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LONG PAPER

Toward emotional interactive videogames for children with autism spectrum disorder

Sandra Baldassarri[1] · Liliana Passerino[2] · Silvia Ramis[3] · Inma Riquelme[4] · Francisco J. Perales[3]

Abstract
Technology and videogames have been proven as motivating tools for working attention and complex communication skills, especially in children with autism spectrum disorder (ASD). In this work, we present two experiences that used interactive games for promoting communication and attention. The first game considers emotions in order to measure children's attention, concentration and satisfaction, while the second uses tangible tabletops for fostering cognitive planning. The analysis of the results obtained allows to propose a new study integrating both, in which the tangible interactive game is complemented with the emotional trainer in a way that allows identifying and classifying children's emotion with ASD when they collaborate to solve cognitively significant and contextualized challenges. The first application proposed is an emotional trainer application in which the child can work out the seven basic emotions (happiness, sadness, fear, disgust, anger, surprise and neutral). Further, a serious videogame is proposed: a 3D maze where the emotions can be captured. The second case study was carried out in a Special Education Center, where a set of activities for working cognitive planning was proposed. In this case, a tangible interactive tabletop was used to analyze, in students with ASD, how the communication processes with these interfaces affect to the attention, memory, successive and simultaneous processing that compose cognitive planning from the PASS model. The results of the first study, suggest that the autistic children did not act with previous planning, but they used their perception to adjust their actions a posteriori (that explains the higher number of collisions). On the second case study, the successive processing was not explored. The inclusion of the mazes of case study 1 to a semantic rich scenario could allow us to measure the prior planning and the emotions involved in the maze game. The new physiological sensors will also help to validate the emotions felt by the children. The first study has as objective the capability to imitate emotions and resolve a maze without semantic context. The second study organized all the actions from a semantic context close to users. The attention results presented by the second study are coherent with the first study and complement it showing that attention can be receptive or selective. In the first study case, the receptive attention was the focus of analysis. In the second case, both contributed to explain and understand how it can be developed from a videogame.

Keywords Videogames · Emotions · Tangible interaction · Serious games (SG) · Autism spectrum disorder (ASD) · Education and therapy · Interactive tools · Technologies platforms · Computer graphics

1 Introduction

Autism spectrum disorder (ASD) is described as a serious neurodevelopmental disorder, which involves delay in the development of many basic skills including the ability to socialize and communicate, as well as the ability to speak. Children with ASD are characterized by having several limitations in communication and social interaction [1]. Their social and communication skills, including imitation, empathy and shared attention, present differentiated developments and in some cases, evident limitations [2]. Children with autism have difficulty in understanding people as intentional agents. This understanding goes through the development of what is known as Joint Attention, a complex of skills and social interactions necessary for learning and human development [3]. Attention and communication are closely connected from early childhood. In the case of children with ASD, they present serious problems of joint attention and perspectivation [4]. Various researches show the potential offered by technology for such situations that require

✉ Francisco J. Perales
paco.perales@uib.es

Extended author information available on the last page of the article

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attention and complex communication needs, with expressive results in subjects with ASD [5–8]. Children's brains are still under development and the chances of improving their social and communication skills are greater compared to adults, because they are not fully exposed to the harshness of society.

In particular, games and videogames have been revealed as a natural environment to stimulate different cognitive processes, since they link abstract thinking with concrete experience. The children rehearse and put into practice, without fear of being wrong, the skills and tasks that they will perform in other more formal contexts. In the game, the child creates an imaginary situation that involves both affective and cognitive aspects. The action in an imaginary field leads the child to learn to act, not only by his/her direct perception of the object or situation, but rather based on the meaning of that situation [9]. The game/videogame creates a zone of proximal development, with action in an imaginary field, in which intention, motivation, attention, planning, among other cognitive processes, that takes the child to a higher level in development [9]. A special type of computer games or videogames are widely used with this educational/rehabilitation purpose. The so-called serious games [10] promote the improvement of cognitive and motor skills transparently to the user. In particular for ASD, recent studies show greater improvements in planning/organizing skills that use these types of games [11]. In [12], a review of 40 serious games designed for children with ASD classified the games into four categories; technology platform, computer graphics, gaming aspect and user interaction. Interesting conclusions are presented in [12], although the majority of Serious Games (SG) focus on visual aspects. Due to the nature of multi-sensory stimuli and multimodality of digital technologies, it is possible to combine vision, auditory, and vestibular in serious games for ASD or in general for sensory processing disorders (SPD).

In the past years, sundry serious games have been proposed for children with ASD. An interactive serious game in order to improve communication fluency was developed in [13]. While in [14], the authors present a set of serious games guided to the education of first aid to ASD people, using Android smartphones. An intercultural study has been carried out involving children with ASD from United Kingdom, Israel and Sweden, directed to teach them emotion recognition in a funny and enjoyable way [15]. In [16], the authors present an interactive serious game to enhance intelligibility in autistic children communication. Nonetheless, more recent works, as [17], focus on developing a better understanding of cognitive processes in children and teenagers with ASD for categorizing their emotions.

On the other hand, several studies show the meaningful benefits of working, not only with videogames or tactile interaction, but also with adding the possibility of manipulating objects by using tangible interactive tabletops, particularly for very young children [18], for children with motor limitations, and specially, for the education of disabled people [19]. The users' location around the table intensifies the interaction and visual contact between students and educators. Furthermore, animations and digital sound are key for motivation and attention. Among the features of the tangible interfaces, there are three reasons that made them ideal to be a great part of therapeutic and learning applications [20, 21]: they promote collaboration through a shared media, they allow free movements, and they make flexible the design of a system's physical interface. In the special education area, multimodal interaction has a higher value, since it allows to incorporate different ways of communication between the users and the computer, improving in that way the applications' accessibility [22]. Several research studies with this kind of tools are focused in children with ASD [8], especially in regard to aspects of collaboration and social skills [6, 23]. Quite a few authors show developments in multitouch tabletops [24, 25] guided to children with high-functioning autism (HFA). Moreover, [8] shows a comparative study between several works in tabletops with or without tangible interaction, mainly guided to improve collaborative learning, social abilities and to develop expressive language in children with ASD. Although tabletops and videogames have been widely used for improving learning in children with ASD, there are no works that focus in how the communication processes with these interfaces affect the attention, memory, successive and simultaneous processing that compose cognitive planning.

In particular, our research analyzes, through two different cases studies presented in Sect. 2, how it is possible to improve interaction and joint attention among people with ASD through the use of videogames and technology as an important factor in motivation and engagement. After the presentation of the results of both experiences, Sect. 3 proposes an integration proposal that exploits the potential of both works. Finally, the conclusions obtained and the lines of future work are presented.

2 Case studies

This section provides a complete description of two case studies in which videogames are used as motivation tool to improve communication and attention, especially focused to children with ASD. These skills are essential for ASD children, since communication, social interaction and behavioral flexibility have been defined as central in the diagnoses of autism (autistic disorder, Asperger's disorder and pervasive development), and became known as triad of impairment [26].

The first experience is centered in measurement of children's attention, concentration and satisfaction by using of serious videogames that detect their emotions. The second experience is aimed to promote cognitive planning, analyzing how communication plays a central role in attention processes and by using interactive tangible technologies. In both experiences the methodology followed, session development and, finally, the obtained results are detailed.

2.1 Case study 1: emotion trainer and 3D serious game

The main goal of this experience is to determine attention, concentration and satisfaction grade in students with ASD while using serious games. For that purpose, two applications for PCs have been developed. The first is an "Emotional Trainer" for students to work with seven basic emotions and the second is a serious game that provokes reactions and captures the players' facial expressions during the game ("Emotion Detector"). In order to be aware of the different children's needs, 10 levels of difficulty were developed for the first game and 20 for the second.

2.1.1 Methodology

The first application proposed is an emotional trainer application in which the child can work out the seven basic emotions (happiness, sadness, fear, disgust, anger, surprise and neutral). Further, a serious videogame is proposed: a 3D maze where the emotions can be captured [27].

The first phase of the experiment is an emotional trainer, to evaluate the different emotions of children with ASD. It is an interactive application to determine which emotion is the child able to express. The proposal is to imitate the seven emotions that will be shown individually on the computer's screen randomly with and without mirroring.

The second phase is a 3D maze video game that provokes reactions from players depending on the stimulus that they face on it. It is made by 20 levels with unique exit and several dead end points. Until level 7, positive stimuli such as coins show up that increase the available time by 5 s and give players one extra point. From level 14, there negative stimuli such as bombs show up that bring the player back to the initial level starting point. In order to capture emotions inside the maze, some critical points have been designed that can generate a feeling on users. This version of 20 levels was at the time of writing being evaluated at an autism center. The results presented in this paper correspond to a previous version of only 10 levels.

The emotional expressions registered and other parameters of game attention like execution time, road length, collision number, etc., are analyzed to assess the attention kept while they were playing. These parameters were used in papers such as [28], which also performed experiments in a maze game.

2.1.2 Participants

Both the first as well as the second applications are done with a control group and with an ASD group. The control participants were 4 students between 5 and 10 years old (3 girls and 1 boy). The ASD participants were 5 students between 14 and 18 years old (1 girl and 4 boys). Both before therapy and at the end of it, a series of instruments were applied in order to determine the knowledge level and emotional regulation of each student. The ASD group presented a minimum level of speech (short phrases sometimes echolalia) and cognitive levels between normal and moderated mental deficiency.

2.1.3 Instruments

In order to test the knowledge changes and emotional regulation, the following questionnaires were used:

- Emotion Matching Task [29]: Tool based on children facial expression identification is composed by 4 parts that check different emotional knowledge aspects: emotional expression identification, verbal emotion identification and emotional situation knowledge. This gadget uses children's photographs with quotidian facial expressions (fear, happiness, sadness and anger). The test was completed by the children with their teachers' help;
- Emotion Regulation Checklist (ERC) [30]. It checks the emotional and affective regulation as well as the emotional expression sufficiency. This questionnaire was filled in by children's parents;
- Child Behavior Checklist (CBCL) [31]. Considered as a multiphasic personality inventory for children, it allows to set up a taxonomic system that classifies behavioral problems in two primary categories: intra-directed and extra-directed. The questionnaire was filled in by children's parents.

2.1.4 Sessions

Each session consisted of two phases. In the first phase, the emotional trainer takes place. The emotional trainer starts with a first round where the child has to imitate the photograph that is shown on the screen. At the same time, the student can see her/himself on the screen as if it was a mirror (see Fig. 1). Then, in a second round, the child continues to imitate the expression but she/he cannot see themselves on the screen (see Fig. 1). In order to finish a task and go through the next emotion, the participant has to press the camera button or the spacebar to take a

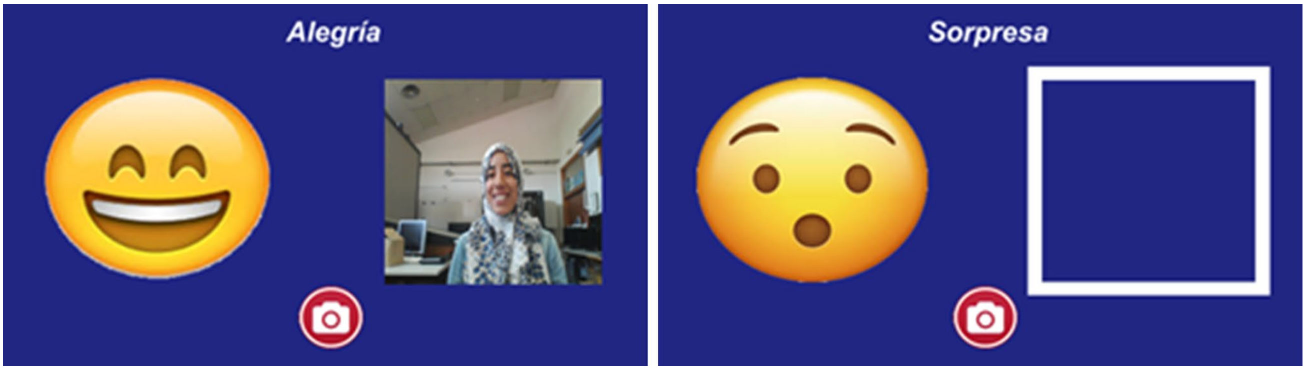


Fig. 1 Trainer with mirror (happiness) and Trainer without mirror (Surprise)

Fig. 2 User playing with the Maze videogame

Table 1 Emotional trainer results with children in the control group

	Trainer with mirror (%)	Trainer without mirror (%)	Coherence (%)
Happiness	91.6	100.0	90.0
Sadness	91.6	87.5	80.0
Fear	90.0	80.0	75.0
Disgust	90.0	90.0	80.0
Anger	91.6	100.0	80.0
Surprise	91.6	100.0	95.0
Neutral	75.0	100.0	85.0

photograph. When the photographs are taken, the game finishes and presents the results.

The results consist of a set of expressions from the computation of performing the same expression four times in a random way each round. Therefore, 56 photographs of each participant per session are available. These results will allow us to start to discuss the coherency between the different expression that the child has realized both in the first round and in the second, as well as between the first and the last session.

With regards to the 3D maze, the video game created is a 20 levels maze that inducts reactions to the users depending on the different stimulus they face on it (coins as positive and bomb as negatives). Indeed, in order to capture emotions inside the maze, critical points have been designed that can generate emotions to the users (see Fig. 2). The following critical points have been considered to generate positive, negative and neutral emotions:

- Negative critical point: All the roads of the maze that lead to a dead end. Other negative points are if the time blows up before they reach the exit or if they collect the bombs which appear in the maze. These bombs bring you to start point. All these points generate negative emotions, such as anger;
- Positive critical point. All the roads of the maze that contain coins. If the participant collects them, he/she obtains 5 extra seconds of play time. Another positive point is won if the participant reaches the exit of the maze. All of this generates positive emotions, such as surprise or happiness;
- Neutral critical point. All the roads that conduct to ways without any stimulus. In this case, it generates neutral and concentrated faces in the participants.

Eventually, attention and concentration are tested from the results provoked by the stimulus and game parameters as collision number, time wasted per level and road length done (Table 1).

2.1.5 Results

Table 2 shows the results with the emotional trainer. It can be seen that children with ASD are better at imitating the expressions when they can see themselves. They are, in general, quite coherent on their expressions. We measure the coherence between images with and without mirror that reproduces the same expression. From this outcome, it can

Table 2 Emotional trainer results with ASD children

	Trainer with mirror (%)	Trainer without mirror (%)	Coherence (%)
Happiness	100.0	90.0	96.0
Sadness	61.5	50.0	76.0
Fear	100.0	92.3	96.0
Disgust	73.3	40.0	76.0
Anger	93.3	70.0	76.0
Surprise	100.0	100.0	100.0
Neutral	46.6	40.0	84.0

be deduced that the expressions that can be reproducer easier by this group of ASD children are happiness, fear and surprise. However, most of the children did not understand the neutral expression and they felt it was harder to reproduce the sadness face. However, the control group achieved better results in all the emotions, especially when they could not see themselves (Table 1).

In relation to game attention, all the participants showed a high concentration level while they were playing. The ASD children showed some great skills in video games, overcoming in speed the control group kids, finishing at approximately half the time (see Tables 3 and 4). Alternatively, they did not take into account the collisions. In general, the control group tried to precise the ball position to avoid collisions, a fact that increased the time they needed to finish the game. In relation to trajectory, both groups followed similar ways, except at levels 3, 6, 8 and 9, where the travel difference was higher for ASD children as they did not plan their travel before starting the maze. They just adjusted the route while they were playing.

As an outcome of the study, we can uphold that the high interest and motivation of the users to take part into the game has been verified, fulfilling with satisfaction the required tasks. Most of the users with ASD reproduce correctly happiness, fear, anger and surprise, while the most

Table 3 3D Maze results with children in the control group

	Time (s)	Way (blocks)	Collisions
Level 1	9.5	8	0.75
Level 2	19.25	14.5	1.5
Level 3	23.75	20.5	2
Level 4	19.5	23	1
Level 5	22.75	24.75	1.5
Level 6	59.25	56.5	3.5
Level 7	53.5	48.5	3
Level 8	33.75	32	2
Level 9	66.75	47.5	3.75
Level 10	27.6	28.6	2.3

Table 4 3D Maze results with ASD children

	Time (s)	Way (blocks)	Collisions
Level 1	6.4	8.4	1.6
Level 2	8.6	13.6	3
Level 3	13.8	28.4	3.4
Level 4	8.8	22	1.8
Level 5	9	24.2	2.2
Level 6	21.6	49.4	5.4
Level 7	20.4	47.6	3.2
Level 8	19	46.2	4.2
Level 9	38	62.4	6.4
Level 10	10.75	31.75	1.5

difficult emotions to reproduce were identified as disgust, sadness and neutral. The fact of using or not a mirror influences the expression execution, with using no mirror being less successful. With regards to the 3D maze, the positive expressions show up in all levels with control children. Contrarily, in children with ASD this positive expression is shown in every level except 3, 7 and 9 where they showed more concentration. Summarizing, the neutral expressions are visible in all levels, both for the ASD group and the control group. To conclude, negative expressions are only evident in levels 7, 8 and 9 and therefore are the most difficult said the users have indicated.

2.2 Case study 2: tangible interactive tabletop

The second case study was carried out in a special education center, where a set of activities for working cognitive planning was proposed. In this case, a tangible interactive tabletop was used to analyze, for students with ASD, how the communication processes with these interfaces affect the attention, memory, successive and simultaneous processing that compose cognitive planning from the PASS model [32]. In this section, we discuss the results related to attention and communication.

2.2.1 Methodology

This research has a qualitative nature, using case study techniques with intervention. To implement the cognitive planning proposal using a tangible interactive tabletop, a program called "Hugh and the Can" was developed for the tabletop NIKVision [33]. The NIKVision is a tabletop in which the interaction is carried out by the physical manipulation of conventional objects and toys over the table surface, as can be seen in Fig. 3. Tangible interaction roots on visual recognition hardware and algorithms. An infrared USB camera captures video from underneath the table and streams it to the computer workstation. ReacTIVision software [34]

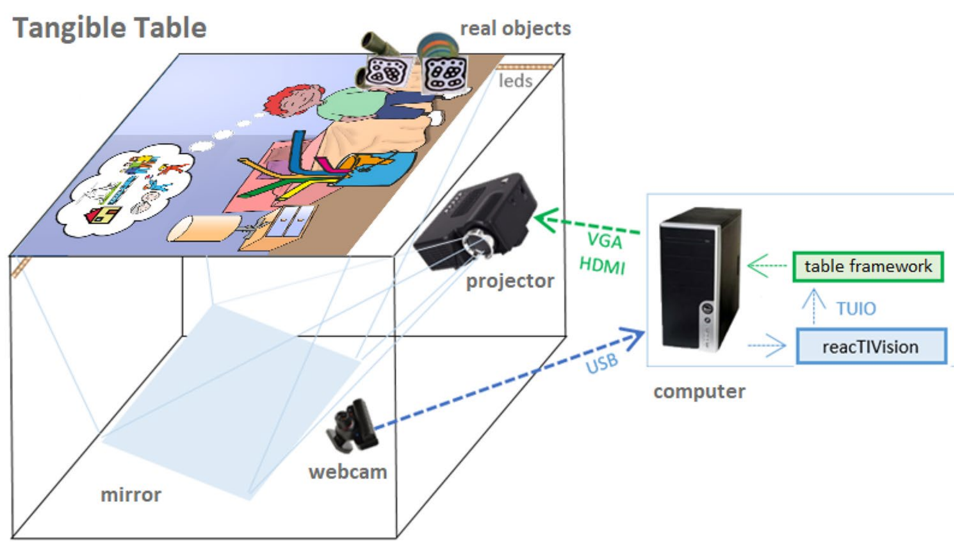


Fig. 3 NikVision Tabletop

is used to detect and analyze the incoming images allowing to track the position and orientation of toys placed on the surface thanks to the printed markers (fiducials) attached on their base. Through retroprojection, the tabletop gives image feedback on the table surface supported with a mirror inside the table (see Fig. 3).

In this work, real objects and small toys are used to interact with the game. The objects fulfill a double function: their manipulation allows generating events and actions in the program "Hugh and the Can" and, at the same time, enables the students to experiment in 3D the representation of these objects through their different senses.

The process of developing the program begins with the generation of a storyboard (see Fig. 4), followed by a typical software engineering process.

The pedagogical proposal begins with a male character (Hugh) of the same age as the participating children, who collects objects from the places he visits. These objects are stored in a can, which is the second character in the story and offers flexibility to implement the cognitive tasks of the PASS model.

The program is structured in three difficulty levels and with a greater number of cognitive tasks in each level executed. The tasks have been developed based on the needs of the participants. The program proposes the students to discover what is contained in the can, what an object is for, what it can represent and what kind of things can be done in the places that Hugh visits.

Each screen (see Fig. 5) is divided into levels with different degrees of difficulty and gives feedback in audio, pictograms and text to address the cognitive diversity of the participating students.

The objects used for interacting with the tabletop attend the variability of representations in the comprehension that the ASD students with abstraction limitation have. Therefore, children can use pictograms, drawings, real objects, and reference objects (parts of real objects or elements that indicate an object) (see Fig. 6).

2.2.2 Participants

The study involved 13 students between 10 to 16 years old, of whom 7 have an ASD diagnosis, while the rest have specific communication needs. The ASD group is formed by 3 girls and 4 boys, aged from 10 to 16 years old. The initial profile of the students was collaboratively built with the pedagogical team of the school by using interviews and two instruments: Communication Matrix and adapted ND-CAS.

In this case study, 4 of the students did not have functional oral communication while 3 of them used an alternative and augmentative communication system.

2.2.3 Instruments

During the development of this study, the following instruments have been used:

- Communication Matrix: is a tool that allows identifying the intentionality level in communication and oral skills. This matrix was collaboratively developed with the speech therapist and from participant observation [35];
- Adapted ND-CAS test [32] is a test for children with intellectual disabilities and communication problems with the inclusion of pictograms. The test is organized in cognitive tasks classified in global and bridge. Global tasks emphasize activities in which there is no need to use reading, while bridge tasks require literacy skills

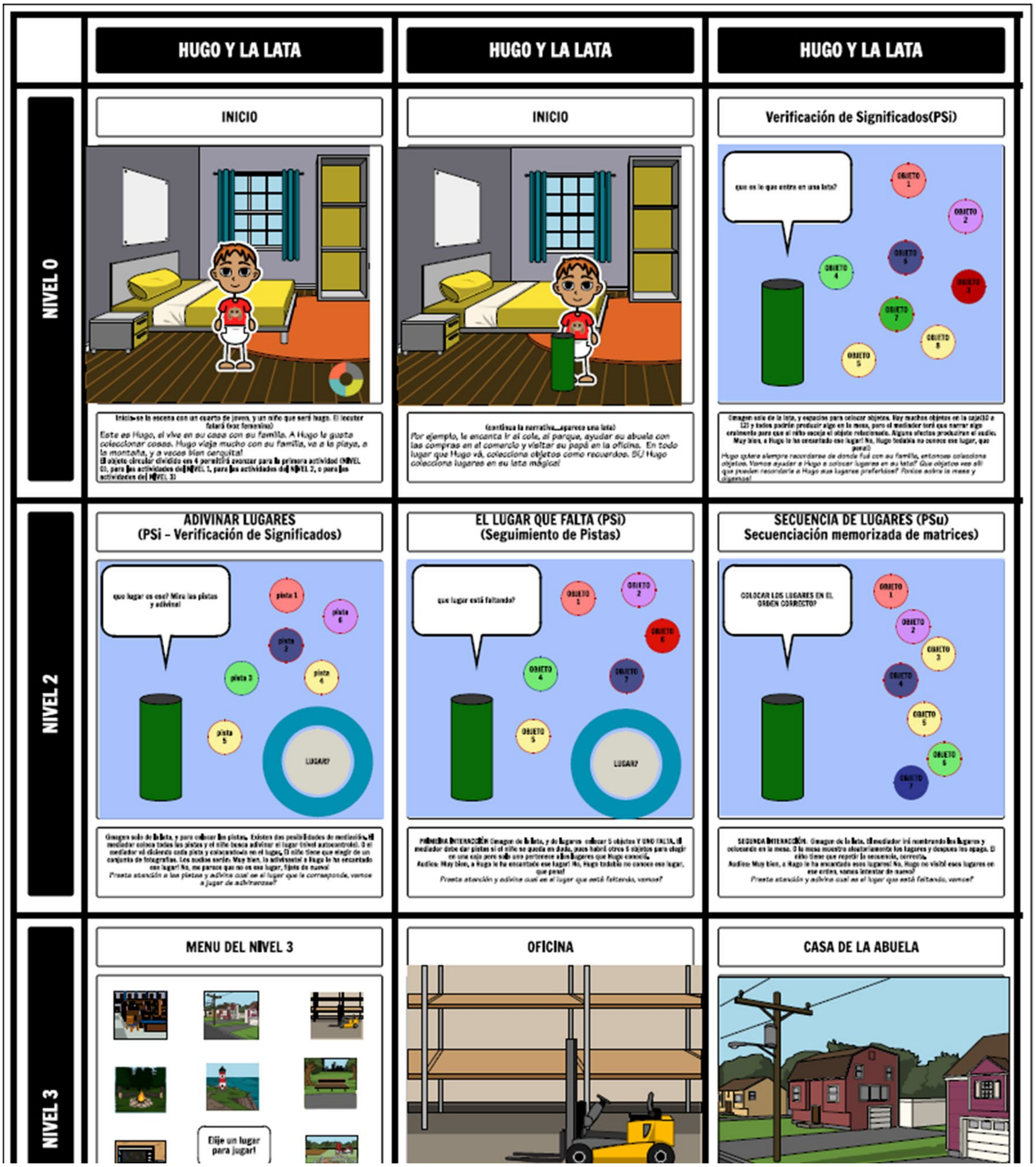


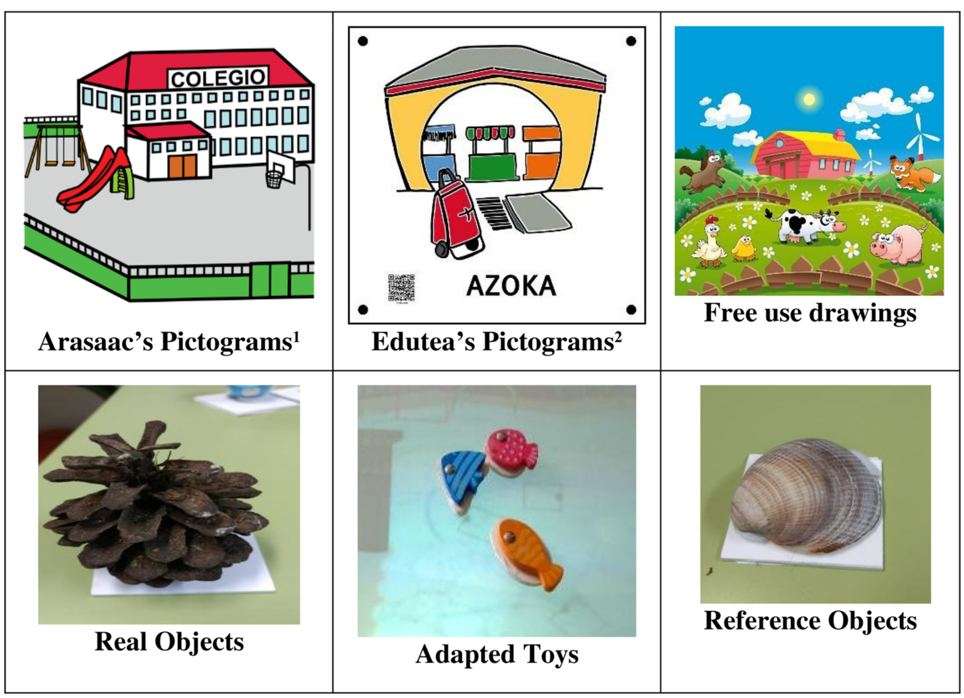
Fig. 4 Fragment of the storyboard of "Hugh and the Can"

(replaced by pictogram tasks, since most students did not have literacy skills). To determine a ground truth for the cases, the tasks were initially developed on paper as a pretest and, subsequently, in the tangible interactive program called "Hugh and the Can" for facilitating processes of mediation and interaction in children with ASD. This test was applied in the classroom with the help of the tutor;

- Participant observation: used as a research technique in all stages of the study. In the first stage, it was used to define the initial profile of the students. In the second stage, it contributed with the elements for the design and development of the application, and finally, in the intervention oriented the registry of the mediation and the attention evidenced in each session. The observation was accompanied by video records for later comparison;
- Observation protocol: a registration model filled in by the tutors and researchers in a collaborative process was defined, in order to document the intervention and evaluate the process of mediation and the expected attention.

Fig. 5 "Hugh and the Can" screenshots

Fig. 6 Objects with fiducials



2.2.4 Sessions

The research was divided into 3 stages. The first stage was aimed to identify the profile of the students, the second was devoted to preparing the cognitive tasks to program the tabletop, and the third was the intervention itself, with the records of the participant observation that allow to make the necessary changes in the application. In this way, the second and third stages provided continuously feedback each other throughout the research:

- The first stage was aimed to identify the communication and interaction profile of the students. The observations were made twice a week during 1 month with sessions recorded on specific forms, photographed and/or filmed;
- The second stage was focused in preparing the cognitive tasks scheduled on the interactive tabletop. The challenge was to design a method that allows to detect evidence for the cognitive planning considering the mediation possibilities of the tabletop. Instead of measuring planning abilities, we sought to identify intention and memory for the action, the comprehension of the communication and of the interaction, based on the mediation proposed in the project. The methodological design consisted of programming a set of 10 cognitive tasks, from which 6 were aimed to improve the successive processing and 4 the simultaneous processing. The tasks were divided in global tasks and bridge tasks. The global tasks focused in activities for which there was no need to read, while the bridge tasks require literacy skills. In this research, the bridge tasks were replaced by tasks with pictograms, since most of the children did not have reading-writing skills. In order to draw a baseline for the cases, the tasks were initially done manually in paper, as a pretest and in the computer program "Hugh and the Can", for the educational intervention with the tangible tabletop, for promoting mediation and interaction process in ASD children. For the development of the program, a deep study of the PASS model [32] was necessary and also the participant observation to identify the profile of the students and the pretest carried out in the first stage. Therefore, the first and the second stages were developed independently;
- Finally, the third stage was the actual intervention with the children using the application on the interactive tabletop (see Fig. 7). Students participate for 4 months, twice a week, in sessions of approximately 30 min, either individually or in groups. In each intervention, all students performed the tasks, which correspond to a level of the game, while a researcher and the speech therapist observed them. Each one of the levels seeks to develop tasks that apply to one or more cognitive processes. After each intervention, we proceeded to register the observation in a specific protocol in addition to register in video the interaction, as reported in the instruments. The final stage of qualitative analysis of the interventions with the support of the audiovisual record allowed to identify the situation in each one of the desired cognitive processes, as discussed in the results subsection.

2.2.5 Results

This study presents results in different areas; however, we will focus here in reporting those results related to the methodology applied and those concerning with the attention and interaction processes.

Table 5 shows a synthesis of the attention processes of each student in the different sessions (S0, S1, S2, etc.). The pretest (S0) and the posttest (S16) have been highlighted in the table and the numbers 0, 1 and 2 that indicate Not-used, Attention Emerging, and Surpassed, respectively. Analyzing the data presented in the table, it is possible to verify that, in most cases, there was an increase in attention capacity. Only two students did not present modifications. Regarding the type of attention, our study showed that selective attention was less developed than sustained attention, given that selective attention requires that students focuses in just one or two stimuli. As expected in the case of children with ASD, in many situations, the excess stimulation caused little support of selective attention. In these situations, the sustained attention in the global activity allowed the student to continue in the activity and recover their guided participation with the help of an adult.

Table 6 shows a synthesis of the interaction processes of each student in the different sessions (S_0, S_1, S_2,…). The pretest (S_0) and the posttest (S_{16}) have been highlighted in the table and the numbers 0, 1 and 2 indicate No-interaction, Interaction Emerging, and Surpassed Interaction, respectively.

Analyzing the data presented at Table 6, it is possible to verify that, in most cases, there was an increase in interaction process similar to that in the attention process. Only two students present few modifications, i.e., M and J. Analyzing both process (see Fig. 8), it can be noticed that J fell behind to begin the interactions but then he/she maintained them after S9, while the opposite happened with M, who had some interactions but few sustained throughout the sessions. In the case of M, the process was affected by changes in medication that made him/her to be drowsier until his/her adaptation. In the case of M, low performance could be related with for lack of an alternative and augmentative communication system (AACS) to mediate the interactions. The usual AACS of M had been broken and we needed to wait for the technician to return the equipment to reinsert it in the classrooms.

Fig. 7 ASD children playing with "Hugh and the Can" program

In spite of the significant improvement of attention, it did not directly impact on the simultaneous processing (improvement in only 57% of the students), because (a) it is not the only cognitive process involved in such processing (memory, for example, is another), (b) communication problems impact on this type of processing and (c) the understanding of the semantic relationships between objects, classification relations, ordering relations and belonging relations, that impact on signification and planning.

While attention and simultaneous processing presented improvements in the group of students with ASD, it is evident that the successive processing did not have the same type of development (only 42% of students had some type of improvement). Successive processing is a type of analytical reasoning in which the stimuli are presented in an orderly and sequential way. This type of processing seems to have a close relationship with memory, which showed the same performance (42%). An explanation for this performance may be related to the choice of activities that focus more on attention than memory. A second explanation might be the lack of semantic understanding for poor vocabulary. Although the information offered by the application prioritized auditory orders and pictograms, some students knew few concepts and showed difficulties of comprehension. Even so, the planning showed a slight improvement that indicates that it is possible to develop the planning in children with delays in language development. Also, it can be noticed in both tables that no students could achieve the goals in S9, since this session was conceived for simultaneous and successive processing; it required a high level of attention and was proportionally more complex than the others.

The second result of the study refers to its methodology. Considering that intentionality is one of the affected areas in autism, we decided to give greater emphasis in programming the application of the tabletop for a known and significant context for the students. For this reason, the application was developed only with the results of the pretest stage and the participant observation. The methodological problem that

Table 5 Results of attention process

Student	Sessions																
	S_0	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S_{16}
E1	0	0	1	–	1	2	1	1	–	–	2	–	1	1	1	1	1
E2	1	2	2	–	0	1	1	1	1	–	1	–	–	1	1	1	1
I	1	2	1	2	2	2	2	1	1	–	1	1	2	2	2	2	2
J	0	1	1	–	0	1	1	1	–	–	1	–	1	1	1	–	2
L1	1	1	1	2	1	2	1	1	1	–	2	–	2	0	2	2	2
L2	1	2	1	1	2	2	2	2	2	–	1	1	2	2	2	2	1
M	1	0	–	–	0	–	0	1	–	–	2	–	1	2	0	1	2

Table 6 Results of interaction process

Student	Sessions																
	S_0	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S_{16}
E1	0	0	0	–	0	0	1	1	–	–	2	–	0	2	1	1	1
E2	0	0	1	–	0	1	1	1	1	–	1	0	–	2	1	1	0
I	0	1	1	2	1	1	2	2	2	–	2	2	2	1	2	2	2
J	0	–	–	–	–	–	–	–	–	–	1	–	1	1	1	1	1
L1	0	1	1	2	1	2	2	2	1	–	1	–	2	2	1	1	2
L2	0	0	1	0	0	1	1	1	1	–	1	–	2	2	2	1	1
M	0	0	–	–	0	0	0	0	2	–	2	–	1	2	1	1	1

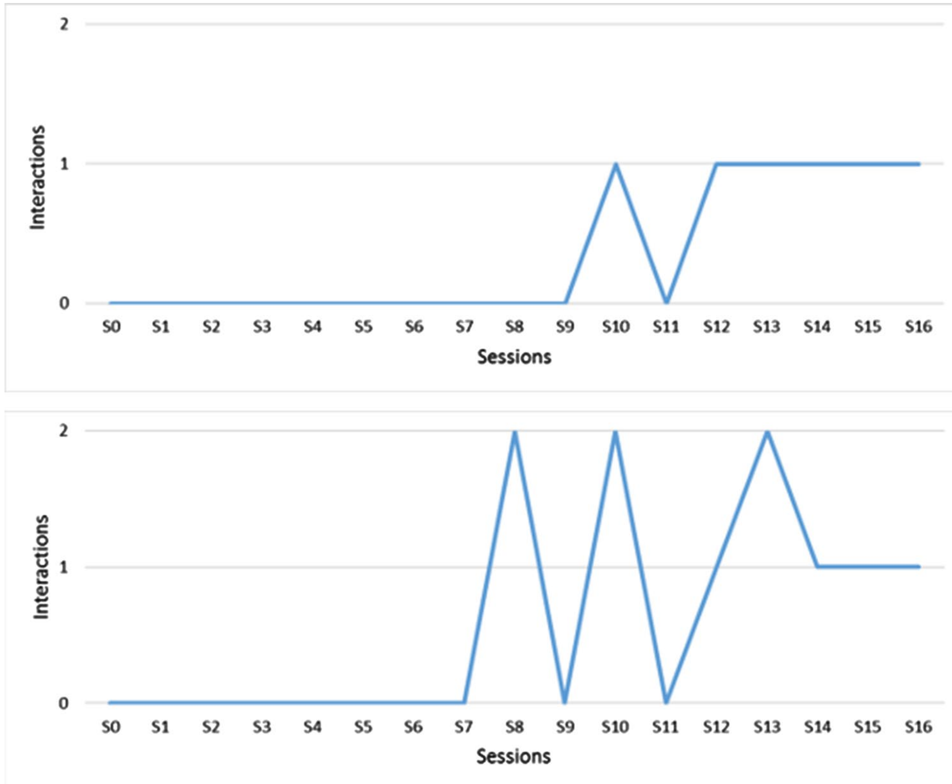


Fig. 8 J Interactions (Up) and M Interactions (down)

arises in this type of research is to map the attention of the student with ASD in solving problems in a family environment (natural), but without forcing them to change their routines. In the PASS model [32] the semantic context of the tasks seems to have low importance, rating decontextualized tasks that measure the attention processes, successive and simultaneous processing and planning. In the adaptation that we made, the significant context was valued from the metaphor "Hugh and the Can", and for being extremely versatile, it was possible to define places and tasks, and also extend them. The planning of the young children is based on the action, and in this way it was thought for the students with ASD: planning for action, where attention was the initial trigger. It was not an individual action, but in groups, since in the investigations conducted by Das et al. (1994) social interaction was important for planning performance [32].

Our initial results point to an increase in participation, interaction and selective and expressive attention as well as a greater number of joint and shared attention scenes between subjects and their mediators. This increase is shown in a situation where both, successive and simultaneous processing, become emergent in most tasks. Despite the indicators, it is still early to draw conclusions, especially because there are limitations of the study that need to be better analyzed, such as the environment, the difficulties of methodological design, the diversity of student levels, and working in a natural environment in which there are few variables that can be controlled empirically.

It is important to remember that in their early childhood, children obtain knowledge from the world, especially from games [36]. The manipulative and interactive activity proposed by the games, the use of specific social rules for each game, are the basis for the cognitive, affective and social development of the child, since the game is located in the Zone of Proximal Development (ZPD). However, the relationship between playing and development is not a direct relation, rather one mediated by the actions and the attention, cognition and affective processes. These facts must be taken into account when learning activities of playful type are planned, since the potentialities of the cognitive development of concepts depends on the child's capacity of communication and language understanding. In that respect, it is necessary to realize that the generalization and internalization that results from the well done mediation process in the ZDP will be only possible from the language perspective (pictographic, textual, gestural, oral, written, etc.) [9]. For this reason, it is important to present activities that create a qualified interaction space for the communication, exploration, participation and the development of imagination with different levels of complexity.

In the graph of Fig. 9, one can observe the interaction process of each participant in a quantitative way. The graphic shows visually the participants who could not perform a task (gray), as well as those with No-interaction (red), Interaction emerging (blue) and Surpassed Interaction (green).

3 New proposal: tangible interactive tabletop with contextualized emotional tools

Notwithstanding the differences between the two case studies, both in methodology and in goals, the purpose of this article is to analyze the possibilities to take advantages of the studies' strengths and overcome their boundaries.

The emotion study shows that it is possible to work with emotional learning with a videogame. However, its fragility is bounded in the fact that the activities are decontextualized, enhancing the imitation (with or without mirror). Alternatively, in "Hugh and the Can", the emotions are always positive since Hugh is always happy encouraging the student's participation.

In order to develop an application that works with emotions from a contextualized videogame but at the same time permits users to identify different emotions from a unique and coherent narrative will offer results that can be used with confidence. The proposal of unifying a semantically contextualized game with the character's emotions that permits to swap the roles and functions between users and characters will force the user to imagine the character's feelings in order to continue playing in the game. This will probably show more secure results regarding emotion learning, in other words, to train not only the comprehension of the objects with their meanings (as in "Hugh and the Can"), but also the character's understanding and their emotions. In this way, it is possible to join the emotional trainer's results to measure emotions with the tangible interactive tabletop and to incorporate in the trainer not only faces, but also many situations than can generate different feelings. Therefore, an emotion recognition database can be created in order to adapt the game based on the child's emotions. Moreover, smartwatches, brain sensing headbands, heart rate and electrodermal activity sensors (EDA), and other physiological activity sensors, can be used in the videogame in order to detect the emotions felt by the children [37, 38]. These emotions can be used for the evaluation of the application, but also for improving the interaction or for changing different contextual parameters of the game [39].

The maze game used in case study 1 is easily adaptable to the interactive tabletop to integrate it in "Hugh and the Can". In this way, not only emotions will be identified, but also measurements of the attention level, memory and successive and simultaneous processes will be done in order to understand the cognitive planning.

The results of the first study, suggest that ASD children did not act according to previous planning, but they used

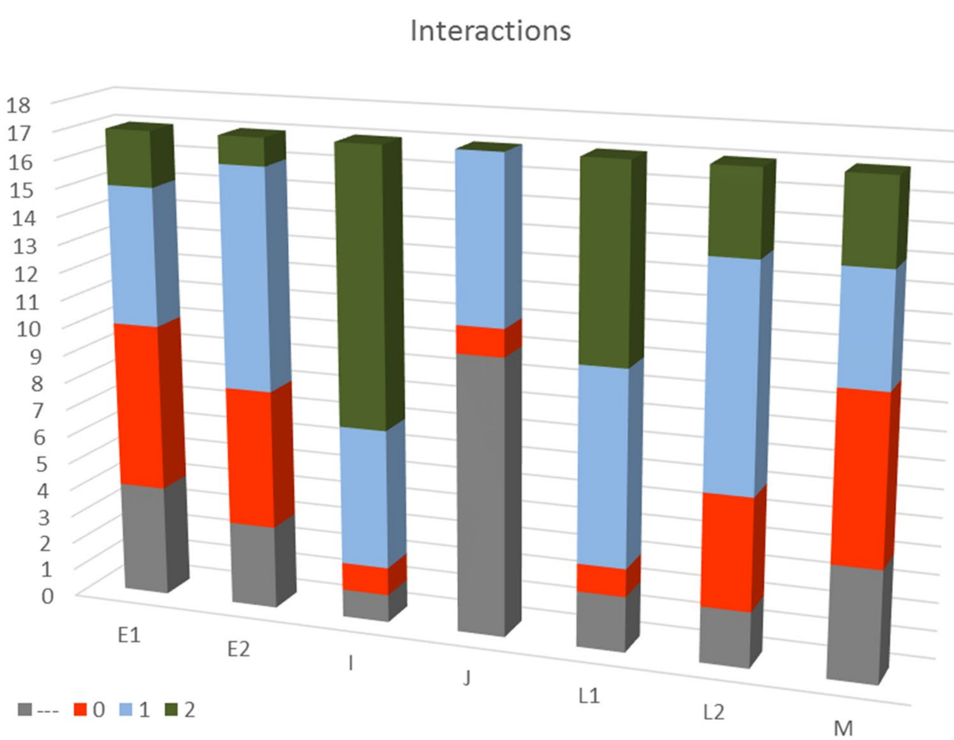


Fig. 9 Quantitative representation of the interactions evidenced

their perception to adjust their actions a posteriori (that explains the higher number of collisions). On the second case study, successive processing was not explored. The inclusion of the mazes of case study 1 to a semantic rich scenario could allow us to measure the prior planning and, also, the emotions involved in the maze game. The new physiological sensors will also help to validate the emotions felt by the children.

- The complete process planned to carry out for developing our new proposal is presented in Fig. 10 and consist of the following stages: Analysis, to select the theme and structure of the application. This stage has already begun. "Hugh and the Can" is the metaphoric theme selected since it proved to be very motivating and easily understandable for the children. The different tasks (including the Maze3D) and levels and also the structure of the application are now in the process of definition;
- Design and development, to generate the prototypes. This stage is aimed to organize the challenges and the different tasks to be included in the application, to determine the hardware and software tools necessary for the final implementation, and to generate the iterative prototypes to test with the students. Also, the specific tasks that the character will carry out, including the emotional feedback in each case, must be determined in this stage;
- Preliminary Tests, to verify the prototype and protocols, either with children with and without ASD. This stage is focused in testing the different prototypes generated, collecting results with automatic tools and through observation, in order to improve the design and to establish the suitable protocols for carrying out a systematic evaluation later;
- Case Study, to carry out the experiment and collect the data. Different experiments are planned to be carried out, with children with different degrees of ASD, and also with other developmental disorders. The experiment will be assessed to verify skills improvements in attention and interaction, but also to evaluate the emotions of the students during the use of the game.

In parallel with this process, better ways to include the emotional aspects are also being studied. As a first approach, four categorical emotions [40] were considered to be expressed by our character, Hugh: happy, sad, angry and neutral (Fig. 11), plus the neutral emotion.

The expression of these emotions will be used to give feedback to the students during the interaction with the game, but also, to detect the reactions and feelings that the game generates on them. For this purpose, children's emotions could be captured through different devices:

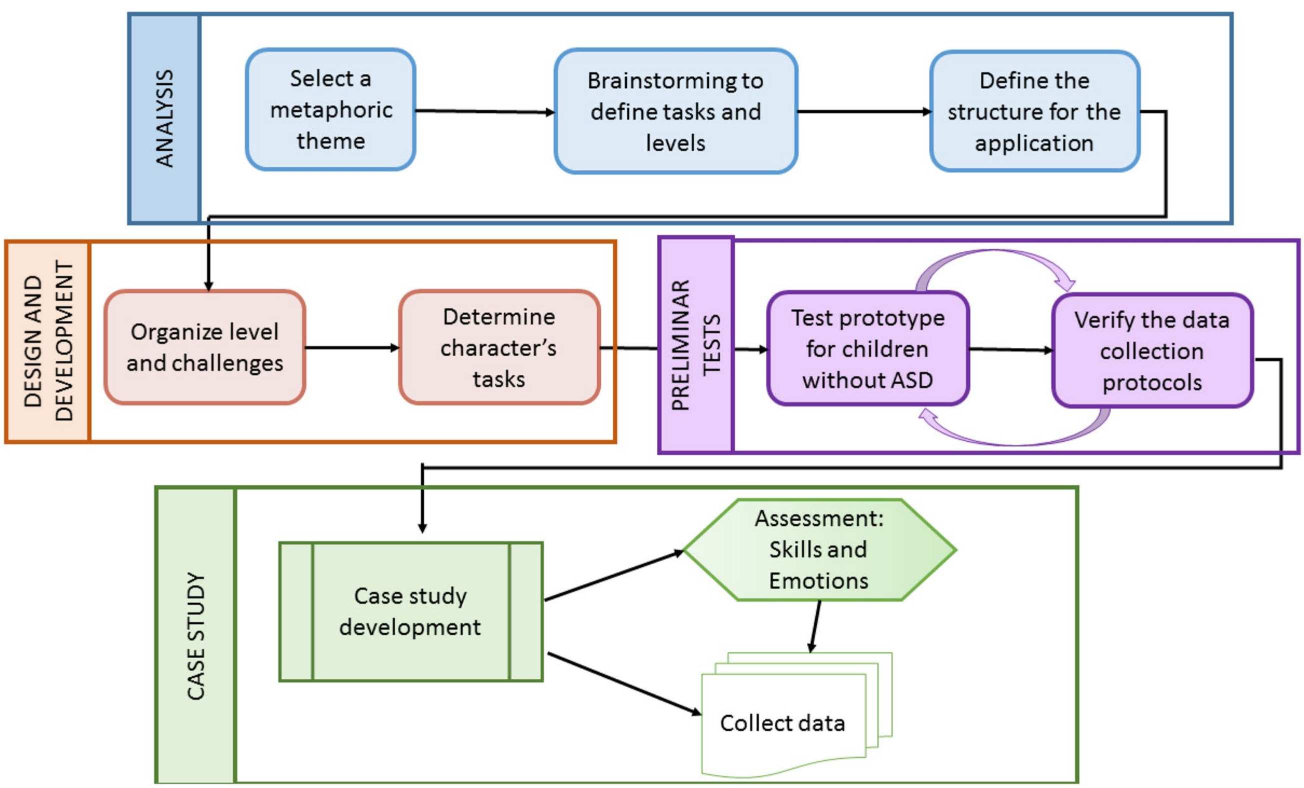


Fig. 10 Development process of the new proposal

- Webcams will be used for recognizing emotions by analyzing facial expressions [27], [41];
- Robust commercial smartwatches will allow to capture information about their heart rate in order to detect discomfort or stress [42];
- Specially developed physiological devices that capture electrodermal activity (EDA) or skin conductance (SK) in order to perceive changes in the level of arousal [43];
- Neurofeedback information about children attention, concentration, distraction or boredom can be detected by Electroencephalogram (EEG) headband devices [44].

All these devices must be carefully studied in order to determine those which are less invasive and that do not obstruct the interaction with the game, with the other players or with the teacher. For example, although there are several commercial EEG headbands devices, most of them are not adequate for very young children. Also, the specific place to put them must be analyzed, i.e., how the camera will capture the required expressions or where the EDA sensor can capture the best signal accuracy [45] with less inconvenience. During that iterative process, the results of each stage must be exhaustively analyzed in order to determine the impact for the students and to detect lacks and improvements, and also to detect the emotions produced in this kind of children during the use of the game [46, 47].

4 Conclusions

The first study presented in this paper has as objective the capability to imitate emotions and resolve a maze without semantic context. The second study organized all the actions from a semantic context close to users. The attention results presented by study two are coherent with the first study and complement it showing up that the attention can be receptive or selective. In the first case study, the receptive attention was its analysis focus. In the second case, both contributed to explain and understand how it can be developed from a videogame.

The first case study focused on each student's performance and his/her emotions, meanwhile the second proposed individual and group intervention without taking into account the emotions. In that respect, the second study reveals that it is possible to work on social interaction from a tangible tabletop, although it has not taken into account the basic emotions of the first studio. Results, not definitive, show that the children with ASD do not regulate their behavior to work cooperatively, but execute individual tasks coordinated by the teacher related to turn swap. Therefore, being able to detect emotions in the cooperative game would help in the mediation. Moreover, being able to detect emotions in the cooperative game, not only for empathy with the character of the game but also with the playmate could help in the technological mediation proposed by the game to guarantee the shift change, interaction and collaborative learning.

The results presented in this paper show that it would be important to develop a new study complementing the "Hugh and the Can" with emotional trainer and the mazes in a way that allows identifying and classifying the emotions of children with ASD when they collaborate to solve cognitively significant and contextualized challenges. We plan to extend the previous cases 1 and 2 to a new proposal that integrates both perspectives in a contextualized environment as well as promote the use of new multimodal sensors in order to increase the sensory stimuli as tactile, olfactory and oral inputs. Finally, brain computer interaction and biosignal sensors are promising channels to recover objective information regarding the arousal of children with ASD.

Fig. 11 Emotions expressed by Hugh: happy, sad, angry, neutral

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Affiliations

Sandra Baldassarri[1] · Liliana Passerino[2] · Silvia Ramis[3] · Inma Riquelme[4] · Francisco J. Perales[3]

Sandra Baldassarri
sandra@unizar.es

Liliana Passerino
lpasserino@gmail.com

Silvia Ramis
silvia.ramis@uib.es

Inma Riquelme
inma.riquelme@uib.es

[1] Advanced Computer Graphics Group (GIGA), Computer Science Department, Engineering Research Institute of Aragon (I3A), Universidad de Zaragoza, Ed. Ada Byron, C/María de Luna n. 1, 50015 Saragossa, Spain

[2] Centro de Estudos Interdisciplinares em Novas Tecnologias da Educação - Campus Centro. Av. Paulo Gama, 110 Anexo III - 3º andar, Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brazil

[3] Computer Graphics, Vision and Artificial Intelligence Group A. Turmeda, DMI-UIB, EPS. Crta. Valldemossa, KM 7.5 S/N, 07122 Palma de Mallorca, Spain

[4] Facultat d'Infermeria i Fisioteràpia, Institut Universitari d'Investigació en Ciències de la Salut (IUNICS), UIB. Crta. Valldemossa, KM 7.5 S/N, 07122 Palma de Mallorca, Spain