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FROM E-LEARNING TO VR-LEARNING: AN EXAMPLE OF LEARNING IN AN IMMERSIVE VIRTUAL WORLD

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A first experience of use of "In Your Eyes", an Immersive Virtual Reality (IVR) game to foster Spatial Perspective Taking (SPT) skills in young adults with mild cognitive impairments is described along with a brief discussion of the outcomes. IVR is an innovative tool thanks to which a new chapter in the history of e-learning begun. It is now possible to have a personal direct experience of virtual situations as if they were real, involving all the five senses and allowing for a kinaesthetic approach to learning. All those skills that have an embodied component find in the immersive world a perfect training situation. Spatial Perspective Taking is an important skill for orientation in space and mastering it supports independent mobility in town. The fact that the virtual world is perceived as if it was real, and the possibility to move freely into it, allows stimulating the embodied component of spatial reasoning. The gaming situation helps in keeping the player's

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interest high and therefore helps in having as much training as needed. Furthermore, IVR makes learning transfer to real situations easier, especially for our target users.

1 Introduction

In literature, a unique definition of "e-learning" cannot be found. The concept is constantly changing since it is closely linked to technology evolution and to the perspective from which it is described. Sangrà *et al.* (2012) have tried to come to a general definition of the term by analysing different data from various nations. One of the key points in the definition of e-learning is the use of electronic devices with the aim of facilitating the acquisition and use of new knowledge. With time, as the electronic devices evolved, the very concept of e-learning has changed along with the integration of the new media: audio-visuals, the first computers, internet, multimedia systems, CD-ROMS, etc.

Immersive Virtual Reality (IVR) has now become accessible to the wide public thanks to new products and devices with affordable prices. This opens up new possibilities, allowing for first hand experiences that were before very difficult if not impossible. Using IVR students can have a direct experience of a virtual environment that involves all their senses.

This is particularly important for all those cases in which the skills or knowledge to be learned refer to situations that cannot be accessed directly, either because they are too dangerous or impossible to experience with the human body. As an example, Williams-Bell *et al.* (2014) describe an application developed for firefighters training. The trainees feel as if they were involved in a real fire and they exercise their ability to make decisions in stressful situations. Detlefsen (2014) describes a virtual world where the player, while fluctuating in outer space, can move between the planets of the solar system and see directly "with his own eyes" their orbits.

IVR gives the possibility to "live" a virtual world with one's own senses and act directly into it. It is especially meaningful in all those cases in which the students' learning style is mainly kinaesthetic, but also in all those situations in which the ability to be learned has a strong "embodied" component, in other words when it implies the activation of the mental mechanism that are in charge of movements of the body in space.

In the present paper, we describe "In Your Eyes", an IVR game developed to support the acquisition and the consolidation of the Spatial Perspective Taking (SPT) skill in young adults with mild intellectual disabilities. The game is part of the "Smart Angel Project"[1] (Freina *et al.*, 2015), whose goal is to support independent living and autonomous mobility of intellectually disabled people.

SPT is the ability to imagine how the world would look like from another

[1] www.smartangel.it, a project co-financed by "Programma Attuativo Regionale 2007-2013 (PAR-FAS)"

person's point of view. It is one of the skills involved in spatial reasoning and orientation. For example, it allows recognizing a monument when seen from a point of view that is not the usual one, or understanding correctly a sequence of directions to reach a specific place by transposing the concept of "right" and "left" to the new position in space.

People with intellectual disabilities tend to learn more slowly and need a lot of practice. Traditionally, in order to reach a good level of independence, a long training is performed with the constant presence of the tutors. Furthermore, learning transfer is usually difficult so that the newly learnt skills may not be transferred to real world situations. In these cases, the use of an IVR game can be very effective by keeping high the involvement and the interest of the player and maximizing transfer of the newly learnt skills to real life while lowering the need for the physical presence of tutors.

2 Perspective-taking: stepping into another's eyes

Surtees *et al.* (2013) describe two different levels of perspective taking skills: at the first level, which usually develops in children when they are about five, allows understanding if a given object can be seen from a different point of view. The second level, which usually develops in 6-8 year olds, makes it possible to imagine how a given scene would look like from a different perspective. In people with intellectual disabilities, these skills tend to develop some years later.

Newcombe and Frick (2010) define SPT as the ability to correctly identify the position and rotation of a person in space and understand that their perspective can be different from ours. It is the ability to imagine ourselves in the place of the other person and be able to predict what will be seen after the corresponding movement in space. It involves occupying the place of the other person and understanding the relative position of objects.

According to an experiment carried out by Surtees *et al.* (*op. cit.*), SPT is an embodied process, in which the person actually imagines moving to the other person's place and then generates the new perspective from there.

3 Immersive Virtual Reality

Virtual Reality (VR) is defined as an artificial environment that is experienced by the player through sensory stimuli and with which it is possible to interact in a natural manner using electronic tools.

In VR, spatial immersion refers to the feeling of being actually there, physically present in a non-real world. This perception is usually generated by surrounding the player with images, sounds and, sometimes, other perceptual stimuli that are perceived by the player as if they were genuine, and therefore make him feel as if the world surrounding him was real.

When this happens, the brain recognizes the virtual world as if it were the real one; this makes learning transfer to the real world easier (Rose *et al.*, 2000). Furthermore, in the virtual world the player can actually make the physical movements that are characteristic to the abilities that he is practising, supporting a kinaesthetic approach to learning.

IVR offers several other advantages: the player can practise in many different scenarios, widening the range of his experiences; his interest is kept high by the gaming situation, which usually guarantees a better performance; the player is motivated and therefore will play enough time to gather all the needed experience (Freina & Ott, 2015). On the other hand, the tutor can supervise several different players at the same time optimizing his effort; finally, researchers have the possibility to replicate experiments in the virtual world several times avoiding unintentional changes in the settings.

Within this frame, we have decided to develop "In Your Eyes", an IVR game specifically designed to train SPT skills for young adults with mild intellectual disabilities. The game was designed to be used with the guidance of the end users' tutors, as an additional tool to support the long training needed for autonomous mobility.

Since the use of IVR can sometimes cause sickness in the users, special attention has been paid to minimize the problem. The environment in which the game takes place can be recognized as real and the rhythm of the game, as well as all the movements in the virtual room are always defined by the player. Playing sessions can be interrupted at any time and resumed when the player feels ready again.

4 The "In Your Eyes" game

4.1 Description

The game takes place in a virtual home environment. The player is in a living room, where there is a table with some objects on it. On the wall, four screens show the table from the four sides, the coloured frames of the screen are used to identify them easily. In the room, a virtual friend welcomes the player and helps him along the whole game. The player can choose to interact with a man or with a woman, in the following description we will refer to the virtual friend as Bob. Before starting the game, the player is free to move in the room so that he can see the table and the objects on it from every possible perspective. The room has been designed so that it is appealing and engaging for the player, with enough details to make it look as if it was a real living room so that the feeling of immersion in the virtual world is stimulated. At the same time, attention has been paid not to overload and distract the player from the relevant task (Bellotti *et al.*, 2011).

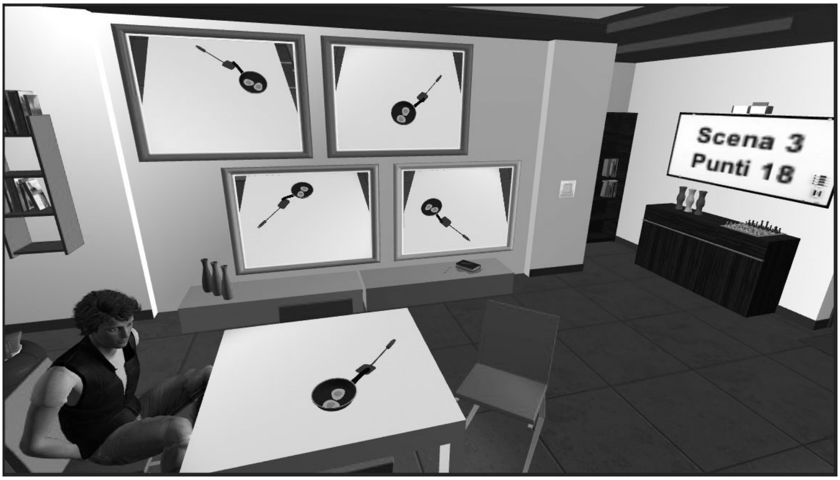

Fig. 1 - The virtual Living Room of the "In Your Eyes" game

The goal of the game is to train the player to recognize the screen that shows the table from Bob's perspective. The game is organized on five different levels that gradually move from the player's personal point of view to Bob's. The gradual shift from the egocentric point of view to taking the other person's position is designed to support the learner to gradually develop the abilities that are at the core of the playing activity (Bottino *et al.*, 2009). At each level, several scenes can be played, each of which is automatically generated by placing randomly on the table a definite number of objects chosen from a pre-defined set.

The five levels are as follows:

1. The player, from the play position, selects the screen that shows what he sees on the table. The main goal, at this level, is the association between what is seen on the table and the corresponding screen.
2. Bob sits on a chair at the player's side and asks to select the screen that shows what he sees on the table. Since he is near the player, they both have the same view of the table. At his point, the focus of the game starts to shift from the player to the avatar.
3. Bob sits at one of the other three sides of the table and asks the player to move from the play position to his side. After the player has moved, Bob asks him what he sees on the table. As for the previous level, since the player is now standing beside Bob, they both see the table in the

same way. Nevertheless, at this level the player starts to experience a change of perspective: when the objects are put on the table, he is in the play position, then he has to move near Bob and, as he does so, he can see the table's perspective change.

4. Starting from this level, the player has to answer from the play position. Therefore, he will have to select a screen that shows the table from a perspective that is different from his own. Bob sits at one of the other three sides of the table and asks the player to imagine moving to his side and then to tell which screen shows what he sees on the table. Since SPT is an embodied process, imagining moving around the table facilitates the change of perspective, and it recalls what has been done at the previous level.
5. At the final level, Bob simply asks the player to choose the screen representing what he sees on the table without any further suggestion.

Each correct answer gives the player some points. As the score reaches a threshold (that can be tailored to each single player's needs), the game goes to the following level.

At any moment of the game, the player is free to move, he can go beside Bob check what the table looks like from there. This allows him to decide autonomously how much help he needs, nevertheless, the number of points given is decreased at every movement out of the play position. In this manner, as scaffolding theories state (Bottino *et al.*, 2013), the player is provided with all the support he may need to solve a problem that may be a little beyond his capabilities without any help. As his skills improve, the quantity of help he will ask will diminish up to the moment when he will be able to play by himself.

At each mistake, the wrong answer is blackened (the screen is switched off) and a brief hint is given to help the player. If the player cannot find the right answer, after the third error he has the possibility to move around the table and compare the view he sees with the correct image in the screen. He can take as much time as he needs before continuing the game.

The number of objects that are present on the table, their position and rotation, can be configured individually for each player and for each level he plays. A default configuration is given with 10 different levels, but it can be changed to match better the player's needs and capabilities.

4.2 Technical choices

"In Your Eyes" has been developed with Unity 3D[2], an environment that makes it very easy to work with 3D objects. This will make it very simple, in

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[2] For further information on Unity 3D please refer to http://unity3d.com/

future, to increase the number and the types of objects used in the game.

To create immersion into the virtual world, we decided to use a Head Mounted Display (HMD). We chose Oculus Rift[3] in its SDK2 version because it had a reasonable price and it could be easily integrated into Unity 3D. Nevertheless, since some people have sickness issues in using a HMD, we organized a preliminary trial involving some of our target users with intellectual disability in order to check if the complete immersion was feasible. In general, the people involved in this trial were enthusiastic, only two of them had some sickness and decided to interrupt the experiment taking off the headset before it was completed. In order to minimize unpleasant feelings, the game is always used for short training sessions, not more than 10 minutes each, and always with the presence of the tutors.

When wearing Oculus Rift, the player can look around the room freely just by turning his head. The computer mouse is used to move forward: by pressing the left mouse button, the player walks forward in the direction he is looking at, while the right button makes him move backwards.

Furthermore, to make the game more accessible, we have developed it in such a way that it can also be used without the HMD. In this case, the room is seen on a regular computer screen and all the movements in the virtual environment are managed with the computer mouse.

All the interaction between the player and the game is based on speech. Bob, within the game, describes the tasks to the player, asks the questions and helps him when needed. The player answers by saying the colour of the frame of the chosen screen. We have decided not to integrate an automatic voice recognition because many of our target users with Down syndrome have some difficulty in pronunciation, which would require configuring the speech recognition module for each single player. Since the tutor is always present, he translates the player's verbal answer into the pressure of a key.

5 A first experience with the game

After the development, the game has been used with some target users for a two months period. Due to the limited number of users and short time available in the project, it has not been possible to organize a complete experiment. The game has been played by the end users with their tutors during the regular meetings along with other planned activities for a few short game sessions.

5.1 Game Effectiveness

All the tutors agree in saying that the game is very useful, mostly as a tool

[3] For further information on Oculus Rift, please refer to https://www.oculus.com/en-us/rift/

to engage and interest the users. The game can be a starting point for some real world activity aiming at explaining the basic concepts to be used to solve the task, as, for example, the left / right position of the objects on the table, the relative position of different objects, their orientation, etc. After the real life training, the users go back to play with the virtual game.

A drawback of the present version is that it is very simple and offers only one environment. It can successfully to involve the player for a limited number of sessions, after which new tasks and environments would be needed. An extended version of the game is currently under development.

5.2 Use of Immersive Virtual Reality

Immersion appears not to be appealing to our target users after the first few sessions. Most of the users, at their first approach were very interested and enthusiastic about Oculus Rift. However, after a few sessions, most of them prefer to play directly on the computer screen, without using the headset. This may be due to the fatigue generated from wearing the HMD. Tutors report that some users have more difficulty than others do, one player took Oculus Rift off after each scene for a short break and then started playing again. Furthermore, the tutors notice that the use of the HMD makes it more difficult to interact with the player during the game. A further experiment is being organized with the aim of assessing the impact of immersion on the perspective-taking task.

5.3 Duration of the Play Sessions

From the analysis of the collected data, a general rule can be defined: in order to get beyond the starting levels and reach that part of the game where the SPT skill is actually used (from level 3 onwards), a minimum of 20 minutes of global playtime is needed.

There are great differences in the length of the single sessions between those who play with Oculus Rift and the ones who used the game on the computer screen. While end users in IVR tend to interrupt playing after a few minutes (ranging from less than 2 minutes to a maximum of 9 minutes), those who do not use Oculus Rift play sessions that range from 22 to 31 minutes.

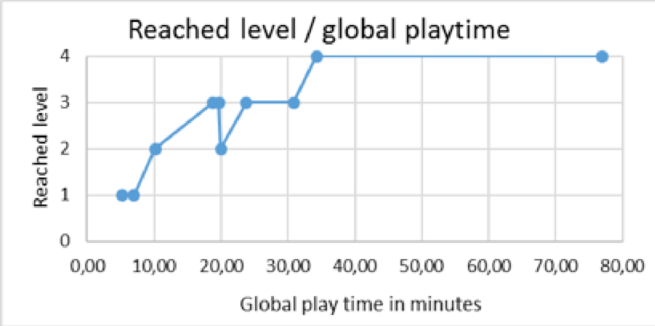

Fig. 2 - Relation between the global playtime and the maximum level reached.

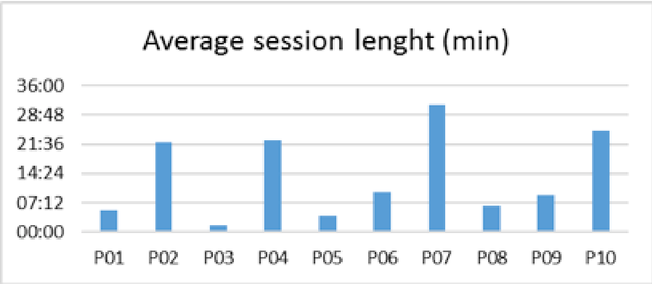

Fig. 3 - Average session length in minutes for each player.

5.4 Common Errors

As stated in literature, solving a scene that has only one object on the table is easier than facing one with two objects (Frick *et al.*, 2014). This is because there is less information to process since there is no relative position between different objects.

Table 1
ERRORS COMPARED TO THE NUMBER OF OBJECTS ON THE TABLE

	One object	Two objects
Tot number scene played	99	120
Total number of errors	29	58
Percentage of errors	29,29 %	48,33 %

During our experience with the game, all users played scenes either with one or two objects and the percentage of errors in scenes with only one object is around 30%, while it goes up to 48% in those scenes where there are two objects.

As we expected (Bernstein, 2004), more than half (51%) of the errors made in those levels in which the SPT skill is involved are egocentric, which means that the players choose the screen that shows their point of view instead of the one showing Bob's. Further trials are needed to assess whether the first levels, where the players' egocentric perspective is the correct answer, may influence negatively later performance.

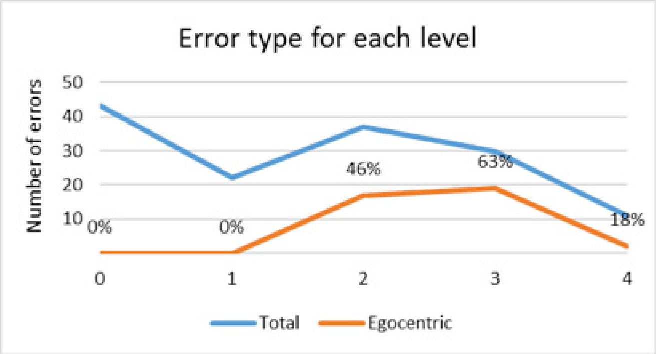

Fig. 4 - Total number of errors for each level and the percentage of egocentric errors.

5.5 Play Styles

Most of our players involved in using the game have the Down syndrome, a few have the fragile X syndrome. There are great differences between the two disabilities that affect the style of play. Players with the Down syndrome tend to be more careful and move slowly, often the tutors had to encourage their active participation. The other players tended to answer as quickly as possible, without listening to directions, which is in some cases one of the major causes of errors.

A newer version of the game, which is already available, is more interactive, the number of different feedback messages has increased and all changes of level are stressed by a specific introduction from Bob, which is meant to draw the player's attention to the characteristics of the new task. In this way, the slower players are more stimulated by a greater variety of messages, while quicker player's attention is captured more easily when the task in the game changes.

5.6 Discussion

The described experience has been, for the involved tutors, a complete novelty with respect to the commonly used approach to training. Using an IVR game implies managing several issues as, for example:

- the timing of each session (tailored on the needs of each player in order to avoid fatigue and sickness);
- the interaction with the player (making the player feel the reassuring tutor's presence without breaking the feeling of immersion);
- the correct support to the player (different playing styles need different kinds of support to overcome specific drawbacks).

These issues have been addressed in a specific training module for tutors, where the gained experience is shared to build a common knowledge for future uses of the game. At the same time, new versions of the game are under development to make it more appealing and engaging for the players.

Conclusions

In the present paper, we have described "In Your Eyes", an IVR game aimed at supporting the development of the SPT skill, which is one of the basic skills to be able to orient oneself into space. The game has been developed as part of the Smart Angel project in support of independent life for people with mild intellectual disabilities.

In the game, the player is in a virtual living room where he is asked to state how the scene in front of him would look like from a different perspective. Using IVR offers the advantage that the player can move all around the room while observing it from every possible perspective. This allows him to create a good mental image of the scene and the objects in it. Furthermore, the player can choose how much help he needs, simply by moving around the table and directly checking the right answer. The player's involvement in the game is kept high by the gaming mechanism and the possibility to move around and explore the virtual world. Finally, the high similarities between the virtual world and the real one make learning transfer easier.

A trial usage of the game has been done and several observations have been drawn. On these bases, next versions of the game are currently under development to respond better to the users' needs and future experiments are planned to investigate the real impact of IVR on the SPT skill.

Our future work will focus on the consolidation of such skills in elementary children (ages 8-10) and on how our immersive game used as a training tool will enhance their spatial reasoning abilities. In fact, SPT is one of the skills involved in spatial reasoning, and it has been demonstrated that spatial reasoning is strictly correlated with success in STEM (Science, Technologies, Engineering and Mathematics) areas (Newcombe, 2010). Some experiments have shown that training spatial reasoning is effective, the results are durable and transferable (Uttal *et al.*, 2013). A focused training on these skills may have positive effects on children's school success and on their future job careers.

The game is a concrete example of how IVR can be used for e-learning, actually it should, possibly, be regarded as a starting point contributing to the opening of a genuinely new chapter in the history of e-learning.

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