. Miesenberger, J. Klaus, W. Zagler, A. Karshmer (Eds.) ICCHP 2008. LNCS, vol. 5105*, p. 446–453. Springer, Heidelberg. 2008.

[3] Efthimiou, Eleni; Fotinea, Stavroula-Evita; Goulas, Theodore; Dimou, Athanasia-Lida; Kouremenos, Dimitis. From Grammar Based MT to Post-processed SL Representations. *Universal Access in the Information Society (UAIS) journal*. Springer, (DOI 10.1007/s10209-015-0414-3), 2015.

[4] Schnepp, Jerry; Wolfe, Rosalee; Mcdonald, John. Synthetic Corpora: A Synergy of Linguistics and Computer Animation. In *Proc. of 4th Workshop on Representation and Processing of Sign Languages: Corpora and Sign Language Technologies, (LREC-2010)*, p. 217–220. Valletta, Malta. 2010.

[5] Hanke, Thomas. HamNoSys – representing sign language data in language resources and language processing contexts. In *Proc. of 1st Workshop on Representing and Processing of Sign Languages (LREC-2004)*, p. 1–6. Paris, France. 2004.

[6] Neidle Carol. SignStream™: A Database Tool for Research on Visual-Gestural Language. In *B. Bergman, P. Boyes-Braem, T. Hanke, E. Pizzuto (Eds.), Sign Transcription and Database Storage of Sign Information, special issue of Sign Language and Linguistics 4, 1*, p. 203–214. 2002.

[7] Glauert, John; Elliott, Ralph. Extending the SiGML Notation – a Progress Report. In *Second International Workshop on Sign Language Translation and Avatar Technology (SLTAT-2011)*, Dundee, UK, 2011.

[8] Efthimiou, Eleni; Fotinea, Stavroula-Evita; Hanke, Thomas et Al. The Dicta-Sign Wiki: Enabling Web Communication for the Deaf, In *K. Miesenberger, A. Karshmer, P. Peňáz, W. Zagler (Eds.) ICCHP 2012, Part II. LNCS,* vol. 7383, p. 205–212. Springer, Heidelberg. 2012.

[9] Efthimiou, Eleni; Fotinea, Stavroula-Evita; Goulas, Theodore; Kakoylidis, Panos. User friendly Interfaces for Sign Retrieval and Sign Synthesis. In *M. Antona, M. & C. Stephanidis (Eds.). Proc. of the 9th International Conference, UAHCI 2015, Part II, held as Part of HCI International 2015*. Los Angeles, CA, USA, August 2–7, 2015, LNCS vol. 9176, p. 351–361, Springer, Heidelberg. 2015.

Evaluation of Mathematical Information Created by a Text-Based Communication Tool for Visually Handicapped

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Keywords: Visually Handicapped non-visual user interface

Abstract

Our target documents are related to elementary geometry and include some graphical elements. These graphical elements cannot be ignored since some important concepts are directly related to such elements. We develop software tools to create text-based documents and express the contents for visually handicapped people. The expression software is for visually handicapped people, and the creation software is for their support staff. We describe the outline and also evaluate the confusion ratio of the documents and the usability of the system.

1 Introduction

We are attempting to develop an input and expression system for the mathematical content in elementary geometry [2]. We assume a case in which the receiver is visually impaired and the supplier is his/her support. Note takers are the standard support staff for hearing-impaired students. They obtain information elements that is provided verbally. These are translated into hand-written texts or text information created by some software tool for support. In any case, the task is not easy; however after considerable training, such support can be provided without any significant problems. Visually impaired students also need some immediate support for obtaining visual information. However, it is very difficult to provide visual information immediately by using nonvisual expression methods. Hence, we need some software tools to create and express visual information in such situations.

Figures in mathematical documents are presumed to be major barriers in communication for people with visual disability. Our long-term aim is to create a useful system for real-time support for visually impaired students. In particular, in a document related to elementary geometry, important concepts and properties are often expressed by using some elements of figures. However, the translation of these elements to nonvisual information elements is very difficult and the information contained in complicated documents is difficult to express by nonvisual expression methods. Hence we need some detailed consideration for mathematical documents related to elementary geometry.

We have created software tools for the creation of text-based documents and for the expression in voice. We assume that visually handicapped students will use the expression tool, their supports will use the creation tool, and that the students have an understanding of graphic elements. We will give some evaluations in terms of the difficulty levels of documents, and usability of the software through questionnaire survey results for sighted people with an eyemask.

2 Format of the Document

We describe mathematical documents using XML rules. In this section, we explain our rules of XML expression for mathematical documents with figures.

2.1 Tags and attributions

The following table shows a list of tags and attributions for our expression rules.

[Table 1] Tags and Attributions

Mnemonic	Meaning	Type
InfoBody	Totality of document	
GrElm	An element in the gure	
TextElm	An element in the text	
DispPt	point of display	
Center	circle center for display	
id	Identier	integer
etype	Type of element	string
ename	Short name	string
refId	Id of a link target	integer
pos	position of a point	2-dim. vector
radius	radius of a circle	real number

“InfoBody” is a tag for one XML document, that is, there is one “InfoBody” in an XML file. “GrElm” is a tag for a graphical element and “TextElm” is a tag for a text element. For the expression of the position of points, we use “DispPt.” Every XML element, with tags “GrElm” or “TextElm,” has an unique id number and this is expressed by using “id.” Usually an XML element has a name and is defined by using “ename.” In the case where an element is already defined, an attribution “refid” is defined instead of “ename.” There are 20 types of graphical elements and 9 types of text elements. These are expressed by using string attribution “etype.”

2.2 Rules for General Elements

An XML element consists of start and end tags, several subelements, and a string element. We add a rule that a string element must be in front of the subelements. In the case where there are no string element and subelements, an end tag remains. Then, the tag starts with “⟨“ an ends with “/⟩.”

2.3 Rules for Graphic Elements

For a graphic element, we have to define the attribution “etype.” There are 9 types of polygons, “Triangle,” “Square,” “Rectangle,” etc. To determine the position, we define the coordinates of vertices by using the tag “DispPt.” Each “DispPt” element has one attribution “pos.” For example, this element is defined as “〈 DispPt pos=“(1.5, 3.5)” /〉.”

For a “circle” element, we have to define “Center”; moreover for a “circle,” “Center” must include attribution “radius.” For an “arc” or a “sector” element, we have to define the “Center” element and two “DispPt” elements.

2.4 Rules for Text Elements

For a text element, we also have to select the attribution “etype” among 9 text types: “Definition,” “Property,””Explanation,” etc. Usually, a main part of the element is the verbal explanation. This string element must be in front of other subelements.

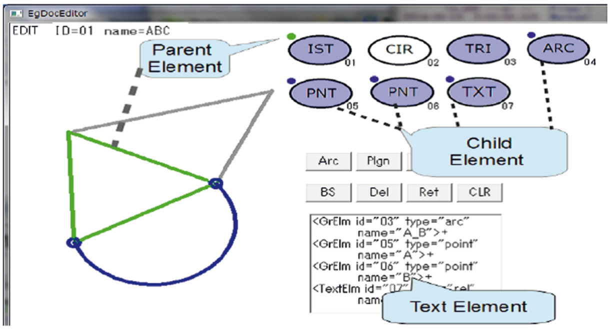
In the text document, links to a graphical element are expressed using the string “[@??]”, where “??” is replaced by the corresponding id number. When we describe that “Triangle ABC [@02] is congruent to Triangle ABE [@05].”, we can obtain associated properties or elements with respect to these triangles.

3 Software Tool for Creation of Documents

In this section, we explain how to create XML documents using our software tools. We input graphical elements using a mouse as follows.

1. A point is input by a click of the left button.
2. If another point has already been input, a line segment connecting the new point with the previous point is input.
3. Moreover, if the new point is the same as the first point of the polyline, a polygon is input.
4. A circle is input using the mouse drag operation. The starting point is the center and the end point is on the circle line.
5. After an input of one point, an arc or a sector can be input by using a mouse drag (The first point is the center, and the range is determined by the drag).
6. Just after the line segment is input, this can be transformed into an arc by a drag operation with the start point on the line.
7. During the input of an arc, its center point appears. By clicking at the center, we can create a sector.

We input text elements using a text box in the system.



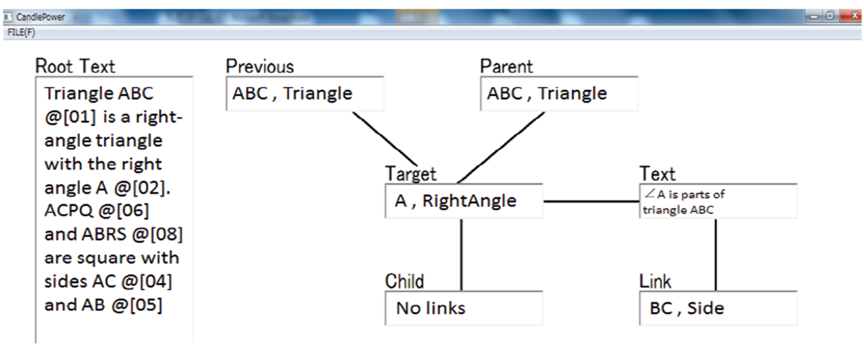
[Fig. 1] Input Tool

4 Software Tool for Expressing Documents

We developed a software tool for creating text documents. However, our documents are not sufficient for the visually handicapped. In this section, we explain our expression tool.

4.1 XML file corresponding to the System

First, the system loads an XML file. Then, seven text boxes are filled with some strings. In the "Root Text," the system sets the string element for the root element. In each of the text boxes, "Previous," "Parent," "Target," "Child," or " Link," the system inputs the corresponding string attributions, "name" and "type," if applicable. The link element is the element corresponding to the id number expressed as "[@??]", which is a string element (see subsection 2.4) in the text box "Target." There are several link elements or child elements in general, and the name and type of the first element is listed in the corresponding text box. The user can change an element by a push of a key (see Table 1). In a similar manner, using several key push buttons, the user can control the document and obtain the contents by voice output.



[Fig. 2] Software Tool for Expression

The large text box on the left is the "Root Text." A brief explanation of the whole document or a list of the contents should be provided in the root element. Non-browsability is a major demerit in nonvisual communication. Hence, this part is the most important part for our system. The text box on the right of "Target" is "Text." In first step, the first line of the string element of the target element is listed. This string line can be replaced by other lines using the up and down arrow keys along with "SHIFT." The text box under "text" is link. To jump to a linked element in a string element, we use the down arrow key along with "CTRL." In the case where the linked subelement has attribution "refId," the target element is replaced by the element corresponding to this number ("id" of the element equals "refId").

4.2 System Operation and Keystroke

As this software tool is developed for the visually impaired, the main operations are controlled by a key push (see Table 2) and the voice outputs of the contents are also controlled by a key push. By using a screen reader, some basic tasks can be performed without screen output (for example, load a file, exit the system, and so on). These may not be easy to perform when accessing a text document in our system. We assign our main functions to keystrokes for quick and convenient use of our system. Table 2 lists these keystrokes.

[Table 2] Key Functions

Key	Action	Key	Action
→	Next Child Element	A	Voice output of Target Name-type
←	Previous Child Element	Q	Voice output of Parent Name-type
→ + SHIFT	Next Link in Text	Q+SHIFT	Voice output of Previous Name-type
← + SHIFT	Previous Link in Text	Z	Voice output of Text (One Line)
↓	Change to Selected Child	W	Voice output of Selected Child
↓ + SHIFT	Next Line in Text	W+SHIFT	Voice output Selected Link
↓ + CTRL	Change to Selected Link	R	Voice output of Root Text
↑	Change to Parent Element		

5 Confusion Evaluation of the Document

"What part of the document is hard to understand?" is an important question to consider for the improvement of the document. Our system provides methods for the creation and expression of a mathematical document related to elementary geometry, the extent to which it is understood is another problem. In this section, we describe a method to evaluate the level of difficulty in understanding the document.

In this study, we assume that a sighted person creates the document. Hence, estimating the understandability of the visually handicapped is not easy and we require an automatic evaluation method for this evaluation. In our previous study [1], we proposed a semi-automatic evaluation method for estimating the difficulty level of the document. We call the evaluation value of the level of difficulty the "confusion ratio." In the previous method [1], we need to add some data corresponding to the complexity of contents of an XML document. We improve the method and can estimate the level of difficulty without requiring any additional contents in the new method.

5.1 Questionnaire Data for the Confusion Ratio

We use the questionnaire data given in our previous study [1]. There are 3 subjects for this survey. All of them are University students (sighted persons). They pointed out elements for which some additional explanation was required. The desired value of the "confusion ratio" is

$$\text{Confusion Ratio} = \frac{\text{Number of people who need an explanation}}{\text{Total number of people}}. \quad (1)$$

We prepared three mathematical documents for the questionnaire survey. These were the proofs of "the theorem of the circumferential angle," "the pythagorean theorem," and "the power of point theorem." There are some gures in the document and it may be difficult to understand the proofs without them.

5.2 Evaluation Method of the Confusion Ratio

In this subsection, we define the feature values extracted from a document and determine an adequate confusion ratio using the feature values. The confusion ratio is defined for each graphical element. The feature values are calculated for each graphical element and we define the "confusion ratio" as a linear function of the feature values. Its coefficients are determined by linear regression and we use the questionnaire data for this regression. We define three feature values: "Dimension," "Complexity," and "Generation." "Dimension" is defined to be 1 + geometrical dimension. For a point element, the feature value "generation" is defined as follows:

1. Generation value of a point in the base element is 0.
2. For a target element, the base generation value is the maximum value of a known generation value.
3. Each generation value of another point is the base generation value +1.

Then, the generation value of an element is maximum of the generation values of all sub-point elements.

We use the new values, "alternative point," "freedom coefficient," and "firmness," for the definition of complexity. We define the value "alternative point" based on whether the existing uncertainty factor lies outside the coordinates of the point or not. For example, if a vertical line AB is on one side of a square, then it is uncertain whether a point on this square is on the right or left side of the line AB. Based on whether the uncertainty factor exists or not, the value is 1 or 0.

The value of the "freedom coefficient" is defined as follows:

1. In a case where the points are completely fixed, the degree is 1.0.
2. If the point can move on a line (a straight line, an arc, etc.), then the degree is 0.8.
3. For other cases, the degree is 0.6.

The firmness of an element is defined as follows:

1. The firmness value of a point in a base element is 1.
2. For a target element, the base firmness is the minimum value of the known firmness values of the points in the element.
3. Unknown firmness values are defined as "freedom coefficient × base firmness."

Then, the "complexity" is defined by

$$\text{Complexity} = \frac{1}{0.2 \times \text{alternative point} + 0.8 \times \text{freedom coefficient} \times \text{firmness}}$$

Among the elements given in the questionnaire, we use 12 elements for training data, 12 elements for test data, and Table 3 shows the regression results.

[Table 3] Linear Regression for the Confusion Ratio

Element Number	Graphical Information	Confusion Ratio	Regression Value	Error Value
1	On the Circumference	15%	14%	1%
2	Triangle	15%	33%	18%
3	O	30%	9%	21%
4	AB	67%	58%	9%
6	∠ APB	59%	60%	0%
7	∠ AOB	26%	38%	12%
8	APB	63%	58%	5%
11	P	22%	29%	7%
12	Q	67%	64%	2%
17	△ AOP	44%	55%	10%
18	∠ AOQ	78%	75%	2%
19	∠ AOP	52%	56%	4%

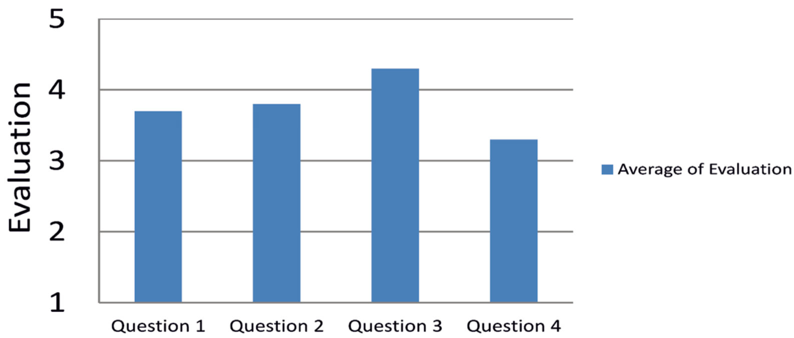
6 Evaluation of Usability

We carried out a questionnaire survey for 10 people to evaluate the system usability. Each test subject is a student of the Kyushu Sangyo University. First, a collaborator wore an eye mask and used the expression system. After that they replied to the following question by selecting a value from 1 to 5 (higher the number, better the evaluation).

- Q1. Is the system easy to use?
- Q2. Can you understand the voice Output?
- Q3. In terms of the relations between pairs of graphical elements, can the system appropriately express the situation?

- Q4. Are information elements provided by the voice output sufficient?

Figure 3 shows the system evaluation result.



[Fig. 3] System Evaluation

7 Conclusion

We developed software tools for the creation and expression of mathematical documents in elementary geometry to support visually handicapped people. We improved system and extraction feature as compared to previous studies and evaluated the usability of the system.

References

[1] Fukuda, R.; Toyosaka, Y. Text-Based Communication Tool for Mathematical Documents for Visually Handicapped. In *Proceedings of the 20th Asian Technology Conference in Mathematics*. 2015.

[2] Fukuda, R.; Kojo, M. Graphic Input System in Elementary Geometry for Nonvisual Communication. In *Proceedings of the 19th Asian Technology Conference in Mathematics*. 2014.

[3] Fukuda, R.; Miura, A. Ubiquitous Mathematical Graphic Viewer for Visually Impaired Students. In *Proceedings of the 16th Asian Technology Conference in Mathematics*. 2011.

The Journey of Making Information for Learning Accessible for All

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Keywords: Accessibility, Accessible Information, Education, Guidelines, Human Rights, ICTs Learning for All

Abstract

In 2013, 6 organisations joined forces to develop the Guidelines for the Implementation of Information Accessibility for Learning aiming to support practitioners in their production of accessible information for learning. This project was supported with funds of the European Commission. This article describes the journey towards the Guidelines, beginning with the key arguments for their relevance and importance, and continuing with how they were developed to be as universal as possible and adaptable to context and a rapidly evolving environment. In addition to the development process, examples of concrete activities undertaken are shared, and an outlook given on the foreseen impact of the Guidelines as they continue to be widely disseminated and systematically used.

1 Introduction

Today's knowledge societies require lifelong learning and request inclusiveness. Regional and international organisations and national governments identify these aspects as key for sustainable development. The United Nations 2030 Agenda for Sustainable Development [1], adopted by world leaders in September 2015, includes "17 Goals to Transform our World", with one on Education (Goal 4): "Ensure inclusive and quality education for all and promote lifelong learning". Inclusiveness and lifelong learning are identified as important to positively transform our world. It even points out that inclusiveness must be for all. This raises the issue of the meaning of inclusiveness for education practitioners and policy makers and explains the use of the clearer notion of accessibility for all in both the title of this article and the project it describes.

Knowledge societies must rest, according to UNESCO, on four pillars: freedom of expression, universal access to information and knowledge, respect for cultural and linguistic diversity, and quality education for all. Universal access to information and knowledge is not a reality for many reasons, such as copyright and costs, but also a lack of awareness. Many see the spread of information and communication technologies (ICT) at all levels of learning as a chance to address this issue. One objective of the European Commission's "Opening up Education" programme [2] is to "increase equity – knowledge more accessible to all, and individuals getting access to new learning opportunities" by capitalising on the digital revolution's benefits.

The main objectives of the ICT for Information Accessibility in Learning (ICT4IAL) project were to provide a tool to help education practitioners provide learning content that is more accessible to all and help people with disabilities pursue education at all levels, when and if they need it, thanks to the use of ICT.

It was a multi-disciplinary network of European and international partners representing learning and ICT communities. The European Commission co-funded the network under the Lifelong Learning Transversal Programme, Key Activity 3: Information and Communication Technologies. The project took place from 2013–2015.

Throughout the project, the European Agency for Special Needs and Inclusive Education (EA), European Schoolnet (EUN), the International Association of Universities (IAU), United Nations Educational, Scientific and Cultural Organization (UNESCO), the DAISY Consortium (DAISY) and the Global Initiative for Inclusive ICTs (G3ict):

- raised awareness and increased the visibility of the issue of accessible information provision and its relevance for equitable lifelong learning opportunities;
- supported accessible information provision by developing, trialling and evaluating guidelines to help practitioners provide accessible information.

2 Rationale

Effective participation in lifelong learning requires the ability to access relevant information for and about education. Inaccessible information creates barriers that potentially affect over one billion people with disabilities worldwide. [3]

Accessibility is an underlying premise of the UN Convention on the Rights of Persons with Disabilities (UNCRPD) [4], which outlines State Parties' obligation to "provide accessible information to persons with disabilities" (Art. 3 and 4) and calls for "the design, development, production and distribution of accessible information and communications technologies and systems" (Art. 9). This clearly implies that accessible information is vital for education and learning.

The UNCRPD has increased debates on critical issues regarding equal access to information to all – especially in education. The justifications for this concern are clear not only at international level, but also at European level. The European Commission study *Measuring Progress of eAccessibility in Europe* [5] shows that there is still a disparity between current accessibility policies and their practical implementation. In addition to the UNCRPD and the Digital Agenda for Europe, organisations working in the field of lifelong learning must comply with numerous policy initiatives – including legally binding documents – relating to accessibility issues.

The 2011 Monitoring eAccessibility Consortium study [6] notes: "despite the policies implemented over the past decade, the overall level of eAccessibility remains quite low" (p. 19). Digital literacy and e-accessibility are key factors in supporting access to lifelong learning; access to information is not only a factor in equal opportunity in education, but also in wider social inclusion. Crucially, these factors underpin individual learners' opportunities to access information about lifelong learning.

During this time of technical innovation, anyone can potentially be an author of information that is used for learning, but not everyone is an expert in making information accessible. However, it is important for everyone to be aware that information may be inaccessible to different users, depending on how it is presented.

Key information providers within lifelong learning – such as the ICT4IAL project partners – need clear guidance on translating policy (e.g. Council Conclusions on an Accessible Information Society, 2009) and standards (e.g. Web Content Accessibility Guidelines 2.0 relating to information accessibility) into practical tasks for implementation that use innovative ICT solutions in a sustainable way.

The ICT4IAL network partners are all international-level information providers for education and/or ICT which have faced and considered these issues in differing ways within their work and based on their mission.

IAU members, for example, adopted a policy statement on Equitable Access, Success and Quality in Higher Education in 2008 [7] that states: "Equitable access and broadening participation in higher education are fundamental to 'knowledge societies' in all parts of the world. The International Association of Universities calls for all stakeholder groups, especially governments and higher education institutions, to act on the promise and potential of these principles and recommendations. Only robust and collective action, based on ongoing research, data analysis and the systematic monitoring of progress, will help achieve these goals. Access and participation in higher education are essential for the empowerment of all, especially those often excluded". This, of course, supported IAU's candidacy to become an ICT4IAL project partner.

The network partners are also all networks of members covering Europe and beyond, IAU representing higher education institutions and organisations from 120 countries and every continent, and EA all European countries.

The ICT4IAL network was therefore an initiative that combined their different perspectives in an attempt to address these shared concerns.

3 Methodology

Four central objectives supported the achievement of the project aims:

3.1 Developing and Trialling of Practical Guidelines

The Guidelines were developed to support the work of practitioners and organisations in education in providing accessible information to all learners who require and will benefit from such information. The Guidelines, as the main project output, were created in a reiterative process of feedback loops, resulting in two versions:

- Draft Guidelines which were trialled within three partner organisations, and
- Final Guidelines which were published as an open educational resource (OER).

The draft Guidelines were developed during the first year of project activities, which included desktop research of tools to support information accessibility, as well as exchange and knowledge-sharing within the partnership. Key elements were collected at a meeting held in Lisbon, Portugal, with the support of the Portuguese Ministry of Education, where experts selected by the partners convened. These experts comprised representatives from the higher education sector, school teachers, experts from different ministries, and people with disabilities, mainly from Europe (with all European countries having at least one participant) but with a few from outside Europe to check whether the direction taken in drafting the Guidelines would be trans-regional.

Once the partners agreed on draft Guidelines, they were trialled in three organisations (EA, EUN, IAU) active in the compulsory and higher education sectors, with support and direct input from key advisory bodies for ICT (DAISY, G3ict, UNESCO).

IAU decided to test the draft Guidelines both within the organisation and at a university. The Open University of Catalonia (UOC), Spain, a public online university and IAU member, volunteered to trial the Guidelines in its education service and provide feedback for improvement. While IAU focused on documents and websites, which constitute its core offer of information for learning, UOC looked at online courses. The main comments were the need to clarify (wording) and explain the reason(s) for using the Guidelines (impact on people with disabilities of not implementing them). However, both said that the draft Guidelines were easy to apply – one of the objectives – and very rewarding, in that applying them can potentially make information for learning accessible to a greater number of students.

The experience gained through implementing the Guidelines in these different contexts served as feedback for developing the final Guidelines.

3.2 Reflection and Evaluation upon Implementation

The Guidelines' implementation process was closely monitored and evaluated to identify learning points that could be useful to other organisations considering future developments in this area.

Each of the implementing organisations recorded details of the implementation, including challenges and successful means of overcoming them within work processes. These reports were synthesised and published as *Making your Organisation's Information Accessible for All* [8], which is available in 23 languages and contains the following seven recommendations for organisations:

- Include an accessibility statement in the organisation's long-term strategy.
- Develop a strategy or plan for implementing accessible information.
- Make someone responsible for implementing the information accessibility plan and provide them with the required resources.
- Plan an incremental implementation – be ambitious and modest at the same time.
- Embed accessibility into your information production and dissemination processes.
- Provide information, education and training on accessibility for all staff.
- When outsourcing information production, make sure accessibility requirements are addressed and undergo a quality check.

Any organisation can use *Making your Organisation's Information Accessible for All* to support its accessibility efforts, as it provides a model of the processes involved in making organisations more accessible, as well as a simple self-audit tool.

3.3 Validation of Guidelines

During both the development and implementation phases, different ways of validating the Guidelines through the target group were built into the project design:

- Feedback on the Guidelines from the European and international country network members of EA, EUN and IAU, as well as UNESCO's global membership, was organised through a Guideline Development Workshop. This workshop collected input from nominated experts on key questions to ensure the Guidelines' applicability, leading to an agreed version of the draft Guidelines.
- Collection of feedback from an international group of people with disabilities and/or special needs, their advocacy groups, and ICT and accessibility experts through an accessible online survey and document review. The survey focused on clarity and usability as well as on applicability in a large variety of contexts.

IAU organised a session linked to a related project to test the Guidelines' value on a completely unaware – and hence unconvinced – audience. The IAU Reference Group on Higher Education for Education for All (the UN Education for All (EFA) initiative that preceded Sustainable Development Goal 4 on Education) was presented with and asked to comment on the Guidelines. The event was at Hacettepe University, in Ankara, Turkey, in November 2014. This audience's work did not have the issue of disability as its main focus and the participants (mainly university professors) comprised people from 14 non-European countries The participants discussed barriers to accessibility, commented on the Guidelines, and considered how to link the ICT4IAL project with the work on higher education for all (HEEFA).

The participants suggested that the Guidelines should comprise two versions, one for the general public and another for IT specialists; include visual examples of how to provide e-accessibility; use simple language; showcase accessibility with basic information available in all languages; include audio-visual materials; be tested with people producing e-content (pilot studies). It is important to regularly update the Guidelines with feedback from users, as technology changes quickly. Similarly, participants considered it important to include feedback from other parts of the world and to involve teachers' unions and regional associations of universities in the testing.

The abovementioned activities, together with the evaluation of the Guidelines' implementation, were the basis of revisions – with as many proposals as possible taken into account – and led to the final Guidelines for the Implementation of Information Accessibility in Learning.

3.4 Dissemination and Exploitation of Results

Each partner organisation disseminated project outcomes and news within its respective networks and through its established channels.

The final Guidelines for the Implementation of Information Accessibility in Learning were presented at an International Conference which was an official event of the Latvian Presidency of the European Union in 2015. An additional Dissemination Seminar was held in the last month of the project activities, aimed at practitioners in Italy.

The continuous involvement of education and ICT experts, from Europe and beyond, supported widespread dissemination and an early feeling of ownership of project results by all involved.

Key to all dissemination activities was that all resources were developed as models of accessibility themselves, thereby ensuring that all people interested in the results could access the information and act upon it. All recommendations in the Guidelines were applied to the project results, thus making its outcomes accessible to a larger group and supporting wider dissemination. The partners strongly agree that not only does information for and about learning need to be open and freely available to all, but also accessible in order to be truly open.

UNESCO is further investigating the possibility of international endorsement of the Guidelines and implementation process findings through its official bodies. G3ict will continue with a global dissemination campaign among education professionals and people with disabilities, as well as including the Guidelines in events and capacity-building programmes planned for 2016 onwards.

Dissemination was the most important project activity and will continue after its finalisation. The Guidelines must continue to be shared, discovered, discussed, implemented and adapted according to context and needs to achieve the project aim: to raise awareness about the need and support the sharing of accessible information in general and for learning in particular.

4 Project Outcomes

Two key outcomes support practitioners and organisations as a whole to provide accessible information easily and systematically.

4.1 Outcomes for Practitioners: Guidelines for the Implementation of Information Accessibility in Learning

The Guidelines for the Implementation of Information Accessibility in Learning focus on various elements of information, such as text, image, audio and video as well as the media in which these elements are delivered and were originally aimed at school staff, librarians, academics, university staff, communication officers, and publishers as well as support groups and non-governmental organisations. For each element and dissemination method described, practical suggestions and resources that support the provision of accessible information are provided. The resources are organised to show the level of pre-knowledge they support. The procedure for creating accessible information is universal. Therefore, the Guidelines support all individuals or organisations wishing to create information that is accessible in different formats and are not limited to information produced for learning.

The Guidelines build on two steps for action: Step 1 describes how to create accessible information via text, images, and audio. Step 2 considers how to make media accessible – for example, electronic documents, online resources or printed material. Each step provides recommendations categorised into "easy" actions which can be completed with a general knowledge of common software programs; "advanced" actions which can be completed with an in-depth knowledge of common software programs; and "professional" actions which can be completed with a professional knowledge of software and general knowledge of programming. One does not have to be a professional to implement the Guidelines. On the contrary, the process and the Guidelines are organised so as to be easily implemented by all. Even applying the easy recommendations will facilitate access to information for people with disabilities.

For example, when writing a text, a professor should be aware that for navigability and adaptability reasons it needs to be structured, that for readability, it should use the simplest language that is appropriate, specific fonts, minimum point size, etc.

University websites must also be accessible. These are usually developed by the university's technical services or outsourced. The Guidelines help to set a list of criteria for procurement and selection of contractors and product testing. These criteria include the use of metadata, responsive web design, style sheets, information divided into manageable blocks, etc.

The Guidelines were published in multiple accessible formats, including an OER under a Creative Commons License Agreement. The full Guidelines are available from the project website (www.ict4ial.eu) in 26 languages and in two formats: PDF and Word; the latter permits repurposing of the content. In addition to European languages the Guidelines are available in Arabic, Chinese and Russian, which are UNESCO languages and are key to additional exploitation.

4.2 Outcomes for Organisations: Making your Organisation's Information Accessible for All

This guide is for organisations that wish to provide accessible information, both in the education sector and more widely. It includes recommendations for organisations that summarise lessons learned during implementation, when the draft Guidelines were trialled within EA, EUN and IAU. The guide includes an audit tool to easily assess an organisation's accessibility, as well as models of how to systematically implement the Guidelines within an organisation.

As the IAU Secretariat is a small organisation of 15 people, most recommendations, such as designating someone to implement the information accessibility plan, will not be applied. However, it was decided that the Guidelines must be used in defining the new communication strategy, which will include new corporate identity guidelines.

As a result of the ICT4IAL activities, EA is developing its own accessibility policy. The policy and the process will build on the recommendations in the guide. All outcomes were produced as open source materials, available from the project website: www.ict4ial.eu.

5 Outlook

The Guidelines were developed as an OER, allowing them to be sustained beyond the project duration, be updated as new technologies emerge, and be adapted to varying educational and geographic contexts. Consequently, they are not final. They were the final project output, but are expected to evolve to fit new technological developments and better serve information providers. They may also push IT companies to develop easy-to-use, cheap devices or tools to enable information providers to open up information for learning to all.

References

[1] United Nations. *Sustainable Development Goals: 17 goals to transform our world* [online]. 2015. Available in URL <http://www.un.org/sustainabledevelopment/sustainable-development-goals/>.

[2] European Commission. *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Opening up Education: Innovative teaching and learning for all through new Technologies and Open Educational Resources.* {SWD (2013) 341 final}. European Commission, Brussels, 2013.

[3] World Health Organization/World Bank. *World Report on Disability.* WHO, Geneva, 2011.

[4] United Nations. *Convention On The Rights Of Persons With Disabilities* [online]. 2006. [cit. 23-01-2016]. Available in URL <http://www.un.org/disabilities/convention/conventionfull.shtml>

[5] Cullen, K.; Kubitschke, L.; Boussios, T.; Dolphin, C.; Meyer, I. et al. *MeAC – Measuring Progress of eAccessibility in Europe. eAccessibility status follow-up 2008.* Study commissioned by the European Commission, 2008.

[6] Monitoring eAccessibility Consortium. *Monitoring eAccessibility in Europe: 2011 Annual Report*. Study commissioned by the European Commission, 2011. Available in URL <http://www.eaccessibility-monitoring.eu/researchResult.aspx>.

[7] International Association of Universities. *Equitable Access, Success and Quality in Higher Education.* 2008. Available in URL <http://www.iau-aiu.net/sites/all/files/IAU%20Policy%20statement%20on%20Equitable%20access%20Final%20version%20August%202008%20Eng_0.pdf>.

[9] European Agency for Special Needs and Inclusive Education. *Making your Organisation's Information Accessible for All.* European Agency for Special Needs and Inclusive Education, Odense, 2015.

“Förderwolke” A Cloud-based Exchange Platform of the Faculty of Rehabilitation Sciences at the TU Dortmund for the Qualitative Enhancement and Improvement of Inclusive Education

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Keywords: inclusive education, assistive technology, CRPD, cloud-based exchange

1 Introduction

In the UN CRPD inclusion in education is formulated as a main goal in Art. 24. The convention names accessibility in Art. 9, the use of (assistive) technology in Art. 4 and universal design in Art. 2 as requirements for inclusion.

In this way, a framework for education is defined by the Convention, which has to be implemented in the signatory countries. Especially the school area has to face a variety of tasks to be tackled. Legal, structural and organizational issues, training and cooperation among teachers, parents and pupils are just a few relevant items. In the context of inclusive education a rethinking of teaching is necessary. It causes a lot of questions for the realization in the classroom every day.

2 Application idea

It is assumed that by considering assistive technologies the success of inclusive education for all students can be achieved. For the success of inclusive teaching methods all of these aids have to meet versatile requirements on the part of teachers, pupils and the learning environment. The basic assumption is that a positive educational value for students in inclusive education can be achieved by targeted consideration of the technical possibilities in the classroom and in the school context. It can be assumed at this point that aids which are integrated into the school day are no longer perceived as such.

There are also general evaluation criteria of usability of assistive technology for children in the school context determined. These relate to the usability of the school day as well as the individuality of the pupils. Is a tool easy to understand and can be used flexibly for several pupils increases the probability that a teacher takes the time to deal with. In addition, the child-oriented design of technology reduces the threshold to work with the student. The appropriate adaptability for individual technology is essential and may also affect the willingness of a student to learn.

To achieve a pedagogical value assistive technology has to be flexible and easy to handle for teachers and available in the immediate vicinity of the teaching situation.

A training and cooperation with extracurricular professionals in order to learn how to deal with the technology is essential to achieve the therapeutic and medicinal benefits of technical aids which have a supportive effect on everyday life. To support the development of inclusive teaching networking of all teachers in inclusive education processes can be useful. At this point the possibility of cloud-based exchanges are recognized with the platform “Förderwolke” of the Faculty of Rehabilitation Sciences at the TU Dortmund.

3 State of the art

The potential of technical tools in the implementation of inclusive education by which the children are provided or which are already present in the schools will be one part of the networking offer. The tools are recorded on the one hand in the field of assistive technology, the children with disabilities bring with them every day, but there are also nursing aids and teaching technologies, which are kept by the school.

The aim of „Förderwolke“ is to close the gap of networking of students and lecturers of the University of Dortmund with teachers in special and regular education and former students. Other similar offers are only addressed to teachers (e.g Logineo NRW), or only to a university audience (e.g. moodle of TU Dortmund) or aren't focused on inclusive education (e.g. gpaed.de).

4 Methodology

“Förderwolke” gives all users who are interested in inclusive education the possibility of a cloud-based exchange of educational materials and ideas. The offer is aimed at teachers in public schools and special education, corresponding trainee teachers and students, teachers and scientists of universities, therapists, and other experts with educational profession. The possibility of a cooperative feedback and professional advice with mutual support can generate new knowledge and stimulate learning from each other about inclusive settings and impetus for inclusive education.

Students have the possibility to get feedback for certifications which can give new impulses for inclusive didactic ideas.

5 Conclusion and planned activities

Currently, information which is initially necessary for the use of the exchange possibility about assistive technology of “Förderwolke” is implemented. Promptly first teachers, students and lecturers have the chance to use the cloud-based exchange to learn more about assistive technology and to comment this. An administration team will accompany this first phase, to evaluate how the provided information about assistive technology can be improved before a larger user group has the opportunity to participate.

The research objective is to find positive examples of using assistive technology in an inclusive context in school. The conditions under which the use of assistive technology is leading to an educational value for all students should be found in order to detect whether assistive technology offers potential for the success of inclusive education

A Technological Proposal to Support Music Education Shared between Blind and Sighted Students

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Keywords: Assistive technology, Education of blind, Braille Music

Abstract

This paper discusses aspects of the integration of blind and sighted children in inclusive music classrooms and launches new ideas so that the use of computers would enable the creation of a more favorable environment for teaching Braille music. It proposes the creation of a specific computer tool, designed under Universal Design principles, that allows the application of an adequate pedagogical approach for basic music teaching assuring that the process of inclusion must be placed in the foreground.

1 Inclusion of Visually Disabled Students in Brazil: New Challenges for Music Teaching

In Brazil since 1988 musical education is mandatory by law in all schools. The purpose of this legislation is not to foster the preparation of future musicians, but to develop creativity, sensitivity and integration of students. As a result, it is expected that children with and without disabilities be motivated to share learning in basic music education classes. However, complex pedagogical problems arise when trying to teach simple concepts involving writing and reading music [9].

In the context of inclusive education, if teachers of ordinary classrooms could dominate musical writing in Braille, or could work in pairs with another teacher, specialized in this kind of writing, there would be no major problems in the simultaneous use of writing in ordinary scores and in Braille, except for some additional transcription work - which can be greatly simplified through specific computer programs. However, if only Braille writing was used, the blind student could not share his development in the discipline with colleagues, because what he writes tactually, almost any fellow seer could read [2]. On the other hand, these computer tools that have provoked a decrease in the ability of the blind read Braille [12] also don't work well for the specifics of musical writing.

The root of the problem is that the theoretical and practical content of music teaching is always the same, just the way of writing is different. So, how to share the essence of the musical record, regardless of the form of writing? How to allow that what the writing of seers could be instantly read by the blind and vice versa? How to make computer technology, which allows high degree of automation of musical writing, could be combined with the maturity of the data transmission process and the many possibilities for information sharing, to create new opportunities for music education?

As a background stage of these questions is the configuration of the current communication systems changing the logics of distance, inclusion and exclusion, introducing new dimensions to these logics (spatial, temporal and social) and enabling new communication flows overlapped with existing structures [6]. Information and communication technologies should therefore be enhancing the skills of everybody, being able to recognize the particular dynamics of them, understanding and supporting how they globally relate and ensuring that in amplification processes of access and use, the logic of singularity is not compromised. The technologies for Information and communication can therefore play a key role in the integration of groups and individuals that are traditionally segregated and leverage a richer relationship and a deeper mutual understanding between different individuals, communities and cultures.

2 Conceptual research framework

The research on which this article is embedded crosses the problems of Communication and Information Sciences (CIS) with the Educational Sciences (ES). It is obvious that focusing shared learning refers to the study of the educational phenomenon, but it is worth noting that in its root there is also an info-communicational phenomenon that cannot be avoided. The success of the teaching-learning process is necessarily, for an informational work quality and high communication effectiveness. It also passes by careful examination of the mediating role of educational agents, the use and enhanced digital platforms and the ability to engage students in two complementary dynamics: the digital inclusion and of proper information literacy.

It is not up scrutinizing here the deep epistemological relationship between the CIS and the ES, because the idea is to draw a positive contribution to the development of closer relations between sighted and blind, students and teachers. The implementation a digital tool or platform that enables the dialogue between them, with the elimination the exclusive use of the Braille code only for those who cannot communicate through the characters of natural languages, is a relevant objective that produces a wide-reaching impact which is still difficult to evaluate. There is no doubt that there is a clear goal that urges to reach in the most effective and possible way.

For this purpose, an effort for basic conceptual clarification is necessary to help us to integrate the thematic scope of this article in the scientific field of Information and Communication. This effort is greatly facilitated by using the main concepts explained in [14], which propose operative definitions to mark and help in the exploration of all kinds of questions posed inside and at the borders of this interdisciplinary field.

The concept of information is of course the first that is highlighted with this formulation:

"… structured set of mental and emotional coded representations (signs and symbols) and modeled with/by social interaction, which can be registered in support any material (paper, film, magnetic media, CDRom, etc.) and therefore communicated asynchronously and multi-form" (p. 85).

By this definition it is clear that Braille can be a taught and learned by a group of people who need it to express their mental and emotional representations (of any kind and in any situation and context) tending to process that is both communicational and educational.

The second concept to reveal may be the communication that is distinct and complementary, *"while the information is the content of the communication order"* (p. 102). Clearly, communication is established as an exercise of cooperation, negotiation, joint direction construction, which implies respect and attention to the caller.

"… think communication in the era of information triumph and technical means to emphasize the complexity of the nature of the communication process with its triple dimension of questioning the relationship of otherness and receptor." (p. 103)

To complete the triad of key concepts we cite the concept of information systems:

"An information system is a totality formed by the dynamic interaction of its parts, or has a permanent structure with a stream of states in time. It consists of different types of recorded (or not) information external to the subject, no matter in what media (material or technological) according to a structure (agency producer / receiver) that extends its action in the timeline. (p. 116)

This is a "space" technological complex that, in essence, continues to consist of hardware and software, but which converge various technologies and services in order to make it an instrument of info-communicational mediation. Music theory, music compilation, man-machine communication, voice synthesis, hardware control, and many others subjects interact through command and control techniques and algorithms that try to mimic some aspects of human behavior of a educational mediator, theme which could be mapped on the interests of a new field of research: Affective Computing [15]. However, this interesting approach for our research is not being explored at this moment.

Much of this text talks about aspects of technological mediation and distance education, concepts explained in many references, e.g. [10]. In particular, technological mediation imposes itself as an indispensable concept because it covers both the roles of a communicator and an educator. The mediating function is not neutral, but it is natural and critical, with implications for the info-communication process. If the media is linked to this deeply human and social function, the momentum triggered by the binomial teaching-learning / teacher-student loses intelligibility out of questions embodied in mediation.All these concepts don't exhaust the theory necessary for understanding the present research. We affirm the importance of studying other concepts, less relevant to the context of this text, but of transcendental importance if a wider study is on perspective. We emphasize here the subjects related to memory, emergent literacy, cognition / knowledge, document and interaction / interactivity.

3 Music production and teaching for the blind, mediated by technology

As cited in [8] the main products for the international market that support writing and reading music for the blind are GOODFEEL, Tocatta and Braille Music Editor (BME). These products operate philosophically the same way: they take a digital file representing a conventional music pentagram and automatically generate a digital file with some representation that allows printing.

The input file is encoded in a proprietary format or in MusicXML – which may have been produced in a musical editor (such as Sibelius, Finale or PrintMusic) or created with a music scanning program, like SharpEye Music Reader, Musitek SmartScore or PhotoScore Neuratron. Some programs (like GOODFEEL and BME) even allow a blind person interact with the generated file with "Braille representation", reproducing it in a MIDI musical instrument or in a simulated synthesizer on the computer. Feedback from musical elements is done through a speech synthesizer associated with a screen reader, being the Jaws program the product for which there is a greater number of specialized scripts that support this reading.

As we can see, none of the products are really focused on two-way interaction. In other words, the destination is always Braille. There is no emphasis on exploring the possibilities that the semantic compatibility between the representation in ink and Braille have. The emphasis is always that a seer (or even the blind) will produce texts for the blind, and the blind will interact with Braille.

This functional unidirectionality is a huge obstacle for teaching in inclusive classes. In other words, the blind person can get information that others produce, but what it produce does is not gotten by colleagues. The huge potential of learning sharing, the musical manifestations generated from it, so as discoveries and intuited ideas, nothing is explored, because the technology was not built to deal with them.

The emphasis of these products is not music education, but production of texts in Braille to be used by blind musicians. In other words, support for education is clearly precarious. This does not mean that teachers would not use these technologies at school with their blind students, but this almost always takes place using segregated education strategies, and in particular, individualized instruction.

The adoption of logics and practices of implementation and the use of digital technologies by students with special needs should therefore be developed in a coordinated manner in an interdisciplinary logic [13]. It is also essential to ensure specialized training for both music teachers in the area of inclusive technologies and for ICT specialists in music. This may generate motivation and flexibility, added to the work of the different agents involved, with the distributed and distance communication to be considered as an important modality that could ensure this specialized training [7], [16].

We understand as essential, therefore, to observe the importance of making digital technological resources accessible to blind people to facilitate them to learn Braille Music and to interact with sighted musicians, reinforcing the sharing practices between these two groups. This will be done by the resource given by the real-time access to a digital platform of music scores that allows communication of blind and sighted students, music teachers and musicians in scenarios such as music schools and universities.

4 The Musibraille system, its limitations and advantages

In Brazil, one of the main technologies for Braille Music transcription is the Musibraille software, created by us, which can be considered as part of actions promoted to revitalize the use of Braille music in our country [3]. Thanks to this effort, several hundred people have been trained in this form of writing. The system has spread in all Brazilian states, with the financial support from the private sector and government projects. The Musibraille is free software, distributed freely over the Internet.

Musibraille is also focused in interactive writing of music scores in Braille. Data entry can be done using the computer keyboard, typing on a 6-key keyboard simulator (Perkins mode) or through transcription of files represented in the MusicXML format. The information in Braille is translated in real time to a conventional musical score, which helps the seer transcriber to verify the correction of typing.

The program displays an audible feedback with the translation of Braille music symbols into synthesized speech or musical tones as they are typed, and also allows playing the music during its creation. It contains an interactive Braille music dictionary and also includes a small screen reader tuned to its operating interface, which relieves the installation of external screen readers or specialized scripts. A small virtual library on the Internet, with simple songs for beginners, completes a basic set of tools for the student.

Recently some tools have been created to educational purpose only, as shown in [4]. Other tools have been introduced into the program to allow very simple input data through using icons clickable by the mouse, very useful for sighted users. However these facilities did not change Musibraille's main objective: easily editing with excellent feedback of Braille Music.

Despite these limitations, Musibraille is really a technological item of huge importance to the development of new products and especially to this proposal. We explain why: it was created within a university project, nonprofit, using methodologies of open and reusable code, and more, *under our technical guidance*. In other words, we have complete knowledge about its code, being able parts of its code it to modify it and even to create new products, so that if its interface is not suitable for teaching purposes we know that it is fully possible to reuse their algorithms and implementations to leverage and simplify programming of a new software architecture, with fully targeted focus for inclusive music education, with a cost and time infinitely smaller than would be required in a design usual situation.

This proposal would be impossible to produce with our small budget, working almost with students, without the availability and technical knowledge, made publicly available by the Musibraille project.

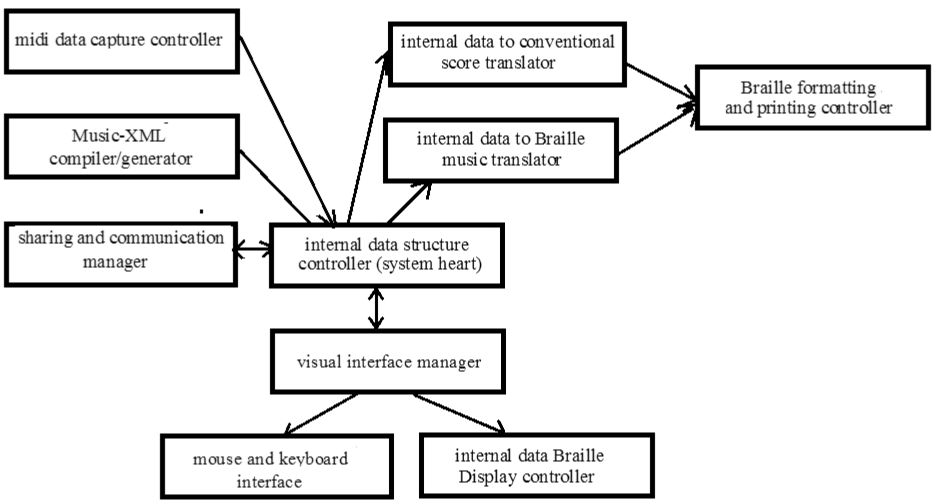
5 Proposal for a new architecture for music education with operating sharing

The premise that makes this project possible is the fact that the representations used in Braille Music and conventional musical notation (musical score) refers to semantically equivalent entities, so that the bidirectional, automated and real-time translation is possible. Thus, what is stored is, in essentially, a musical data structure, whose sound representation, visual presentation, tactile sensations, etc., could be produced and selected on demand and interactively, and whose most appropriate feedback should be freely chosen by user.

The execution interface, should be bimodal: the conventional and Braille writings have the same operational importance, and the act of writing, reading, listening and print is interchangeable and supported by specific selection and configuration interfaces. In particular, five outputs are available (as they are also available in Musibraille): conventional graphical form, Braille output on screen, output on a Braille Display, score printing with ink and Braille printing.

Data entry has also to be multimodal, with entries taken from the keyboard, touch screen, Braille display and Midi interface, at least. It is expected to include, in the future, the translation of sound capture (from singing, for example), but it should, at least at first, restricted to no polyphonic input. The system also provides the translation for files represented in MusicXML (within the limit of using an agenda at a time) by using a variation of the Musibraille XML compiler. The important is that it allows obtaining material from the internet, as well as supporting a broader sharing of information.

The key point of the program is its real-time communication. In other words, what is produced or selected in an instance of the program is immediately transmitted to the other instances of the program that are located on the same Local Area Network, as having being previously interconnected. Thus, the interaction on the musical information can be established and, given that the internal representation of musical information is the same, sharing can occur independently of the input mode or output chosen. It allows, for example, writing with a mouse in some computer, and immediately read in the Braille Display in other machine (automatically or on demand).



[Fig. 1] Architectural sketch

Figure 1 shows the main structure that are being planned to implement. We must note that this product is not designed to be a music publisher but as a basic teaching tool, with well defined pedagogical and architectural limits. This is an important design decision, otherwise the architecture would be much more complicated, going far beyound our project possibilities.

6 Prototype implementation and evaluation

A prototype for functional evaluation, provisionally called PianoVox is currently under construction and validation with a small group of volunteers. The first discussions with them have shown clearly that PianoVox should not grow to become a transcription tool: it is a tool to make easier the shared study of Braille Music. In particular a significant programming investment has being done to provide simple but effective intercommunication between instances of the program, allowing synchronized executions in different devices in real time.

It was necessary to limit the prototype to be used in non-mobile environments, to avoid further implementation difficulties and uncertainties of the design. The music items that are supported are a small subset of the Music Universe, enough to fulfill the needs of the most common tasks of a basic music course.

Our emphasis at the moment is to clearly define what should be essential or accessory in the final program, assuring that the interface will be kept very simple and intuitive, and always remembering that its purpose is mainly educational. It is expected that the program will be fast in its responses, even in modest equipment (in Brazil the majority of school computers is not new), so a teacher can use the simple machines that exist in real schools. The program should be intuitive and trivial to understand and operate. The most important of all: the system has to assume equal operational importance to blind and sighted users, giving to both the opportunity to create and interact with the same efficiency and productivity.

Among the dubious points to the project, is the emphasis on supporting certain expensive technology items. The emphasis on using Braille printers and Braille displays are now points of disagreement with teachers who know that they will hardly have access to these technologies in third world countries. In practice the student will work mainly with the sound interface, and Braille printing will not be available locally. However, in our opinion, the program should provide a sophisticated setting as the ideal, knowing that should behave effectively in a more modest environment, likely to be the model used in most schools in Brazil.

7 Conclusion: on the coverage and importance of this project

The models of education of people with disabilities have been accompanied by the progressive use of digital technologies to support communication processes, collaboration, participation and social and professional inclusion of these subjects. In consequence, it's essential to promote further study and experience in this area. In this context, it is observed as especially urgent to ensure the availability of adequate resources and materials and to create networks and distributed structures to support communication, collaboration and training of the many actors involved.

The open and inclusive space of communication we want to promote with these new tools is neither an exclusive design of the blind community, nor refers only to the teaching of music: it aims to simultaneously and complementarily deepen areas of theory and practice from both blind and sighted people's cultures, pointing new directions for a deeper understanding of the role of digital technologies in music and in inclusive education.

This project is also important because one of the boldest goals of this development is to support the development of a future project involving the introduction of Braille Music in Portuguese-speaking countries in Africa and in Portuguese-speaking countries, the main PhD research of one of the authors (Dolores Tomé). In this context, we propose to investigate how the distributed access may favor this audience, considering the multitude of people from these countries who use and is benefitted by the Internet, particularly blind people, enhancing their interaction with everyone.

Indeed, distributed communities are generating collective knowledge, and the online availability of Braille Music techniques constitute an example of relief in this field, as they may provide inclusive educational potential for a full and unrestricted music education. Blind people become beneficiaries and responsible to promote their own inclusive and participatory progress.

Acknowledgement

Dolores Tomé is a doctoral student granted by MEC/CAPES-Brazil. This research is partially funded with resources from CNPq project 458633/2013-5.

References

[1] Bates, A. W. *Technology, E-learning and Distance Education*, chap. 2. Routledge Ed., 2005.

[2] Borges, J. A. *Do Braille ao Dosvox – Diferenças nas vidas dos cegos brasileiros*. Doctoral thesis on System Engineering and Computing – COPPE/UFRJ. Federal University of Rio de Janeiro, 2009.

[3] Borges, J. A.; Tomé, D. The Musibraille Project – Enabling the Inclusion of Blind Students in Music Courses. In *ICCHP 2012, Part I, LNCS 7382*. p. 100–107. Springer-Verlag – Berlin - Heidelberg, 2012.

[4] Borges, J. A.; Tomé, D. Teaching Music to Blind Children: New Strategies for Teaching through Interactive Use of Musibraille Software. *5th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion, DSAI 2013. Procedia Computer Science.* Volume 27, p. 19–27. 2014.

[5] Bronfenbrenner, U.; Morris, P. A. The ecology of developmental processes. In Damon, W.; Lerner, R. M. (Orgs.). *Handbook of child psychology.* Vol. 1: Theoretical models of human development. New York: John Wiley, 1998. p. 993–1028.

[6] Castells, M. The Network Society – the information age. *Economy, society and culture.* Vol. I. Wiley-Blackwell, 1999[2].

[7] EADSNE – European Agency for Development in Special Needs Education. *Information and Communication Technology for Inclusion, Research Literature Review*. EADSNE, 2013. ISBN 978-87-7110-466-0.

[8] Hersh, M. Johnson, M. (Eds.). *Assistive Technology for Visually Impaired and Blind People*. Springer Verlag, 2008.

[9] Jellison, J., Brown, L., Draper, E. *Peer-Assisted Learning and Interactions in Inclusive Music Classrooms: Benefits, Research, and Applications.* SAGE, 2008. Available in URL <http://gmt.sagepub.com/content/28/3/18.abstract>.

[10] Koehler, M. J.; Mishra, P. What Happens When Teachers Design Educational Technology? The Development of Technological Pedagogical Content Knowledge. *J. Educational Computing Research*. 32(2), 2005. p. 131–52.

[11] Lamizet, B.; Silem, A. *Dictionnaire encyclopédique de l'information et de la communication*. Ellipses: Paris, 1997.

[12] NBCNEWS, Inc. *Fewer Blind Americans learning to use Braille*. 2009. Available in URL <http://www.nbcnews.com/id/29882719/ns/us_news-life/t/fewer-blind-americans-learning-use-braille#.VrD9H_krIdU>.

[13] NIELSEN, L. B.(1999) Necessidades Educativas Especiais na Sala de Aula, Um Guia Para Professores. Porto Editora: Porto, 1999.

[14] Passareli, B. ; Ribeiro, F.; Oliveira L.; Mealha, O. *Identidade conceitual e cruzamentos disciplinares in e-Infocomunicação: Estratégias e Aplicações*. Ed. SENAC: São Paulo, 2014.

[15] Picard, R. Affective Computing. MIT Press, 2000.

[16] UNESCO. *Global Report Opening New Avenues for Empowerment. ICTs to Access Information and Knowledge for Persons with Disabilities*. 2013.

Web Guide to Physical Accessibility of Buildings

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Abstract

Masaryk University has developed a web-based application[1] providing practical information and specifications of university buildings which enable individuals with mobility difficulties to use the environment of the buildings effectively and without barriers.

The application is a kind of virtual tour, simulating a location and composed of panoramic and static images, recommended trace lines, text descriptions and specifications with special accent on features and pieces of information which are of interest to the target group.

1 Introduction

Support Centre for Students with Special Needs at Masaryk University is a purpose-built facility operating across the university. Its aim is to put principles of Universal Design for Learning into practise and provide the greatest possible access for students with disabilities, whether sensory, physical or psychological, to be able study at Masaryk University.

An integral part of making study at Masaryk University accessible is not only eliminating physical and virtual barriers in educational setup, but also creating (technological) tools which enable students to orientate themselves effectively in the environment and to use university premises without barriers. Doing that we take into account not only the variability of the premises, but also the heterogeneity of the target group meant to benefit from the accessibility information — from persons with reduced mobility using e.g. forearm crutches to electric wheelchair users.

When we started looking into the issue of mapping the accessibility of buildings, we found the solutions employed by most public institutions insufficient in terms of their information value and relevance precisely for users with different types of physical impairments.

In the case of some educational institutions, e.g., [1], [2], [3], [4], a very frequent measure was the use of a partly interactive map plotting barrier-free entrances into university buildings, or, in some cases, marking accessible roads and paths at university campuses and in their surroundings (including indications of curb ramps etc.).

The second most frequently used method is verbal description [5] of the individual elements of the system (door width, the slope of natural or artificial terrain, toilet dimensions, etc.). Another scenario is the combination of the two aforementioned: interactive maps with a brief description or with pictograms colour-coding the degree of accessibility (typically using this scale: green – accessible, orange – with limited accessibility, red – inaccessible). This last model is frequently used especially with maps of relatively large

1 http://www.teiresias.muni.cz/guide-to-accessible-buildings

areas, e.g. city centres [6], national [7] or international maps [8, 9], and these maps are often updated directly by the user community.

However, almost all the mentioned tools are restricted to stating "accessible – (with limited accessibility) – inaccessible". Only exceptionally do the applications reveal more details that allow users to get a more precise idea about the given environment [5]. It is often rather unclear for whom the assessment of accessibility is primarily determined, to what kinds of users it is relevant, or what is meant by accessible/inaccessible (a considerable difference concerns even mechanical and electric wheelchair users, to whom different accessibility criteria apply).

2 Methodology

After some initial research, we decided to use a method that will enable us to offer such information which will allow users to conclude themselves whether a given environment is accessible or inaccessible, based on technical and other data that will be available to them at one place.

For mapping buildings and their immediate surroundings, we have decided on a combination of an interactive plan, textual technical description, and, above all, accurate visual information in the form of a photograph. To allow continuity, the monitored environment is depicted in 360-degree photographs that enable simulation of movement in real environment.

Practically, the application is a kind of a virtual guide (combination of panoramic and static images) with special accent on features and information of interest to the target group; mainly:

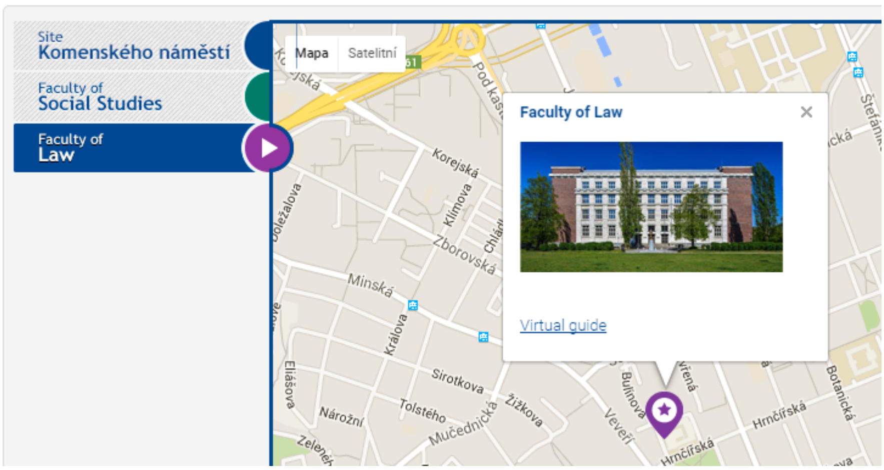
- barrier-free entrance to the building;
- barrier-free options of moving within the building vertically (location of elevators, ramps, lift platforms and their dimensions);
- barrier-free cloakrooms (their location, disposition, dimensions, etc.);
- highlighting of typical tracks to the most frequent destinations (teaching rooms, libraries, dining hall, etc.);
- text information on operating conditions of the arrangements.

On the other hand, the application does not map the location of departments within the building. It only provides information on the purpose of the rooms (teaching rooms, offices, library, etc.) as the locations of particular departments, rooms, laboratories, etc. are stated by other information systems of the university.

3 Structure of the Application

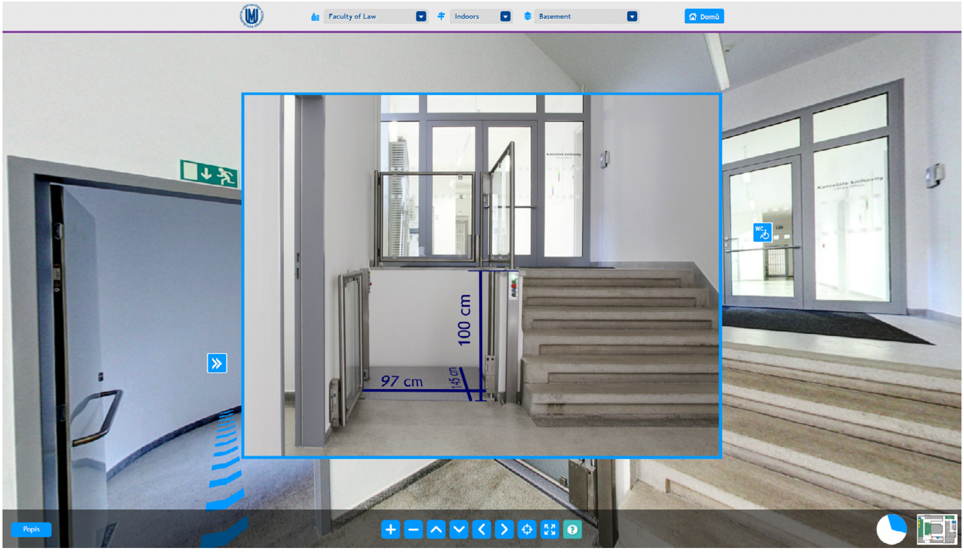
- starting index of university buildings — kind of guidepost, list of faculties with map (see Fig. 1); notifications on current situations in premises (reconstructions, closed areas, etc.);
- panoramic and static images of key points of the building which are relevant to independent orientation of individuals with mobility difficulties (see Fig. 2);
- static images of significant details including technical specifications (see Fig. 3);

- text descriptions of the key points (containing mainly technical specifications such as dimensions, instructions to use technical devices, operating conditions of entrances, etc. — see Fig. 4);
- interactive plan of each floor with the key points highlighted and angle of current view (see Fig. 2);
- controls to navigate among the floors of the building;
- controls to interact with the current scene;
- trace line indicating typical tracks in the building between the key points and to the most used destinations (see Fig. 2).

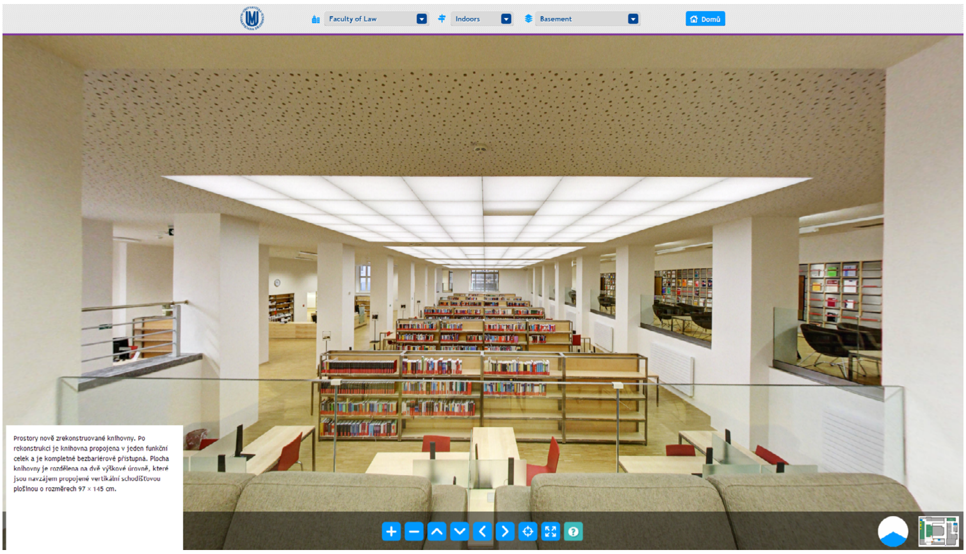


[Fig. 1] Home screen with list of buildings available

[Fig. 2] Application interface — main navigation controls to interact with the view of a key point



[Fig. 3] Static image including technical specifications



[Fig. 4] Text descriptions of the key points

4 Used Technology

As stated above, the system is a kind of web virtual guide extended with features to provide interactive floor plans, static images, trace lines and text descriptions attached to the panoramic images. As such it is based on a standard technology for virtual tours — *Krpano Panorama Viewer* [10] and *Panotour system* [11] for processing data. The website framework which includes starting index of buildings, news, help page, etc., is run by *Kentico CMS* [12]. The application has been optimized with respect to responsive web design for multi-platform usage (including smaller mobile devices on which, for instance, the application utilizes gyroscope sensor to control the panoramic images, etc.).

5 Recent and further activities on the project

The main framework of the application was developed in summer and fall 2014. We ran pilot part of the project from December 2014 to March 2015 — specification and details of two university buildings were processed and published in the guide. Now the guide includes three buildings and others are being prepared.

New features are going to be implemented: mainly user's notification system to report changes, malfunctions, or updates of conditions discovered on the spot in the premises, as well as closer interconnection with the central information system for implementing a searching tool within the application.

6 Conclusion

We hope that the application and the presented approaches will contribute to the debate about methods of providing information on architectural accessibility of public sites. Due to the very diverse needs of individuals with mobility difficulties, we consider providing technical and practical details of the premises more useful and valuable than defining general accessibility levels of buildings. The users themselves know the best what limits them in motion, which kind of activity they are going to perform, how much time they are going to spend in a given location, etc. Based on this knowledge, they can select the most relevant information.

References

[1] Boston University. *Boston University Maps* [online]. [cit. 16-1-2016]. Available in URL <http://www.bu.edu/maps/>

[2] Harvard Planning & Project Management. *Harvard Univeristy Campus Map* [online]. ver. 2.2. © 2013, The President and Fellows of Harvard College. [cit. 16-1-2016]. Available in URL <http://www.map.harvard.edu/?ctrx=759881&ctry=2961624.5&level=7&layers=Campus%20Base%20and%20Buildings,Accessibility,Map%20Text>.

[3] Stanford University. *Campus Access Guide* [online]. © Stanford University. [cit. 16-1-2016]. Available in URL <http://maps.stanford.edu/ada/>.

[4] Accessibility at Western, Western University. *Western's Campus accessiblity map* [online]. © 1878–2016 Western University. [cit. 16-1-2016]. Available in URL <http://www.accessibility.uwo.ca/doc/floorplan/campus.pdf>.

[5] *Stadtführer barrierfreies Bremen. Informationes für Alle* [online]. Bremen, April 2009. [cit. 16-1-2016]. Available in URL <https://www.bremen-tourismus.de/action/download?id=d42b2563-f292-68eb-965b-b9c863007012>.

[6] *Accessibility Guide of Brno City Centre for People with Limited Mobility* [online]. City of Brno. 1st edition, 2012. [cit. 16-1-2016]. Available in URL <https://www.brno.cz/fileadmin/user_upload/sprava_mesta/magistrat_mesta_brna/OZ/Atlas_pristupnosti_2012.pdf>.

[7] Charta 77 Foundation – Konto Bariéry. *Maps without barriers* [online]. 2015 [cit. 16-1-2016]. Available in URL <https://mapybezbarier.cz/en>.

[8] Sozialhelden. *Wheelmap* [online]. [cit. 16-1-2016]. Available in URL <wheelmap.org>.

[9] Czech Paraplegic Association. *Vozejkmap* [online]. [cit. 16-1-2016]. Available in URL <http://www.vozejkmap.cz/>.

[10] krpano Gesellschaft mbH. *Krpano Panorama Viewer*. © 2016. [cit. 16-1-2016]. Available in URL <www.krpano.com>.

[11] Kolor. *Panotour*. [cit. 16-1-2016]. Available in URL <www.kolor.com/panotour>

[12] Kentico Software. *Kentico CMS*. © 2004–2016 Kentico Software. [cit. 16-1-2016]. Available in URL <www.kentico.com>.

Bebras IT Contest for Blind Pupils – Universal Design of Tasks

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Keywords: blind pupils, Beaver contest, difficulty of tasks, accessibility

Abstract

In this article we propose special adaptations allowing blind pupils of lower secondary schools to participate in Bebras contest. This contest plays an important role in determining trends in the area of informatics education. More specifically, we present a set of tasks developed and verified during the real contests running in 2015. We analyze the success rate of blind pupils. Tasks for blind were solved also by able-bodied pupils. We compared the percentage of both types of pupils. We found that able-bodied pupils were more successful than blind. This could suggest that the tasks are inherently easier for pupils who are able to have visual imagery. Therefore blind pupils should have a separate category in the contest.

1 Introduction

In the paper, we present our idea for enabling the participation of blind pupils in the Bebras contest. The idea for the Bebras information technology (IT) contest originated in Lithuania in 2003 [4], [5]. At the moment, the competition takes place in about thirty countries [2]. "*The main aim of the Bebras contest is to promote interest in IT and informatics for all school students. The competition should help to engage children to take an interest in computers and IT application from the very beginning at school. It should bring all school students together and encourage them to learn the skills that will be needed in the labour market in the future.*" [4].

While the competition has the ambition to reach all children, the tasks are generally not accessible to pupils with different types of visual impairment. We have taught informatics in the school for visually impaired children (aged 6 to 15) since September 2011. There are three types of pupils – blind, partially sighted and those with normal vision. To prevent discrimination, our effort is to perform the same learning activities with all the pupils. As regards the Bebras contest, partially sighted pupils with a mild or moderate level of disability can participate without problems. On the other hand, children with a severe disability need more time as they do not have a preview of the full screen. They can see only a part of it and often need to scroll. Pupils with colour perception disorder can't solve the tasks that refer to colours. However, blind pupils can't participate at all. In keeping with the UN Convention on the Rights of Persons with Disabilities [12] protecting the rights and dignity of persons with disabilities, we believe that learning is a basic right of every individual. Therefore we have been looking for the ways that would enable blind pupils to participate in the Bebras contest. As a result, we suggested adaptations of rules and tasks [6] that we describe in the next section. We verified them during the three real runs of the competition. We present overview of tasks used in the last run in Section 3.

These tasks we verified with blind and able-bodied pupils from lower grades of secondary education. This verification is described in Section 4. In the last section we summarize the results and present our plans for the future. Our ambition is to find concrete recommendations enabling us to create tasks for all pupils that would meet the principles of universal design of learning [11].

2 Adaptation for blind

Competition for blind students in 2015 was conducted for the third time. In order to enable blind students to enter the competition, it was necessary to make extensive changes of rules [6]. We created a separate category for blind pupils (aged 11 to 15). As a rule, able-bodied pupils of the same age can solve 15 tasks (5 easy, 5 medium and 5 hard) within 45 minutes. An average time for solving one task is 3 minutes. When testing blind pupils, the time is usually increased according to their individual needs. RNIB [8] suggests increasing the time by 25% to 100%. According to the recommendations of Allman [1], the time should be extended by 50%. Since a standard school lesson lasts 45 minutes, we decided to set this as a limit for solving 9 tasks (3 easy, 3 medium and 3 hard). An average time for solving one task is 5 minutes. This means that blind children were given 60% more time than the able-bodied pupils.

The tasks were presented in a text document on the computer. We have chosen this option because our blind pupils were able to use a text editor smoothly. This cannot be said about their experience with a web browser. Our text document meets accessibility principles [13] as follows:

- All relevant information is in a **text format**.
- There are **no images**.
- There are **no references to colour**.
- Information in **the tables is arranged linearly**.
- Solutions are entered **via keyboard**.

We realized that blind pupils have to memorize a lot of information because the screen reader interprets the contents of the screen gradually. By Pasch [9], the short-term memory of an average individual can hold a maximum of 7 items for 15–30 seconds. However Pasqualotto [10] suggests that blind individuals, especially those without any visual experience, possess superior verbal and memory skills. In some contest tasks it is necessary to remember several lists of items and solve rather abstract problems. For these tasks, we attempted to **shorten the sequence of elements**.

3 Overview of tasks

With regard to the necessary modifications, tasks for blind pupils can be divided into the following categories.

- Tasks with **no change**. (NONE)
- **Tasks referring to colours**. In some tasks, important objects in the drawings are distinguished by colours. Such tasks are problematic both for blind pupils and for pupils with impaired colour vision. (COL)

- **Tasks using images** to present important information. In many tasks, important information is presented through images without a text alternative. These tasks are not accessible for blind pupils. (IMG)
- **Tasks using tables** with nonlinear order of information. These tasks are incomprehensible to blind pupils. (TAB)
- **Tasks with long sequences of elements**. Blind pupils have to remember these sequences and use them for solving abstract problems. (SEQ)
- **Interactive tasks** enabling the input only by mouse and not by keyboard. These tasks are unusable for blind pupils, who cannot use a mouse at all. (INT)

[Table 1] Overview of tasks

Name	Topic	Difficulty		Modifications
		Blind	Able-bodied	
E-mail	COM	Easy	Easy (ages 10–12)	NONE
Coins	INF	Easy	Easy (ages 10–12)	NONE
Birthday balloons	INF	Easy	Medium (ages 7–9)	COL, IMG
Baguettes	INF, ALG	Medium	Medium (ages 10–12)	COL, IMG, SEQ
Cookies	INF, ALG	Medium	Medium (ages 15–16)	TAB, COL
Telephone list	COM	Medium	Easy (ages 15–16)	NONE
Photos on the net	SOC, ALG	Hard	Easy (ages 15–16)	IMG
Drawing robot	ALG	Hard	Easy (ages 15–16)	IMG, SEQ
Secret code	ALG	Hard	Easy (ages 10–12)	IMG

There is an overview of tasks used in the last run of competition in Table 1. In the last column there are codes of modifications that we have done so that the tasks were accessible for blind pupils. In terms of thematic focus, tasks can be categorized into the following categories.

- Information comprehension (INF)
- Algorithmic thinking (ALG)
- Software and hardware (SWHW)

- ICT and society (SOC)
- ICT and communication (COM)

Now we present several tasks we refer to them later. Typical task which needs no change is the task **Coins** (Table 2). This task uses only text format without tables and without long sequences of elements.

To obtain the task **Baguettes** (Table 3, second part) we have modified the task **Car transportation** (Table 3, first part). Original task included several problematic elements for blind pupils. There were images and references to colours. Another difference in the original task was that cars were stored in two rows of four. In task for blind, baguettes were stored in one row of eight.

The task **Secret code** (Table 4) required just small modification. We just replaced the image by text.

We adapted the task **Drawing robot** (Table 5) by producing a shorter sequence of commands in example, so that we could describe the final drawing by text.

[Table 2] Task Coins

In the country of Bebranada, they have an interesting set of coins in their currency. The coin values are: 1 cent, 7 cents, 12 cents and 22 cents.

Beaver Mike wants to withdraw 15 cents.

What is the fewest number of coins that he can get in total?

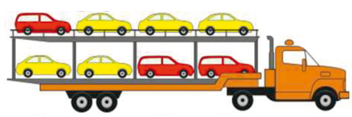
A) 2 coins
B) 3 coins
C) 5 coins
D) 15 coins

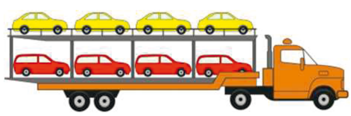
[Table 3] Task Car transportation (1. part) and task Baguettes (2. part of the table)

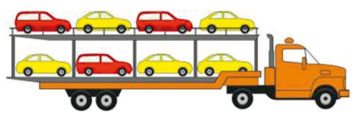
A new red car comes from a manufacturing line every 7 minutes. A new yellow car comes from another line every 5 minutes. A driver parks the cars in a car transporter in order they leave manufacturing lines. Top floor of the car transporter is loaded first. Both manufacturing lines start working the same time.

How will the car transporter look after loading?

A) 

B) 

C) 

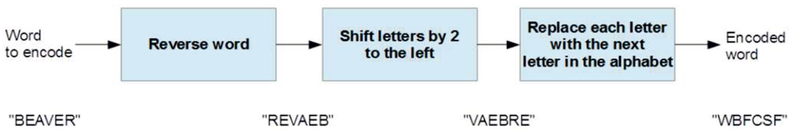
D) 

Two workers prepare cheese and ham baguettes in a sandwich shop. First one prepares the cheese baguette every 5 minutes. Second worker prepares the ham baguette every 7 minutes. Each worker places the prepared baguette on a tray in order they were finished Both workers start working the same time.

How will the tray look after loading eight baguettes?
A) cheese, ham, cheese, ham, cheese, ham, cheese, ham
B) cheese, ham, cheese, ham, ham, ham, cheese, cheese
C) cheese, cheese, cheese, cheese, ham, ham, ham, ham
D) cheese, ham, cheese, ham, cheese, cheese, ham, cheese

[Table 4] Task Secret code – original task on top, adjusted task at the bottom

Beaver Alex and beaver Betty send each other messages using the following sequence of transformations on every world.



For example the world BEAVER is transformed to WBFCSF.
Beaver Alex wants to send the message FLOOD to beaver Betty.

What should he send to her?
A) EPMFH
B) WJSSF
C) PMGEP
D) POLLD

Beaver Alex and beaver Betty send each other messages using the following sequence of transformations on every world.

1. Reverse word
2. Shift first 2 letters to the end
3. Replace each letter with the next letter in the alphabet (e.g. A replace with B, B replace with C, …, Y replace with Z, Z replace with A)

For example the word BEAVER in reverse order is REVAEB. After shifting first 2 letters to the end we receive VAEBRE. Then we replace each letter with the next letter in the alphabet and the final word is WBFCSF.
Beaver Alex wants to send the message FLOOD to beaver Betty.

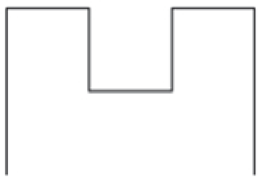
What should he send to her?
A) EPMFH
B) WJSSF
C) PMGEP
D) POLLD

[Table 5] Task Drawing robot – original task on top, adjusted task at the bottom

Tom built a drawing robot that can draw vertical and horizontal lines. The robot is programmed by a sequence of numbers.

- The first number is the length of a line that the robot draw vertically (upwards if positive, downwards if negative).
- The second number is the length of a line that the robot draw horizontally (to the right if positive or to the left if negative) from the position where the first line ended.
- The third number describes another vertical line, the fourth number another horizontal line and so on…

For example this sequence of numbers 2, 1, –1, 1, 1, 1, –2 makes the robot to draw this figure:



Which of these sequences does not make the robot to draw a square?

A) 1, 1, –1, –1

B) 1, –1, –1, 1

C) –1, 1, –1, 1

D) –1, –1, 1, 1

Tom built a drawing robot that can draw vertical and horizontal lines. The robot is programmed by a sequence of numbers.

- The first number is the length of a line that the robot draw vertically (upwards if positive, downwards if negative).
- The second number is the length of a line that the robot draw horizontally (to the right if positive or to the left if negative) from the position where the first line ended.
- The third number describes another vertical line, the fourth number another horizontal line and so on…

For example this sequence of numbers 2, 1, –2, –1 makes the robot to draw rectangle.

Which of these sequences does not make the robot to draw a square?

A) 1, 1, –1, –1

B) 1, –1, –1, 1

C) –1, 1, –1, 1

D) –1, –1, 1, 1

4 Verification

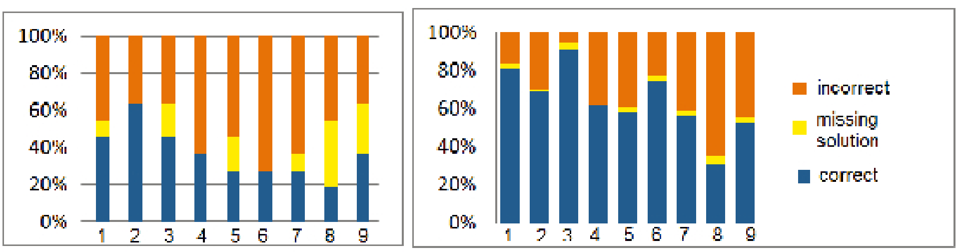
For the evaluation of tasks, a design based research [3], [7] is used. In several iterations we design the contest tasks and verify them with pupils. We analyse their solutions. Our analysis is aimed at suitability of tasks for blind pupils. We also conduct and analyze interviews with blind pupils to find out whether they really understand the tasks. Our verification described in this paper is just a part (the third iteration) of big ongoing research. In the frame of this iteration we verified the set of tasks presented in the previous section during the real run of the contest in 2015. The contest took place in a special school for the blind and partially sighted pupils. The group of contestants consisted of 11 pupils (five 5-graders, one 6-grader, two 7-graders and three 9-graders). The contestants were either totally blind or partially sighted – they all had to use screen reader.

Verification was done also with able-bodied pupils from a mainstream school. The aim was to compare the results of both groups – blind and able-bodied – to find out whether the tasks are suitable for all of them. Tasks were solved by 74 able-bodied pupils (twenty one 5-graders, eight 6-graders, thirty one 7-graders and fourteen 9-graders).

We can see results of both types of pupils in graphs on the Figure 1 (blind pupils on the left and able-bodied pupils on the right).

It is obvious that tasks were quite difficult for the blind pupils. Only the task Coins was solved correctly by more than 50% of pupils Success rate in solving all other tasks were less than 50%. The lowest number of correct answers was for the task Drawing robot. Tasks Birthday balloons, Cookies, Drawing robot and Secret code were not solved by big number of pupils.

In case of able-bodied pupils almost all tasks except the task Drawing robot were solved correctly by more than 50% of pupils. This task was the most difficult for both types of pupils. We can see that able-bodied pupils had fewer tasks with missing solution. The task Baguettes was the only one solved by all blind and able-bodied pupils.



[Fig. 1] Success rate of pupils in solving particular tasks (blind pupils on the left and able-bodied on the right)

If we compare success rate of blind and able-bodied pupils, we can see the following:

- Blind pupils had more tasks with missing solution.
- Blind pupils had fewer correct answers in each task.

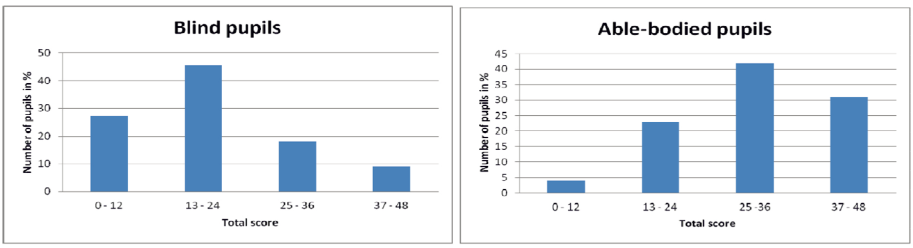
Now we analyze solutions of particular tasks. We focused on those which turned out problematic. About 38% of blind pupils solved the task **Baguettes** correctly. It is interesting that the majority of wrong answers was the same (answer A). This could mean that the task was not formulated clearly, respectively misinterpreted by pupils. Interviews with blind pupils showed that the task was quite difficult for them and they did not understand what to do.

The task **Drawing robot** was solved correctly only by 18% of blind pupils. It was difficult for them to imagine the movement of the robot. Percentage of able-bodied pupils was also relatively low. We found out that most of them have not read the assignment carefully. The task was to identify the sequence that does not make the robot to draw a square, but they were looking for the sequence that makes the robot to draw a square. Therefore they choose the first answer.

The task **Secret code** was solved correctly by 38% of blind pupils and more than 50% of able-bodied pupils. Interviews with blind pupils showed that they enjoyed the task. According to the graph on Figure 1, the difficulty level should be lower. Analysing solutions of pupils we found out that most of them made the same mistake – pupils managed to realize first two steps well, but they could not imagine how to realize the third step (to replace each letter with the next letter in the alphabet).

We found out that able-bodied pupils were more successful in solving particular tasks. As we can see on Figure 2 on the left, about 25% of blind pupils had lower score then 12 (total score was 48). Score higher than 36 had less than 10% of blind pupils. Almost 50% of blind pupils had score from 13 to 24.

As for the able-bodied pupils (Figure 2 on the right), less than 5% of pupils had score less than 12. More than 40% of pupils had score from 25 to 36. More than one third of pupils had score higher than 36.



[Fig. 2] The total score of blind (on the left) and able-bodied pupils (on the right)

5 Conclusions and plans

The Bebras contest plays an important role in determining trends in the area of informatics education. In this article we proposed special adaptations allowing blind pupils of lower secondary education to participate in the contest. More specifically, we presented set of tasks developed and verified during the real contest running in 2015. Verification was done with blind and able-bodied pupils of the same age. Tasks turned out accessible for both types of pupils. Analysis of the pupils' results shows better results of able-bodied pupils. We noticed that blind pupils with better results are able to have visual imagery. It is therefore possible that visual perception is helpful for solving most tasks. To proof or deny this it is necessary to undertake extensive qualitative research. We would like to check out the tasks with more blind contestants from other special schools (both in our country and abroad).

Worse results of blind pupils in Bebras contest does not demonstrate that blind pupils are not able to carry out tasks related to computing and informatics. This just suggests that tasks in the contest are easier for pupils who are able to have visual imagery. Therefore the nature of tasks does not meet the principles of universal design. In this case it is necessary for blind pupils to have a separate category in the contest.

Our ambition for the future is to find and verify criteria for good tasks that would meet the principles of universal design.

References

[1] Allman, C. B. Test Access. *Making Tests Accessible for Students with Visual Impairments: A Guide for Test Publishers, Test Developers, and State Assessment Personnel.* 4th Release, American Printing House for the Blind: Louisville, Kentucky, 2009.

[2] *Bebras* [online]. [cit. 2016-01-19]. Available in URL <http://www.bebras.org>.

[3] Bell, P. On the theoretical breadth of design-based research in education, In *Educational Psychologist.* 39 (4). Taylor & Francis, 2010. p. 243–253.

[4] Dagienė, V. Competition in Information Technology: an Informal Learning, In *Proceedings Eurologo.* Warsaw, Poland, 2005. p. 228–234. ISBN 83-917700-8-7.

[5] Dagienė, V. et al. Task Types at "Beaver" Contests, In Mittermeier, R. (Eds.) *ISSEP 2006, Vilnius, Lithuania: LNCS 4226.* Springer, 2006, p. 509–519. ISBN 3-540-48218-0.

[6] Jašková, Ľ., Kováčová, N. Bebras contest for the blind pupils. In *Proceedings of the 9th Workshop in Primary and Secondary Computing Education.* London, UK, November 9–11, 2015, New York, 2015. ISBN: 978-1-4503-3753-3.

[7] Kalaš, I. et al. *Metamorphoses of Schools in the Digital Age* (in Slovak). SPN – Mladé letá: Bratislava, 2013. ISBN 978-80-10-02409-4.

[8] *Overview of exam access arrangements* [online]. [cit. 2016-01-19]. Available in URL <http://www.rnib.org.uk/sites/default/files/Overview_of_exam_access_arrangements_May_2014.doc >.

[9] Pasch, M. et al. *Teaching as decision-making: Instructional practices for thesuccessful educator*. 2nd edition. Longman Publishing Group: New York, 1995. ISBN 80-7178-127-4.

[10] Pasqualotto, A. et al. Congenital Blindness Improves Semantic and Episodic Memory, In *Behavioural Brain Research*. Volume 244. Elsevier B.V, 2013. p. 162–165.

[11] Rose, D. H. et al. (Eds.). *The Universally Designed Classroom: Accessible Curriculum and Digital Technologies*. Harvard University Press: Cambridge, MA, 2005. ISBN 978-1891792632.

[12] United Nations. *Convention On The Rights Of Persons With Disabilities* [online]. 2006. [cit. 17-01-2016]. Available in URL <http://www.un.org/disabilities/convention/conventionfull.shtml>.

[13] W3C. Web Accessibility Initiative. *Accessibility principles* [online]. [cit. 2016-01-17]. Available in URL <http://www.w3.org/WAI/intro/people-use-web/principles>.

LUDI Database of Technology Based Play Experiences with Children with Disabilities

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Keywords: Database, Play, children with disabilities, assistive technology, LUDI

Abstract

Due to functional limitations, the lack of supporting technologies, and social and cultural contexts children with disabilities are often deprived of the right to play; play in fact is frequently seen as secondary when compared to rehabilitation interventions. One of the ultimate forecasted outcomes of LUDI is the production of guidelines for the design and development of technologies to support play for children with disabilities and of methodologies to evaluate their usability, accessibility and effectiveness. In this paper, a database of available technology to support play for children with disabilities, including methods for assessing usability, accessibility, and effectiveness, is presented.

1 Introduction

The Article 31 of the *Conventions on the Rights of the Child* establishes the "right to relax and play, and to join in a wide range of cultural, artistic and other recreational activities" [1], emphasizing the child's right to play. On the scientific point of view, since the 1950s, play has been scientifically recognized as a motor for child development [2], [3], [4], thus producing a change in the previous frameworks of play as a mere leisure activity.

When the focus is on children with disabilities, it should be noticed that they are often deprived from the right to play due to their own physical and/or cognitive impairments but also to the fact that their social and cultural contexts may exclude them from playing activities.

To overcome these barriers, technologies are being used in every daily activities and moreover in several children's occupations as well as play.

The use of technology to support the play activities of children with disabilities can be useful if the issue of accessibility is taken into consideration within the design process [5], [6]. Some studies have addressed the theme of technologies that enhance their ability to access play activities; some examples could be: robots used by Cook et al., as an assistive technology for play, learning and cognitive development [7]; social robots in Cabibihan's et al.'s study used to increase the autonomy of children with autism spectrum disorders [8]; virtual reality used in the research of Miller & Reid, where competence and self-efficacy were increased in children with cerebral palsy engaged in a virtual reality play intervention [9].

Technology is also considered within the International Classification of Functioning, Disability and Health (WHO, 2001) endorses that technology can influence the child's health dimensions and other environmental determinants of health.

As a consequence, technology is widely considered as a possible support to play, giving access to even more play scenarios and offering opportunities to a meaningful time between the child and the adult [10], [11]. However, the use of technologies is not well established and universally accepted by professionals working in the related fields. Some of them have concerns regarding the evolution of technology that could reduce their therapeutical influence and also refer that many proposed tools are only prototypes, consequently not completely reliable or not user friendly enough [12].

Therefore, aiming at presenting an holistic view on play for children with disabilities as a multi-disciplinary research field – such as education, (rehabilitation) medicine, engineering, psychology – the COST Action "LUDI – Play for Children with Disabilities" (2014–2018) was established. LUDI is a Pan-European network of professionals (researchers, scientists, and practitioners), users and their families, which includes 31 European countries.

The key aims are: "*collecting and systematizing all existing competence and skills: educational researches, clinical initiatives, know-how of resources centers and users' associations; developing new knowledge related to settings, tools and methodologies associated with the play of children with disabilities; disseminating the best practices emerging from the joint effort of researchers, practitioners and users*" (LUDI Memorandum of Understanding, 2014).

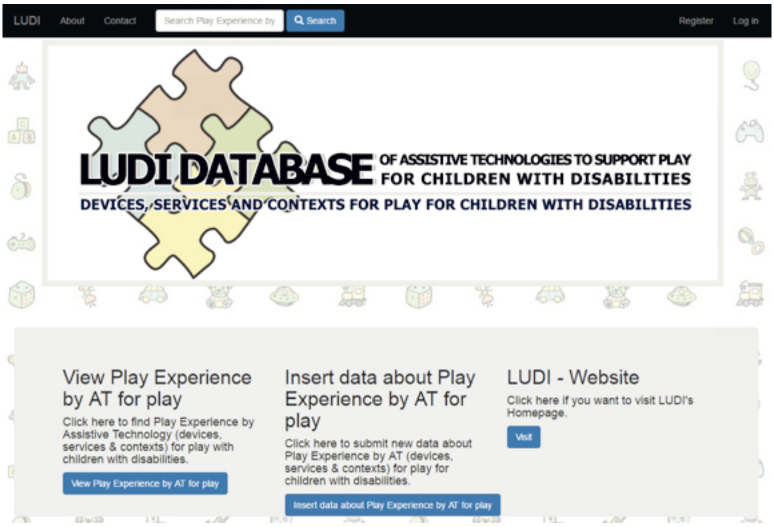
One of the first foreseen LUDI objectives is a database of available technology to support play for children with disabilities, including methods for assessing usability, accessibility, and effectiveness. In what follows, the LUDI Database is described.

2 LUDI Database

The main objective of the LUDI database is to collect a vast number of examples that can inspire users and clinicians. Whenever completed, parents should be able to retrieve technologies available for their child with a particular age and type of impairment, researchers should be able to find technologies that have been already developed to support play of impaired children, and clinicians should be able to find not only technologies but also assessment methods for an intervention with a particular technology. The database (Figure 1) is available from the LUDI Database webpage (http://ludi.utad.pt) and is open for everyone to contribute and consult.

The conceptual development of LUDI database started with the discussion about its main focus. Building repertoire of toys, tools and (assistive) technologies can stimulate awareness of possible tools for the play of children with disabilities. However different organizations (e.g. LUDUPOLE in France, National Lekotek Centre in the USA, AIJU in Spain) provide already information about play opportunities for commercial available toys as well as for adapted toys for children with different needs; toys are reviewed according to criteria which are different.

Work Group no. 2 of the Action LUDI then decided to specialize and focus the LUDI database on the play experiences with assistive technology devote to children; this was also meant to accomplish a second goal that underlies the database itself, which is providing an overview of tools for evaluating usability and accessibility of technologies for play for children with disabilities. Play experiences, in fact, are related to usability and accessibility of devices, services and contexts: therefore collecting data on how usability and accessibility of assistive technology are evaluated has been included.



[Fig. 1] Homepage of the LUDI Database

2.1 Database Design

LUDI database provides information about play experiences with assistive technologies in the broadest sense (e.g., assistive solutions and/or adaptive solutions to be able to use toys available on the mainstream market, but also high technology which is not yet commercially available); examples of environments enabling inclusive play, clinical interventions addressing play, etc. These are examples that demonstrate the diversity and variation in this field, and information to inspire users and other stakeholders (e.g., designers, policy makers, anyone involved) in developing play experiences with assistive technologies.

Furthermore, it provides information to formal and informal caregivers to stimulate evidence based working with children and also information to stimulate researchers to conduct sound research by taking into account the work which has be done in the field.

Finally, it invites interested people not connected to the LUDI network to share their experiences and outcomes.

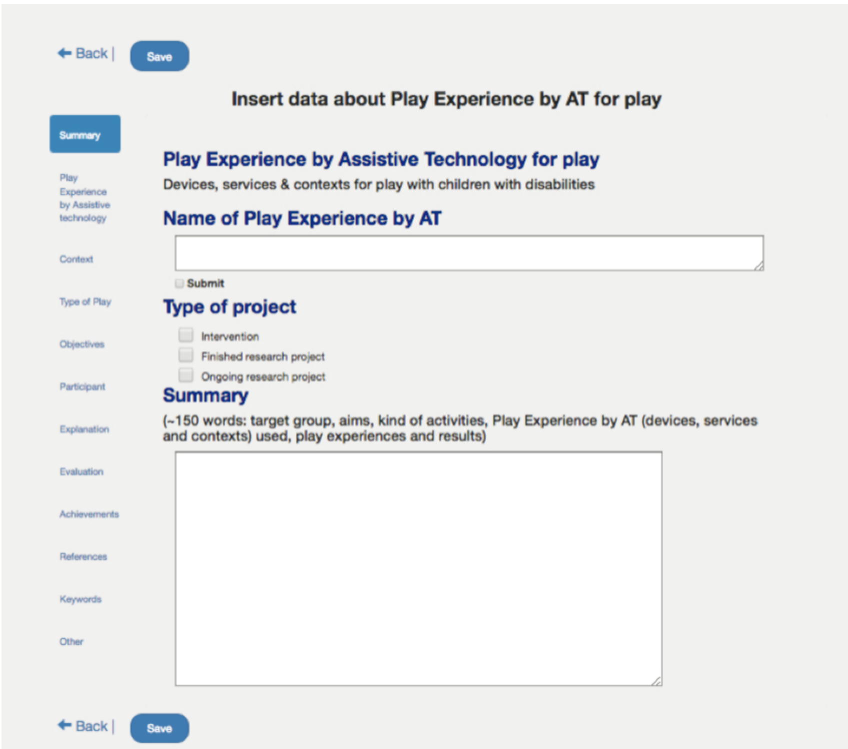
LUDI database is intended to reflect the work carried out by other Working Groups of the LUDI network. The holistic vision on play for children with disabilities is mirrored in collecting characteristics about the child, the goals of play, the technology used, and the physical and social context of play data. Examples of play experiences in different environments, such as parks, in- or out-door playgrounds, are welcomed as well.

2.2 Database Features

LUDI database allows users (researchers, clinicians, other stakeholders) to access and submit data (Figure 2) about play experiences with assistive technology). Thus, there are two types of users, depending on their navigation permissions.

If the user only wants to access data (read or search projects) does not need to be logged to the database, since he can access the "View Play Experience by AT for play at LUDI database" section.

If the user wants to add, edit, submit or cancel data, he/she must first register to the database (making the "login"). Whenever logged in, he/she have the following editing permissions: create, delete, edit and submit a project. When he/she is satisfied with the data entered about a project, he/she can submit the project. When this step will be completed, the project will be available for all users (registered and non-registered) in the section "View all Projects".



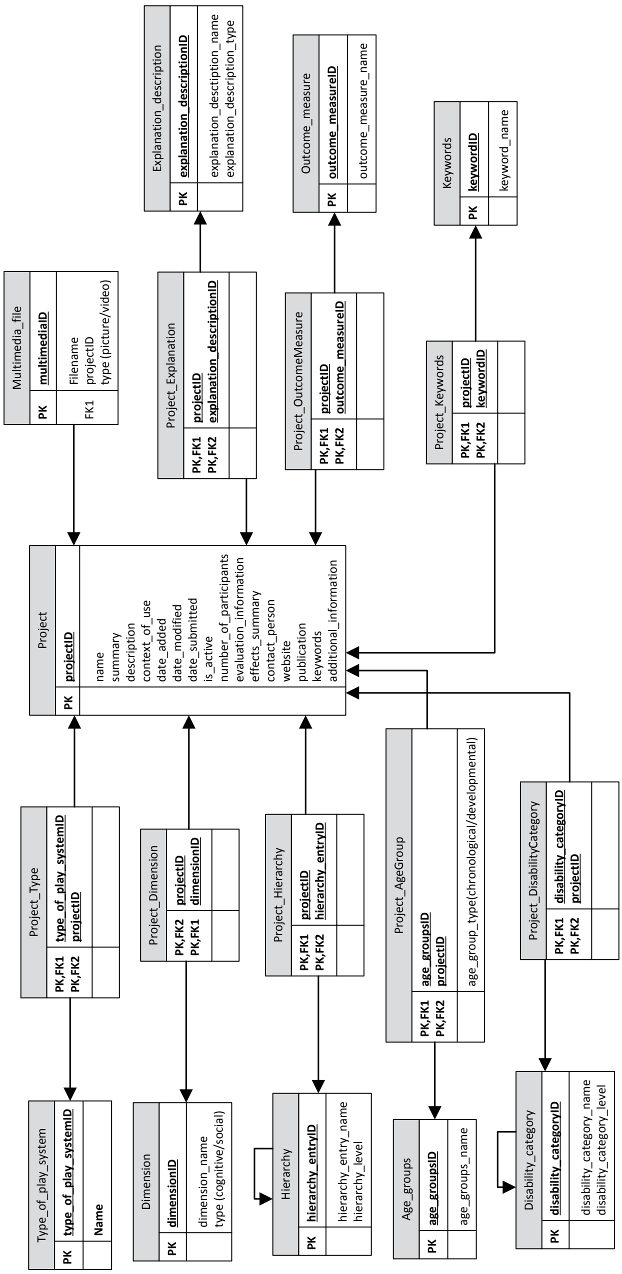
[Fig. 2] Interface to insert data into the database (similar to edit and view)

1.1 Database Optimization

The development of the database followed an iterative design process through a number of cycles of prototyping, evaluating and revising stages leading to the final version (Figure 3 demonstrates the final database architecture).

Initially a first version of the database template was consolidated, implemented and evaluated to ensure that it could properly accommodate the information regarding play experiences with assistive technology for children with disabilities. The database was then adjusted according to the feedback collected.

Then, members used the database to record information about play experiences, research projects, clinical interventions, etc., that they have been conducting or were aware of. Users (different stakeholders submitting data as well as for consulting data) then evaluated this process and the feedback was once more used for improving the database structure. After the conclusion of this cycle the database was opened to the public.



[Fig. 3] Architecture of LUDI Database to store play systems data

After having a final version of the database a set of performance measurement procedure was conducted. The main objective of these procedures was to test response behavior of the database while searching data.

The first case was conducted on a low selectivity query and retrieved about 95% of the project table: the average result without index (query based on LIKE) was of 10082,3 ms and the average result with full text index (query based on CONTAINS) was of 11492,8 ms. So in the first case the queries have about the same performance. The second case was conducted on a high selectivity query and retrieved two rows (less than 1%) of the project table: the average results without index (query based on LIKE) was of 2724,4 ms and the average result with full text index (query based on CONTAINS) was of 56,4 ms. Therefore, in the second case, the query was about 50 times faster with full text index.

3 Conclusion and future work

LUDI COST Action aims at creating a multi- and trans-disciplinary research area that focuses on play for children with disabilities. Low and high technological devices, services related to assistive technology and different environment can elicit inclusive play.

Evidence for children with a specific disability in playing games, playing with adapted toys or robots is growing in the research field; interesting results are obtained, regarding playing and playfulness, child's developmental and often feelings of autonomy and self-efficacy as well [9]. [10], [7], [11].

However technology development is often approached with a main focus to the technical possibilities and it become more and more clear the need that the focus is moved to play experiences of the children, in which technology is a mean, a vehicle, instead of the main objective.

The database still gathers little data on the experiences of technology users regarding play, while many areas might still be developed by taking into account the features of child and of the technology itself, the contexts in which the activities concretely happens; examples could be: challenging the child to express his/her own capabilities, the attractiveness of technology, etc.

Future guidelines regarding usability and accessibility of technology could prove very valuable under many respects. LUDI database aims to be an exhaustive source of data, both about play experiences of children with disabilities and about technology usability and accessibility. It will stimulate a user-centered approach of all stakeholders involved and evoke cooperation and joined future technological developments with focus on children with disabilities' play experiences.

Acknowledgments

We want to thank all the members of Working Group 2 of the COST Action "LUDI – Play for Children with Disabilities", who directly or indirectly helped in the development of the database.

References

[1] UNICEF. *Convention on the Rights of the Child, A summary of the rights under the Convention on the Rights of the Child*. 1989. Available in IRL <http://www.unicef.org/crc/files/Rights_overview.pdf>.

[2] Piaget, J. *The Construction of Reality in the Child*. Great Britain: Routledge, 1954.

[3] Huizinga, J. *Homo Ludens. A Study of the Play-Element in Culture*. Boston, Beacon Press, 1955.

[4] Vygotsky, L. *Mind in Society: The Development of Higher Psychological Processes*. Cambridge: Harvard University Press, 1978.

[5] Heah,T.; Case, T.; McGuire, B.; Law, M. Successful participation: the live experience among children with disabilities. *Canadian Journal of Occupational Therapy.* 74(1). 2007. p. 38–47.

[6] Copley, J.; Ziviani, J. Barriers to the use of assistive technology for children with multiple disabilities. *Occupational Therapy International.* 11(4), 2004. p. 29–243.

[7] Cook, A. M.; Encarnação, P.; Adams, K. Robots: Assistive technologies for play, learning and cognitive development. *Technology and Disability.* 22 (3), 2010. p. 127–145.

[8] Cabibihan, J.-J. ; Javed, H.; Ang, M. J.; Aljunied, S. M. Why robots? A survey on the roles and benefits of social robots in the therapy of children with autism. *International Journal of Social Robot.* (5), 2013. p. 593–618.

[9] Miller, S. Reid, D. Doing Play: Competency, Control and Expression. *Cyber psychology & behavior.* 6, 2003. p. 623–632.

[10] Rincon, A. M. R.; Adams, K. D.; Magill-Evans, J.; Cook, A.M. Changes in playfulness with a robotic intervention in a child with Cerebral Palsy. *Assistive Technology: From research to practice.* 2013. p. 161–166.

[11] Whiterspoon, L.; Manning, J. P. Active gaming: The future of play? *American Journal of Play.* 4(4), 2012. p. 464–487.

Is Play Easier for Children with Physical Impairments with Mainstream Robots? Accessibility Issues and Playfulness

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Keywords: Toys, Physical Impairment, toy robot

1 Introduction

Play "is a range of voluntary, intrinsically motivated activities normally associated with recreational pleasure and enjoyment" [6]. It is irreplaceable for human development, being the main support for the child's physical, cognitive and social development [4], [9], [14].

Children with physical and motor impairment (PI) experience substantial physical motor limitations, due to a damage to the performing system (skeleton, neuromuscular system, joints) or to the directive system [15]. Often PI is associated with intellectual and neuropsychological impairments, language and speech disorders, sensory impairments, as well as emotional and social difficulties [13]. Cerebral Palsy (CP) is a type of PI caused by brain damage occured around the time of childbirth, causing generalized disorders.

In children with CP, practice play can be limited because they cannot manipulate and use the objects. Symbolic, constructive, and rule play can show difficulties as well, given the needed integrity of the gross and the ne motor functions [1]; this situation can be even worse if there are also additional impairments – cognitive, sensorial. As to social dimension of play, children with PI have been described as frustrated by their motor impairment and with poor trust in themselves as players and play companions [10]. They feel "included"in a physical activity when they gain entry to play, feel like a legitimate participant, have friends [12]. Nevertheless, according to Skär [11], they can improve their self-perception if they use assistive technologies that can give them more autonomy in play activities without recurring to the aid of an adult.

Robotic toys could be considered as an opportunity to offer play opportunities to children with PI. Some prototypes have been developed but their efficacy with children with PI is controversial (Iromec [2], PALMIBER [5]). While research is still needed in this field, robot development is very expensive. Thus, mainstream robotic toys assume particular interest for research purposes, because a wide variety of robots is available, they allow different play scenarios and interactions modalitie, they are easily purchasable on the web. Consequently, it is possible to experiment the use of many different robots, chosen accordingly to specific criteria. Obtained results could be useful for further research and development of new tools.

2 The GioDi project

The Italian project GioDi (*Gioco per la Disabilita* – Play for Children with Disabilities)[1] exploited exactly the idea of experimenting a certain number of robots of the mainstream market with children with severe PI, to verify the playfulness of these tools and suggestions for further studies in the field of play for children with disabilities.

GioDi aimed at assessing the ludic use of 5 robots during interactions between a child with PI and other partners (peers or adults) in different contexts. The project encompassed four main objectives:

1. to analyze these robotic toys' accessibility in play session with children with severe CP;
2. to study the playfulness of these experiences, that is the degree to which the child is involved in play and is having fun during the activity [8];
3. to develop modifications to the toy input systems for making them more accessible and usable;
4. finally, to develop guidelines for parents, for using robotic toys for the play of their children.

The current paper reports the first results of the GioDi Project, with respect to the evaluation of the toys accessibility: this has been described in detail both in relation to the different scenarios proposed by the robots and to the needed child's requirements, functional and cognitive. Additional information has been introduced with respect to possible critical environmental aspects.

In this way, the analysis conducted gave the possibility to describe the experimentation outcomes with respect to the children's abilities from one hand and to the robot characteristics from the other hand; and this information will be precious to realize the next steps of the research, with special reference to the development of toy modifications and the creation of playful contexts of play.

In this paper, while the overall results of the toys' accessibility analysis are described, we will focus in particular to the details related to two very different robots:

1. **Edison**, which can elicit different types of play and present various levels of interaction complexity with the child;
2. **Zoomer**, which proposes an elementary interaction and only one type of play.

2.1 Method

Seven children (1 girl) were involved in the study; they had been selected according to their diagnosis (severe PI: PC in 6 children and degenerative muscle disease in 1 child) and their age (between 6 and 12 years).

After a targeted research on the Internet, 5 robotic toys of the mainstream market were identified according to:

- types of play allowed by the toy (practice, symbolic, constructive, rule [3]);
- types and variety of behaviours allowed by the toy;

1 Funded by the CRT Foundation (Turin, Italy) to L'Abilità onlus (Milan), Università della Valle d'Aosta, Politecnico di Milano, and Universita di Torino

- types of input systems, modiable through technological interventions according to the children's needs;
- variety of aesthetic features and congurations;
- affordable price.

The following robots were acquired from the market:

- Air Swimmer[2]
- Cubelets[3]
- Dash & Dot[4],
- Edison[5]
- Zoomer[6]

Children were observed while playing with the robots in three different situations, involving different partners:

- Laboratory (controlled context) in interaction with two adults expert in robotic toys and play interaction;
- Home (natural context) in interaction with familiar partners (parents, siblings, peers, etc.);
- Leisure center (natural context) in interaction with unknown peers.

Each play session lasted about 45–55 minutes, and was focused on two or three toys, accordingly to the child's interest in the activity.

2.2 Toy Description

In this section Edison and Zoomer will be described, reporting the main play activities they can offer and the cognitive, physical, and motor qualities they require for a proficient interaction.

2.2.1 Edison

Characterized by its essential look and versatility, Edison is a simple autonomous robot with Lego interfaces. It shows extraordinary resistance (can sustain heavy weights), and has several sensors (sound, light, and line reader) and actuators (lights, speaker, and motors).

Edison can be programmed through a bar code, choosing among 6 different coded games, or via a connection with a computer through a programming interface, possibly used by operators to devise new games. To complete the toy experience several complements can be downloaded from the product website; as an example a *game mat* is available: a printable poster reporting the barcodes and a playing area. Moreover, it is possible to design its program through an open source simplified IDE (Integrated Development Environment), enabling the user to decide directly the behavior of the robot. Finally Edi-

2 William Mark Corporation – http://airswimmers.com/

3 Modrobotics website – http://www.modrobotics.com/cubelets/

4 Wonder Workshop official website – https://www.makewonder.com/dash

5 Meet Edison – https://meetedison.com/

6 Zoomer official website – http://zoomerpup.com/

son can be integrated as intelligent core in Lego projects or even assembled with other robots, sharing information.

For this research purposes, it was possible to play only with the 6 pre-coded games: letting the children design the device program was beyond their capabilities. The available programmed games are:

- Line Tracking: Edison follows a black line on the plan (game mat);
- Follow Torch: a light attracts Edison;
- Avoid obstacles: Edison uses its sensors to avoid hitting obstacles;
- Clap controlled driving: One clap makes Edison turn, two make it move forward;
- Bounce in borders: Edison wanders inside a closed shape drawn on the plan (game mat);
- Sumo Wrestling: Edison seeks its opponent and try to push it out of the ring (a track on the game mat).

The player interacts with Edison in many different ways, at different levels. The robot programming and activation requires the timely interaction with 1cm-large buttons and the correct placement of the robot to scan the barcode. This activity requires quite fine fingers, hand control, and coordination. The same qualities are required for the construction of decorations made of Lego components. Nonetheless, depending on the chosen game, the player can interact with the toy though objects (e.g., torch, obstacles) or with his/her body (clapping hands, putting hands in front of the robot to make it changing its direction), requiring a less precise motor control. It is worth noting that the simplest game, controlling Edison with clap, can also be performed at the table, simply hitting the surface once or twice.

2.2.2 Zoomer

This toy is a robotic pet dog, able to recognize vocal commands. It can act autonomously, emulating the behavior of a dog which explores a random environment. It is programmed to perform several different actions, most of which can be funny or intriguing for the children, making Zoomer a stimulating play companion. Just to make few examples, it can roll, play dead, sing, pee, and much more. The actions can be triggered by the children in two main ways: pressing a button which runs a random action, or issuing a specific vocal command.

The intended game flow starts by putting Zoomer in listen mode (by pressing gently his head), to issue the command, and the execution of the action, after which the dog returns in listen mode waiting for the next request. After some time in autonomous mode, it goes in standby mode, miming sleep.

The interaction with the toy requires the capability to produce clear and quite loud speech. Zoomer is designed to adapt and learn the owner voice, facilitating the commands recognition. A few physical interaction is anyway necessary to put the dog in listen mode. Whenever speech is not sufficient, it is still possible to trigger random actions, requiring a fair hand and fingers control. Even if possible, the toy encounters difficulties acting on a table or a desk: its movements are fast and broad, more suited for floor activities, requiring unimpaired walk or at least autonomous movement on wheelchair. It is not no neglect that it is possible to enjoy Zoomer passively, when activated by another child or an adult. Finally, it is worth noting that the commands to be issued are fixed, and are not interpreted by the toy, requiring a good memory and a precise speech.

3 Results: crossing toys characteristics, play scenarios and children's abilities

Tables 1 (Edison) and 2 (Zoomer) report the crossing between the toy features, the children's functional and cognitive abilities required by the toys to be used, the environmental aspects necessary to support the play activity, and the GioDi experimentation outcomes.

4 Discussion: crossing toys' characteristics, play scenarios and children's abilities

In Table 1 (related to Edison) and Table 2 (Zoomer), the toys' characteristics and the play scenarios have been crossed with the needed children's characteristics, in terms of functional and cognitive abilities. Critical environmental aspects necessary to support the play activity have been also included. In this way, accessibility is described as the "encounter between a person's functional capacity and the design and demands of the physical environment". The last column presents the outcomes of the use of the robots during the experimentation activities with the children; it is intended to give exhaustive information about the obstacles detected in the play sessions, so that modications can be planned for future improvements, as well as the positive peculiar aspects, so that they can be implemented and stabilized. Even if only 2 of the 5 robots are here presented in detail, some results of the experimentation can be reported as common; generally speaking, the robots were not easily accessible to these children according to their functional abilities. This implied two main consequences:

- a passive use of the robots by children (an onlooker play) was required;
- the adults had to play a relevant role in the play activity.

Nevertheless, some of these robots were evidently playful for these children, also in the "passive mode": they were happy to take part to the activity and to interact with them as they could. Adults acted to increase the potential playfulness of these passive activities by creating a persuasive playful background (narrative, motivational, supportive), in which both the robot and the child could find their own place.

Another important finding is that playfulness increases if the children are able to interact personally and autonomously with the robot, and if they can understand clearly what happens to the robot as a consequence to their actions. This could confirm that self-efficacy and a feeling of control on the play situation is important for playfulness [8].

Both functional and cognitive abilities are implied in creating obstacles to the robots' use; in some cases, the robot is mainly not accessible because of the type of physical interaction it requires, in some cases because of the type of scenarios it proposes, and in further cases both aspects are implied to prevent a child from being able to use these robots as play tools. However, while – at least in some cases – some assistive solutions can be studied and implemented to overcome physical obstacles, cognitive requirements are more challenging, since they are related to the quality and the type of scenarios, and consequently to the intellectual abilities of the child and the type of play he/she is able to manage.

[Table 1] Relationship Child/Robot – Edison

<table>
<tr><th colspan="2">Child Abilities</th><th rowspan="2">Environmental Aspects</th><th rowspan="2">Experimentation Outcomes</th></tr>
<tr><th>Functional</th><th>Cognitive</th></tr>
<tr>
<td>• Move the small lever of activation
– Coordinated use of the two hands
– good ability to separate the use of one finger per hand to move effectively the small lever
• Hand-clapping to activate the robot
– Hand-clapping effective enough to be detected
– Speed of the clapping
• Use of the buttons needed to implement the new program on the robot (through a bar code)
– good ability to separate the use of one finger to press
– pressing of one button three times in a short time
– precise pressing and speed of another button after a short pause</td>
<td>Passive Use (little signicant)
• Maintaining the attention on the robot's action
• Understanding of the concept of "winner" when observing a simple play with rules (scenario "Sumo wrestling")

Active Use
• Understanding of the relationship between one's own action and the robot's behaviour
• Counting up to three
• Capacity to recognize different buttons and to manage times to press them
• Selection and planning of robot's uses in relation to play scenarios
• Use of robots within symbolic scenarios by adding Lego bricks
• Planning of symbolic scenarios by adding Lego bricks</td>
<td>• Necessity of playing on a wide horizontal at surface, where Edison can be easily seen
• Potential adjustment of the relationship child (wheelchair)/horizontal surface to favor the best autonomous use of the robot
• During inclusive play with other children, necessity of optimizing the solution to share the play surface
• When programming the robot with other children, necessity of coordinating the activities accordingly to each child abilities and proposals, supporting negotiation</td>
<td>Passive Use
• The most used Edison play scenarios were "Line tracking" and "Sumo wrestling"
• The small lever of activation has been always managed by the experimenter

Active Use
• The only play scenario in which children could act was "Clap control"

Proposed Play Background
• Car race: based on the play scenario "Line tracking", a car race was realized, among Edisons with Lego bricks on the top to personalize them, so that each child could recognize his/her own car, in order to end up with a winner</td>
</tr>
</table>

Child Abilities		Environmental Aspects	Experimentation Outcomes
Functional	Cognitive		
Programming • Programming new scenarios through sequences of actions within a devoted software – Reference should be made to accessibility of hardware tools and software environments • Use of the remote control – Possible critical aspects related to the type of remote control	**Programming** • Planning of activities or sequences of activities to implement in the robot • Capacity to evaluate the outcomes obtained with the planned robot and to modify the programming on the basis of the needs or of the planning • For programming: – Understanding and using symbols – Understanding and using schemes and graphic representations – Creating and modifying sequences **Note** • When playing with other children, capacity to express one's planning and to negotiate them with the others, in a collaborative way		• The scenario "Sumo wrestling" was realized, among Edisons with Lego bricks on the top to personalize them, so that each child could recognize his/her own robot, in order to end up with a winner • The personalization of Edison was supported by the experimenter who helped the child fixing the Lego bricks, or who fixed the Lego bricks for the child **Playfulness** • The scenario "Clap" was particularly funny for the children, because it allowed them to voluntary control Edison • The hand clap was substituted by hitting the table: this movement was effective but less difficult because it did not required the movement and the strength control

[Table 2] Relationship Child/Robot – Zoomer

Child Abilities		Environmental Aspects	Experimentation Outcomes
Functional	Cognitive		
• Move the small lever of activation – Co-ordinated use of the two hands – good ability to separate the use of one finger per hand to move effectively the small lever • Activation of the robot through verbal pronunciation of commands made of words and sentences: – adequate tone of voice, fluency of the sentences – correctness of the sentence under any aspect (phonological, lexical, grammatical, prosodic) – introduction of the name "Zoomer" before each command – lowering the dog's head before each command	• Understanding the relationship between one's own action and the robot's behavior • Selection of different uses of the robot • Control over the verbal language under various respects: – Phonetic correctness and adequacy (phonemes, tone of the voice) – correctness of the repetition of strings, also as to prosody • Wilingness to exercise one's verbal production until the dog can recognize it • Memorization of sequence of actions and word to produce for activating the robot (Zoomer + touch the head + command) • Counting up to two	• Necessity of playing on a wide horizontal at surface, where Dash & Dot can be easily seen (in case of a table, pay attention to possible falls) • Potential adjustment of the relationship child (wheelchair)/ horizontal surface to favor the best autonomous use of the robot	**Active Use** • One child only succeeded in controlling Zoomer through his voice, given the required vocal and linguistic precision of the command • Probably a stable use of the robot improves this possibility (Zoomer gets used to a specific voice) • The easiest modality was activating the robot through the button that generates casual behaviors • The robot activation was easy because the button was big enough; nevertheless, some children faced difficulties in understanding that just one pressure was needed; they faced difficulties in stopping pressing the button to observe the robot behavior (one child ended up in pressing continuously the button)

Child Abilities		Environmental Aspects	Experimentation Outcomes
Functional	Cognitive		
• Activation of the robot through hand-clapping – Hand-clapping effective enough to be detected – Speed of the clapping • Activation of the robot through a button – Pressing of the button, which can be easily found and usable as to its dimensions			**Playfulness** • Zoomer was very interesting for the children, because of its "real animal" shape and movements • The difficulty of giving a precise vocal command ended in a negative feedback by the robot and this created frustration and demotivation in the children

Zoomer is an interesting case in this sense, because it is funny and could be used in an autonomous way; there are problems to control it by voice, but the pressure of a button can be considered a good alternative. However, the scenarios it proposes and the types of play it is related to are really elementary. The cognitive gain with respect to usual non-robotic toys is not really evident; it is only possible to refer to a sort of "emotional" gain, because the small dog is really nice and funny, to the point that also a passive use can be considered. From the theory of play point of view, it is very rigid, since it proposes only a basic practice play, based on cause-effect relationship. Edison can be considered at the opposite side. Per se, it is not very attractive, and a passive use is not very interesting. It can raise curiosity if the user can understand, enjoy, and, above all, control its numerous functions to move, to follow a track, to bounce. Moreover, it becomes a real challenging and good tool to play with peers, if the user is able to program it, to realize sequences of actions to the point of creating complex play scenarios. From the theory of play point of view, it is quite flexible, it allows different types of play and it supports play development. However, Edison presents nontrivial obstacles to accessibility, as it is described in Table 1; in fact, the most interesting scenarios are activated via the PC after programming, while the basic scenarios lead only to a passive attitude. For a playful use of Edison both physical and cognitive abilities are implied, and perhaps a totally different design should be needed to make the robot accessible – or at least more usable – for children with PI.

5 Conclusions

The first results here presented of the GioDi project will be completed in the next future by further deepening of the following areas:

- the development – and the testing – of possible modifications to the robots, according to the functional and cognitive abilities of the children;
- an improved accessibility of the robot will give children the possibility to play in an autonomous way: their play abilities should be differently exploited and playfulness should also increase;
- the implementation of suitable changes in the play contexts, so that play backgrounds proposed by the adults are no more surrogates for a lack of playfulness of the toy, but only a support for play development.

Many further areas of research have been opened by this first experience, that could be faced in the future; one area that seems particularly promising is related to the social aspects of play, being unavoidable a specific consideration of the inclusive aspect of the play activity. This could be done, for example by studying the playfulness of the toys' scenarios, by including also the variables related to the partners of play (peer vs. adult, familiar vs. unfamiliar) and the contexts in which play occurs (home vs. laboratory, dyadic vs. group interaction). In conclusion, mainstream toys have proved as potentially interesting solutions to support play of children with disabilities. Anyway, they also proved to be very far from being accessible to these children, and consequently they could not be used in an autonomous way, thus decreasing their playfulness. Nevertheless, assessing their accessibility in strict relationship with the children's functional and cognitive abilities can inspire interesting general considerations for increasing the usability of mainstream robots and for developing new robotic toys.

References

[1] Besio, Serenella; Amelina, Natalia. Play for children with motor impairment. In BESIO, Serenella et al. *Theoretical models descriptive of play development of children with disabilities*: LUDI COST Action TD1309. Deliverable no. 1, 2016.

[2] Besio, Serenella; Caprino, Francesca; Laudanna, Elena. *Proling robotmediated play for children with disabilities through ICF-CY: the example of the European project IROMEC*. Springer Berlin Heidelberg. 2008. p. 545–552. ISBN 978-3-540-70539-0

[3] Bianquin, Nicole; Bulgarelli, Daniela. Conceptual review of play. In BESIO, Serenella et al. *Theoretical models descriptive of play development of children with disabilities*: LUDI COST Action TD1309, Deliverable no. 1, 2016.

[4] Bruner, Jerome S.; Jolly, Alison; Silva, Kathy (Eds.). *Play. Its role in Development and Evolution*. New York: Basic Books. 1976. ISBN 0465057810.

[5] Ceres, Ramon; Pons, J. L.; Calderon, Llanarys; Azevedo, Luis. A robot vehicle for disabled children. *IEEE Engineering in Medicine ad Biology Magazine*. 24, 6. p. 55–63. 2005. ISSN 0739-5175.

[6] Garvey, Cathrine. *Play*. Harvard University Press: Cambridge, 1990. ISBN 978-0-674-67365-6.

[7] Iwarsson, Susanne; Stahl Agnetha. Accessibility, usability and universal design – positioning and denition of concepts describing person-environment relationships. *Disability and rehabilitation*. 25, p. 57–66. 2003. ISSN 0963-8288.

[8] Okimoto, Ann Mari; Bundy, Anita; Hanzlik, Jodie. Playfulness in children with and without disability: Measurement and intervention. *American Journal of Occupational Therapy*. 54, p. 73–82. 2000 ISSN 0272-9490.

[9] Piaget, Jean. *Play, dreams and imitation in childhood*. Norton: New York, 1962. ISBN 0393001717.

[10] Pollock, Nancy; Stewart, Debra; Law, Mary et al. The meaning of play for young people with physical disabilities. *The Canadian Journal of Occupational Therapy*. 64, 1. 1997. p. 25–31. ISSN 0008-4174.

[11] Skär, Lisa. Disabled children's perceptions of technical aids, assistance and peers in play situations. *Scandinavian Journal of Caring Sciences*. 16, 1. 2002. p. 27–33. ISSN 1471-6712.

[12] Spencer-Cavaliere, Nancy; Watkinson, Jane. Inclusion understood from the perspective of children with disability. *Adapted Physical Activity Quarterly*. 27, 4. 2010. p. 275–293. ISSN 0736-5829.

[13] Tingle, Myra. *The Motor Impaired Child*. Taylor & Francis: Abingdon (1st ed. 1990), 2005. ISBN 0-203-27585-3.

[14] Vygotskij, Lev. *Play and its Role in the Mental Development of the Child*. In J.S. Bruner, A. Jolly, K. Silva (Eds.), cit. p. 537–554. 1976. ISBN 0465057810.

[15] World Health Organization. *The ICD-10 classication of mental and behavioural disorders: clinical descriptions and diagnostic guidelines*. Geneva: World Health Organization, 1992. ISBN 9241544228.

Caregivers' Support for Children with Motor Impairments in Robot-mediated Play Contexts. A Case Study for the Investigation of Adult/child Relationship in Supporting Play Development

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Keywords: children with disabilities, inclusion, play, robotic technologies

1 Introduction

This article investigates the mediating role of robotic technologies in supporting the play skills and performances of children with Cerebral Palsy. The results presented here are the outcomes of experimentation conducted by the research group the University of Aosta Valley. At the beginning the research goal was to test the hypothesis that children's spatial visualization abilities could be influenced by playing sessions that involved the use of these abilities. During the analysis of the videos and notes taken by therapists and researchers who took part in the experimental sessions it emerged that this hypothesis had to be discarded, but another research topic became evident: the caregivers' verbal and physical prompts was a crucial determining factor in letting children acquire play competence through the interaction with robotic technologies.

2 Background

Play is widely considered a fundamental experience for the overall development of cognitive, socio-psychological and relational skills. Play is also a unique and invaluable mean to guarantee a typical functional child development: play is necessary to learn new skills, to explore the physical environment and to broaden social relationships [2]. Children with severe motor impairments can't fully be benefited by the richness of play experience because they lack adequate play contexts and materials and they are therefore deprived of the possibility to have the same play skills and opportunities as their typically developing peers [8]. Although play's relevance in children development, the subject of play activity for children with motor impairments as a way to gain self-confidence, to take advantage of their abilities and to accept and overcome the limitations associated with their impairments has become a popular research topic only recently [3]. Researches in this area have focused on the enabling technology for play such as robotic companions for children with cognitive and motor impairments [2]. Among these researches many have addressed the role of the environment and that of educators, rehabilitation professionals and adults in general in facilitating play competence and provided useful assessment tools such as the Test of Playfulness (ToP) and the Test of Environmental Supportiveness (TOES) proposed by Bundy [6]. These tests provide an account for children and caregivers' behaviour in the interaction with robotic technologies but they leave open the issue of a detailed classification of adult prompts. Therefore in this paper the mentioned tests will serve as a tool for analysis in combination with a scheme of adult prompts devised within the framework of the IROMEC project1 by the research group of the University of Aosta Valley [2]. IROMEC is a prototype designed to address cognitive and motor impairments in the framework of a EU financed research project. The deliverables of IROMEC project regarding the analysis of Critical factors involved in using interactive robots for education and therapy of children with disabilities [4] along with IROMEC Methodological Framework [1] and Guidelines [2] serve as a starting point for the results presented in this paper.

3 System description

Three different robots have been used for the experimentation. Besides IROMEC, a robot developed in the context of a research project, the other two were I-SOBOT and Wall-E, two commercial robots whose interfaces were adapted by the research group of the University of Aosta Valley [1] so to let children with severe motor disabilities interact with the robots through touch switches. The play scenarios used for the experimentations were based on those devised during the project IROMEC [9]. The switches allowed children to use one hand to make the robot rotate and the other to make the robot move forward in a direction. Before the play session an assessment of the sensorimotor abilities was conducted for each child so to better choose the kind of switch they had to use to control the robot. The experimentations have been conducted using ten different play scenarios, each with increasing levels of difficulty. Every scenario was a problem-solving task that required many different steps for each level to be accomplished. The higher the level the mores complicated were the steps children had to make. A step could either be to rotate the robot or to make it move or to use it to reach some objects and the other therapist in the room. In fact, play consisted for the beginning levels in making the robot reach one therapist sat in the opposite side of the room and make it go back to the child. The advanced levels instead included also the interaction with other objects such as toys that the child had to locate in the room making the robot exploring it. Children were instructed by two therapists about how to interact with the robot. One therapist sat close to the children to supervise and help them during the play session by explaining the rules and keeping children's attention focused on the activity. Another therapist was the children's playmate for the scenarios of lower levels and supported children verbally by encouraging them to play.

4 Research questions

As it has already been mentioned, the research initially concerned whether spatial visualization skills of children affected by Cerebral Palsy change due to play activity with the robots, but evolved reviewing the video material of the experimentation into an investigation of how the caregivers' support change session after session. Two types of support have been singled out:

1 IROMEC is a Specific Targeted Research Project (contract number IST-FP6-045356) co-funded by the European Commission within the RTD activities of the Strategic Objective SO 2.6.1 "Advanced Robotics" of the 6th Framework Programme. (http://www.iromec.org/)

- a physical and verbal contribution aimed at helping the child in the problem solving process (i.e. explaining the rules of the play scenario, guiding them to understand the cause-effect relationship between activating the switch and the rotation and advancing of the robot, helping them to understand their errors in controlling the robot);
- a contribution aimed at keeping the children's attention focused on the activity by relying on the emotional involvement in the activity and to generate a playful and engaging experience.

It is also necessary to make a distinction between prompts – caregivers' help to the child during the play activity that can be related to problem solving and to attention – and reinforcements – caregivers' verbal encouragement in making the child continue playing or to identify the correct action accomplished by the child. In the proposed scale only prompts are evaluated since the reinforces given to children were too different from child to child due to the individual differences in the severity of disabled condition.

Both types of support can be organized in terms of support needed by the child on an increasing scale of:

1. Limited verbal prompts (i.e. *Do you like this robot? Would you like to play with it? Come on, let's play! Look at the robot! It is moving forward!*);
2. Verbal instructions (i.e. *Try to push the red button and see what happens*);
3. Verbal instructions associated with gestures about the actions to carry out;
4. Verbal instructions and physical modelling that shows the child the correct sequence of actions and the results of that action (i.e., *Look what I do, I push the button and the robot moves and now I push it again and the robot stops, do you want to try it?*);
5. Restricted physical assistance (i.e. touch the child's arm or hand to invite him/her to do something);
6. Complete physical guidance (i.e. support the hand or arm to allow the child to push a button).

The considered scale includes for attention only the first 3 categories whereas the contribution for problem solving belongs to all the six categories proposed. Furthermore, it is necessary to mention that the considered prompts only relate to the play activity and don't take into account the therapists physical guidance specifically related to the child disability (i.e. Therapists who place children's arm closer to the switch can be considered as physical guidance in the scale, but therapists who have to offer mere postural support isn't considered in this scale).

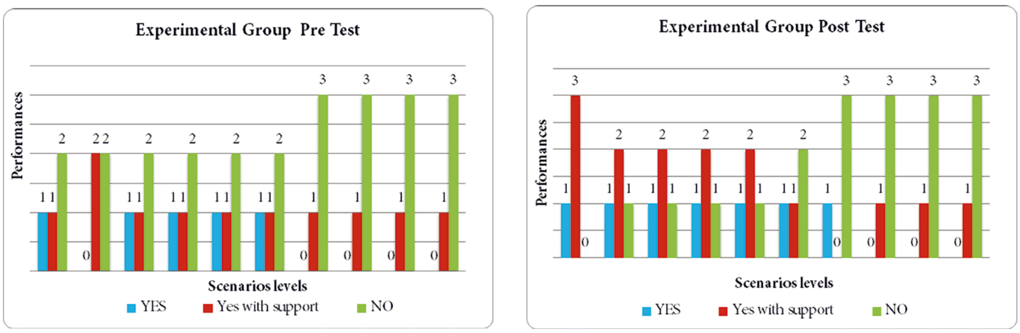
5 Method

8 children affected by Cerebral Palsy took part in the pre-test phase. Children were randomly assigned to an experimental or a control group. Both groups were instructed to complete a spatial visualization ability assessment using switches to move an object on a computer screen. The test consisted in ten levels of increasing difficulty. Each child was given a scoring point in the trials on the basis of the number of levels accomplished so

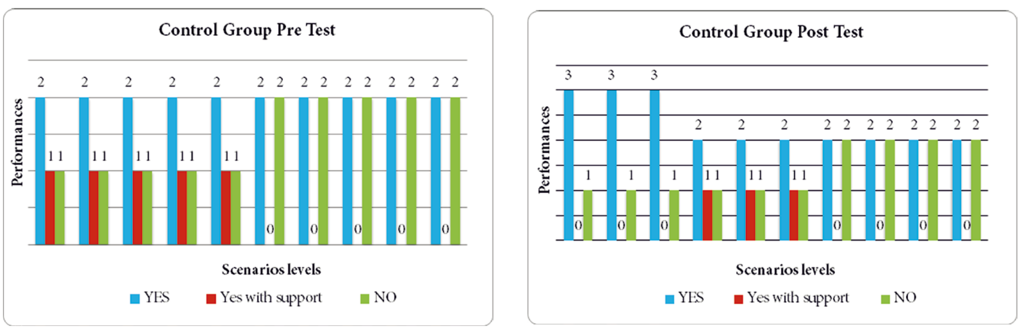
to get a baseline to compare the performances of both the experimental and the control group with the results obtained on the same test in the post experimentation phase. Each child in the experimental group participated to 8 play sessions. Each session lasted about 50 minutes. During the experimental sessions the children were involved in scenarios of increasing difficulty moving towards more difficult levels every time the child could successfully repeat the correct actions to accomplish each level at least three times.

6 Results

The following charts do not show how either performances of the experimental group are significantly different after the participation to the play sessions or these performances seem to be improved in a more evident way compared to the performance of the control group of children. Therefore it is not possible to consider attending the play sessions as a significantly determining factor in modifying children's spatial visualization ability, since children in both groups seem to slightly improve in their performances.



[Fig. 1] The performances of the experimental in the pre-test and post-test phase[2]



[Fig. 2] Control group's performances' in the pre-test and post-test phase

On the other hand it was possible to observe that therapists' support changed during the play sessions. At the beginning adults' contribution mostly belonged to the categories 4, 5 and 6 showing that the prompts in the area of problem solving were the most often

2 The first column represents the number of children who passed each level without any support from therapists; the second column represents children who had a determining support to pass a level and the third column the number of children who didn't pass the level.

required by the children. In the final session it is possible to observe a decrease in these kinds of prompts. The adults' prompts mainly belong to the categories 1, 2 and 3 for two of the four children in the experimental group while the other two still needed a restricted physical support. Therapists used many limited verbal prompts not only to help the child make the right action but also to reinforce children's keeping attention focused on the play activity. Based on the caregivers' diaries and on the observation of the videos of the experimental sessions while the contributions related to problem solving decrease between the first and the last session, the verbal contributions related to attention are substantially constant. Further results are reported in other studies [5].

7 Discussion

This paper can't provide an answer to the question about changes in spatial visualization skills after the play sessions because the results show that both the experimental and control group performed slightly better in the post-test phase so it's not possible to define the impact of the play on visual skills. The results about the therapists' contribution suggest more interesting research insights. The decrease in the use of prompts related to problem solving in terms of support given shows that children needed less support to understand how to accomplish each level, showing that therapists' application of the method of prompts fading [7] was successful. All the children effectively learnt the rules of the play scenario, they required less prompts to understand how to interact with the robot and managed to accomplish at least the lower difficulty levels where they only had to interact with the therapists.

On the other hand the prompts related to attention mark a significant difference from the prompts related to understanding how to play. The fact that children need little support to understand what to do but are still easily distracted and require to be encouraged to focus on the play scenario is a sign that the sessions do not constitute a sufficiently engaging playful activity for children affected by severe motor impairments such as Cerebral Palsy and suggest further research in the definition of play scenarios and to a wider extent in the redesign of robotic mediated play activities.

8 Next steps

The results presented suggest further investigation to construct an assessment tool able to understand and describe the type and the degree of therapists' contribution in supporting children with severe motor impairments. This tool should embody a classification of all the verbal and physical prompts and reinforces that therapists use both for problem solving and to keep children's attention focused on the activity. Defining a classification of these contributions requires verbal expressions to be correctly interpreted. As an example it is possible to consider how an expression that would normally be classified as belonging to the attention area (i.e. *Look at the robot!*) can instead belong to the problem solving area if the therapists' communicative intention is to make the child understand how to control the robot. The solution proposed for further research then, is to design a diagram that can overcome the ambiguity of spoken language by considering verbal expression not only for their meaning in general but also for their contextual communicative aim.

References

[1] Besio, S.; Caprino, F.; Laudanna, E. *Methodological Framework to set up educational and therapy sessions with IROMEC*. Uniservice, *Trento*. 2009.

[2] Besio, S.; Caprino, F.; Laudanna, E. *Guidelines for using robots in education and play therapy sessions for children with disabilities*. Uniservice, *Trento*. 2010.

[3] Besio, S. An Italian research project to study the play of children with motor disabilities: the first year of activity. *Disability & Rehabilitation*. 2002. Vol. 24, no. 1–3, p. 72–79.

[4] Besio, S. *Analysis of Critical Factors Involved in using interactive Robots for Education and Therapy of children with disabilities*. Uniservice, *Trento*. 2010.

[5] Besio, S.; Carnesecchi, M.; Converti, R. M. Prompt-fading Strategies in Robot Mediated Play Sessions. In *From Research to Practice, Proceedings of Assistive Technology: AAATE 2013*. IOS Press, Amsterdam, 2013. pp. 143–148.

[6] Bundy, A. C; Waugh, K.; Brentnall, J. Developing Assessments That Account for the Role of the Environment: An Example Using the Test of Playfulness and Test of Environmental Supportiveness. *OTJR: Occupation, Participation and Health*. 2009. Vol. 29, no. 3, p. 135.

[7] Foxx, R. M. *Tecniche base del metodo comportamentale*. Ed. Centro Studi Handicap MH Erickson, Trento. 1986.

[8] Hamm, E. M. Playfulness and the environmental support of play in children with and without developmental disabilities. *Health San Francisco*. 2006. Vol. 26, no. 3, p. 88–97.

[9] Robins, B.; Ferrari; Dautenhahn, K. Developing scenarios for robot assisted play. *In Proceedings of Robot and Human Interactive Communication, 2008, The 17th IEEE International Symposium on Robot and Human Interactive Communication.* 2008. pp. 180–186.

Professionals View on IROMEC Play Sessions for Children with Severe Physical Disabilities

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Keywords: Robot, play, children, physical disabilities, evaluation

1 Introduction

Play is a fundamental right for every child, and it is essential in children's cognitive, social, physical and emotional development [1], [5]. Play is a major and irreplaceable activity in childhood, and it is a main vehicle for inclusion [2]. For children with disabilities play activities often become problematic. They experience difficulties in starting, developing an performing play activities in a natural way. The importance of play is becoming more prominent. A currently running European Cost Action TD1309 called LUDI aims to create a novel, autonomous and multidisciplinary field of research "play for children with disabilities". Experts in the field of play for children with disabilities are currently establishing definitions to make a clear distinction between play-like activities, to support extrinsic goals using ludic tools and play for play's sake [3].

Assistive technology, for example robots and ICT may improve the accessibility of play and play materials for this target group. There are already a number of examples of ICT and robots supporting play in children with severe physical disabilities, for example the IROMEC robot [6]. Because the IROMEC robot has potential in supporting play, it was decided to investigate its possibilities more in depth.

First the research was started with a qualitative study with professionals and parents involved to determine the goals for which the robot could be applied and what adaptations were needed before starting a pilot study. The aforementioned study resulted in an indication of the potential of IROMEC in supporting play for children with severe physical disabilities, especially in the domains of movement functions, learning and applying knowledge, communication/interpersonal interactions and relationships, and play. Before starting the pilot study the most important recommendation was to change the appearance of the robot.

This study aimed to explore the application of the IROMEC robot-based play intervention in rehabilitation and special education and to evaluate this with professional on aspects of feasibility, usability, barriers, facilitators and to gain an indication of the possible effects.

2 Methods

A multi-center explorative pilot study was conducted during a two month period (October – November 2015). Eleven children with severe physical disabilities (e.g. as a consequence of cerebral palsy) with a developmental age between approximately 2 and 8 years old were involved at two organizations for children with physical disabilities in the Netherlands. Six IROMEC intervention sessions per child took place. Five IROMEC play scenarios were available and could be used during the intervention sessions (turn taking, turn taking for sensory reward, make it move, follow me and get in contact) [4]. The professionals could choose (if possible together with the child) from four different appearances for the robot: a pig, a car, a lion or a chameleon. In sessions of approximately 30 minutes with small groups (3–4 children) or individuals the professionals were able to decide on the use of the robot based on their own experience and the preferences of the child fitting to the goals of the individual educational plans of the child. Before the pilot the professionals had a training sessions to become familiar with the robot.

Next two a quantitative evaluation of this pilot study, which will not be discussed in this paper, a qualitative evaluation with professionals participating in our pilot study took place. Qualitative semi structured interviews were conducted to evaluate aspects of feasibility, usability, barriers and facilitators of the IROMEC robot intervention. The professionals were able to reflect their own impression of the intervention and possible effects of the robot during this interview. The data was categorized based on the topics from the interview guide.

3 Results

Four professionals participated in qualitative interviews after the pilot period. The most important results are described in this section.

3.1 Experience of professionals working with IROMEC

Professionals who were able to use and test the tablet to control the robot experienced this as easy to use. Others indicated that it was too complicated to control the robot combined with paying attention to the child and the robot. Control of the robot with buttons and the touchscreen was positively evaluated and the robot was safe. Positive aspects mentioned were that the robot supported cooperation, control skills and transportation and the different appearances of the robot were positive, interesting and fun. The children were unaware of training e.g. motor skills, because the intervention distracted them from their original exercise. Next to this, barriers were mentioned; the size of the robot which is large and unpractical for small children, for children in a wheelchair, and for the transportation (by the professional). The motor skills necessary to control the buttons or to turn the robot can be hard for children with physical disabilities, a range of control options was suggested. Interest of the children in the robot often decreased because of the instability of the robot and the lack of adaptability (e.g. volume and new scenarios).

According to the professionals six sessions were too limited to let the children play independently and without instructions from the professional. More training and preparation time for the professionals would have enabled them to prepare and execute the sessions in a better way. For some professionals it was not easy to establish goals before the sessions, because they did not know how the children were going to react. Specific goals for the individual children worked out better than general goals for the entire group, because these goals were tailored to the needs of the child.

3.2 Added value for the children

According to the professionals the added value of using a robot was most visible for the severely motor impaired children. Besides problems with motor functions, the children often also experienced problems with decision making. Deciding about the appearance of the robot or about the direction in which the robot is going to move does have an added value for them. The robot provoked gross motor skills, walking, turning and balance. The robot stimulated enthusiasm, social interaction, communication and action. Malfunctioning of the robot was often disappointing, because structure in daily life is very important for the target group. For the child as well as the professional it is important that the robot functions as expected. The professionals do see potential in using robots on a regular basis, but only when it is possible to apply the robots on spontaneous moments when application might be beneficial. Because of e.g. charging issues and time to start up the robot this is currently impossible. Goals for which professionals think application of IROMEC is most relevant are: communication, spatial awareness, social interaction, movements, gross motor skills, speech and language skills.

To be able to control the robot, children should have certain basic cognitive and motor functions. For some children the robot did not match with their levels of functioning. Certain motor abilities are required, for example to control a button or to sit independently, more control options will make it more accessible for different disabilities. The robot is expected to be interesting for children with a developmental age until 6 years old. When comparing IROMEC with other play materials professionals indicate that for children with more severe physical disabilities it was sometimes hard to reach the robot and other play materials are easier to reach or to place on a table or wheelchair.

3.3 Application of the robot

Sessions were difficult to prepare and execute for the professionals, because they were not familiar enough with the technology. One professional was confident with the course and progress of the sessions and thought adding more options to the platform would be too much for the children. Application of the robot for play for play's sake appeared to be tough. One of the professionals indicated that it was hard to aim at play for play's sake, because they are used to use play as a means to achieve therapeutic objectives. Professionals thought that the younger children were too young to be able to experience play for play's sake. Others said that for children with a lower cognitive level play for play's sake is not possible, because these children need much assistance and hardly show own initiative. IROMEC might be beneficial before children start to control an electric wheelchair. By playing with the robot they can improve their spatial awareness and the children can learn to use different control options (if available in future). Another professional suggested to use the robot at the start and end of a therapy session, as an introduction or motivation, therefore this professional saw IROMEC as an additional tool.

3.4 Influence of the environment

Both physical as well as social environment have important influence on IROMEC sessions. The room in which the sessions took place contained minimal stimuli, which supported the attention of the child. Some sessions took place in a therapy room which was too small, which negatively influenced the behavior of the robot: it did not work as expected. For children with walking abilities it was suggested to have future sessions in a larger room. A positive aspect was that the rooms were all familiar for the children, which created a safe environment.

Social environment was pointed out as a crucial factor. The children have to feel safe with familiar people around. According to the professionals the presence of technical support and the researcher during the sessions might have influenced the attention span of the child. Furthermore, in group sessions it was sometimes hard to challenge every child and to adapt on the different levels of the children. In individual sessions it is easier to challenge a child and to adapt on the preferences of that particular child.

4 Discussion and conclusion

From the interviews appeared that the professionals did see meaningful application possibilities for IROMEC. Unfortunately, the lacking adaptability, extensibility and technical stability of the platform make its use in daily care practice so far impossible. Before our pilot study professionals indicated that they were creative and used to work with a lot of different play materials, so working with IROMEC would not be a problem. In the evaluation it appeared that this robot is a completely different toy than the materials they are used to work with, and more training to get familiar with it is necessary. They might have underestimated the complexity of working with robots and the difference with other materials.

IROMEC was seen as an added value especially for goals related to social interaction and motor functioning. Especially the use of the robot to support play for play's sake appeared to be difficult. Professionals are not used to work with play for play's sake, and do not choose this aim as the most relevant for application of the play robot. While beforehand they indicated play as a relevant goal for IROMEC interventions.

The social as well as the physical environment are crucial factors. The professionals did not reflect on their own role in the intervention sessions, while this role might also be of crucial influence on the effect of the intervention.

For future robot research with this target group it is recommended not to have unfamiliar people around during the intervention session, because this could distract the children from their play. Assistance from a distance might be a solution. Furthermore, the robot should be stable, adaptable and extensible, to be able to be used for a wider range of children with physical disabilities. This research might have had a positive influence on the awareness of robot possibilities and open mind in thinking about robot applications in special education and rehabilitation for children with severe physical disabilities.

Robot interventions might contribute to play and therapeutic objectives for children with severe physical disabilities. It is important to have a well-functioning plug and play robot to be able to test a robot in a large effect study and make practical application possible.

References

[1] Besio, S. *Analysis of critical factors involved in using interactive robots for education and therapy of children with disabilities*. Editrice UNI Service, 2008.

[2] LUDI. *Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action TD1309: Play for Children with Disabilities (LUDI)* [online]. Brussels, 2013. [cit. 13 May 2016]. Available from: http://w3.cost.eu/fileadmin/domain_files/TDP/Action_TD1309/mou/TD1309-e.pdf.

[3] *LUDI website* [online]. LUDI network. 2016 [cit. 13 May 2016]. Available from: www.ludi-network.eu.

[4] Robins, B.; Dautenhahn, K.; Ferrari, E.; Kronreif, G. et al. Scenarios of robot-assisted play for children with cognitive and physical disabilities. *Interaction Studies*. 2012, 13(2), 189–234.

[5] United Nation Of Human Rights. *Convention on the Rights of the Child* [online]. 1989. [cit. 13 May 2016]. Available from: http://www.ohchr.org/en/professionalinterest/pages/crc.aspx.

[7] Van Den Heuvel, R. J.; Lexis, M. A.; Gelderblom, G. J.; Jansens, R. M.; De Witte, L.P. Robots and ICT to support play in children with severe physical disabilities: a systematic review. In *Disability and Rehabilitation: Assistive Technology.* 2016, 11(2), 103–116.

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UNIVERSAL
LEARNING
DESIGN

International conference
Linz, 13–15 July 2016
www.uld-conference.org

Proceedings of the Conference Universal Learning Design, Linz 2016

Published by Masaryk University
Brno 2016
1st edition
Printed by MSD spol. s r.o., Lidická 23, Brno, Czech Republic, www.msdbrno.cz
ISBN 978-80-210-8295-3
ISBN 978-80-210-8296-0 (online : pdf)
ISSN 1805-3947

Please note that the texts have not been proofread or edited by a native speaker.