Immersive vs Desktop Virtual Reality in Game Based Learning

Laura Freina[1], Andrea Canessa[2]

[1] CNR-ITD, Genova, Italy

[2] BioLab - DIBRIS - Università degli Studi di Genova, Italy

freina@itd.cnr.it

andrea.canessa@unige.it

Abstract: Virtual environments are recognized as more effective than other digital approaches for the acquisition of several abilities. This is because the brain recognizes the virtual world as real and this facilitates the transfer of the newly acquired skills to the real world.

In this paper, we present a game that has been designed and developed with the aim of teaching spatial orientation abilities to teenagers with mild intellectual impairments. In particular, the game focuses on the training of two basic skills: perspective taking and mental rotation. Perspective taking refers to the ability of imagining how the world looks like from another person's point of view, while mental rotation is the ability to mentally represent and manipulate physical objects in one's mind.

The game, which takes place in a virtual environment, shows the player a scene with some objects on the table. The player has to choose among four provided alternatives, the one that shows how the scene would look like from a different side of the table.

The game was first developed to be used with either a desktop pc monitor or an interactive touch table. In this case, a virtual world is represented, but the player is not completely immersed in it, he just looks at the scene from outside. A second version of the same game has then been developed using a Head Mounted Display (HMD), which makes the player feel immersed in the virtual environment, where he can freely move around just as if it was real.

In this paper, we discuss both advantages and disadvantages of the immersive Virtual Reality (VR) compared to the desktop VR. In fact, on the one hand, having the possibility to "dive" into the virtual world allows the player to:

- Better build a mental model of the scene and the involved objects by freely moving around the table and examining the objects from all the possible perspectives;
- Manage by himself the amount of help needed: it is always possible, at any time of the game, to move to the other side of the table and see what the scene looks like.
- Increase his involvement in the game by exploring the virtual world as he pleases.
- Have a better learning transfer thanks to the similarities between the virtual and the real worlds.

On the other hand, using a HMD can be tiring and cause sickness to some players. Furthermore, the presence of a complete environment in which to move and explore, can draw the attention away from the main task of the game and therefore influence learning negatively.

Experiments are planned to verify the foreseen advantages and disadvantages involving young adults with mild intellective disabilities.

Keywords: Innovative games-based learning, Virtual worlds, Perspective taking, Mental rotation.

1. Introduction

1.1 What is Virtual Reality

Virtual Reality (VR) is defined as "an artificial environment which is experienced through sensory stimuli (as sights and sounds) provided by a computer and in which one's actions partially determine what happens in the environment." (Merriam-Webster, 2015).

In VR, a concept that is frequently mentioned is "immersion". Jennett et al (2008) define immersion in games as the involvement in the play, which causes lack of awareness of time and of the real world, as well as a sense of "being" in the task environment. Immersion is not necessarily linked to the presence in space, but rather refers to an intellectual / emotional deep involvement into an activity.

When “immersion” is applied to VR, it usually refers to “spatial immersion”. Spatial immersion into VR is the perception of being physically present in a non-physical world. The perception is created by surrounding the player with images, sounds or other stimuli that provide a very absorbing environment. Spatial immersion occurs when a player feels the simulated world is perceptually convincing, it looks “authentic” and "real" and the player feels that he or she actually is "there".

Even if immersion seems to be a crucial element for VR, as Robertson et al (1993) say, VR can also be non-immersive when it “places the user in a 3D environment that can be directly manipulated, but it does so with a conventional graphics workstation using a monitor, a keyboard, and a mouse”. We will refer to this as a desktop VR.

Two main types of immersive VR can be identified:

- Cave Automatic Virtual Environments (CAVE): the user is in a room where all the walls and the floor are projection screens (or flat displays). The user can wear 3D glasses, he feels floating in the projected world where he can move around freely.
- VR glasses or other sorts of Head Mounted Displays (HMD), often used with headphones that can easily produce the visceral feeling of actually being in the simulated world.

Virtual environments are supposed to be more effective than other digital approaches with respect to the acquisition of several abilities. This is because the brain recognizes the virtual world as real and this facilitates the transfer of the learned skills to the real world (Rose et al. 2000), that is the ability to apply acquired knowledge or skills in different situations or environments. Furthermore, in an immersive virtual environment, the player can actually perform the movements that are characteristic to the skill he is practicing, favouring a kinaesthetic learning style.

From a literature survey (Freina and Ott, 2015), VR has been largely used for learning and training, especially in those cases in which the real world cannot be accessed. Such are, for example, the cases in which learning in the real world can be dangerous (e.g. crossing a street with heavy traffic) or impossible (e.g. floating in the solar system watching the planets move around the sun).

Nevertheless, VR can offer several advantages also in different situations: a large number of different scenarios in which the specific ability can be trained, the possibility to train several people at the same time with less tutoring effort, a better engagement of the students in the gaming activities, etc.

1.2 Promoting autonomy for people with mild intellectual disabilities

According to the Disabled World website (Disabled World, 2015), the “intellectual disabilities”, which include several different types of impairment, affect in between one and three percent of the world population. Fortunately, more than 90% of this population is able to reach some level of autonomous life and become socially engaged and active: they live on their own, have a job, attend courses, do some form of sport, etc.

In order to achieve these objectives, the ability to move around town autonomously and safely is fundamental. Nevertheless, acquiring this ability is not easy: spatial orientation can be a big issue, the acquisition of new skills can be a long and tiring process and transferring them to the real world situation is not straightforward. People with intellectual disabilities tend to learn more slowly and need a lot of field practice; the basic abilities for moving around in urban contexts are traditionally reached after a long training under the constant guidance of specialized tutors. The use of VR, in this case, would allow each user to have as much practice as needed and it could facilitate learning transfer.

Within this frame, the Smart Angel project (Smart Angel, 2014) co-financed by the Italian Liguria Region is oriented at supporting the social inclusion of people with intellectual disabilities, in particular by supporting their mobility in town and autonomous home living. Besides giving them a mobile cloud based system to help them face unplanned situations in their daily movements and a specific support for time management, a set of Serious Games has been developed to promote the acquisition of some basic abilities.

1.3 The addressed skill: spatial intelligence

A certain level of spatial intelligence is needed in order to allow people to move around town avoiding getting lost. This basic level of spatial intelligence allows people to recognize a monument or a place in town also when seen from a different point of view and understand a sequence of directions by transposing the concepts of left and right to the new position.

Furthermore, spatial intelligence has been demonstrated to be an important complement to verbal thinking, it helps reasoning and shows correlation with success in STEM disciplines. Therefore, supporting the development of a good level of spatial intelligence is useful for all students.

Newcombe and Frick (2010) recognize two important skills involved in spatial intelligence: mental rotation and perspective taking.

- *Mental Rotation* is the capability to rotate an object in one's mind. Usually, children of 4-5 years are able to perform mental rotation, but the skill continuously strengthen through early childhood.
- *Perspective taking* is the ability to imagine ourselves as the observer and predicting what will be seen after an actual physical movement. In other words, the ability to identify the position and the orientation of other people in the space and understand that their perspective can be different from our own. This skill is under development during the early elementary years.

In intellectually impaired people, both these skills may develop later in age. Actually, while some people can easily reach good performances, others seem to have spatial impairments and lack the ability to perform specific tasks. The two abilities appear to rely on different cognitive operations even though they share common processes.

Surtees et al (2013) identify two levels of perspective taking: the first level that develops earlier in age is the ability to understand if a specific object can be seen or is hidden from another person's point of view. The second level, which appears to develop a little later, regards how someone else sees the world, therefore how a specific object, or an entire scene, would look like from a different position.

While some perspective taking tasks are visually based, therefore imply visual perspective taking abilities, others are more grounded into space. Spatial perspective taking is mentally occupying another's position in space and being able to understand the relative position of objects in space.

Surtees at al report their experiment in which the participants have to say if an object is placed in front / behind or left / right of another person. While performing the task, the body position of the participants is rotated, while the head is kept straight. Results show that rotation of the body influences response times only in identifying the left / right position, but not the in front / behind task. This suggests that an embodied representation of the scene and the person's movement are used. According to these results, it appears that embodied perspective taking processes are needed in some tasks; they are robust processes, effective in generating visual perspectives of other people. They are relatively costly and solve problems that are beyond the abilities of very young children.

2. The game idea

In this paper, we present a game that has been designed and developed with the aim of promoting the development of spatial orientation abilities in teenagers with mild intellectual impairments.

The game focuses on the training of two basic spatial skills: perspective taking and mental rotation. In particular, the chosen approach is based on the development of the embodied ability to mentally self-rotate oneself in order to be able to imagine how a scene would be seen by another observer. The target population we are referring to has already developed the skill to be able to understand if a given object can be seen by another person and if it stands in front or behind him. All the tasks within the game ask the player to imagine himself in a given position and tell what he would see.

The game, which takes place in a virtual home environment, shows the player a scene with some objects on a table. The player has then to choose, among four provided images, the one that represents how the scene would look like from another side of the table. The game is designed to be used by the target population with the constant presence of a tutor; nevertheless, it is possible to use it independently.

Two different versions of the game have been developed, both using Unity 3D. The first version was based on a desktop VR approach, while the second generates a complete immersion of the player in the virtual environment using a HMD.

Due to the specific needs of our target users, the chosen approach pays particular attention to providing sufficient scaffolding to each player to enable him to solve the given tasks and keeping the error rate as low as possible.

Scaffolding refers to the support given to the student in performing a specific task, which is beyond his reach independently (Bottino et al, 2011). It will allow the player to go through the game levels with the feeling of being able to solve the tasks, maintaining a good level of satisfaction and motivation. Scaffolding will have to be tailored to each single player in order to make the game difficult enough to be challenging and motivating, but easy enough to be solved in order not to disappoint the player and, at the same time, keep the error rate as low as possible. As the player's capabilities increase, the level of scaffolding is lowered until the he reaches complete autonomy in performing the requested tasks.

At the initial levels, the player is asked to move and take the avatar's perspective. Later, he can still move freely but has to be in the play position to answer. At the final levels, movement is always permitted, but the score is decreased, so that the best performance is obtained when the player can answer without any support. Game configuration allows personalizing the pace through the game to the player's needs.

Keeping error rate down is, as suggested by the "Errorless Learning Approach" (Terrace 1963), a way to make learning easier and quicker since there is no concurrent stimuli by errors. If an error is not recognized as such, it could be encoded into memory, and result in wrong responses later or conflicts between the correct and the erroneous information.

When the correct answer is chosen, positive feedback is always given and the player's score increased. When a wrong answer is given, the game provides specific clues in order to help the player understand his mistake. Furthermore, the presence of the tutor allows human intervention if needed. The game can always be paused and specific explanations given.

The games also include data mining to allow both having a detailed evaluation of the game itself and, as the game will be used by more people, studying the performance of a big population and defining general guidelines for its use.

3. First development: the "Smart View" game

The game has first been developed to be used with either a desktop pc monitor or an interactive touch table (Bottino et al, 2014). In this case, a virtual world is represented, but the player is not completely immersed in it, but he just looks at the scene from the outside.

In the Smart View game, some objects are placed randomly on a virtual table as shown in Figure 1. The number of objects and their placement depend on the level of difficulty. On the screen, the game shows four different views of the table from the four sides. The player is then asked to choose one of the four possible answers according to the given task.

Before the game starts, some familiarization tasks are given. At the beginning, the player can move around the table to see how the scene changes. Each time he moves to a specific side of the table, by pressing a button he can change the view to the correct one. The different sides of the table are identified with different colours. The second familiarization task asks the player to choose, among the possible answers, the one that shows the table as he sees it, from his current position. The player is then ready to face the next levels, which are designed in order to promote the development of the embodied self-rotation.

Figure 1: The Smart View game.

The tutor plays an active part in the game. At first, he moves to a side of the table (e.g. the yellow side) and then the game askes "What would the tutor see from the yellow side of the table?". In this manner, the game suggests the player to imagine himself in the tutor's place before choosing the answer. Later on, the tutor stands back and the question is "What would you see if you moved to the yellow side of the table?". The second task is more difficult because the player has to imagine himself at the specified position without having the possibility to identify himself with the tutor's body.

In this version of the game, the mental rotation skill is also directly addressed by another set of tasks based on a round table that can be turned. At the familiarization level, the table with some objects on top is presented randomly rotated, and one image, showing the table from a different angle, is presented. The task is to rotate the table until the player's point of view matches the picture shown. The following tasks ask the player to rotate the table up to a position in which the shown picture represents what is seen from another side of the table. Again, two different tasks are possible: one in which the tutor actually occupies a position around the table, the other one in which the player has to freely imagine himself in the correct place without the body of the tutor giving him any suggestion.

4. Second development: the "In Your Eyes" game

Figure 2 shows the second version of the game, developed in an immersive VR environment. Compared to the first version, the focus of the game is on the first exercise: the table cannot be moved and the player is asked to point to the image on the wall that shows what the table would look like from another point of view.

In Your Eyes takes place in a virtual home environment. The player, at the beginning of the game, is standing in front of a table on which some objects have been placed. He is always free to move, explore the room he is in, and observe the scene on the table from any possible angle, just as if he were in a real world. Only when he is ready to play will he decide to tell the avatar to start the game.

Figure 2: The In Your Eyes game

An avatar is always present and interacts with the player giving him instructions and feedback as needed.

The aim is training the player to take the avatar's perspective by asking him which of the screens on the wall represents what the avatar actually sees on the table. The game is organized in different levels starting from a very easy task and gradually moving to the most difficult one.

At each level, several scenes can be played. Each is randomly defined with respect to the objects that are on the table, their position and rotation. A correct answer will give the player a score, which is reduced each time there is an error or an exploration within a task. When the player reaches a certain total score, he automatically moves to the following level. All thresholds can be manually changed by the tutors according to the needs of each player.

At the first level, the player is simply asked to say which of four screens on the wall shows what he is seeing on the table. This level is meant to facilitate understanding of the game mechanics by making the association between an image on the wall and what is seen on the table.

The next levels, gradually, lead the player to change his point of view with that of the avatar. At first the avatar walks near the player and simply asks him which screen on the wall shows what they both see on the table. Then the avatar walks to one of the other three sides of table and asks the player to reach him. When they are both on the same side, the avatar asks the player what they both see on the table. The player is forced to walk from his position to that of the avatar and, while doing so, he will see the objects changing.

In the following level, again the avatar moves to one of the three free sides of the table, but the player has to answer from his position without moving. Since mental rotation is an embodied process, and it has been shown that imagining oneself moving around the table actually helps in detecting the correct answer, the avatar suggests this strategy to the player by asking him “Imagine to walk around the table to my position, what would you see on the table? Which of the screens on the wall shows what you would see?”

Finally, at the last level, the avatar, placed at one of the sides of the table, simply asks, “Which of the screens on the wall shows what I see on the table?” The player is, at this point, free to use the strategy he prefers to answer.

The game is completely configurable on a personal basis, so if a player needs to stay longer at a specific level, the tutor can change his configuration file accordingly and keep him at the specific level as long as needed.

At any moment, the player can move from his playing position and walk freely in the room. In such a way, whenever the player feels that he needs to analyse the scene better, he can do so.

When the correct answer is chosen, the avatar gives a positive feedback. When faced with a wrong answer, the avatar switches off the corresponding screen and focuses the player’s attention on the other possibilities.

5. Discussion of the development choices

It has been demonstrated that perspective taking is an embodied process. The first version of the game: Smart View, has been developed in a desktop VR environment, the objects on the table are actually seen as images and cannot not be perceived as “real” objects. Furthermore, moving around the table can only be done by clicking a button, which causes the scene on the screen to change to the new perspective. We felt that giving the player the possibility to actually walk around the table and look at the objects from all the possible angles would have been very helpful.

Another weak point of Smart View is the tutor’s involvement in the different tasks. Tutors are not always trained to manage the game correctly, and even if they guarantee a more personalized approach to the games, this jeopardizes objectivity. Data collected on the use of the game would be influenced by the interaction with the tutor and the analysis on the usability and effectiveness of the game would not be possible.

For these reasons, a second version of the game has been developed in a completely immersive VR. Due to its reduced costs and ease to interface with Unity 3D, Oculus Rift (Oculus VR, 2015) has been identified as a possible solution.

Before opting for Oculus Rift, a short experiment has been done in order to evaluate the real usability of such a device with our population. A small group of nine intellectually impaired young adults has tried to wear Oculus Rift and move around a virtual town for some minutes. The outcome has been rather promising: most of the involved people showed interest in the device, managed to wear it without major distress and actually said to have enjoyed the virtual world. Only two people showed distress and took Oculus Rift off their head before the end of the experiment.

According to these results, we have decided to proceed with the development. Nevertheless, since the tool may not always be available and some users have problems in wearing the HMD without being sick, the game can also be used on a common computer screen. In this case, the mouse is used to manage all the movements of the player.

When Oculus Rift is used, the image is mirrored on the computer screen so that the tutor is always aware of what the player is seeing and doing. This is useful for the following reasons:

- Controlling the players’ activity and motivation. If the tutor sees that the player loses interest in the game, he can decide to step in according to the single player’s needs and characteristics.
- Helping the player in case he should be stuck in the game.
- Understanding if the player gets too tired or stressed by the use of the HMD and stop the game.

The player’s head movements are detected directly by Oculus Rift, while the forward movement can be detected in a couple of different manners: with the use of a common computer mouse, or with the Wii mote control. Should the player have problems in moving around the virtual environment, the tutor can always move him around using the keyboard.

While the player is immersed in VR, all his interactions are limited inside the virtual world. He can move around in the most natural manner and all the needed instructions are given by the avatar. The interaction between the player and the game is designed to be managed by a voice recognition device, but no such system has yet been integrated. The target population we are going to test the game with will mainly focus on Down syndrome and some of them have speech difficulties, which would cause the automatic voice recognition to make several errors. Misunderstanding from the game would cause disorientation in the player and drop of motivation. Since the tests are planned to be carried out with the constant presence of a tutor, he can translate the player's commands by pressing a key on the keyboard. This choice has no impact on the player interaction with the game; he can speak freely and see the game reacting accordingly without being aware of presence of the tutor.

6. Conclusions

In this paper, we have described a game, whose objective is to support the development of some basic spatial skills that are needed for urban mobility of young adults with mild intellectual disabilities. The described game has been developed in two different versions: in desktop VR and an immersive VR.

Among the spatial skills addressed, the perspective taking ability has been proved to be based on embodied processes, which can be more easily trained in an immersive VR. The presence of an avatar offers a human body the player can identify with, and the free movement in the virtual room allows the exploration of the scene and suggests the strategy to be used to answer to the game tasks. Furthermore, the deep similarities of the VR with the real world tend to facilitate learning transfer.

On the other hand, using a HMD can be tiring and cause sickness to some learners. Furthermore, the virtual room can draw the attention away from the main task of the game and influence negatively the players' learning.

An experimental evaluation of the two games will soon be carried out with a group of intellectually impaired young adults who have already developed some basic spatial abilities and have the possibility to develop, at least in part, some spatial perspective taking skills.

A specific assessment of the users' skills with respect to mental rotation and perspective taking abilities has been defined and will be used before and after the planned training sessions. Furthermore, questionnaires and monitoring sheets will be used to collect the users' reactions and appreciation at each session of the game.

At the end of the test, all the collected data will be analysed with the aim of giving an assessment of the skills learnt, the ease of use of the games and the main differences between the two VR approaches.

7. References

Bottino, R.M. et al. (2014) SMART VIEW: A serious game supporting spatial orientation of subjects with cognitive impairments, *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 8514 LNCS(PART 2), pp.489–500.

Bottino, R.M., Ott, M. and Tavella, M. (2011) Scaffolding Pedagogical Planning and the Design of Learning Activities, *International Journal of Knowledge Society Research*, 2(1), pp.84–97. Available at: https://halshs.archives-ouvertes.fr/hal-00908888/ [Accessed January 15, 2015].

Classen, C. (2010) Foundations for an anthropology of the senses, *International Social Science Journal*, 49(153), pp.401–412. Available at: http://doi.wiley.com/10.1111/j.1468-2451.1997.tb00032.x [Accessed January 19, 2015].

Disabled World. (2015) Cognitive Disability: Information on Intellectual Disabilities.

Freina, L. and Ott, M. (2015) A Literature Review on Immersive Virtual Reality in Education: State Of The Art and Perspectives, in *eLSE Conference Proceedings*.

Jennett, C. et al. (2008) Measuring and defining the experience of immersion in games. International Journal of Human-Computer Studies, 66(9), pp.641–661. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1071581908000499 [Accessed November 30, 2014].

Merriam-Webster. (2015) Online English Dictionary, Available at: http://www.merriam-webster.com/dictionary/virtual reality.

Newcombe, N.S. and Frick, A. (2010) Early education for spatial intelligence: Why, what, and how, *Mind, Brain, and Education*, 4(3), pp.102–111.

Oculus VR. (2015) Development Kit, Available at: https://www.oculus.com/dk2/.

Robertson, G., Card, S.K. and Mackinlay, J. (1993) Three views of virtual reality: nonimmersive virtual reality, *Computer*, 26(2), p.81.

Rose, F.D. et al. (2000) Training in virtual environments: transfer to real world tasks and equivalence to real task training, *Ergonomics*, 43(4), pp.494–511.

Smart Angel. (2014) Project Description, Available at: www.smartangel.it.

Surtees, A., Apperly, I. and Samson, D. (2013) The use of embodied self-rotation for visual and spatial perspective-taking. *Frontiers in human neuroscience*, 7 (November), p.698, Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3817588&tool=pmcentrez&rendertype=abstract.

Terrace, H.S. (1963) Discrimination learning with and without “errors”, *Journal of the experimental analysis of behavior*, 6, pp.1–27, Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1404228&tool=pmcentrez&rendertype=abstract [Accessed February 10, 2015].