Tangible User Interfaces applied to Cognitive Therapies

Elena de la Guía
Computer Science Research Institute
University of Castilla-La Mancha
Albacete, Spain
MariaElena.Guia@uclm.es

María D. Lozano
Computer Systems Department
University of Castilla-La Mancha
Albacete, Spain
maria.lozano@uclm.es

Victor M. R. Penichet
Computer Systems Department
University of Castilla-La Mancha
Albacete, Spain
Victor.Penichet@uclm.es

ABSTRACT

Interactive games to support cognitive training are increasingly becoming an indispensable resource in cognitive therapies. At the same time, technological advances are definitely causing the appearance of new paradigms and different styles of interaction. In this paper, we take advantage of real physical objects and the benefits that new technologies offer us, in order to design a new way to interact with interactive games in cognitive therapies. The system is based on physical objects that integrate NFC technology and allow the final user to interact with Distributed User Interfaces. We analyze the effects of interacting with smart objects in Multi-Device Environments developed for people with intellectual disabilities.

Author Keywords

Tangible interaction, NFC technology, Distributed User Interfaces, Collaboration

ACM Classification Keywords

H.5.2. Information interfaces and presentation: User Interfaces. – Graphical user interfaces

General Terms

Design, Human Factors, Experimentation.

INTRODUCTION

Nowadays three per cent of the world's population has some type of intellectual disability [29]. This disability limits their life and the life of those around them. Recent research on brain plasticity emphasizes that conducting a systematized practice and repetition makes the brain favourably modify its structure and operation, offering the possibility to optimize the performance and cognitive abilities [23].

Technology is a crucial tool in cognitive therapies, as it offers an interactive way to improve, stimulate and develop the user´s cognitive abilities [24]. People with special needs experience difficulty using traditional computers. For this reason engaging and enjoyable software is necessary to encourage them to use it. In this way videogames are elements with a high level of motivation. They can have a positive effect on people by helping them focus their attention and enhance their interest in the tasks they are performing [28].

Nowadays a number of games for people with special needs or intellectual disability have been developed. These games offer many advantages, nevertheless interaction based on using mouse and keyboard and virtual reality devices can be an obstacle for people with limitations.

This paper presents a system, called TraInAb, based on a set of interactive games that uses Tangible and Distributed User Interfaces to offer an amusing environment so as to improve and stimulate cognitive capabilities of people with special needs. The main goal is to create an amusing scenario especially designed for people with special needs overcoming the technological barrier between people and technology.

Tangible User Interfaces (TUI) refers to user interfaces which give physical form to digital information, making the parts directly malleable and perceptible [8]. Tangible User Interfaces are based on smart objects, and provide a natural and easy style of interaction that proves intuitive and motivating for non-experts in technology and people with special needs [10, 15]

According to Niklas Elmqvist in [6], Distributed User Interfaces (DUI) can be defined as a user interface which components can be distributed through one or more dimensions. These dimensions are: input, output, platform space and time. Although some definitions of the term have been proposed, at present there is no formal definition. Some approaches to a definition of this term can be found in [20].

The rest of the paper is organized as follows: Section 2 describes some related works, introducing types of games for intellectual disabilities and styles of interaction in the new scenarios. In section 3 we present the system we have developed.. Section 4 shows the experimental data obtained after evaluating the system with real users. Finally, section 5 presents conclusions and final remarks.

IUI 2014 Workshop: Interacting with Smart Objects, February 24, 2014, Haifa, Israel

RELATED WORKS

This section includes some important concepts with respect to the proposal we present in this paper and a brief overview of several related works to highlight the differences with respect to the system proposed.

A video game is a software program created for entertainment and learning purposes in general. It is based on the interaction between one or more persons and an electronic device that executes the game.

"Serious Games" are games that simulate real situations for people with disabilities, such as shopping in the supermarket. The main objective is to develop the skills that can help them in their daily activities [16].

It is not easy to determine which game is more adequate for intellectually disabled players. The barriers that people with cognitive disabilities may find during the activities are complex and varied as described in [4] and [9]. These studies highlight that the key element in the games must be simplicity.

On the other hand, in Virtual Reality applications using helmets, gloves and other simulators, the user may feel more immersed in the game, and it is very engaging and motivating, but the problem is the high cost of devices, and the difficulty of using certain devices. In addition, an expert is required to control the players and devices [17, 18].

The advantages offered by computer games in general are numerous. They enhance positive attitudes in users while being appealing and encouraging. However these systems present the following disadvantages:

-The user needs a minimum knowledge about computer use. Not everybody can use a computer and some devices, like the mouse or the keyboard are not intuitive for people with cognitive disabilities. They need someone to help them.

-These systems sometimes require highly specialized hardware/software which can be expensive (simulators, virtual reality).

- In some games, impaired users may have difficulty finding specific information.

The rapid evolution of technology has changed the way in which we can interact with interactive systems. New scenarios have appeared such as Multi-Device Environments (MDE). These scenarios implicitly support Distributed User Interfaces. However people with disabilities have significant limitations with new technologies; for this reason it is necessary to provide an intuitive and simple style of interaction so that this is not an obstacle to use the system.

Among the existing interaction techniques in the new scenarios next we highlight those that are more adequate for people with cognitive limitations.

-Touching. This technique involves touching an object, either with a finger or with a mobile device, to perform a task. Some examples of projects using this technique can be found in [1] [7] [21].

-Scanning. The mobile device or any other device is capable of scanning information and interact with the system to provide a service to the user [22].

- Approach&Remove [14]. It is a style of interaction that allows the user to interact with distributed user interfaces by approaching a mobile device to digitized objects.

The system we present in this paper is based on this last style of interaction. Some of the projects that use this type of interaction are the following: Interactive EcoPanel [19] is a system that uses RFID technology to support interactive panels to provide a collaborative application where users can share their opinions and ideas about an environmental issue just by using natural and intuitive gestures.

A map has been digitized in [14], with the aim of allowing users to find and watch on their mobile devices some information related to a specific area. These systems enable users to interact with the digitalized objects, which are used as physical interface.

The main difference with respect to our proposal is that all of them use mobile devices to interact with objects, whether posters, walls, or in the case of the "Touching" technique, touch devices. However, in our proposal not all players need a mobile device. Just one device is required to allow that multiple-users can interact with the system. Thanks to digitized objects, interacting with the system is simple and intuitive for all users. This new style of interaction helps users overcome their fear to interact with new technologies. In this way, people with special needs feel motivated and self-confident when they use the system

TRAINAB SYSTEM

TraInAb (Training Intellectual Abilities) is an interactive and collaborative set of games designed to stimulate people with intellectual disabilities.

The system integrates a new style of interaction. The user can interact with the system through everyday objects such as cards, toys, coins…

The collaborative system is based on the distribution of interfaces and device mobility; it offers the possibility to be used individually or by multiple users.

The functionality of the system is as follows. The game interface is projected onto the wall. Users interact with the game through digitized tangible objects integrating NFC tags inside. The user has to bring these objects closer to the mobile device that incorporates an NFC reader so that the mobile device can identify the object. For example, when the game is waiting for the user to select a concrete object, the user only has to bring the corresponding object closer to the mobile device, and then the system recognizes it and displays the outcome of the game showing whether it was the correct one or not.

Design guidelines

The system has been designed according to some key guidelines described next.

The game interface is executed on a computer and projected onto a wall, what does not require the use of other peripherals like joystick or mouse. This requisite ensures that the game can be set in any environment, provided the existence of the following devices, correctly configured: a projector, the smart objects (tangibles user interfaces) and a mobile device with NFC reader. Smart objects are the main elements to interact with the games.

According to Brundy in [2], there is a need to engage and involve the user in the game. To ensure this requisite, the game sends out ludic cues, as invitations to play. This ludic cues corresponds to animated images and sounds. Ludic cues include verbal messages to facilitate the use of the game and get the attention, generate enthusiasm, and maintain the concentration of users, who are guided by the game interfaces.

Another important requirement is avoiding frustration due to failure [ ]. Our system shows positive and encouraging messages when the user fails. When the user gives a right answer, the system shows immediate reinforcement based on encouraging messages and points, motivating the progress toward goals and skills development.

Besides, the Distributed User Interfaces have been designed taken into account visual impairments. In our system, the game interface is executed on large-print displays, alternative colours on the screen, and voice output to compensate for some reading and attention problems.

Finally, flexibility of performance and continuous gratification is another requirement included in the system. The game automatically adapts to the skill of the user while in performance. This allows a greater control over the challenge proposed on the different skill levels of the end users.

Distributed User Interfaces

The interface is the means by which the user interacts with the system, therefore it is very important that they are easy to understand, simple and intuitive. TraInAb is implemented in a distributed user interface setting composed of t three types of interfaces:.

-MainUI (Main User Interface). It is the main interface of the system. It graphically displays the game information, including animations, texts and sounds. At all times, it shows the progress and course of the gameplay (See Figures 3, 4, 5).

-MobileUI (Mobile User Interface). It corresponds to the graphical interface of the mobile device that incorporates the NFC reader. Its function is to recognise the object chosen by the user when they bring it close to the mobile device (approach & remove). It also shows the instructions of the game at the beginning (See Figure 1).

-TangibleUI (Tangible User Interfaces). These are common physical objects used as interaction resources (IR) to interact with the game. In this case we have three different types of objects: cards with pictures of the different games, coins and notes (See Figure 1.b-c-d). These objects have an NFC tag integrated inside what allows that the system can identify them through the mobile device (See Figure 2).

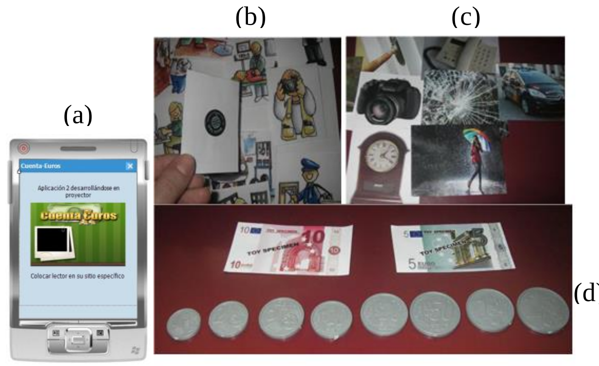

Figure 1. (a) Mobile device interface. (b,c,d) Tangible user interfaces for Game 1(b), Game 2 (d) and Game 3 (c)

Interaction Style

The style of interaction of the user with the system simulates the usual style of the user in their environment. Therefore no prior knowledge is necessary, as using the system is easy and intuitive (see Figure 3). The user only has to bring the chosen object closer to the mobile device. The actions that result from this are transparent for the user.

The game interface displayed onto the wall shows the game executed in that moment. Depending on the game, it may show different objects and the user will have to interact with the system by choosing the correct object and bringing it closer to the mobile device. From that moment all processes are run implicitly. The game interface will display the pictures, texts and sounds according to the final result of the user action. In case of failure, the game will keep the game at the same skill level and in case of success, it will move on to the next level of difficulty.

Next we describe the interaction components and their function in the system:

IR (Interaction Resources). The digitised physical objects. These resources support the interaction with the system. In this case study, we have used everyday objects such as coins or cards to interact with the system. ID (Interaction Devices). The interaction devices correspond to mobile devices. They allow the communication between the digitized objects and the system through NFC and wireless technology.

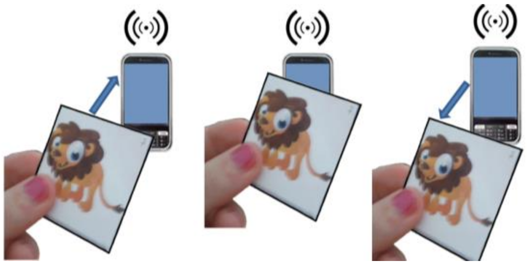

Figure 2. Style of Interaction. The user brings the digitized object (Tangible User Interface) closer to the mobile device (interaction resource) that incorporates the NFC Reader.

Games

TraInAb integrates a set of games focused on improving abilities for the integration of the user in a city. The system has two modules: The first one corresponds to the Management and Administration by the therapists and the second one corresponds to the gameplay management.

Management and Administration Module

This part is responsible for controlling the games and users' statistics. This module has been designed to be used by the therapist, teacher, mentor or psychologist. This person is in charge of administering the system. This module allows the user to choose the game they want to run, as well as to change and save it.

Gameplay Management

The system consists of three different types of game, each aimed at stimulating a different cognitive ability such as memory and attention, calculation, and auditory discrimination.

All the games have been designed with three different levels of difficulty to adapt to the user's skills.. If the user fails, they lose a life and if the user wins they move on to the next level. The feedback messages are motivating for the user to feel encouraged to continue playing. Besides, the system shows this feedback information in a different way depending on the level of difficulty.

In addition, the game shows the status and game results at any moment.

Game 1: Memory

The first game is aimed at memory training. It trains the ability to temporarily retain in memory some information which is later used to produce a specific result. This is a special component of other higher order cognitive processes and includes other cognitive skills such as attention, concentration, mental control and reasoning.

The game presents three cards that the user has to memorise. After a few seconds, the cards disappear and only two of the initial three cards appear again. The goal is that the user remembers the missing card. Then, the user selects the correct tangible objects corresponding to the missing card and brings it closer to the mobile device. The result is displayed on the game interface with positive and encouraging messages regardless of the outcome of the game. The sequence of this gameplay is depicted in Figure 3.

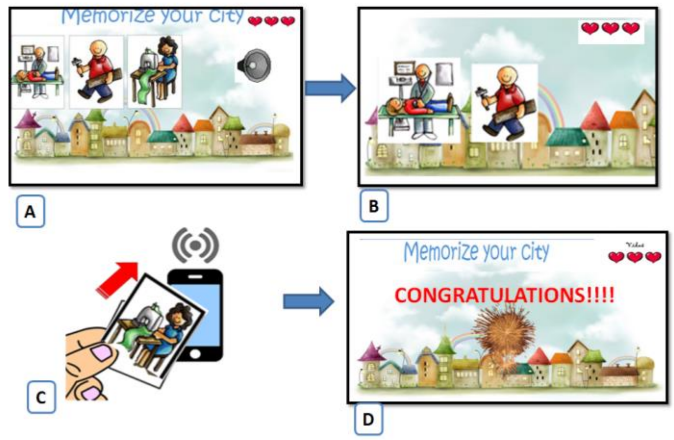

Figure 3. Game 1 Sequence. (a) Main interface of the game. Firstly, users have to memorize the cards (b) One card disappears (c) Bringing the selected tangible interface closer to the mobile device (d) Game results

Game 2: Counting Euros

This game has been designed to improve cognitive abilities related to calculation and logic. The game shows the price of different items such as food, clothes, drinks, and so on. The user has to calculate the price using the coins and notes available as tangible objects. The main goal is to improve concentration as well as the ability to make calculations and handle money (See Figure 4).

Figure 4. Main interface of the game designed to stimulate calculation skills (Game 2)

Game 3. Auditory discrimination

To train hearing skills and increase the user concentration, this game reproduces common sounds in the city such as cars, phones, etc. and the user has to concentrate in order to associate the sound with the corresponding card (See Figure 5).

Figure 5. Main interface of the game designed to improve listening skills, attention and concentration (Game 3).

System Advantages

The main advantages of the system can be summarized as follows:

Reduction of cognitive load. The system has been designed with simple and easily understandable graphics and tangible objects are easily recognized.

Flexibility. It refers to the multiple ways in which the user and the system can exchange information. The information exchanged is displayed as text, voice, cheerful sounds or using graphics. The goal is to adapt the system to any user, regardless of the disability or limitation they may have. Besides, it refers also to the flexibility in the number of users. This is a multi-player game. It allows sharing and exchanging experiences with other users. The situation of each user may be complex and variable and, for this reason, the game can also be used by only one player. Flexibility in terms of space. Players can be moving around while playing, the only requirement is that the mobile device is connected to the server.

Cheap to deploy. Passive NFC tags are quite inexpensive. Besides, only one mobile device with NFC reader is required.

Expandable. It offers the possibility to extend the games. The topics can be easily changed. The only requirement is that the NFC tags must be integrated inside the tangible objects.

Interaction with the system is simple and intuitive. Common items are familiar and can be easily assimilated by users, making it more predictable to use. They do not need prior knowledge of the system or device to use it.

Cognitive stimulation may enhance mental abilities such as perception, attention, reasoning, abstraction, memory, language, orientation processes, while optimizing the users' performance. These games can be an objective therapy for cognitive deficit.

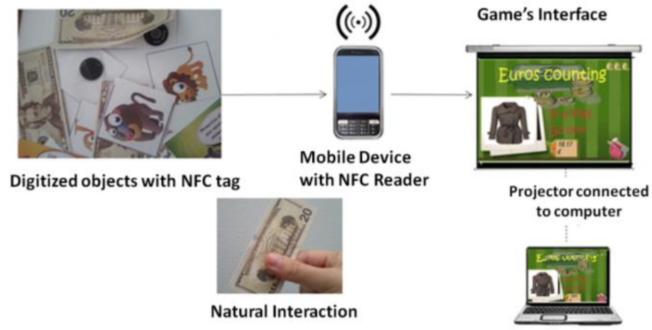

Figure 6. Digitized objects with NFC tags that communicate with the game interface when users bring them closer to the mobile device.

System Architecture

The TraInAb system is a client-server system designed as follows. The client system runs in the mobile device. It is connected to the server application through a wireless network and it is communicated with objects via NFC when the user brings the object closer to the mobile device. A tag (or more) is integrated inside the object or card depending on the size of the object; each tag describes a unique identifier. When the tangible object is brought closer to the NFC reader in the mobile device, the NFC tag inside the object is excited by electromagnetic waves sent by the NFC reader, and then the component controller sends the identifier to the server. The server maps this information in the database and executes the steps necessary to return the information to the mobile device. The games which are running in the PC are displayed onto the wall through the projector (See Figure 6).

EXPERIMENTAL STUDY

This section describes an evaluation of the interactive system performed by people with intellectual disability. The main goals of carrying out the experimental study were:

- To test the strengths and weaknesses of the system.
- To investigate if people´s cognitive abilities improved and whether they enjoyed playing with the games.
- To test the effect of new user interaction based on tangible objects.

Participants

Twelve people with intellectual disability participated in the evaluation (3 female and 9 male). They were recruited from the Center for Assistance to Disabled Persons and Families in Albacete, Spain. Participants ranged from 7 to 62 years (mean=34,83; sd=2,86). Participants had no prior experience with the system.

Apparatus

The hardware used in the evaluation consisted of a Smartphone Samsung Google Nexus S, (16 GB de memory, 512 MG de RAM, processor ARM Cortex A8 1GHZ which incorporates a NFC reader and a private wireless ad-hoc network. A laptop (Processor Intel Core2 CPU t7500 2.20 Ghz with 2,0 GB de RAM) was used to execute the games. It was connected to a projector that showed the game interface onto the wall. The two devices (Smartphone and PC) were communicated through a wireless network. The projector was connected to the PC with a VGA wire. The host application and device application were both developed using C#. The server application and game application are hosted on the same computer. The server application received incoming connections from the mobile device and computer.

Procedure

In order to perform the experiments, we conducted three sessions with the same participants. The first session was divided into three phases: pre-test, test and post-test.

The pre-test phase aimed to obtain information about the participants' profile. In order to find out who had previous experience with technology and stimulation activities we asked the following questions: (1) Have you ever played a video game? (2) How many times a week do you play? (3) Do you like video games (4) What kind of devices have you used to perform the games?: computer, board games or other devices.

The second phase consisted in playing with the interactive system "TraInAb". Firstly, we explained the games and the new way to interact with the system. Then we introduced them the game focused on memory skills (games 1), the game focused on improving calculations and logic abilities (game 2) and the game focused on improving auditory discrimination (game 3).

In the third phase, called post-test, we distributed Smileyometer tests and then we asked them some questions such as: (1) Have you enjoyed playing?, (2) Would you play again? (3) What did you like most about the game?.

While performing the tasks, a video camera was recording the complete session, two evaluators wrote down the playing time and the number of errors occurred, while a psychologist was responsible for assessing the nonverbal messages of users.

The second evaluation session was conducted a week after the first session and the third one two weeks after the first session. In these session, the participants played games 1, 2 and 3. The goal was to analyze whether the participants improved their performance after using the system.

Methods

During the evaluation sessions, we followed the steps defined in [11]. We also used the Smileyometer test that is a method which allows the user to choose from among five pictorial representations, ranging from awful to brilliant, to express their opinion [13] (See Figure 7).

Another method used was Direct Observation [12]. The purpose of this kind of evaluation is to enable designers to better understand how the users make use of the systems in their natural environments. Data is collected in informal and natural ways, with the aim of causing as little disturbance as possible to users. In order to obtain data on the emotions and feelings about the game (playability), we analysed nonverbal messages, gestures [5] and facial expressions [3] shown by the participants.

Figure 7. The Smileyometer test: awful, not very good, good, really good, brilliant

Results

The results of the first evaluation session were as follows: 80% of the participants had played a video game before and they often played for an average of 3.8 times a week, and 72,3% of them liked these games. 31% of the participants used board games compared to the 69% who used computers. None of them had used another technological device such as Kinect or Nintendo Wii. We obtained the following results from non-verbal messages. The first users' reaction was as follows: 44,7 % of the participants were disappointed, 21,3% were unmotivated and only 31,5% were happy and calm. When they interacted with the game, we found that 12,5% of the participants were surprised by the way they interacted with the system. The remaining 20% were still disappointed, and they couldn´t begin to relax until they began to play and win. While they were playing the game, 90% expressed motivation and interest, but 10% expressed indifference to the tasks. 11,1 % of the participants were disappointed, 7.63 % were unmotivated and 65.1 % were happy and calm. Figure 8 shows how the participants felt while playing with the games. The mood of the participants changed, increasing the feeling of calm and relax. That is, the users stated enjoying while playing, decreased fear and users who were unmotivated while playing was just 6.2%.

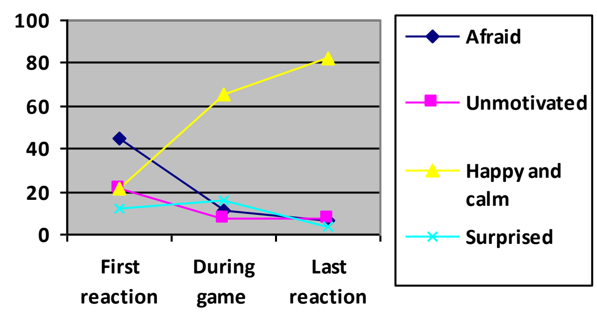

Figure 8. Participants' emotions while using the TraInAb system

In the post-test phase, the following data was collected. In response to the questions stated before, 87% of the participants replied that they perceived the game as innovative and exciting, as opposed to the 13% who were not impressed. 90% would like to play again because they had a good time and were quite entertained. What 70% of the participant liked most was interacting with the system through physical objects, because they were engaged and felt curiosity and interest in the functionality of the system.

The Smileyometer test results were as follows: 7 out of 12 participant thought that the games was "Brilliant," versus 3 out of 12 participant who thought it was "Really good", 1 out of 12 thought it was "good " and 1 out of 12 thought it was "not very good." None of them thought that the games were awful.

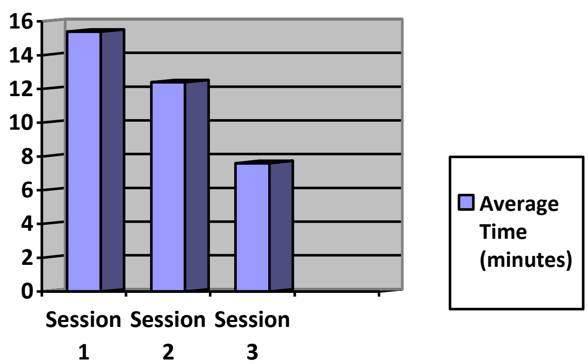

Figure 9. Mean time obtained from the three evaluation sessions performed

To check if the participants had improved their cognitive capabilities, we studied the average execution time of certain tasks. Then, we analysed the data obtained. The average execution time was the dependent variable of the experiment and the independent variable was the session (session 1, session 2, session 3). To analyse if the independent variable influenced the dependent variable we proposed the following hypothesis: the average execution time of the games would be the same from one session to the other. We repeatedly performed the procedure ANOVA on the mean error rate data and found a significant main effect with target width ($F(9, 87) = 27.9$, $p < 0.001$).

Contrary to our hypothesis, we found that the averages were not equal, since the time decreased in each session (See Figure 9). Therefore, the repetition of the game affects the performance and improved cognitive abilities such as memory, calculations and attention.

3. CONCLUSIONS

TraInAb (Traning Intellectual Abilities) is an interactive and collaborative set of games based on distributed and tangible user interfaces developed with emerging technologies such as NFC. The main objective is to stimulate and improve cognitive abilities of people with intellectual disabilities. In order to interact with the system users have to bring tangible objects integrating NFC tags inside closer to the mobile device that incorporates the NFC reader, and then the results and other relevant information is projected onto the wall. This style of interaction is simple and intuitive; its purpose is to eliminate the technological barrier for people with intellectual disabilities. In order to evaluate the beneficial effects of the games and the new style of interaction in the user, we have performed an evaluation based on "Direct Observation". The results have been very positive. Users with Intellectual disabilities were highly motivated and interested in the system. They found it easy to use and enjoyed it. The evaluation was performed in different sessions some weeks apart, in order to check whether cognitive capabilities like memory, calculation and attention improved after playing the game. The results were very optimistic, each session was better than the previous one and the users needed less time to play and concentrated more easily.

ACKNOWLEDGMENTS

This research has been partially supported by the Spanish research project TIN2011-27767-C02-01, from the Ministry of Economy and Competitiveness, and the regional projects with reference PPII10-0300-4174 and PII2C09-0185-1030, funded by Junta de Comunidades de Castilla-La Mancha. We would also like to give special thanks to Erika González and Yolanda Cotillas for their collaboration in the project, without whose support all this work would not have been possible.

REFERENCES

1. Broll ,G. Graebsch ,R., Holleis ,P. , Wagner,M. Touch to play: mobile gaming with dynamic, NFC-based physical user interfaces, Proceedings of the 12th international conference on Human computer interaction with mobile devices and services, September 07-10, 2010, Lisbon, Portugal
2. Bundy, A.C., Play and Playfulness: what to look for. In D. Parham & L. Fazio, orgs. Play in Occupational Therapy for Children. St. Louis, MO: Mosby, 52-66. 1997.
3. Cohen, D. (2007). Body Language: What you need to know. Sheldom Press.
4. Dawe, M.: Desperately seeking simplicity: how young adults with cognitive disabilities and their families adopt assistive technologies. In: CHI '06: Proceedings of the

SIGCHI Conference on Human Factors in Computing Systems, pp. 1143–1152. ACM, New York (2006)

5. Doherty-Sneddon, G. (2009). El lenguaje no verbal de los niños. Lumen, Buenos Aires, Argentina

6. Elmqvist, N. Distributed User Intefaces: State of the Art.Workshop on Distributed User Interfaces2011 (DUI) at the 29th ACM CHI Conference on Human Factors in Computing Systems 2011, ISBN: 978-84-693-9829-6, Vancouver, Canadá, May 7-12, 2011.

7. Hardy, R., Rukzio, E. Touch & interact: touch-based interaction of mobile phones with displays, Proceedings of the 10th international conference on Human computer interaction with mobile devices and services, September 02-05, 2008, Amsterdam, The Netherlands

8. Ishii, H. and Ullmer, B. (1997). Tangible bits: towards seamless interfaces between people, bits and atoms. In CHI '97: Proceedings of the SIGCHI conference on Human factors in computing systems, pages 234–241, New York, NY, USA. ACM Press. 19, 20, 27, 36, 73, 96, 187

9. Lewis, C.: HCI and cognitive disabilities. Interactions 13(3), 14–15 (2006)

10. Marshall, P. "Do Tangible Interfaces Enhance Learning?" Proc. First Int'l Conf. Tangible and Embedded Interaction (TEI '07), pp. 163-170, 2007.

11. MacKenzie, S., Castellucci, S. "Empirical Research Methods for Human-Computer Interaction". Course 28. May 9, 2012 Austin, Texas CHI 2012

12. Preece, J. et al. "Human Computer Interaction" ISBN: 0-201-62769-8. Addison Wesley.

13. Read, J. C., MacFarlane, S. J., & Casey, C. (2002). Endurability, engagement and expectations: Measuring children's fun. Paper presented at the Interaction Design and Children, Germany.

14. Romero, S., Tesoriero, R., González, P. , Gallud, J. A., Penichet, V. M. R.: Interactive System based on NFC to manage Georeferenced Documents. Interacción 2009, X Congreso Internacional de Interacción Persona-Ordenador. Barcelona. Septiembre 2009. ISBN-13:978-84-692-5005-1

15. Schneider, B., Jermann, P., Zufferey, G. and Dillenbourg, P. "Benefits of a Tangible Interface for Collaborative Learning and Interaction," IEEE Trans. Learning Technologies, vol. 4, no. 3, pp. 222-232, July-Sept. 2011.

16. Sik Lanyi, C. and Brown, D. J. Design of Serious Games for Students with Intellectual Disability. India HCI 2010/ Interaction Design & International Development 2010 20 - 24 March 2010 .Indian Institute of Technology, Bombay, Mumbai, India

17. Standen, P.J. and Brown, D.J.. Virtual Reality in the Rehabilitation of People with Intellectual Disabilities, Review, CyberPsychology & Behaviour, vol. 8, no. 3, pp. 272-282, 2005.

18. Takacs, B. Special Education & Rehabilitation: Teaching and Healing with Interactive Graphics, Special Issue on Computer Graphics in Education IEEE Computer Graphics and Applications, pp. 40-48, September/October 2005.

19. Tesoriero, R., Tébar, R., Gallud, J. A., Penichet, V. M. R., Lozano, M.: Interactive EcoPanels: Ecological Interactive Panels based on NFC . Proceedings of the IX Congreso Internacional de Interacción Persona-Ordenador Interacción 2008. ISBN: 978-84-691-3871-7; pp 155-165.

20. Vanderdonckt, J. Distributed user interfaces: How to distribute user interface elements across users, platforms, and environments. In Proceedings of the International Conference on Interaccion, 2010.

21. Vandervelpen, Ch., Vanderhulst, K., and Coninx, K. Light-weight Distributed Web Interfaces: Preparing the Web for Heterogeneous Environments. Proc. of 5th Int. Conf. on Web Engineering ICWE'2005 (Sydney, July 25--29, 2005). Lecture Notes in Computer Science. Springer-Verlag, Berlin, 2005.

22. Want, R., Fishkin, K.P., Gujar, A., Harrison, B.L.: Bridging physical and virtual worlds with electronic tags. In: Proceedings of the SIGCHI conference on Human factors in computing systems: the CHI is the limit, ACM Press, Pittsburgh, Pennsylvania, United States, 1999.

23. Frank Loprestia, Edmund; Mihailidisb, Alex; Kirschc Ned. Assistive technology for cognitive rehabilitation: State of the art. Neuropsychological Rehabilitation: An International Journal. Special Issue: Technology in Cognitive Rehabilitation. Volume 14, Issue 1-2, pp. 5-39. Taylor & Francis Group, 2004.

24. Griffiths, Mark. The educational benefits of Videogames. Education and Health, Vol. 20 No.3, pp. 2002

25. World Health Organization (WHO). World report on disability; 2011.