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Inclusion of immersive virtual learning environments and visual control systems to support the learning of students with Asperger syndrome

Gonzalo Lorenzo [a,*], Jorge Pomares [b], Asuncion Lledó [c]

[a] Department of General and Especific Didactics, University of Alicante, Alicante, Spain
[b] Department of Physics, System Engineering and Signal Theory, University of Alicante, Alicante, Spain
[c] Department of Development Psycholoy and Teaching, University of Alicante, Alicante, Spain

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ABSTRACT

This paper presents the use of immersive virtual reality systems in the educational intervention with Asperger students. The starting points of this study are features of these students' cognitive style that requires an explicit teaching style supported by visual aids and highly structured environments. The proposed immersive virtual reality system, not only to assess the student's behavior and progress, but also is able to adapt itself to the student's specific needs. Additionally, the immersive reality system is equipped with sensors that can determine certain behaviors of the students. This paper determines the possible inclusion of immersive virtual reality as a support tool and learning strategy in these particular students' intervention. With this objective two task protocols have been defined with which the behavior and interaction situations performed by participant students are recorded. The conclusions from this study talks in favor of the inclusion of these virtual immersive environments as a support tool in the educational intervention of Asperger syndrome students as their social competences and executive functions have improved.

1. Introduction

It is currently possible to find a large number of research aimed at applying virtual reality (see e.g. Parsons, Leonard, & Mitchel, 2006) and immersive virtual reality (see e.g. Wallace et al., 2010) to the education of students with special educational needs. Virtual reality (VR) is a term that applies to computer-simulated environments that can simulate physical presence in places in the real world, as well as in imaginary worlds. Most current virtual reality environments are visual experiences displayed on a computer screen. However, the goal of immersive virtual reality (IVR) is to completely immerse the user into the computer generated world, giving the user the impression that he/she has "stepped inside" the synthetic world. To achieve this impression, the equipment described in Section 3 is employed. Generally, in the case of children with Autism Spectrum Disorder (ASD), the virtual reality systems make it possible to plan, practice and implement different behaviors and to observe the children's responses in a computer-generated virtual environment.

These systems offer a three-dimensional representation of controlled and safe real environments that can be used repeatedly. It is worth mentioning some previous works where VR has been used with children with ASD, as for example, to improve the understanding of facial expressions (Fabri & Moore, 2005), Street-Crossing for Teaching Skills (Josman, Ben-Chaim, Friedrich, & Weiss, 2008), or to acquire social skills in environments such as a bus or a coffee shop (Mitchell, Parsons, & Leonard, 2007). This last work provides another advantage of these virtual environments: the possibility to develop the student's imagination and the possibility to learn through different roles. These previous studies show that many students with ASD are motivated by VR environments and that the use of these environments is an important support for the improvement and acquisition of certain social skills (Moore & Calvert, 2000; Parsons et al., 2006). Another important aspect of this kind of systems is that they offer the possibility to establish a communication between different users (Passerino & Santarosa, 2008). This aspect helps to practice and to improve different social skills. For example, Cheng, Chiang, Ye, and Cheng (2010) propose a virtual collaborative environment (CVE) to promote acquisition of social skills for students with ASD. In CVE, geographically dispersed users can communicate with each other via their avatar or virtual character. A user can look around a CVE and interact with other

* Corresponding author.
E-mail address: glledo@ua.es (G. Lorenzo).

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avatars and 3D objects in real-time. Goodwin (2008) indicates that the goal of VR is not to evade real-world interaction but to provide extra material which can be used by teachers to improve certain social tasks.

There is no doubt that this type of technologies offers help and support in the education of children with ASD, however, there are still some doubts or questions relating to its application. As indicated in Rogers (2000), certain stimuli acquired through VR, may not be interpreted correctly by the students with ASD. Regarding this aspect, works like (Cromby, Standen, Newman, & Tasker, 1996) indicated the difficulties that could arise when generalizing tasks in the school environment. In the state-of-the-art presented by Parsons and Cobb (2011), they suggest that children can learn from the VR and that they have observed a partial transfer of this knowledge into the real world. However, they indicate that the non-social nature of the computer generated environments can make the socialization even more difficult. These studies show that the students with ASD could be so attracted by the technology that it could lead them to lose even more interest in social interaction in real life. To avoid these problems, Parsons et al. (2006) propose the integration and use of VR as a school task in which the students do not work in isolation. They also have the support of a facilitator. These aspects have been taken into account when developing the proposed system in this study. Another aspect indicated by the researchers who have used VR with ASD students is that the situations and aspects illustrated in these environments are learned literally and repeatedly without considering the social context (Parsons, Mitchel, & Leonard, 2005). This repetition could cause the students to consider the VR environment as a computer game, without seeing a connection with the real world.

Compared to conventional VR environments, in IVR systems the student is completely surrounded by the environment and constantly receives stimuli and has the possibility to interact with it. As indicated in Blascovich et al. (2002) this type of immersive system provides more information about people with ASD. As they also indicated, these systems can be used to create real environments where the ASD students have a chance to address social difficulties in a safe and controlled environment. Furthermore, they found that the high level of stimuli and realism help to avoid some of the problems found in the traditional VR systems as those described in the preceding paragraph. It was found that the use of immersive virtual environments (IVE) can improve the learning of these students because of the possibility to repeatedly reproduce real environments and situations (Wallace et al., 2010). Compared to previous works, this study proposes a new IVR system to improve the learning and to enhance the development of social skills for students with Asperger syndrome. This syndrome is one of the five pervasive developmental disorders also named ASD by the Diagnostic and Statistical Manual of Mental Disorders, DSM-IV (APA, 1994) and (APA, 2000). In Section 2 of this article, we describe the specific characteristics of Asperger students compared to other ASD. This section shows the factors that have been addressed with the proposed IVR system. As indicated in previous research such as those of Mitchell et al. (2007), Asperger children have difficulties to learn independently and they need to be guided when problems arise. For this reason, IVE can become a guide and visual aid that can be adapted to the needs and characteristics of these students, and subsequently transfer the learned skills into the school environment. Tasks that are present in school learning require that students have a set of skills with which to use problem-solving strategies. To do this, students must be able to perform tasks of planning, decision-making, organized search, control of inappropriate responses and flexibility of thought. They must have the capacity to plan and to control answers and to comply with the norms (how to start, what to do, how to do it and steps to take). All these cognitive processes can be associated with what Grattan and Eslinger (1992) identified as executive function. As indicated in Section 2, Asperger children have deficits in executive functions so the IVR will be used, not only to improve social skills, but also to improve the executive functions.

Comparing the proposed IVR system with other previous works using IVR for students with special educational needs, the proposed system has several innovations. On one hand, it is the first specific approach that takes into account the use of IVR for students with Asperger syndrome. A fundamental aspect of the developed IVR system is the data collection that makes it possible, not only to assess the student's behavior and progress, but also to adapt the system itself to the student's specific needs. On the other hand, the IVR system is equipped with sensors that can determine certain behaviors of the students. This information is employed to determine if a given task is correctly developed in the virtual environment. This information is also employed to study the student's evolution. Although there are no previous experiences in immersive systems for improving social skills and the executive functions of Asperger children, one important aspect is to improve the transfer of the skills acquired in the virtual environment into the real world (Wallace et al., 2010). For this, work has been done to recreate realistic environments, with different elements for the students to interact with. These virtual environments are familiar to students (e.g. a virtual recreation of the classroom where they usually attend lessons). This aspect does not only improve the transfer rate of learned skills but also allows a reduction of the time the student needs to adapt to the virtual environment. Finally, it should be noted that the IVR system is dynamic because it can be adapted to the student's behavior and the social skills and executive functions that need to be improved.

In order to improve the immersion of the students into the computer generated world, they are able to manipulate the existing objects in the virtual world. For this purpose, a technology based on visual servoing (Pomares, Chaumete, & Torres, 2007) has been developed, and it allows the representation of real objects in the virtual world. Thus, the student manipulates real objects in the virtual environment but what he is seeing is a virtual representation of the object. This aspect can increase the realism and the subsequent transfer of skills.

The rest of the article is organized as follows: Section 2 shows the general characteristics of Asperger children and the skills that we want to promote by using the proposed IVE, Section 3 describes the components of the implemented IVR system. Section 4 details the methods and development of the research, indicating the procedure of assessing the pedagogical validity of the developed technology. Section 5 describes the main results and conclusions.

2. Asperger and virtual reality

This section describes the characteristics of Asperger syndrome and refers to the known difficulties and the skills that we want to improve by creating and using the IVR. Some time has gone by since Hans Asperger (1944) identified a group of children, with what he called autistic psychopathy, characterized by problems with the use of language with a communicative purpose, pragmatic communication deficiencies, idiosyncratic verbal expression, nonverbal communication difficulties, specific interests, social interaction difficulties and clumsiness despite an adequate language development and a sophisticated cognitive style. Although Leo Kanner (1943) described autism by the abnormal communicative skills, social interaction and affection development disorders, scientists do not standardize criteria when it comes to addressing the differences and similarities between Asperger syndrome and autism. The Diagnostic and Statistical Manual of

Mental Disorders (DSM-IV) defined Asperger syndrome as a developmental disorder different to autism. The upcoming DSM-V, expected by May 2013, could mean the elimination of Asperger syndrome and the possible absorption by ASD. However, some authors continue justifying their differences and consider Asperger syndrome as a pervasive developmental disorder and that Asperger and autism show two different realities (Saulnier & Klin, 2007). Ehrich and Miller (2009) indicate that the Asperger children are limited in social interactions, they present repetitive behavior patterns, they cannot understand the unwritten rules of communication, they have trouble with teamwork and are usually very impulsive. Previously, Howlin (1998) stated that Asperger children had relatively normal levels of cognitive skills, and did not present delay in language acquisition (this characteristic is decisive in the differentiation of autism). Other works (Leonard, Mitchel & Parsons, 2002; Parsons et al., 2000; Parsons & Mitchel, 2002; Weiss & Harris, 2001) have shown the differences between Asperger syndrome and autism. These previous works focus their study in the following areas: communication, imagination and social skills. Additionally, these works have shown that the Asperger children present difficulties in the school environment due to the nonverbal communication impairment and the problems in social relationships (inappropriate eye contact, producing inappropriate emotional responses). In addition, other works such as Ehrich and Miller (2009) and Wolberg (2009) claim that Asperger children also have trouble understanding the concept of cause and effect. As a consequence, they have difficulties resolving problems since they often memorize the specific situations and, therefore, cannot apply the knowledge in another context. They also show difficulties when playing or learning together with others. Burke, Kraut, and Williams (2010) claimed as a characteristic of Asperger children, the sensitivity to environmental stimuli like bright lights, loud noises, and strong odors. Furthermore, works like Price, Shiffrar, and Kerns (2011) study the problems of these children to detect human behavior.

Thus, from the previous review and other previous works (Saulnier & Klin, 2007; Volkmar, Klin, & Rutter, 2005; Woodbury-Smith & Volkmar, 2009) the cognitive style of students with Asperger syndrome, can be summarized by these properties:

- Visual thinking. They understand, assimilate and retain better information using visual aids.
- Reasoning focused on details. They process more easily parts and details and not the whole and the global (they have difficulties integrating contextual information to find a coherent and comprehensive meaning).
- Inability to plan, organize and implement most of the activities that occur in a school environment.
- Extremely specific, logical and non-abstract reasoning.
- Strong resistance to change.
- Other aspects: a good level of intelligence, excellent memory in terms of data collection.
- In the educational intervention of these students it is required to teach explicitly through instructions and visual aids. Additionally, the learning environment must be structured to become predictable. The tutor shall inform the student about changes in advance and propose other options.

Although there are no documented previous experiences using specific IVR with Asperger children, some of the pioneer authors applying VR with Asperger persons were Swettenham, Baron-Cohen, Gomez, and Walsh (1996). In this study, VR was considered as a tool that provides a predictable environment to work with Asperger people. Cromby et al. (1996) showed that this type of VR based environment can avoid potential hazards present in the real world since the stimuli in the VR can be controlled by the user and it also shares many similarities with the real world. All of these studies (Shane & Albert, 2008) indicate that one of the major benefits of using VR is the possibility to use visual information, which is one of the strengths in Asperger children. Additionally, the VR allows the user to practice several social skills in one environment, or to practice a given social skill in different scenarios where children with Asperger have difficulties (Kandalaft, Didehbani, Krawczyk, Allen, & Chapman, 2012). Not only the scenarios are considered important, but several studies also describe the employment of virtual characters in order to improve the nonverbal social comprehension (David et al., 2010). According to Laffey, Schmidt, Stichter, Schmidt, and Goggins (2009) the VR allows a repetitive training of social skills, a gradual increase in training levels and the possibility to learn with different multimedia formats, without using a typical text. As Standen and Brown (2006) claims, VR offers several advantages when used with children with Asperger: first, the students can learn from their mistakes without suffering the consequences of the real world where they are limited in a large number of situations; secondly, by using VR we can take advantage of the flexibility of these virtual environments and their adaption to the different user needs. Kandroudi and Bratitsis (2010) used the VR as a platform for discussion and social interacting with other children, allowing them to improve social skills in Asperger children.

3. Immersive virtual reality system development

This section describes the different components (equipment, generated virtual environments, and other software modules) of the proposed IVR system. These software modules allow the user, on one hand, to evaluate the behavior and evolution of the student within the virtual environment and, on the other, to improve certain behavior aspects by increasing the interaction between the system and the student itself.

3.1. Equipment

The proposed 3D Immersive system consists mainly of a virtual reality system with a projection on an L-shaped screen, 3d active viewing, high quality audio and a precise positioning system. As shown in Fig. 1, the immersive system comprises two screens (Steward, Aeroview model 100) on which the virtual reality environment is projected (in Fig. 1, the IVE is a classroom). One screen provides the front view and the other is placed in the floor on a platform to allow projection from above. These two screens provide the immersive effect. Several sensors are integrated in order to provide different information. A positioning system with four cameras is also used. This camera system determines the student position and orientation within the immersive system (the screens viewing points are adjusted depending on the student motions). Thus, when the student bends down, the systems detect his/her position and the student will see the same image as when squatting in a real situation. To make this possible, the students must wear a cap with a light-emitting diode (LED) that is detected by infrared cameras. The sensory system is complemented by a Kinect sensor and an additional camera system. The use of Kinect and its

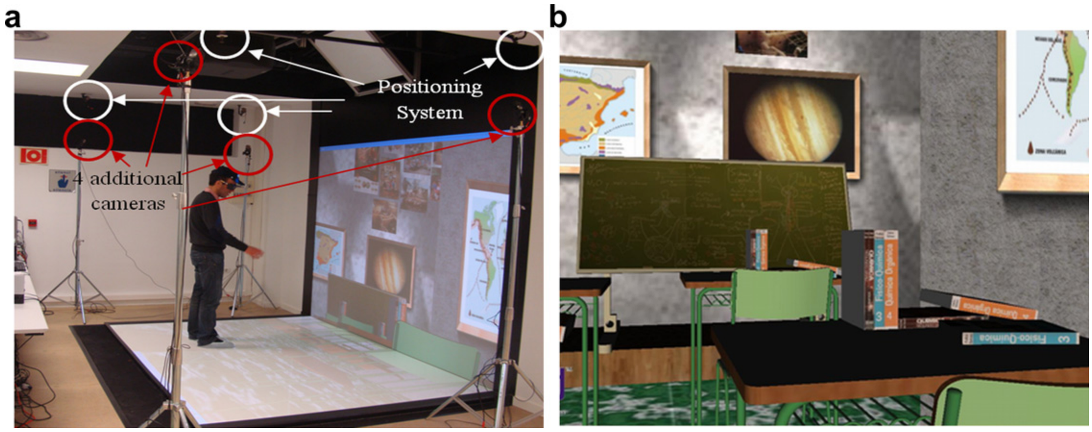

Fig. 1. a. Immersive System. b. Projected virtual environments.

associated software development kit (SDK) allows us capture the student's movement within the IVE and automatically determine the position of his/her arms and legs as well as gestures and performed behaviors. The additional vision system consists of four cameras located around the IVE. These cameras are employed to record any additional required information (e.g. information about the student's face or to determine if a given task is correctly performed, etc.). The 3D view is achieved with the active CristalEyes Stereography glasses. This type of glasses requires an infrared sensor that allows you to synchronize the alternative images of the screen with the LCD lenses of the glasses. Using these glasses, the student gets the feeling that the 3D image is something real in front of his eyes. Several speakers and amplifiers are introduced in the IVR system. This enables the child to hear any voice, sound, song, according to the needs arising in the virtual environment.

3.2. *Virtual environments*

A computer with an Intel core i5 and 6 GB of RAM memory has all the required software to create virtual reality environments. The generated video signal is distributed to the two projectors which show the content on the displays. The tool used to design the virtual environments is Vizard. This environment provides an interface to write scripts in Phyton and disposes of a virtual reality library for the creation of virtual worlds. 3Dmax is employed to design the avatars (virtual persons that appear in the virtual environment) and other more complex objects. In Fig. 2, two generated environments are represented in addition to the one in Fig. 1: a school playground and a bedroom. The school playground environment shows the presence of other students and teachers (avatars). Once the student is within the IVE, he/she can interact with the avatars like in reality. Within the IVEs the student must develop different tasks as those shown in Section 4. According to the pedagogical team, it was considered important to include audio explanations to guide the students in the tasks performed in the IVE.

3.3. *Software components*

The software components of the IVR system are grouped into the following modules: a) Interface, b) IVE generation module, c) Object virtualization, d) Data capture module; e) Decision-making module.

The goals of each of these modules are:

a) The IVR system presents an interface which is employed by a researcher in order to interact with the Asperger children and with the software components. Using the interface, the researcher can use audio to talk with the children to guide them, enable different social situations in the IVE, change the behavior and mood of avatars, etc.

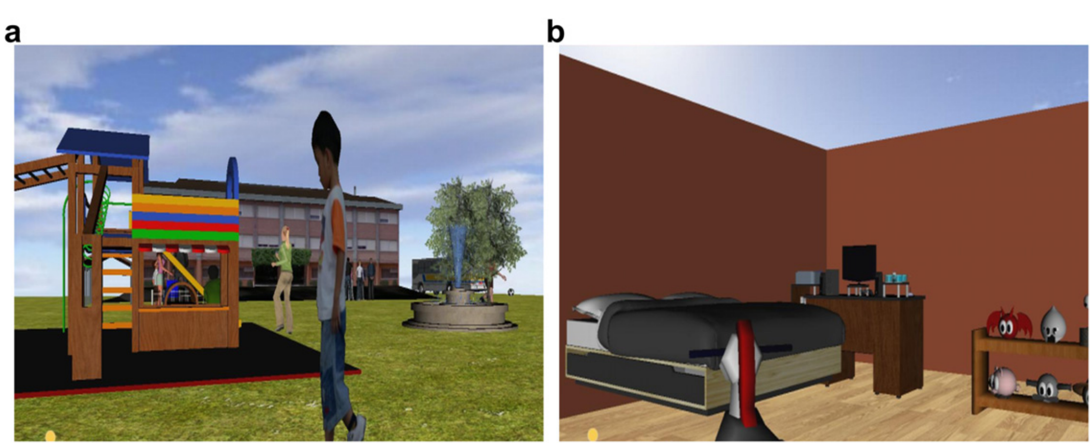

Fig. 2. a. Generated virtual reality environments: School playground. b. Generated virtual reality environments: Bedroom.

b) IVE generation module. This software module generates the virtual environments described in Section 3.2 (see Figs. 1 and 2) and projects the virtual environments in the L-shaped screen.
c) The authors have developed a technology which uses virtual visual servoing (Pomares et al., 2007) to represent real objects in the virtual environment. As shown in Fig. 3, using this technology, the student can manipulate real objects found in the virtual environment. The virtual visual servoing system reconstructs the location of certain real objects and represents them in the virtual environment. This technology gives the child the impression that he/she can "touch" several objects that are in the virtual environment.
d) Data capture module. This component employs different sensors to automatically obtain information from the Asperger student as well as from the surrounding objects in order to keep the VR updated and to take necessary decisions. The information collected by this module can be summarized as follows:

- 3D location of the child. As previously indicated, this information is employed to adjust the student's point of view to offer him/her an adequate visualization of the movements when he/she is wearing the 3D glasses. This information is collected by using the positioning system mentioned above.
- Location of the 3D objects in the environment. As indicated above, this information is used to generate a three-dimensional object representation in the environment that can be manipulated by the student.
- Facial recognition. The additional camera system detects the student's mood. For this purpose, if one of the cameras is able to collect the necessary information, the vision system uses the algorithm described in Kueblbeck and Ernst (2006) to determine if the face reflects fear, joy, sadness, surprise, contempt, etc.
- Position and other information. The Dynamic Time Warping Kinect SDK (DTW) Gesture Recognition (http://kinectdtw.codeplex.com/) has been used to determine the position of the body, arms and legs. This system detects the skeleton of the student and subsequently recognizes certain previously recorded gestures.
- Voice Recognition. The goal of this module is to detect if the volume and intonation of the voice is appropriated for the task.

e) Decision-making module. All the actions performed by the student in the IVE are recorded in order to be analyzed. This information is employed to make a comprehensive and personal evaluation of each child. However, based on certain indications saved in a database, the avatars have artificial intelligence in order to change their behavior depending on the progress of the Asperger student (e.g. the avatars can attract the attention of the student when an indifferent behavior is detected).

4. Methods

This research has the goal to take one step further in comparison to other previous studies about the use of VR in an educational context to improve different skills of autistic people. This is presented with a fully immersive approach to support the learning of social skills and executive functions in school, which is specifically developed for students with Asperger syndrome. A mixed methodology has been used: qualitative, observational, experimental and also quantitative.

This research was carried out in the following phases:

1. Initial phase: Proposal of two questions as a starting point:
   a) Can IVEs support the acquisition of knowledge; improve social skills and the performance of school tasks of students with Asperger syndrome?
   b) Can the learning implemented in the IVEs be transferred to the real school environment?
2. Construction phase: Design of the IVEs and the protocols to implement the tasks in that environment.
3. Gathering phase: Implementation of tasks in the IVE. (In this phase the students develop the protocols defined in the previous phase and information about the student's behavior is obtained).
4. Analyzing phase: Analysis of the obtained results and information from the previous phase.

The general objective of the present study is the inclusion of virtual environments in the educational context as a support tool in the educational intervention of students with Asperger syndrome. The specific objectives are:

1. To design and build IVEs as a school context (classroom and school playground) and family environment (bedroom).
2. To identify changes in the students' behavior using the instruments provided in Section 4.2.

Fig. 3. Immersive system. Manipulating objects in virtual environment.

3. To establish a support task protocol to acquire and improve the executive functions and social skills in school environments for students with Asperger.
4. To implement the defined tasks protocols in the IVR system described in Section 3. These tasks represent school situations as a strategy to avoid difficulties and to improve the social skills of students with Asperger Syndrome.
5. To assess the improvement provided by the IVE relative to the learning difficulties encountered in these students.
6. To evaluate the transfer rate of learned skills from the IVE into the real world.

4.1. Participants

The participants of this study are students with Asperger syndrome in primary and secondary school. The sample includes a first group of 10 students in primary school from public schools in the city of Alicante (Spain) and a second group of 10 students from secondary schools in Alicante. Out of the 20 persons in the complete research group 16 are boys and 4 girls. The age of the participants in the first group, primary school students, ranged from 8 to 11 years, while the age of the second group, secondary school students, ranged between 12 and 15 years.

4.2. Instruments

The multidisciplinary nature of the study demands the cooperation between engineering and new technologies with didactic strategies from the Educational Sciences field. Different instruments were employed to obtain the required information according to the objectives. Table 1 shows and describes the used instruments.

4.2.1. The supportive tasks protocol (TEVISA)

The TEVISA protocol has been designed in order to obtain information about the social skills of the students and their capacity to carry out different school situations in an IVE. The protocol consists of a set of clear and specific tasks and is composed by 32 supportive tasks, 16 for the group of primary school students and 16 for the secondary school group. These tasks describe actions to be carried out by students in the IVE and provide information about the learning difficulties found in students with Asperger.

Considering the deficits that characterize the cognitive style of the students with Asperger Syndrome, the IVEs allows us to design a structured environment in which a set of aspects can be controlled: irrelevant information is eliminated, instructions are clearly and explicitly presented and finally, a visual learning is developed (furthermore, this learning is interactive and close to reality). Asperger's students typically exhibit strengths in their visual processing skills, therefore, the mainly visual learning performed in the IVE helps the student to better understand his/her environment and to acquire the required skills. All these aspects are taken into account in the defined TEVISA tasks.

The 32 TEVISA tasks are grouped into the following blocks, both for primary and secondary students:

Block I. Executive functions in the school environment.
Block II. Tasks to support social skills of students with Asperger syndrome.

The tasks are designed to reproduce various school situations in the IVE and have different difficulty levels according to the groups of primary or secondary school students. The goal with these tasks is to gather information about the following sections:

1. Identification and understanding of the given tasks.
2. The compliance level with the instructions given to carry out the tasks.
3. The students' behavior while carrying out the tasks.

The TEVISA Protocol is characterized by the following types of tasks:

a) Tasks to resolve different problems and situations in the IVE. The objective of these tasks is to develop school situations in the IVE that improves the students' executive functions.
   These tasks are also divided into two categories:
   I. Preliminary tasks. These tasks are a tool to become familiar with the IVE and its components (avatars, virtual objects, etc.).
   II. Support or implementation tasks. The objective of these tasks is to identify steps to be able to plan or to carry out the specific actions and to apply these instructions in the school environment.
b) The school environment application tasks. The tasks performed in the IVE are implemented in the real classroom in identical situations.

Table 1
Instruments.

Instrument	Description
Supportive tasks protocol (TEVISA)	32 supportive tasks for the development of executive functions and social skills. These tasks represent school tasks and different social situations (implemented in the IVR system)
Interviews with school teachers during the implementation of the TEVISA protocol tasks	The researchers held monthly interviews with the teachers to follow up on the student's evolution in the real classroom
Instructional protocol of avatars (PIAV)	Evaluation of 5 individual behavior areas and 4 categories, using the sensory system described in Section 3

In Table 2, the TEVISA protocol supportive tasks are presented both for primary and secondary school students. This table only lists the situations that the student will practice within the immersive system. The situations described in each of the tasks have been recreated using the IVE system. As indicated above, for each support task there is a preliminary task that will help the student to become familiar with the environment and to recognize the necessary elements to resolve the situation. Once the students develop a given task in the IVE, they must answer a set of questions (the responses to this test are employed to evaluate the student's progress). As an example, Table 3 gives a detailed presentation of the TEVISA protocol support task 3, referring to the executive functions and learning of primary school students. In this table, the corresponding preliminary task is also indicated. Both tasks are executed using the IVE shown in the Figs. 1 and 2b (classroom and bedroom).

As shown in Table 2, a set of typical school situation tasks have been designed for the students to practice in the IVE. The student will perform the tasks following the instructions indicated by the corresponding avatars of teachers, students etc. Also, a member of the research team (assessor) will observe and take notes on the student's behavior as well as the answers given in the evaluation test of each task (this researcher can also help the student to carry out the task). Both performances will be assessed with a score from 1 to 4 where 1 = the student does not understand the instructions given in the IVE task and is confused while carrying them out, 2 = Understands the indicated task better but does not follow the required steps, 3 = Understands the task to perform on an acceptable level but is mistaken in some aspect; 4 = Understands and performs the tasks on a fairly acceptable level.

In this study we have designed a real immersive virtual environment that offers a highly structured and explicit information and eliminates any irrelevant information in school situations that allows the students to learn how to solve these situations in a procedural manner. As indicated in the studies of Parsons and Cobb (2011), the transfer of knowledge from the VE into the real world increased if the tasks allowed the student to work with his/her procedural skills, based on rules and not on unpredicted situations. The same authors also mean that the VE offers the possibility to modify the virtual environment, with repetitions, different difficulty levels according to the student's needs, or even, as (Wallace et al., 2010) expressed it, to stop scenes to clarify aspects. These are all elements that we have added to the TEVISA protocol tasks, by offering different types of tasks (previous, support) as well as an open and modifiable repetition of the tasks.

4.2.2. Interviews during the implementation of the TEVISA protocol

The interview is employed as an instrument to know if TEVISA protocol tasks carried out in the IVE are being progressively transferred to the real classroom by the students. These interviews are held with teachers on a monthly basis. The interview permits to collect quantitative data from the teachers. This quantitative data provides the researchers information about the students' behavior in the classroom while carrying out tasks similar to those trained in the IVE and the possible transfer of this knowledge into the classroom. Therefore, the transfer of the skills learned in the IVE is analyzed. Through observation and analysis of the tasks carried out by students, the tutoring teachers evaluate the behavior performed by the students in the different tasks during a month. They use the same rating system as the one described in the TEVISA protocol but for real world tasks. Additionally, the interview has a qualitative part in order to integrate the teachers' contributions into the study (modifications in the IVEs, changes in the protocols, etc.).

4.2.3. Instructional protocol of the avatars (PIAV)

This protocol was created to automatically obtain information about the student's evolution by using the proposed immersive system. The PIAV protocol consists of 5 blocks referring to the students' behavior while carrying out the TEVISA protocol tasks. The Kinect sensor and the camera system described in Section 3 have been used to collect the information about the 5 blocks of the PIAV protocol:

Table 2
TEVISA protocol tasks.

Block I. Executive functions in school learning. Primary education	Block I. Executive functions in school learning. Secondary education
1. In the classroom the teacher informs the student of the work for tomorrow.	1. At home, the student has to plan the work for the following day by checking the class schedule and the work that must be done.
2. Classroom situations in which the student must ask the teacher when he/she does not fully understand an explanation.	2. When the student has doubts at home, he/she must write them down to ask the teacher.
3. In the student's bedroom, the student has to prepare tasks for the following day.	3. The student must prepare the material needed for the following day's class.
4. Classroom situations in which the student has to slowly read the assigned tasks.	4. An exercise is given to the student to be read, with the important information to be underlined, and then solved.
5. The teacher provides the student with a text and he/she must underline the important information.	5. In the classroom the student reads a text and then he/she answers questions.
6. A school environment is simulated through regular schedule changes.	6. Classroom situation where the teacher is absent.
7. The teacher describes a situation to the student which requires him/her to make a decision.	7. The teacher describes a situation to the student, requiring him/her to make a decision.
8. When it's time for recess, the student must prepare to leave the classroom.	8. In the playground several classmates are directed to talk with the student.
Block II Social competences. Primary education	**Block II. Social competences. Secondary education**
9. Joining the line to enter the classroom.	9. The student has to wait for class to begin.
10. A classmate approaches the student, and the latter must initiate a conversation.	10. Other students in the classroom talk and the student has to listen and then answer questions.
11. The student must ask the teacher for the missing material in class in order to complete a task.	11. The student has to ask some questions to a classmate.
12. An attempt is made to recreate a situation that angers the student.	12. A situation is created in which the student should not interpret the task "literally".
13. The teacher introduces different emotions in the classroom.	13. The student must consult a book to answer a question posed by the teacher.
14. In the playground, the student has to say the game that he can play.	14 A situation is created in which the student must establish a topic of conversation.
15. In the playground a classmate plays with the student.	15. The student must share his/her class materials with classmates.
16. The student has to invite a friend to play at home.	16. A classmate asks the student for help and the student must help him/her.

Table 3
Development of Task 3 of the TEVISA protocol.

Part: 1. Executive functions and school learning.
1. PREVIOUS TASK: Identify what is needed to plan the work. IVE Characteristics: Structured Space: Classroom. Task description: A student asks the teacher what tasks must be carried out tomorrow and the teacher replies, “You should look at the assignments for tomorrow in your agenda.” The teacher writes the subject exercises on the blackboard for the following day and the students write in their agendas (school diaries). Task evaluation: Answer the questions: What has the student asked? What has he/she written in the agenda? What do I have to know to complete the exercises that I have to do? 2. MAIN TASK: In his bedroom, the student has to prepare for the tasks that will be done on the following day. Objective: Identify the steps to follow in planning and preparing for his/her studies. IVE Characteristics: unstructured space: bedroom Task description: The student is in the room and is asked: What should you do for the homework for tomorrow? The student must read the agenda and start doing the exercises presented. The student must also prepare the material for tomorrow: look at the schedule for the following day, collect textbooks, and close backpack. Assessment of the task: Complete the questions about the steps to follow in preparing for the student’s studies.

1) Body coordination control, 2) voice control, 3) eye control, 4) attention control, 5) empathy control.

The obtained information about the students’ behavior will focus on the identification of the 4 dimensions that make up the 5 blocks of the PIAV protocol (see Table 4). The first three dimensions refer to the presence of certain incorrect behaviors in the 5 blocks, and the fourth dimension refers to changes that occur under the influence of the existing avatars in the IVE. The dimensions of the 5 blocks which can be obtained automatically with the proposed sensory system are indicated with “*”. All other dimensions are determined manually by the assessor. Currently, we are working on the possibility to automatically determine all the dimensions of the PIAV.

While the TEVISA protocol tasks are being carried out, we count the number of times the student acts according to the behavior defined in the PIAV protocol. To this number we add the times when the students’ behavior is unaffected by certain actions from the avatars. The sum of these two values is the final PIAV protocol score. The following score categories are used: Category 0: null score of the PIAV protocol; Category 5: score from 1 to 3 for the PIAV protocol; Category 10: score from 4 to 6 for the PIAV protocol; Category 15: score from 7 to 9 for the PIAV protocol; Category 20: score from 10 to 12 for the PIAV protocol; Category 25: score from 13 to 15 for the PIAV protocol; Category 30: score over 15 in the PIAV protocol.

4.3. *Design and procedure*

This section describes the procedure carried out during this research. The investigation begins in the academic year 2006/2007 with a control group, selected from schools in the province of Alicante (Spain). These schools had Asperger students and special education teachers. During the academic year we established a list of school situations to develop a set of executive functions and social skills, with which the Asperger students have shown difficulties (this list later became the TEVISA protocol). During this year we also created several questionnaires to determine the student’s evolution throughout the year in a quantitative way. These questionnaires measure the student evolution while they perform the above mentioned list of tasks (see Section 4.2.2). These evaluations were used with other Asperger students during the following two academic years. The number of participating students during these three years varied between 17 and 24. The information collected during these three years was the starting point to create the virtual environments and the protocols. The IVEs and the TEVISA protocol tasks were created during the academic year 2009/2010. The TEVISA, PIAV and interviews were implemented during the academic year 2010/2011in the same school as in previous years. Currently, during the academic year 2011/2012, we are completing the project and disseminating the results and the conclusions.

The participants were selected from primary and secondary school by interviewing the psycho-pedagogical team and the respective tutors. All participants have a confirmed diagnosis of Asperger syndrome and with average intelligence levels, reflected in their respective intelligence coefficients. Teachers, parents and the local associations of Asperger syndrome have supported this research.

The students selected for the research attended some individual sessions, during September 2010, to get to know the IVR system. After this first contact, the students participating in the research carried out 80 individual sessions, 2 per week, 25 min each. The student carried

Table 4
Assessment rubric of PIAV protocol.

1. Body coordination control	2. Voice control	3. Eye control	4. Attention control	5. Empathy control
1.1. Presence of inappropriate body posture.*	2.1. Presence of monotonous voice.	3.1. Presence of inexpressive gaze*	4.1. Absence of attention*	5.1. Absence of proper emotional behavior.
1.2. Occurrence of lack of coordination.	2.2. Inappropriate voice volume for a given context.*	3.2. Presence of non-directed gaze to the speaker.*	4.2. Absence of motivation	5.2. Presence of exaggerated emotional behavior.
1.3. Presence of repetitive movements.*	2.3. Presence of unnatural, affected language	3.3. No response to different facial expressions.*	4.3. Presence of attention difficulties.	5.3. Presence of social isolation behaviors.
1.4. Changes produced from the instruction of the avatars.*	2.4. Changes produced from the instruction of the avatars.*	3.4. Changes produced from the instruction of the avatars.*	4.4. Changes produced from the instruction of the avatars.*	5.4. Changes produced from the instruction of the avatars.*

out one TEVISA protocol task in each session. In total, throughout the research process, each student completed the 16 tasks 5 times. In the first two months each group of students carried out the 16 tasks for the first time and in the last two months they had the fifth and last session. The IVE sessions were divided into two periods of 10 min, separated by a short 5-min break in which the researchers asked a few questions to obtain information about what was identified in the virtual environment. The preliminary task was carried out during the first 10 min period and the support task in the second 10 min period. Once the entire session was finished, the student answered the questions employed to evaluate the task. The researchers and the students' tutors held monthly meetings. In those meetings we discussed the progress of the students performing tasks of the TEVISA protocol and the obtained scores according to the PIAV protocol. At the same time, the degree of transfer into the school environment was analyzed.

5. Results

The results are presented according to the used instruments and are divided into the following sections: 1) TEVISA protocol support tasks; 2) the monthly interviews with the teachers during the process of implementing the TEVISA protocol tasks; 3) Instructional protocol of the avatars (PIAV).

5.1. TEVISA protocol

This section presents the obtained results of the students' behavior in the 16 tasks of the TEVISA protocol during the 80 implemented sessions. In order to determine the students evolution throughout the process, in Figs. 4 and 5 it is possible to observe the percentages of the score categories obtained by all the students in primary school, in both the first and last session of the 16 TEVISA protocol tasks. Figs. 6 and 7 show the percentages of the score categories obtained for all the secondary school students in the first and the last session respectively of the 16 TEVISA protocol tasks.

5.2. Results related to the interviews during the implementation process of the TEVISA protocol tasks

This section presents the results of the students' progress in the real classroom environment. In the monthly interviews that the researchers held with the teachers, the student's behavior while performing tasks in the real classroom was analyzed (these tasks are similar to those performed in the IVE). As described in Section 4.2.2, the teacher of each student established a monthly score for each student.

With the information given by the teachers (from the first month until the end of the process), the researchers have calculated the averages of all the primary and secondary students behavior in the real classroom environment. This information is shown in Fig. 8

5.3. Result related to the Instructional protocol of avatars (PIAV)

Finally, in this section, the results obtained through the PIAV protocol are presented. This protocol employs the proposed sensory system to detect incorrect behaviors performed by the children in the IVE. The following results (Fig. 9) show the score average obtained throughout the process of implementing the TEVISA tasks (the average score obtained by the 20 children are monthly represented, see Section 4.2.3). Fig. 10 is a similar graph that only represents the evolution of the fourth dimension of the PIAV protocol, i.e., the changes produced from the influence of the avatars.

6. Discussion

In this Section a discussion is described in order to interpret the results presented below. As in the previous section, the discussion is presented according to the used instruments.

6.1. TEVISA protocol

Although TEVISA is a tool for systematic observation and structured observational analysis, bearing in mind the limitations of the sample that is not large enough (20 students), a study is performed to check if the different categories that make up the TEVISA protocol tasks show empirical coherence beyond the logical coherence, rationally established around the blocks related to executive functions and social skills,

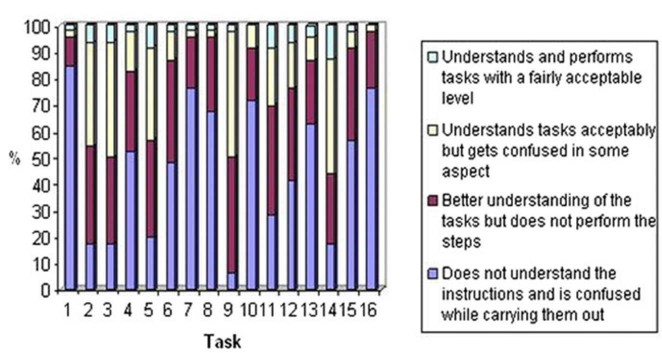

Fig. 4. Percentages of score categories for the 16 TEVISA tasks. Initial assessment for primary students.

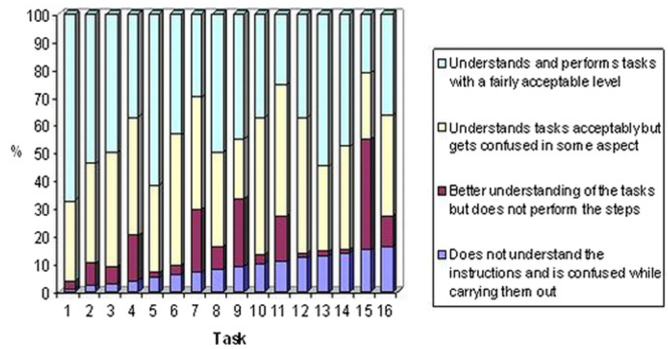

Fig. 5. Percentages of score categories for the 16 TEVISA tasks. Final assessment for primary students.

both in primary and secondary school students. We analyzed the internal consistency for each one of the type of tasks of the TEVISA protocol and the IVE where they were carried out by using the Cronbach's alpha coefficient. The different indices of the internal consistency are shown in Table 5. The reliability indices are from 0.68 to 0.91. These values show certain consistency in the observed behavior. This behavior, observed during the performance of various tasks, depending on the categories of assessment in each block of the TEVISA protocol, show quite high reliability coefficients, both in the IVE classroom and in the school playground, indicating that a similar constructor is being assessed. Additionally, the results indicate that there is no significant difference between the students of primary and secondary schools which shows that the designed tasks are highly structured.

In Fig. 4, corresponding to the first session of the 16 TEVISA protocol tasks, we can see high percentages above 75% in score category 1. This aspect indicates a lack of understanding of the instructions to be performed and as a consequence, difficulties in both executive functions and social skills, in the structured and non-structured environments. This fact is clearly shown in the tasks of block I: task 1 (84. 8%) and task 7 (76. 1%). In block II, task 10 (71. 7%) and task 16 (76. 1%) are remarkable. The results in all tasks carried out by the students have a tendency to fall within the score categories 1 and 2, in a lower number in the latter. The empirically observed results are indicative of the difficulties observed in the performance of the TEVISA tasks in the virtual environment, both in block 1 and block 2. These difficulties increase when the task requires an individual decision in a non-structured environment as the school playground or the bedroom.

Fig. 5 shows the primary school students' results from the last sessions of the 16 TEVISA tasks and we observe a positive progress, although the average rates are between 41.1% and 54.8% in score category 4. In block 1, the higher percentage level in task 1 (67.9%) for category 4 stands out, stating a very positive progress in comparison to the first session. Block 2 shows the same type of results. The results obtained in the last session on the implementation of the TEVISA protocol show a reduction of the typical difficulties of these students, scoring higher percentages in the categories 3 and 4 in block 1 than in block 2. Although we have to highlight the percentage of 41.8% in score category 2 of task 15, that, together with the data mentioned in block 2 indicates, that even though the social skills difficulties in non-structured environments have evolved positively in all tasks, they remain an issue to keep in mind.

As shown in Fig. 6, the results of the first implementation of TEVISA on secondary school students, in comparison with primary school students, indicate lower percentages in score category 1, referring to the lack of understanding of the instructions and the ensuing difficulties. The results indicate a tendency to obtain average percentages in score categories 1 and 2 in most of the tasks in block 1 and 2. The results reveal a clear indication to, that although the secondary school students do not express great difficulty while carrying out the support tasks; they demonstrate a better understanding of them. They still show an average percentage of confusion when performing them but not as extreme as the primary school students. From the obtained results it is worth mentioning the highest percentages in score category 1 in block 1 in the tasks carried out in non-structured environments such as is the school playground and in particular the social relationships established within it. The results from the last TEVISA sessions are represented in Fig. 7 and show that the score categories 3 and 4 have clearly increased, meaning that the tasks have been performed in an acceptable manner but with some remaining confusion. From the results from the last sessions we would like to highlight the percentage of 41.1% in task 12. This means that the Asperger students interpret the tasks literally and have problems following the task step by step.

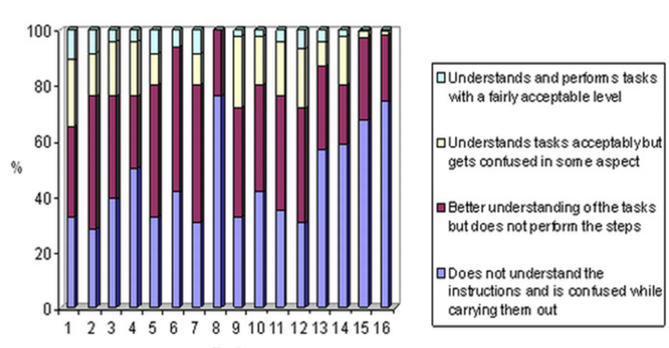

Fig. 6. Percentages of score categories for the 16 TEVISA tasks. Initial assessment for secondary students.

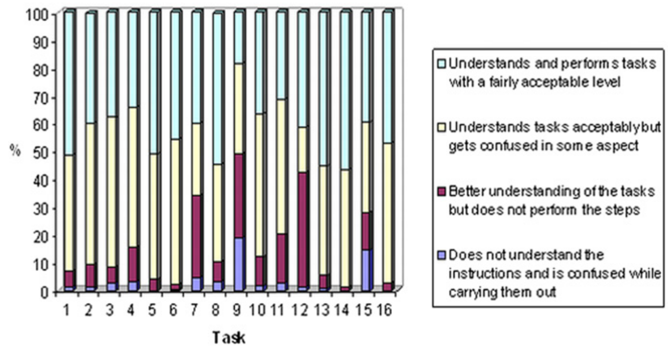

Fig. 7. Percentages of score categories for the 16 TEVISA tasks. Final assessment for secondary students.

6.2. Interviews during the implementation process of the TEVISA protocol tasks

In Fig. 8, the empirical results reveal an increase of the average scores from the beginning to the end of the implementation process of TEVISA tasks (during 10 months). When transferring the IVE knowledge into the classroom, the primary school students obtain an average score of 2.23, while the secondary school students obtain a value of 2.5 (these average values are obtained during the first month). The average score obtained by the secondary school students throughout the process are closer to the average of 3, even 4, than those of the primary school students, although the latter have a more regular evolution. These results indicate that most of the primary and secondary school students have improved the understanding of tasks and instructions. Despite the continuous improvement, both groups showed a regression: the primary school students lowered their score average to 2.5 in the 6th month and the secondary school students to 2.2 in the 5th month. Although both groups presented an important regression they ended the process with average scores close to 4. This means that the execution of the tasks in a real school environment has been done in an acceptable manner, referring both to comprehension and following instructions (the skills trained in the IVE are correctly transferred to the real world).

As shown in Fig. 8, the secondary students have improved their scores with 1.1 units and the primary students with 1,6. As indicated in Section 4.3, we carried out interviews during the three academic years 2006–2009, with the goal to learn more about the Asperger student's evolution in the school environment, carrying out the mentioned TEVISA protocol tasks. These students had special education support (the IVE is not applied) and showed an improvement from 0.2 to 0.6 units in the case of secondary students and from 0.1 to 0.6 in the case of primary students. This shows that after the application of the TEVISA protocol in the IVE a correct transfer has occurred and the students have shown a better progress than in previous years when the virtual environment was not used.

6.3. Instructional protocol of avatars (PIAV)

The obtained results, both from primary and secondary students, indicate a slow but significant improvement in the behavior of the students in the different blocks of the PIAV. At the beginning of the process, the students obtained scores between 20 and 30, this meaning a high presence of inadequate behavior highlighting at the same time, the high scores obtained in "attention control", "voice control" and "motor coordination control". Similarly, at the beginning, in the fourth PIAV dimension, the number of changes in the students' behavior produced by the avatars is not relevant. Fig. 9 shows a decrease in the number of incorrect behaviors while carrying out the tasks for the third time. In the fifth month, they obtain an average score between 5 and 10, showing a decrease in the 3 dimensions of the 5 blocks. In the fourth PIAV dimension (Fig. 10), it is important to highlight an increase of the obtained scores at the end of the study. This aspect indicates the increase of motivation and attention of the participating students. An improvement of the dysfunction of these students (both primary and secondary school students) is observed during the duration of the study.

There are some limitations and problems that appeared during the research. These problems are not reflected in the previous results; however, they must be taken into consideration. Initially, some students did not want to wear the 3D glasses and the cap, requiring a period of familiarization in the first sessions even in the family context. Furthermore some students expressed dizziness during the first sessions. This aspect made it necessary to increase the required number of sessions in order to adapt the children to the IVE. Another important aspect is that the participant teachers must receive a prior and ongoing training. This training is fundamental in order to involve them in the

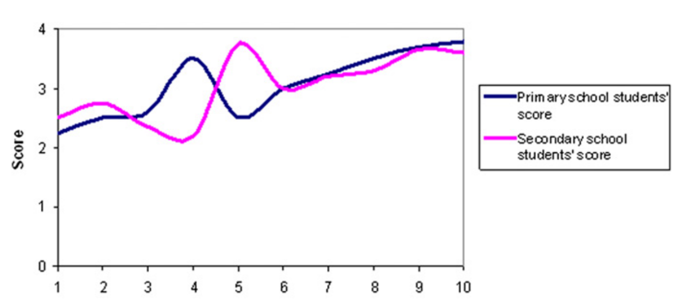

Fig. 8. Averages of the monthly scores provided by the teachers during the development of the TEVISA protocol.

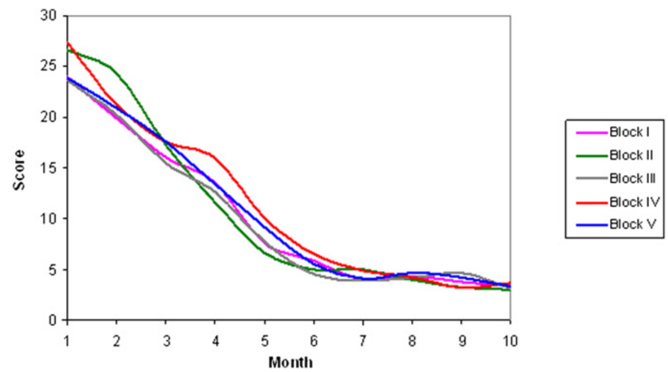

Fig. 9. Score averages obtained in the 5 PIAV blocks (without considering the fourth dimension).

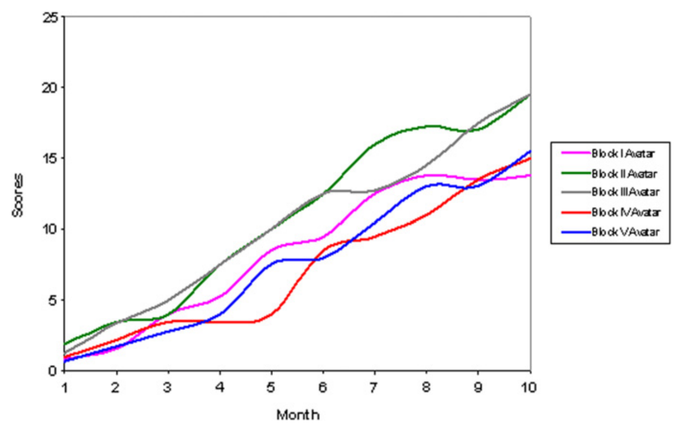

Fig. 10. Score averages obtained in the 5 PIAV blocks (only considering the fourth dimension).

Table 5
Indices of internal consistency for each TEVISA task type and its corresponding IVE.

Students	Block	IVE	Cronbach's alpha
Primary	Executive functions	Classroom	0.71
Primary	Executive functions	Bedroom	0.83
Primary	Social competences	Classroom	0.69
Primary	Social competences	Playground	0.68
Secondary	Executive functions	Classroom	0.91
Secondary	Executive functions	Bedroom	0.85
Secondary	Social competences	Classroom	0.80
Secondary	Social competences	Playground	0.72

process and to provide information about the transfer of the skills from the IVE to reality. Finally, the students must have a geographic proximity to implement the tasks in the virtual reality room of the University of Alicante. This last aspect limits the number of students which can participate in the study.

7. Conclusions

The results of this study have given us the answer to the question formulated in the beginning of the research; what are the benefits of using IVE to support acquisition and improvement in the executive functions and social skills of children with Asperger and how can they be transferred into the real school environment?

According to the specific objectives of the research and the empirically observed results, obtained with instruments designed for the execution of the research, we can state that the students with Asperger syndrome, through visual strategies such as the IVE, and by planning highly structured and repetitive support tasks, can improve the acquisition of executive functions and social skills.

Both primary and secondary school students presented significant difficulties at the beginning of the implementation of the TEVISA and PIAV protocols (lack of understanding of the steps required to carry out these tasks). Several difficulties have disappeared throughout the process of working within the IVE and at the end of the research, the majority of students carried out the tasks with acceptable results, including in the block of social skills where the greater difficulties were found. This happened especially when the tasks were performed in a less structured environment like the playground.

Another conclusion of this study is the positive response to the question asked at the beginning of the research; the possibility of transferring this knowledge into a real school environment. Both groups have shown a quite acceptable application of the instructions practiced in the IVE, transferred into the classroom. This was observed and analyzed by the tutors in both schools.

The involvement of participating teachers, which have been demonstrated throughout the process, as well as the students' motivation to continue using the skills learnt in the IVE in the classroom, are both fundamental aspects in the achievement of such transfer into the school environment. Additionally, the great motivation of students to continue the learning in the IVE is another fundamental aspect in the achievement of such transfer.

Similarly, The PIAV protocol has allowed us not only to record the students' behaviors but also to analyze the evolution of the incorrect behaviors. The students have shown motivation and complicity with the avatars. Furthermore, the use of IVEs allows us to employ visual learning in accordance with the cognitive style of these students. The educational needs of the students to have fully structured and explicit learning environments make the IVR an appropriate support strategy as it is eminently visual and allows repetition and training of these skills. The results indicate the feasibility of such learning that allows the student to interact with full autonomy and motivation.

Currently we continue working with teachers of the school center, monitoring the applicability of transferring the knowledge from the IVE into the classroom environment of each of the participants. To conclude this research, with this work we have not only opted for the inclusion of IVR as support in the educational intervention of the students with Asperger syndrome, but we have also helped to improve social skills and executive functions in the school tasks of the students with Asperger syndrome.

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