# SMART VIEW: A Serious Game Supporting Spatial Orientation of Subjects with Cognitive Impairments

Rosa Maria Bottino, Andrea Canessa, Michela Ott, and Mauro Tavella

Institute for Educational Technologies, CNR, Genoa, Italy
{canessa,bottino,tavella,ott}@itd.cnr.it

**Abstract.** The paper presents SMART VIEW a serious game developed with the aim of helping young people with moderate cognitive disabilities acquire those spatial abilities that are key prerequisites to autonomous mobility. The game was conceived for cognitively impaired teenagers; it proposes exercises supporting the acquisition and consolidation of competences related to space awareness and self-perception in the space; such skills are necessary to develop the sense of spatial orientation, which is critical for the target population. SMART VIEW makes use of Touch Screen tables so to allow easier access to the game content and augmented interaction. Particular attention has been devoted to the game interface design, so to make it free from cognitive barriers and fully accessible to the target population. Contents are as close as possible to reality and the educational strategy entails slow and gradual increase of the game complexity, so to properly sustain the users' cognitive effort.

**Keywords:** Serious Games, Spatial Orientation, Cognitive Disabilities, Perspective Taking, E-inclusion, Technology Enhanced Learning.

## 1 Introduction

The sensation of being sure of our own position in the environment is an element that combine both cognitive and emotional aspects, and its importance appears when this skill is impaired. This is the case of individuals with intellectual disabilities, as for example people with Down syndrome.

Unfortunately, few individuals with intellectual disability practice independent travel, and sometimes they feel lost, even when walking routes that they are familiar with [1].

This is due to a conceptual deficit in spatial representational abilities, which reflect a poor generation of a cognitive map. The term "cognitive map" [2] has been coined by Tolman in the 40's during his research on learning, and successively retrieved in the 70's in studies on orientation and space representation. Cognitive map represents the form by which the spatial knowledge and awareness is acquired, and it can of two type: route and survey maps ([3-6]).

Route maps constitute egocentric representations where a one-dimensional sequential understanding of landmarks leads to learn a route. The information, learned in a progressive manner from a route and its landmarks, is used to effectively reach a

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given target. In this case, the way through which the subject experiences the environment and he creates his own spatial knowledge strictly depends on his actual point of view.

Survey maps are based on an allocentric perspective and they can be seen as a higher-level two-dimensional representation analogous to human-made maps. The direct dependence on the point of view lets the place to multiple perspectives, taken by different orientation, among which there is also a bird's eye view. This ability allows an individual to perceive the spatial relations among different points in the environment, judging their closeness or distance on a two dimensional Cartesian reference frame.

The intellectual disabled individuals rely on an egocentric navigation ability strategy, with great difficulties to adopt an allocentric strategy. Indeed, individuals with intellectual disabilities generate a one-dimensional sequential understanding of landmarks that leads to learn a route, but they have a random two-dimensional configuration of them, which indicates an inability to integrate routes information into a coordinated reference frame [1],[2].

Obviously, this is a real issue since the gaining of independent travel skills and of the confidence to learn and travel new routes are essential for independent living and community participation. These abilities allow the individuals to access a wide range of vocational, educational and recreational opportunities.

The author has been involved in developing educational software for people with intellectual disabilities. This work originates from the fruitful collaboration of the researchers of the Institute of Educational Technology of the Italian CNR and the psychologists and tutors of a socially useful non-profit organisation (NPO) both interested in intellectual disabilities. The starting motivation is the desire to develop new methodologies for the learning and the training of those requirements necessary to gain spatial representational abilities.

The paper presents SMART VIEW, an educational game conceived for training, in cognitively impaired teenagers, some skills that can be useful for correctly mastering the sense of spatial orientation, which is critical for the target population and preparatory for higher level spatial cognitive skills.

## 2 Related Work

Looking at what has been done till now to find ways of teaching skills necessary for independent living, in particular for mobility and orientation, to people with intellectual disabilities we find that great effort has been spent in the last decades to develop solution based on virtual environments (VE).

The VE is increasingly being recognized as a potential tool for the assessment and rehabilitation of human cognitive and functional processes. Different researches show, in fact, that VE, applied to the treatment of motor and cognitive problems, are more effective than other standard approaches since the brain perceives the simulated activities as real and the knowledge built in the virtual world is transferred as concrete competences in the real world [7]. The educational games based on VE provide an environment which resembles everyday life; they therefore may serve as learning "gym" and can be used as a safe test-bed to be freely explored, at one's own pace, attempting hypothesis and obtaining immediate feedback [8].

VEs are increasingly used in experimental research to address questions about spatial processes in typical or atypical populations. Several researchers have used virtual technology for training skills necessary for independent living, and these learnt skills were found to be transferable to real-world environments [5-17].

Notwithstanding there exist different examples of programs oriented to train spatial abilities in cognitive impaired subjects, they mainly focus on environment learning.

Though environment knowledge can be acquired directly through navigation or indirectly with symbolic tools such as navigation systems or maps, with respect to cognitive abilities involved in spatial awareness, visuo-spatial abilities have been shown to have a crucial role in explaining the accuracy of spatial mental representation formed [18].

From one side, it should be noted that in most cases environment learning was tested and trained through navigation in Virtual Environments, but from the other hand we observe a lack of educational software exploring and training the relation between environment learning, spatial awareness and visuo-spatial abilities in cognitive impaired people.

The sense of spatial orientation is deeply grounded on the subjects' cognitive ability to carry out abstract cognitive processes. For instance, for subjects with the Down syndrome the cognitive process of "abstraction" represents a great issue; in adults we often observe a total inability to "abstract" so that they are almost unable to put themselves in someone else's shoes. They are not able to imagine what the view of the world around them could be if taken from another point of view. Thus, they have relevant difficulties in understanding that the same scene, for example, a square or a street cross generates different images if it is seen from different positions.

Hence, we got the idea to create an educational game facilitating the emergence of the ability to change the point of view and supporting its enhancement, by visualizing how the observed world would be from another perspective.

## 3 The Game SMART VIEW

The game SMART VIEW was created in the framework of the project SMART ANGEL, supported by the Liguria Region Administration; this project is aimed at supporting the autonomous mobility of mentally disabled young people. The growth will be supported in a first rehabilitative phase by means of innovative models based on latest generation ICT devices (tablet, touchscreen devices) and in a successive prosthetic action toward the independence with mobile devices, GPS and cloud services. The game was thus conceived having in mind the target population of teenagers with mild mental retardation and the key issue of supporting the development of the prerequisites for them to be able to move around with limited external help; in this respect, spatial orientation was found to be one of the key aspects to be trained.

### 3.1 Objectives and Specific Abilities Addressed

SMART VIEW is a serious game ([19]) which aims to train the mastering and consolidation of competences related to space awareness and self-perception in the space.

In particular, the proposed exercises train those visuo-spatial abilities that allow an individual to execute an embodied self-rotation, through which s/he can actively imagine her/himself assuming different positions in the environment. This ability subserves not only reasoning about where objects are in relation to someone else but also how the objects in their environment appear to them. In particular, the following skills are trained: the perspective-taking and the mental rotation.

The ability to put ourselves into the shoes of another is called perspective-taking: the ability to non ego-centrically represent the aspects of the world around. The key concept is the perspective: a relationship between the subject and the objects and other people in the environment.

The perspective-taking ability is related to the visual-spatial experiences of an individual, and involves a relationship based on if and how other people see an object or a relationship based on the relative spatial locations of the other people and the object. In both cases, the ability to identify the position and the orientation of someone else and the ability to understand that their perspective may be different from our own [20-21] is required.

Visual-spatial perspective-taking (VPT) is the ability to appreciate how the world looks to another person and to predict his visual experience. In particular, one can predict: (1) if another person can see an object and (2) how objects are located in relation to another person's egocentric reference frame.

Studies of VPT distinguish two levels of ability, which develop sequentially. Level 1 visual perspective taking (VPT1) refers to knowledge about which objects in one's reference frame of view another observer can or cannot see. It is related to what lies within someone else's line-of-sight, i.e., which objects are visible and which occluded; the ability to judge that someone else might not see what you see (Figure 1). Level 2 visual perspective taking (VPT2) refers to the knowledge that different people experience seeing an object differently. VPT2 tasks require to realize that an object which both individuals can see at the same time may nevertheless appear different to each of them, for example, if one can see the face of a toy sheep, the other on the opposite side of the table may see only the tail. It is related to how someone sees the world: the ability to judge that two different people with different points of view can experience an object differently [20;22] (Figure 1).

Both levels are not acquired simultaneously. Typically, 2 year olds children pass tests of VPT1. The emergence of VPT2, instead, occurs at the age of 4 and seems to require more sophisticated cognitive abilities.

Michelon and Zacks [23] provided conclusive evidence for a qualitative difference between VPT-1 and VPT-2, concluding that VPT-1 is based on imagining the other person's line-of-sight that determines the relevant inter-object spatial relations, while VPT-2 requires some sort of mental self-rotation, imagining one's own bodily motion [20;22].

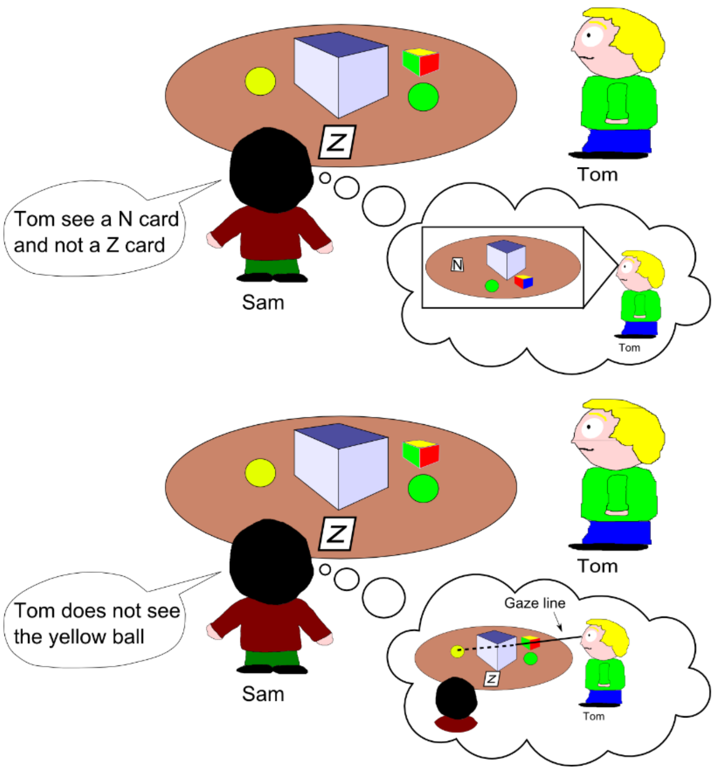


**Fig. 1.** Examples of perspective taking issues

The mental rotation is one particular aspect of a more complex cognitive skill: the visual mental imagery, the ability to see with the mind's eye. It is defined as the ability to mental rotate two or three-dimensional figure rapidly and accurately and to imagine the aspect of the figure after it was rotated around an axes with a certain number of degrees. Mental rotation is the process of transforming the mental image of a three-dimensional object to represent the same object as if seen from a different point of view. The mental rotations as well as the underpinning perspective taking ability have a fundamental importance in orientation tasks: they allow, for example, to recognise a place even when we perceive it from a perspective different from a previous one, or to align our perspective with the one showed on a map in order to be able to read it.

### 3.2 Design Principles Followed

The initial phase of the work was spent trying to understand the problems, to collect information and to define the user needs of the target group through meetings with the carers and the trainers of the NPO.

Particular attention has been devoted to make SMART VIEW “accessible” to the target population while developing the game. Accessibility, here regards not physical but cognitive barriers. In this perspective, a software can only be considered “accessible” if target users are in a condition to use it and, what is more, to make good use of it. In a HCI perspective, this means considering the specific needs of the target population, designing an easy-to-use interface, providing comprehensible contents and adopting a suitable educational strategy. The interface of the SMART VIEW game has been thought to be essential, consistent, clearly organised and not only oriented to make the software appealing. The instructions have been designed in order to be clear, the buttons to be big enough for users with fine motor skills difficulties. The proposed tasks are simple and can also be customized and personalized according to the real capacities of the each student.

One of the key feature of the game is the very slow and gradual increase of the game complexity ([24]) and the smooth change of the difficulty level for each task. Very little/short successive steps are proposed to the users thus attempting to reduce to the minimum the required cognitive effort. As a matter of fact, one of the primary functions of tutoring, according to [25], is to allow the learner to make progress by initially providing scaffolding, for example by controlling those elements of the task that are initially beyond the beginner’s capability.

The closeness to reality of the contents has been considered a key requirement. The reduced capacity for abstraction that affects these subjects, in fact, makes it essential that the scenes reproduced within the game should draw as much as possible real life situations. Indeed, the subjects with intellectual disabilities tend to be concrete in their thinking and reasoning and they have difficulty to generalize and to transfer the knowledge or the behavior learned for doing one task to another task across different settings or environments.

For these reasons, it was decided to develop the game scenes as a non-immersive virtual environment, in order to reduce to the minimum the level of “abstraction” and make it closer to the actual reality.

In order to monitor the learning trend and to evaluate the educational efficacy of the software in the context of training the aforementioned spatial skills we decided to introduce some learning analytics inside the game development. These allows the trainers to measure, collect, analyse and report data about learners and their contexts, for purposes of understanding and optimising learning.

### 3.3 Technological Aspects

Besides influencing choices related to interface and educational strategy, the specific needs of the target population also influenced the type of computer device to be adopted. Because of the overall decisions taken in the SMART ANGEL project and in consideration of the specific requirements for the target population touch technology was adopted. SMART VIEW, then, makes use of TouchScreen (i.e Microsoft Surface or MultiTouch Philips) tables, which allow easier access to the game contents and augmented interaction for disabled users.

To orient ourselves toward a suitable development environment, we considered different Game Engines having in mind these base features:

- Quality of 3D rendering;
- Graphical User Interfaces (GUI);
- Sound reproduction
- Support of common programming languages.

The game engine we chose is Unity3D, a powerful rendering engine fully integrated with a complete set of intuitive tools. It allows the creation of 3D interactive environment, with high performance in term of execution time, frame rate and rendering. In fact, it presents, among other features, an integrated and expandable graphic interface (Editor) that allows visual 3D objects placement. Here the developer can compose realistic virtual scene, adding terrains and managing the lights, the sounds, the physics, the collisions and the animations of the objects, with the possibility to create code in C#, JavaScript or Boo. Finally, it also provides a simple project deployment environment for multiple platforms, with no need for additional configuration, including the web (which makes it possible to run any game on a web browser).

Currently, our framework contains a single exemplar scenario. It takes place in a kitchen, precisely in front of a table. The kitchen model together with a library of common use objects present in the game were created using Blender so as to recreate them as realistically as possible in terms of dimensions, scale and proportions. An example is depicted in Figure 2, which gives a fairly good idea of how realistic such an environment is.

**Fig. 2.** Using Blender to realistically represent object in an environment

### 3.4 SMART VIEW: Exercises Under the Lens

The exercises proposed in SMART VIEW draw on the experimental setups presented in [22] and [26], which were used to test the development of perspective taking abilities in children with autistic spectrum disorder and William Syndrome, with the purpose of training VPT2 and mental rotation abilities.

In the SMART VIEW game, the subject is in front of a touchscreen table, free to move around it, and observes a virtual scene of a table, as if they are sitting on a chair. Different objects are represented on the table, and their number varies, from a minimum of 1 to a maximum of 3, according to the difficulty level reached or selected by the tutor.

In the following, a general view of the available exercises and their actual difficulty progression is illustrated.

**Familiarization Exercises.** Three introductory exercises are foreseen. In the former, at the centre of the display the subject sees the main scene view. He can freely move around the touchscreen table and, by pressing some buttons depicted on the four sides of the monitor, he can change the view of the scene observing how it looks like from different perspectives (see Figure 3). In the second, the subject is presented, together with the main scene view, four images representing four views of the same scene taken from different positions around the table. The user is then asked: “Which scene are you looking at?”. The participant is instructed to click the image that matches the perspective of the objects as they appear on the virtual table. If the subject makes errors, the game corrects him by showing the right answer (see Figure 4). In the latter, the subject is presented one image representing a scene view taken from his actual position around the table, while the main scene presents the virtual table rotated by a random angle. The participant is then asked and instructed to rotate the virtual table in the main scene, until the perspective of the objects, as they appear, does not match the image view (see Figure 5).

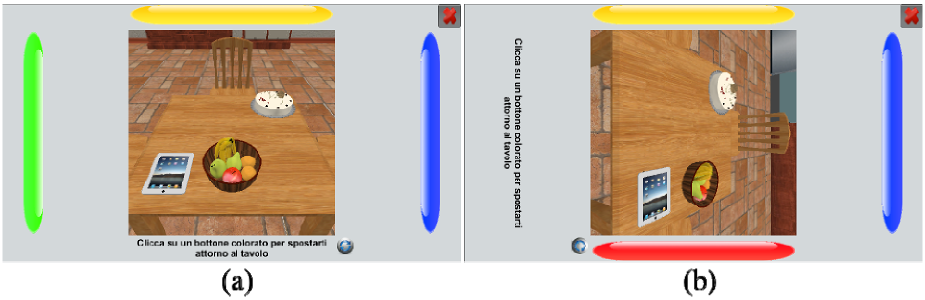


**Fig. 3.** Aspects of familiarization exercises. (a) Imagine observing the table and the objects over it from your actual position. Now suppose you to move on your left, placing yourself on the green side of the table. Clicking the green button (b), the main view changes accordingly to your new position.

**Game Exercise 1: VPT2 Ability.** The game exercise 1 trains the VPT2 ability, putting the accent on the judgement about the other one’s perspective. Once the objects appear on the virtual table, the participant has to watch carefully the scene and choose the image that matched it. Then the tutor changes his location to the left, to the right or opposite side of the touchscreen table with respect to the subject’s actual position. The participant is then asked: “Which scene will the tutor see from his new position?”. The participant is instructed to click the image that matched the objects view that he thinks the tutor would see from his new location (see Figure 4).

**Game Exercise 2: Self-Motion Imagery.** The game exercise 2 trains the VPT2 ability, but in this case the accent is on the one's own bodily motion imagery. Once the


**Fig. 4.** An instance of game exercise 2. At the center of the display the subject sees the main scene view. At the right there are four images representing the view of the main scene taken from the four sides of the table. The colored button allow the subject to change his actual point of view around the table. Below the main scene there is the instruction to follow. In this example, the subject has to click the image he thinks representing what scene s/he will see if s/he moves to the blue (i.e. the right) side of the table. Exercise 1 is similar except for the fact that the tutor moves on the table side indicated in the instructions.

objects appear on the virtual table, the participant has to watch carefully the scene and choose the matching image. Then the tutor makes the subject pay attention to a location to the left, to the right or opposite side of the touchscreen table with respect to his actual position. The participant is then asked: "Which scene will you see, if you move to this position?". The participant is instructed to click the image that matches the objects view that he think he would see from his new imagined location (see Figure 4).

**Game Exercise 3: VPT2 + Mental Rotation.** The game exercises 3 and 4 are similar to exercises 1 and 2, respectively. In this case, however, there is also a training component regarding the mental rotation skill. In exercise 3 the tutor changes his location to the left, to the right or opposite side of the touchscreen table with respect to the subject's actual position. The subject is presented one image representing the scene view taken from the tutor position, while the main scene presents the virtual table rotated by a random angle. Given the tutor's view, the participant is then asked to rotate the virtual table in the main scene until the perspective of the objects, as they appear, does not match what he thinks he should see from his actual position (see Figure 5).

**Game Exercise 4: Self-Motion Imagery + Mental Rotation.** Exercise 4 is equal to the exercise 3 but in this case, as in exercise 2, the subject has to imagine himself in a


**Fig. 5.** An instance of game exercise 3 and 4. At the center of the display the subject sees the main scene view. At the right there is one image representing the view of the main scene taken from one among the four sides of the table. The colored button allow the subject to change her/his actual point of view around the table. Below the main scene there is the instruction to follow. In this example, the subject has to look at the image on the right, which represents what s/he would see from the yellow (i.e. the opposite) side of the table. Hence, given the subject's view taken from her/his imagined position, the subject has to rotate the table, following the arrows, until the scene represented in the main view does not match what s/he thinks he should see from her/his actual position.

particular position. Given the subject's view taken from his imagined position, the participant is then asked to rotate the virtual table in the main scene (originally rotated by a random angle) until the perspective of the objects, as they appear, does not match what he thinks he should see from his actual position (see Figure 5).

## 4 Conclusion

We have briefly presented SMART VIEW a Serious Game aimed at paving the way to further interventions supporting and enhancing the autonomous mobility of young persons with cognitive disabilities.

Actually, the game is intended to help teenagers with mild mental retardation developing a variety of prerequisites for individual mobility such as space awareness, self-perception in the space and basic spatial orientation. All these abilities are critical for the target population and call for specific training activities, which, if proposed in the form of digital games and virtual environments, can effectively contribute to sustain motivation ([27]) and, consequently, to enhance learning. After briefly explaining the context and the basic inspiring principles and concepts, we have focused on the key ideas that have in-formed the game design and development with regard to two aspects that are particularly important for the target population: interface and educational strategy. Accessibility and ease of use were the key pillars underpinning the interface design while the educational strategy was basically grounded on the idea of reducing the users' cognitive effort by acting on the smooth gradual increase of the exercises difficulty.

Field experiments involving the use of the SMART VIEW game are presently being performed, which will provide concrete data about the game appropriateness, suitability and effectiveness. They will, hopefully, also provide further food for thoughts and an in-depth perspective on how the game interfaces and other HCI related aspects of virtual environments can better suit the needs of cognitively impaired subjects.

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