DISCUSSING IMPLEMENTATION CHOICES FOR SERIOUS GAMES SUPPORTING SPATIAL AND ORIENTATION SKILLS

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Abstract

Games are widely considered effective educational tools. They have been profitably adopted to foster the learning of a variety of educational subjects and to sustain the development of those horizontal, cross-disciplinary, non-subject-based competences that are commonly defined as key or transversal skills. Spatial Intelligence (which actually refers to a set of competences involving space awareness and self-perception in space) is included among the basic transversal skills underpinning a variety of cognitive tasks and is a prerequisite for autonomous mobility.

Relevant scientific studies show that people can improve their spatial skills with appropriate training and a variety of experiments shows that both adults and children, after a short training have significantly improved their ability in this area. In this line, two games were developed with the aim of sustaining the development of spatial and orientation skills of people cognitive impairments.

One game is oriented to the comprehension of the terms and the concepts of right/left, with the overall goal of helping cognitive disabled people to be able to understand and follow simple instructions while moving around town. The other one is aimed at exercising "perspective-taking" skills: the ability of identifying the position and the orientation of other people in the space and understanding that their perspective can be different from our own.

Specific choices (both technological and pedagogical) directly linked to the "special needs" of the target population have guided the implementation of the games, which, nevertheless, can also be adopted in mainstream primary education.

In particular, the technological choices reflect the needs linked to each game constraints (e.g. the need for optimal 3D representation or for table touch employment) as well as general specifications emerging from users' requirements (e.g. the need for adaptive features, multiple interaction formats).

Pedagogical choices, instead, are linked to the established educational objectives (e.g. the nature and level of difficulty of the tasks and their optimal sequence). They regard the definition of the most appropriate educational strategies (e.g. drill and practice vs exploratory exercises) and the suitability of the type of feedback and assessment (e.g. formative vs summative evaluation actions; *in itinere* vs final assessment).

Keywords: Serious games, inclusion, disabilities, cognitive disabilities, spatial awareness, mobility, orientation, perspective.

1 INTRODUCTION

Contemporary education is strongly focused on the development of those "horizontal, cross-disciplinary, not subject-based" competences that are also called "transversal" or "key skills". Among these, visual-spatial skills are of great importance for success in solving many tasks in everyday life. For instance, using a map to guide you through an unfamiliar city, merging into high-speed traffic, and orienting yourself in your environment, are all activities that involve spatial ability. Spatial intelligence is mentioned in the theory of multiple intelligences [1] as one of the nine basic types of intelligence.

This kind of intelligence deals with interpreting and making judgments about the shape, size and movement of objects in space, as well as their relative position. It allows people to know where they are placed with respect to other objects in space and influences the person's ability to read and follow maps. Furthermore, it allows people to predict the path of a moving object. As can easily be seen, it is of extreme importance in urban mobility.

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Moreover, research suggests that spatial thinking is an important predictor of achievement in science, technology, engineering and mathematics [2]. More fundamentally, new research suggests that a pre-schooler's visual spatial attention ability predicts his future reading skills [3].

The spatial intelligence, far from being a biologically determined cognitive trait, can actually be improved with appropriate training [4]. A variety of experiments shows that both adults and children, after a short training have significantly improved their ability in this area.

For instance, Jing Feng and colleagues [5] found that undergraduates improved visual attention and mental rotation skills after only 10 hours of playing a 3-D first person shooter action video game. Overall, women made the biggest gains, and maintained them 5 months later.

David Tzuriel and Egozi [6] tested the mental rotation abilities of 116 Israeli first graders (average age, 6.5 years), and randomly assigned about half of them to a training program designed to help kids observe, transform, and keep track of geometric shapes in their "mind's eye." The other kids were assigned to an alternative, non-spatial training program. At the beginning of the study, boys outperformed girls. However, after only eight weekly sessions, the girls in the spatial skills training program had caught up. Therefore, we have good evidence that practicing mental rotation and visual attention can boost spatial skills.

The ability to move autonomously around town is one of the basic abilities that are at the base of independent living. This ability is relies on several skills that range widely from orientation, being able to understand and follow road directions, to sing the mental rotation abilities to recognize a statue from a different point of view.

It is therefore of extreme importance for the society that people learn, at an early age, the needed skills, including those who are affected by some sort of cognitive limitation that may reduce their learning possibilities.

Games are widely considered effective educational tools [7; 8]. They have been profitably adopted to foster the learning of a variety of educational subjects and to sustain the development of non-subject-based competences such as spatial skills. Within an Italian regional project, two different games have been developed with the aim of training with some basic spatial skills cognitive impaired people.

After a brief outline of the project in section 1, the two games are described in section 3. Section 4 gives an overview of the main technological choices, including the special interfaces that have been chosen. Section 5 focuses on the pedagogical choices: it describes the educational objectives as well as the strategies used to help the educators to analyse the player' performance and determine the need for further educative actions. Section 6 concludes summing up our work and supposing further works.

2 THE CONTEXT: THE SMART ANGEL PROJECT

The Smart Angel Project [9] is an Italian regional project financed by the Liguria Region; it is a two-year project, which started in November 2013. Smart Angel aims at supporting people with cognitive disabilities, with particular attention to the Down syndrome, in their daily life and in-house independent living (for example as to their weakest cognitive areas such as time, daily routines and activities). In this framework, the issue of mobility in urban contexts appeared to be crucial to promote and enhance the target users full autonomy; this means enabling intellectual impaired subjects to move around in the urban context and reach relevant places (workplace, leisure, sports…).

Within the project, specific software applications are developed to support autonomous movements in town, specifically giving help in critical unexpected situations (i.e. a bus strike or a road closed for any reason) and in those areas where cognitive impaired are weaker, with specific attention to time management.

Along with the main project stream, some serious games [10] are designed and developed to help the initial phases during which the users are trained to move around town by themselves. The applications are related to basic concepts such as knowing left and right, following simple directions, recognizing street names, avoiding and recognizing dangers, etc.

We expect the use of the serious games to help the final users in learning the basic concepts needed to move around town, while making the needed training phase shorter and more interesting for them.

3 THE TWO SERIOUS GAMES

The two games share several data (together with other components of the Smart Angel project) and relevant characteristics. Final users have a unique profile and all the information about them is available for the educators throughout the whole project. Nevertheless, both games can work in a standalone manner. Furthermore, they are structured in a sequence of situations to which the player has to react in the correct manner. The situations are organized into different levels of difficulty and a score builds up along the game. Correct answers give the maximum points, while any error or help request reduces the points that add up to the global score.

When all the situations belonging to a level of difficulty have been “solved”, if the player has reached a minimum overall score, he is allowed to enter the following level; otherwise, the same situations are shown again.

The educator can define motivational strategies for groups of users, which may go beyond the single game. For instance, the educator may decide to organize the players as a group to stimulate the co-operation and give them all a price (be it virtual or real e.g. an ice cream) when the overall score reaches a defined threshold. On the other hand, the educator may decide to create a competition among users to stimulate their personal use of the game [11]. The use of competitiveness for motivation is left to the educator who can decide, according to the different users, if it can be a good motivating strategy or rather if it is better to avoid it.

The system offers access to a variety of data regarding the students’ performance and behaviour to help the educator understand the user’s abilities and difficulties. During each play session, for each situation, all the given answers (and therefore the errors) and the response times are collected along with the question. At the end of each session, data are transferred onto the central database.

For each player, the educator has access to:

- The total number of errors in one play session or globally
- The mean answer time per session or global.
- The list of errors
- Recurring errors (those errors that have been made repeatedly, which show that the player needs some specific training to overcome the difficulty).

This information allows the educators to decide specific educational strategies. They may choose to make a player go to a more difficult level even if he has not yet reached the threshold. As a matter of fact, in order not to demotivate the player who is stuck at a certain level, the educator may decide to push him forward.

The list of recurring errors too is a key information to the educators. If a player keeps on making the same error repeatedly, a specific training may be needed in order to overcome the difficulty.

When an error occurs, an error message is given. All error messages are studied specifically with the aim of helping the player to understand the situation correctly and find the right answer. The system has a standard set of error messages, but the educators can change them according to the specific needs of a single player.

Each situation/scene, if not solved correctly, is repeated several times (the number of repetitions is defined by the educator according to the player’s needs). If the player still does not answer correctly, the system goes on to the next situation and the educator is alerted.

3.1 The Left-Right Game

The main objective of the game is to teach the player the concepts “left”, “right”, “straight”, and the ability to recognize and understand correctly the words representing the concepts both in their written and oral forms. These concepts are very important for urban mobility since only by knowing them it is possible to understand and follow correctly road directions.

The goal of the player is to find a hidden treasure, which represents the reward. During the game, the player finds several different treasures allowing him to collect the prizes. Since the game can be used by different types of players (different ages, interests, cognitive abilities, etc.), the educator can define what the content of the treasure is a short funny video, golden tokens to be collected, etc.

Some of the user inputs are given using Microsoft Kinect, therefore, the player can just react naturally by moving his body. In other parts of the game, a touch screen or vocal inputs are used.

At the simplest levels, the single terms "left", "right" and "straight" are presented and used. For example, when the system asks the player to "go left", he has to move in the correct manner to get nearer the treasure. The more difficult levels stimulate the player to understand, follow and produce a short sequence of directions. For example, the system may ask: "you have to turn right and then go straight".

The game is divided in two different parts: the first is focused on the comprehension of the words and the corresponding concepts; the second trains the player to produce the required directions. Within each part of the game, there are several different levels of difficulty.

In part one, the treasure is hidden and the system guides the player along a path towards the treasure, which is shown only at the end. The aim of this part of the game is the recognition and understanding of the words "right", "left" and "straight". The difficulty levels are:

1. At the beginning, the target words are addressed in a simple "heat up session". Instruction like "point to the phone on the right" or "ring John's bell, it is the one on the left" are given. The player, standing in front of Kinect, has to lift an arm to answer.
2. In the next level, only one direction per situation are given. The system tells the player to "go left" and the player has to step in the correct direction. After the correct answer, the scene changes in a consistent manner and the following direction is given. The player has the feeling that he is moving along a path at the end of which he finds the treasure.
3. The following level the instructions from the system get more difficult: two directions are given at the same time (e.g. "turn right and then left"). As soon as the user makes the first correct movement, the scene changes and get ready for the second one. The player can always ask the system to repeat the instructions, but he loses some points in doing so. At the end of the path, the treasure waits for the player.
4. The next level is like the previous two, but makes the instructions more difficult by adding in some extra information. E.g., "Turn right at the traffic lights" or "turn left at the second road". This means that the player has to answer also to some implicit directions: if the game tells him to "go right at the traffic light", he has to keep going straight until he gets to the traffic light and only then turn right.
5. The final level mixes all the previous kinds of instructions.

In part two, the player gives the instructions to a character in the game guiding it towards the treasure. The player sees the treasure from the beginning and has to give the correct instructions for the character to reach it. He, therefore, has to be able to produce the words representing the direction concepts. Furthermore, at the more difficult levels, the system shows the player how the meaning of the direction words may change by changing the point of view.

At the beginning of part two, the player has to choose or build the character that he will then guide all the way to the treasure. Then the following levels are played:

At the first level, the player sees his character from behind (they share the same point of view). He sees also the treasure and has to tell the character in which direction to move to reach it (see fig 1).

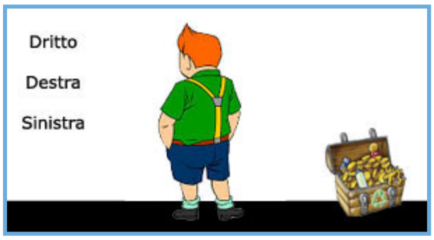

Fig 1 – the character waits for the player to tell him where the treasure is.

The following level requires the player to give two different directions, one after the other. The player gives the first direction, after which the scene changes and then the player gives the second direction. This shows the player that the point of view changes with the movement of the character (i.e. in Fig 3, the second direction is not "straight" as may seem when looking at Fig 2, but becomes "left" after the first turn).

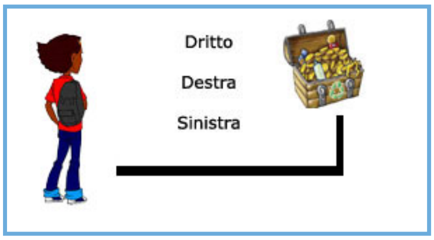

Fig 2 – first part of the answer is "right".

Fig 3 – according to the previous direction,
the scene changes and now the correct answer is "left".

At the beginning, there are no alternative ways, but as the game advances, there more possibilities are shown. The map gets more complex as it includes some roads that do not go to the treasure.

After these abilities have been learnt, the game shows how the meaning of "left" and "right" changes according to the listener's position. These situations are the same as the first level in part two, but the character in the game can be turned around (see Fig 4).

Fig 4 – the meaning of "left" and "right" changes with the character's position.

After the relativeness of the direction words has been understood, the game goes back to the previous type of situations, where the character in the game has to be guided along a sequence of turns, but this time the map on the screen does not change as the character moves. In this situation, the user has to imagine with his "mind-eye" the position of the character to give him the correct direction.

3.2 The Smart View Game

The "Smart View" game is based on the concept that a scene including one or more objects looks differently according to the viewer's point of view. The users learn to recognize the same objects from different perspectives.

The game aims at developing basic abilities needed for autonomous movements around town. Two are the abilities developed:

- Recognition of the overall structure of the scene from different perspectives
- Attention to small details that are needed to recognize an object seen from different points of view.

The game starts with two different tutorials:

- The first aims at showing how a scene with objects may look different when seen from different sides. The player can move freely around a table and, at each side of the table, he can ask the system to show him the scene.
- The second tutorial shows the player the game interface by asking him to select among the ones presented on the screen, the image that represents what he sees on the table.

After completing the tutorials, the game begins. A scene is presented and the player is asked to choose from a lateral menu showing four different images the one that represents the same scene from one of the other sides of the table (e.g. the side identified with the blue colour).

Fig 5 – The Smart View Game.

The scenes that are presented as possible answers can have different levels of difficulty due to the four criteria:

1. The complexity of the objects and their relative positions.
2. The presence of distractors (i.e. some objects may have been replaced with similar ones).
3. Objects that have been moved from the original position.
4. Objects that have been rotated compared to the original position.

The combination of these criteria allows addressing different cognitive skills: the ability to understand that my view on a scene can be different from the known one because my position is different and the capability to recognize the single object from similar ones even when seen from a different perspective.

A person with these abilities can easily manage to recognise a well known square also when reached from a different road from the usual one because he recognizes the statue in the middle, and, furthermore, he can find the correct way to leave the square thanks to the analysis of the orientation of the statue.

All the used objects are classified according to two different dimensions: the difficulty of the single object and classes of similar objects.

The complexity of the objects and their relative positions depends on the following:

1. The difficulty of the single object: a bottle is round and looks very similar from all the different points of view while a statue has many details that give the viewer clues about its orientation.
2. The number of objects involved: having two objects allows to consider their relative position, but having too many may be confusing
3. The repetition of the same object or the presence of similar ones: having objects that are very different makes the game easier.
4. The position of the objects on the table: a lateral position gives more clues than a central one.
5. The relative position of the different objects on the table.

Due to the complexity of these criteria and their interrelations, only a specific test with the final users can guarantee that the different types of scenes are correctly classified. When the user chooses the wrong answer, an error message is generated to help the player recognize the correct answer. The scene is then presented again.

4 TECHNOLOGICAL AND INTERFACE CHOICES

All the games developed within the Smart Angel project are specially aimed at people with cognitive impairments; therefore, a special attention has been put on accessibility [12] and natural interfaces. Furthermore, it is important that the games are played as much as possible to help the player practice thoroughly the newly learnt abilities. This is the reason why all the games, even if they may be implemented to work with special interfaces, can also operate on a normal home computer.

All the games are developed for a window-based computer and can be played without an active internet connection, but internet is needed in the setup and configuration phases and for data synchronization. User’s data is stored in a centralised database where it can be analysed by the tutors.

This allows storing the users’ data in one unique place that can be reached from anywhere. In a school, the singe player can always find his environment, the score he previously gained, his personal interface choices, etc., even if he connects from different computers. At home, on the other hand, the players can use the game mainly in a standalone manner.

The educators have the opportunity to analyse data from any location, and always have both up to date data and accessibility to the previous experiences. All the users’ data is available during the whole Smart Angel project, also after the initial training phase of a specific end user has ended.

As previously described, all games are structured in a sequence of situations organized into difficulty levels. Special attention has been made to provide situations which match with real world ones as far as possible. In the Left-Right game, each situation is shown on a wide computer screen in the most realistic manner as possible. The situations are enriched with the common environmental noises to help cognitive impaired people to recognise the scene as a possible real life situation. Furthermore, also people with slight visual impairments can play the games.

In the Smart View game, a Table Touch may optionally be used. The game would therefore be played around a table, where the player can move freely from side to side to analyse the scene from the different perspectives. In case the Table Touch should not be available, however, the game can always be played on a normal computer screen.

One of the main drawbacks for people with the Down syndrome is lack of abstraction [13]. This has an influence on the choice of the user interface in order to make them as natural as possible.

The user inputs, where possible, are given using Microsoft Kinect therefore the player can just react naturally by moving his body. In the Left-Right game, the user can follow the given directions simply by moving his whole body to the direction required. Kinect may require some weak restrictions with respect to the room where the game takes place: there is the need to have some free space in front of the screen where the player can stand and move. Furthermore, the player needs to stand in front of Kinect; therefore, there is a starting position to which he has to return before each situation in the game. We strongly believe that these restrictions do not influence the game.

Since reading written texts may be a problem to some of our users, all the games messages, instructions and help texts, which are always given in a written form, can be heard as vocal messages. Furthermore, also users’ input may be vocal. For instance, when the user has to tell his character in the game to “go left”, he may just say the words aloud.

We decided to use the mouse as an input system since most of our users are quite friendly with computers and are used to both touch screen and mouse devices. However, we avoided completely the keyboard: written inputs are never needed apart from the setup and configuration phases.

5 PEDAGOGICAL CHOICES

The games have been designed, from a pedagogical point of view, to cover a large part of the educational objectives as they are identified in the revised Bloom Taxonomy [14]. Within the Smart Angel project, our final users are all people with some degree of cognitive disability; therefore, it is not feasible to cover the whole complexity of the possible educational objective. In fact, those who are affected by the Down syndrome have difficulty in conceptualization and generalization of the learnt concepts, which means that the analysis and the evaluation of the known facts is often impossible.

The educational objectives for the Left-Right game have been identified as follows:

- LR-objective 1: Remember and understand the directions given using the words “left”, “right” and “straight”.
- LR-objective 2: Follow the given directions correctly. The directions may be single commands (“go right”), a sequence (“go left then straight”) or have some implicit statements (“go left at the traffic light”).
- LR-objective 3: Produce the correct directions to guide a character to the treasure.
- LR-objective 4: Understand how the meaning of the direction words changes according to the listener’s position and produce the correct command.

The Smart View game, on the other hand, is aimed at the following educational objectives:

- SV-objective 1: Understand that an object or a scene can look differently according to the viewer’s point of view.
- SV-objective 2: Recognize a given object among similar ones when the objects may be rotated.
- SV-objective 3: Recognize a scene from a different point of view.

In the following table, the revised Bloom Taxonomy is shown and the educational objectives of the developed games have been enhanced.

The Cognitive Process Dimension of the revised Bloom Taxonomy.

	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	LR obj 1					LR-obj 3, 4
Conceptual Knowledge		SV-obj 1	LR obj 2 SV-obj 2			
Procedural Knowledge			LR obj 2 SV obj 3			LR-obj 3, 4
Metacognitive Knowledge						

LR-objective 1 is actually aimed at factual knowledge, i.e. the ability to recognize and understand the given directions, which have to be correctly applied. LR-objective 2 requires the player to analyse the given directions, complete and follow them. This involves both procedural knowledge and some conceptual knowledge to be able to complete the implicit parts of the directions. LR-objective 3 game focuses on the production of the direction words. It is therefore linked to a process of creation. Again, the different levels in the game addresses different kinds of knowledge. LR-objective 4 involves some procedural knowledge: the player has to get mentally into the character’s position in order to interpret correctly the direction words; therefore, he has to apply basic procedures to “turn the scene around”.

SV-objective 1 involves some conceptual knowledge since the player has to generalize from what he sees and from previous experience, how the object or the scene may look like from a different position in space. This knowledge is first acquired and then actively used in the next two objectives that are based on a recognition activity. The ability to imagine, with the mind-eye, the scene from a different point of view involves the same kind of abilities as LR-objective 4.

As stated earlier, the cognitive processes linked to analysis and evaluation are often impossible for our target users. Nevertheless, our objectives cover also the creative processes, which usually follow all the previous dimensions.

The cognitive processes classified under the “create” dimension can be of different types. The simple production of a word is a kind of creation, meaning that a person is able to access his knowledge to find the needed information and use it correctly. On the other hand, the mental processes needed when a person actually needs to build on previous experience to originate new information or behaviours are more complex.

Within the developed games, the players are asked to use actively information that they have already experienced. For example, in part one of the Left-Right game, they receive the directions to reach the treasure and in part two they need to produce the same directions to guide the character in the game. In this case, there is no need to build on known facts and repeated training can generate the correct production even without going through any analysis or evaluation of the learnt abilities.

Furthermore, people with the Down syndrome show very different cognitive limitations, some of them may be able to solve the more difficult levels. Additionally, the game has been designed for a wider audience; it may be used with success also with elementary level children.

6 CONCLUSIONS AND FURTHER WORK

Spatial skills are of great importance for several tasks of everyday life. In particular, they are needed for mobility. In this paper, we describe two serious games that have been developed with the aim of helping people with some degree of cognitive impairment to learn skills that are needed for autonomous mobility in town. The two games teach to understand, follow and produce simple road directions and to recognize a scene or an object when seen from a point of view that is different from the usual one.

The games also give the opportunity to practice more and alone, to keep the user motivation high and give him the challenge to reach pre-defined goals. This facilitates the educator’s role by helping the player in creating a good and solid basic knowledge on which it is much easier to build the other mobility skills.

Even though the games have been developed for young adults, they can easily be used for children at elementary age. Children need to learn these skills in order to be able, later in life, to be independent. Furthermore, spatial intelligence has an impact on education from two different points of view. Having a smarter spatial intelligence enhances the student performances in various different fields and mobility has a strong impact on inclusive education.

Adaptation to other countries is also foreseen. The localization to different cultures has been taken into account during the development of the games in order to minimize the needed effort.

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