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LONG PAPER

Empowering soft skills in children with ADHD through the co-creation of tangible tabletop games

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Abstract

There has been a push in recent years to introduce soft skills at different levels of education, and tangible technologies are an excellent tool for achieving this. However, integrating digital skills for children with ADHD remains challenging, and educators need effective strategies to promote these skills. Thus, we investigate which methods and frameworks are the most appropriate for children with ADHD when designing technology and promoting creativity and social skills. A pilot experience is also presented in which a team of children with ADHD co-create a game using tangible tabletops. The results show that the strategies used promoted positive behaviors in terms of communication, collaboration, and creativity during the sessions. The contribution of this research is that it provides examples of effective strategies to promote soft skills in children with ADHD.

Keywords Co-creation · Children with ADHD · Neurodiversity · Tangible interaction · Frameworks · Soft skills

1 Introduction

Children around the globe are being raised in environments saturated with smart devices. At the same time, there is a growing need for a future workforce that understands technology. However, not only STEM (Science, Technology, Engineering, and Mathematics) literacy [1] is needed, but also soft skills [2, 3]. Formal and informal learning settings (such as home, after-school, and makerspace environments) benefit of STEM engagement to work on soft skills [4].

The term "soft skills" is quite ambiguous and may encompass a variety of qualities, traits, values, and attributes, usually ligated on what are the needs and requirements in the world of work [3]. The category emerged from the division between those skills that were cognitive and technical in nature—frequently referred to as hard/technical skills—and those that were not, but a unified view of the term in the literature has not been achieved. The term comprises categories that include (but are not exhaustive to:

(a) Qualities including adaptability, flexibility, responsibility, courtesy, integrity, professionalism, and effectiveness, and values such as trustworthiness and work ethic;
(b) volitions, predispositions, attitudes like good attitude, willingness to learn, learning to learn other skills, hard-working, working under pressure, or uncertainty;
(c) problem-solving, decision making, analytical thinking/thinking skills, creativity/innovation, manipulation of knowledge, critical judgment;
(d) leadership skills and managing skills;
(e) interpersonal and communication skills (social skills and team skills): effective and productive interpersonal interactions, negotiation, conflict resolution, and persuasion skills.

Several studies have shown the potential of co-creation, participatory design (PD), and playful strategies in the development of STEM and soft skills [5–7], in particular creativity and social skills. However, although there are

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frameworks for adapting the participatory design to neurodiversity [8, 9], programs specifically designed for attention-deficit/hyperactivity disorder (ADHD) students are scarce.

This paper tries to help bridge this gap in current research by exploring the following research questions:

- R.Q.1. What principles and strategies are suitable for designing co-creation activities with children with ADHD?
- R.Q.2. What soft skills are worked and developed by children with ADHD in a co-creation experience adapted to their needs?

This paper is structured as follows: first, we present a review of the literature on ADHD, soft skills education, and related work frameworks; then, the method followed to co-create a framework adapted to children with ADHD is presented, and the exploratory study and main issues of the experience; next the limitations of the study are described, and finally, the results and conclusions are summarized and analyzed.

2 Literature review

In this section, we describe the basis of our study concerning ADHD and soft skills, co-design and ADHD, and related frameworks for designing technologies for children with ADHD.

2.1 ADHD and soft skills

Attention-deficit/hyperactivity disorder (ADHD) is one of the most frequent neuro-developmental disorders among children, having a prevalence of around 5% in Spain and about 10% in the USA. Children with ADHD face challenges related to attention and concentration, lack of emotional self-regulation, and a high level of impulsivity. But like all neurodiverse children, they also have strengths [10]: they can be spontaneous, innovative thinkers, creative, risk-takers, and pay high attention to detail; some are indeed labeled as gifted and talented.

Although according to the Mental Health Foundation [11], having ADHD constitutes a risk of exclusion from the labor market, some characteristics that can be considered as deficiencies in terms of performing in today's society and the labor market, such as distraction or impulsivity, can be strengths in other areas, as they increase a person's degree of flexibility and therefore their capacity to adapt, this being one of the keys to innovation. Besides, as stated before, one of the strengths of people with ADHD is creativity, enabling them to come up with new imaginative solutions that would add value to design processes [12]. Another identified strength is the ability to take risks which, combined with impulsiveness, can be a driver for innovation and the design of new solutions. In addition, these characteristics are related to the retail industry [13].

On the other hand, soft skills are increasingly in demand by companies [3]. According to a LinkedIn survey in 2020 [14], the five soft skills most in need by companies were: (1) creativity, (2) persuasion, (3) collaboration, (4) adaptability, and (5) emotional intelligence. We see that some of the most in-demand soft skills coincide with strengths identified with ADHD people, such as creativity or adaptability. On the contrary, some others, such as collaboration or emotional intelligence are a challenge for ADHD as their difficulties with attention, concentration, emotional regulation, and impulsivity have a negative impact on them. In the same survey, ten hard skills, or specific knowledge most in demand, were identified, of which six were directly related to technologies. These capabilities can enhance other hard skills associated with creating technologies. Taking all this into account, in this paper, we propose a co-design framework to strengthen soft skills in children with ADHD. We focus on enhancing creativity and social skills by creating technological solutions. In the following section, we describe the methods we consider suitable for co-designing activities with children with ADHD.

2.2 Co-design and ADHD

Co-design as a paradigm of design is primarily involved in designing new artifacts, for our research goals, in technologies for learning and innovation [15]. Thus, the design involves users following PD techniques [16].

Participatory design experiences represent opportunities for neurodiverse children to be listened to and to demonstrate their knowledge [8]. The reported beneficial impacts include enjoyment, gaining a sense of empowerment, feeling a sense of ownership or pride, improved behavior, increased engagement, increased confidence, and feelings of competence. One of the key skills within PD is creativity. According to Warr and O'Neill [17], invention in design increases the likelihood of creating useful and usable technological solutions. Therefore, people with ADHD who possess this characteristic and other talents such as risk taking and spontaneity can help design new and very valuable technological solutions. Moreover, the possibility of fostering children's creativity and social skills makes PD experiences very suitable for children with ADHD.

In our case, after working for three years with children with ADHD, developing interactive tabletop games and activities for them, we thought it would be interesting to allow them to create their own games. To do this, we had already installed a tangible tabletop, NIKVision [17], in a center devoted to children with ADHD. We had developed

KitVision, a software dedicated to creating games and activities for people with no programming skills (therapists and teachers up to that point) [18]. We hypothesized that well-organized activities could be very positive and motivating for them (these children are usually quite unmotivated after long-term interventions and repetitive school activities). Their therapists agreed it could be a great opportunity to work their social abilities, but it was clear to all of us that the action should be very well thought out. Surprisingly, and despite the prevalence of ADHD, we found that there were very few PD experiences with children with ADHD reported in the literature [19]. However, there were several frameworks available that could help us in the development of skills using and creating technology. In the following section, we describe some of the related frameworks that support our proposal.

2.3 Related frameworks

Although the literature shows a variety of research involving children in the technology design process, most of it focuses on the difficulties rather than the strengths of these children [8]. Among the existing frameworks involving children with special needs, we can cite the model of [20]. This model has three levels: (a) the level of participation, (b) the type and severity of the disability, and c) the support capacity. Another related framework is that proposed by Kärnä et al. [21] called Children in Centre (CIC). This framework has five levels, where the main level focuses on the children's strengths, interests, and needs. In addition, there is a framework specially created to design technologies with neurodiverse children called D4D [9] (see Fig. 1). This framework is supported by two main pillars: the structured environment and the support provided. In addition, the characteristics of neurodiversity and the skills and talents of people are considered. These considerations are obtained through understanding the culture and individual adaptations. Some authors have adapted this framework to neurodiverse cases, such as ADHD [8].

On the other hand, to respond to the second question, to know which soft skills are worked in a co-creation experience, Positive Technological Development (PTD) [22] can be used. The PTD framework tries to overcome the difficulty of assessing the benefits of STEM engagement [23] in diverse learning settings [24]. PTD is rooted in Seymour Papert's pioneering work on Constructionism; a theoretical approach concerned with the unique metacognitive learning opportunities afforded by computer programming [25] and on research from the field of Positive Youth Development, which focuses on how to foster positive and pro-social developmental outcomes in children and young adults. PTD is based on six key behaviors, three related to intrapersonal skills (content creation, creativity, and choices of conduct) and three related to interpersonal skills of communication (collaboration and community building). PTD behaviors are evidence that children are developing positive character assets and can be supported by technology-rich classroom activities [24]. This framework has also been used in children with neurodiversity to develop key competencies, such as computational thinking [26].

We decided to adapt these previous frameworks to the case of children with ADHD and to carry out a co-creation experience in which a group of children with ADHD designed and implemented their own tabletop game (Table 1).

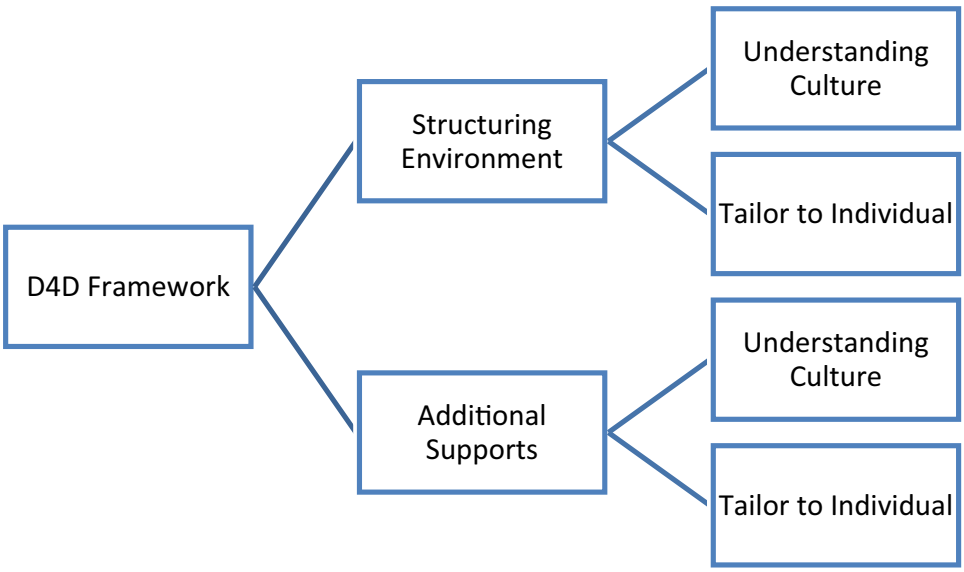

Fig. 1 D4D framework. [9] Adapted from Benton et al.

Table 1 Strengths and weaknesses of children with ADHD [10]

ADHD characteristics	Weaknesses	Strengths
Attention and concentration	X	
Emotional self-regulation	X	
Impulsivity	X	
Spontaneity		X
Innovative thinking		X
High attention to detail		X
Creativity		X
Risk taking		X

3 Method

When conducting this study, we applied a mixed methods approach [27], a methodology combining quantitative and qualitative data within a single research work to better understand the research problem. Thus, the qualitative and quantitative data were collected and analyzed, and then, during the interpretation and discussion, the results were explained and compared. The instruments used provide the criteria for designing and evaluating digital educational experiences with children with ADHD. The quantitative instruments applied were questionnaires. The qualitative instruments used were observations during the sessions.

3.1 Participants

Following Lazar [28] in the recommended research methods for human–computer interaction (HCI) in the case of people with disabilities, we focused on the study of a small number of instances within a specific real-life context (from three to ten participants being acceptable to have 5–10 users with a particular disability take part in a study) [29]. Thus, a total sample of $N=5$ children with ADHD (1 girl and four boys) from 9 to 14 years old participated in this research (see Table 2).

The participants of our study shared ADHD; in particular, all participants presented motivation problems, but some comorbidities were presented, such as Asperger syndrome or dyslexia. The ADHD and the comorbidities occurrence is presented in Table 2 and will be described in deep in Sect. 4. The participants attended the Atenciona center, located in Zaragoza, Spain. The center's therapist selected these five children to participate in the workshops mainly because of their need for more motivation in regular sessions. The therapist and two researchers participated in this study.

Table 2 Sample characteristics

Child	Gender	Age	Characteristics
R	M	9	ADHD, Asperger
A	M	11	ADHD, Asperger
D	M	11	Impulsivity, gifted
I	F	12	ADHD, dyslexia
F	M	14	Hyperactivity, gifted

The study follows the principles of the Declaration of Helsinki. We prepared an informed consent form in which the experience was explained, together with the authorization to obtain the families' permission to take pictures, record the sessions, and use the materials in scientific publications. The authorizations were requested if any family preferred their children not to be recorded or the materials published. The association sent both documents to the families and arranged a meeting with those interested in their children participating in the experience.

An informed consent form was provided to all research participants. In the case of children, their parents signed the informed consent.

The most common ADHD comorbidities are learning disabilities, anxiety, depression, sensory processing disorder, and oppositional defiant disorder.

The objective was to study the entire group by measuring the effectiveness of the intervention through the co-creation and the development of positive behaviors. Thus, there was no comparison group for this study.

3.2 Tools: NIKvision tabletop and kitvision software

We used a NIKVision [17] tabletop already installed on the association's premises. NIKVision is a tangible tabletop based on the physical manipulation of traditional toys over a table surface. Any toy can interact with the tabletop on the condition that a printed marker (called a fiducial) is attached to its base (see Fig. 2).

Once the fiducials have been glued to the toys, children can manipulate them over the tabletop surface (Fig. 3a). There is active image output on the table surface, and a conventional computer monitor (Fig. 3f) adjacent to the table is also used to bring tabletop games closer to the traditional

Fig. 2 Toys with attached fiducials

Fig. 3 NIKVision tabletop

multimedia graphics approach that looks attractive and fun to little children. This last characteristic is optional, and the monitor has been removed in the current version of the NIKVision tabletop. Technically, NIKVision uses reacTIVision visual recognition software [30] to track the position and orientation of the toys placed on the surface (Fig. 3c). An infrared light USB camera (Fig. 3b) captures video from underneath the table and streams it to the computer station, which executes the visual recognition and game software. Active image projection on the table is provided by rear projection (Fig. 3d) through a mirror inside the table (Fig. 3e). At the same time, the audio of the activities is reproduced by the speakers (see Fig. 3g).

The KitVision graphic assistant is a desktop application that eases the modeling of tabletop activities. The assistant uses a WYSIWYG (What You See Is What You Get) approach that allows the designers of activities to incorporate graphics, animation, and audio, placing them on the screen in the same way that they will appear on the tabletop surface later.

To create an activity, it is necessary to first define the following:

- A background: the image that will appear on the tabletop surface (Fig. 4a);
- An icon: an image that represents the activity and that will appear on the screen of the tabletop allowing the user to select the action (Fig. 4b);
- The areas: positioning a playing piece in these square-shaped areas will have a specific meaning in the activity. Areas can be associated with the board, as used in board games such as Ludo or Chess, or with a physical object, as used in non-board-based games such as the Domino. An area associated with the board is defined in a fixed position on the screen, and that position does not change during the activity (Fig. 4c). However, an area associated with a physical object moves (and optionally rotates) with that physical object, so its position is variable;

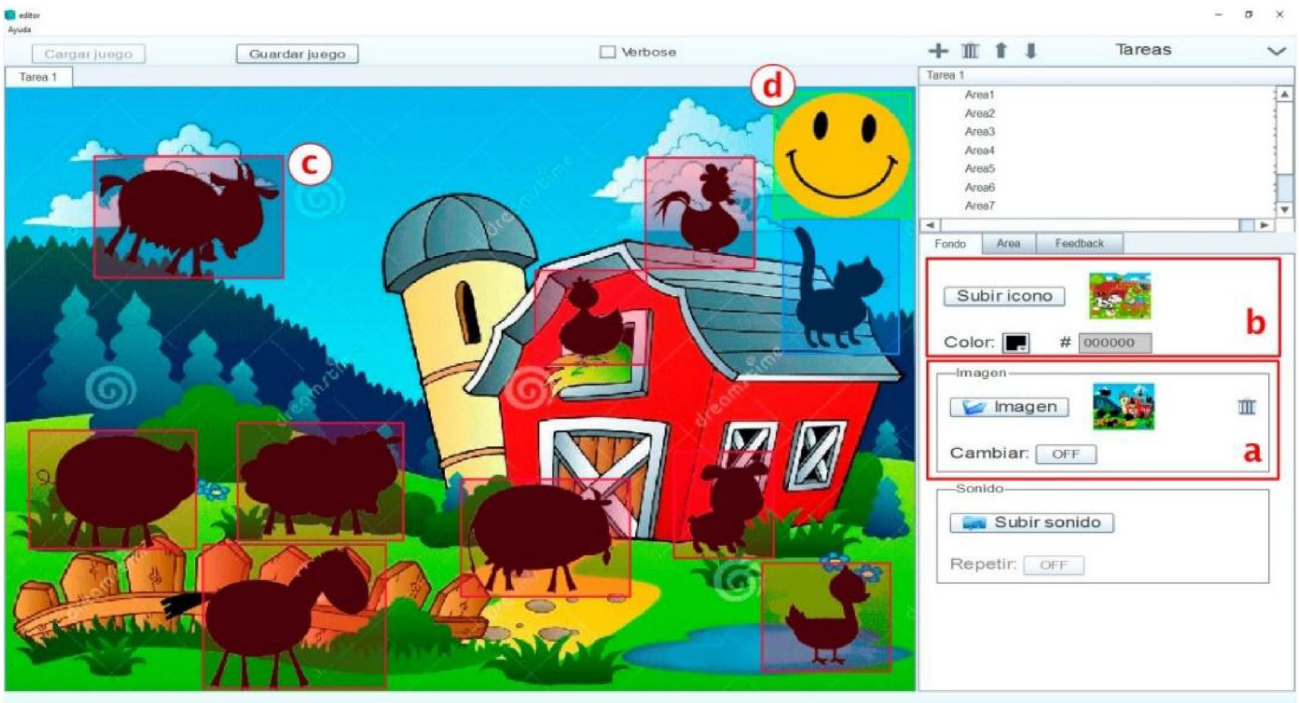

Fig. 4 KitVision Graphic Assistant

- The playing pieces: every area of the game has a set of correct playing pieces and a set of incorrect playing pieces associated with it. As mentioned, a playing piece is identified by the fiducial that is glued to its base, so to assign the lists of correct and incorrect pieces to each area, we use the number of fiducials;
- The feedback: graphic and/or audio elements which show the consequences of children's actions. For example, in Fig. 4, the feedback is the face that smiles when the child situates a correct toy in the area and turns sad when the child does not do this correctly (Fig. 4d).

When the activity is completed, the graphic assistant automatically generates a file containing the activity's information and gathers the resources used (images, animation, and sounds). All these files are stored in a folder the player accesses to display and run on the tabletop.

3.3 Procedure

This section sets out a proposal to adapt the D4D framework for children with ADHD, the idea being to encourage positive behavior while the children work with technology. The structure and the dynamics of the co-design sessions conducted with children with ADHD are also described.

3.3.1 Adapting the D4D framework for children with ADHD

As remarked in the previous section, Benton et al. [9] made three general recommendations for adapting the D4D framework for neurodiverse children: (a) to understand their culture, (b) to structure their environment and lend support, and (c) to understand each child. Our recommended adaptations for children with ADHD are as follows.

Understanding the culture of ADHD We consulted the PASS Model [31] during the design stage as a theoretical basis for understanding the behavior of children with ADHD together with their learning difficulties. The PASS (planning–attention–simultaneous–successive) model combines neurological, psychological, and educational features and sheds light on children's behavior during the learning process. The model also illustrates how attention difficulties can affect various learning processes. Firstly, such challenges can interfere with the planning process, responsible for the construction, execution, and control of plans. It is, therefore, important to work on strategic behavior and metacognitive knowledge with these children, concentrating on the planning process and encouraging interaction. Children need guidance to improve their planning capabilities and regulate themselves, so the role of the educator is fundamental in this respect. In previous work, we put forward a set of recommendations for the design of games for children with ADHD based on a combination of this theoretical framework (Pass and Feuerstein models) and our direct experience in designing such activities [32]. To design the co-creation experience for these children, we propose adapting the general game design guidelines as shown in Table 3. *Structuring the environment and providing support* Further guidelines adapting the D4D framework are proposed as follows:

- Including the children's therapist in the design team to provide the necessary support and to help them feel more comfortable;
- using a visual plan to introduce the structure of the sessions to the children. A review of completed activities or contents and future tasks should be made at the start and finish of each session;
- incorporating structured activities in the early sessions to promote teamwork and skills;
- using graphic design templates as a reference in the generation and recording of ideas by individual members of the design team and combining them with those of the other members.

Understanding the individual children An initial meeting was held with the children, their families, and their therapist to get to know them all and identify their needs and preferences. We demonstrated the NIKVision tabletop and explained the activities created up to that point. We also presented the various sessions to be carried out with the children. The parents were asked to sign consent forms, and they all permitted us to record the sessions and use the material.

Before the first session, personalized invitation letters were prepared for each child. These were sent by Atenciona to the parents (see Fig. 5).

3.3.2 The co-creation experience

Five two-hour weekly sessions were carried out on Fridays from 6 p.m. to 8 p.m. after the children had finished their afternoon activities in Atenciona. Five A4 posters were prepared, displaying visual guides to the sessions. Children with ADHD tend to lack concentration, so it is important to illustrate the tasks they will be performing visually. This enables them to understand at which point of the experience they are at any given moment, and which lessons they have already completed, and which are yet to be done (see Fig. 6). The five sessions are now explained in detail.

Session 1: presentations The first session comprised five activities (see Table 4). Some of the children were already familiar with the tabletop, having played with it during their therapy sessions. However, they were given thirty minutes to play with it so they could all become accustomed to it. It also allowed them to play together, which was important because, apart from two brothers, R and A, they had never met before. They were invited to

Table 3 Guidelines to develop co-design activities with ADHD (general guidelines from Cerezo et al. [30])

General game design guideline	Adapted guideline for co-design activities
G1. The level of difficulty of the game should be adaptable	All activities in the sessions should be tailored to the abilities and potential of every child
G2. The game's objective and how to achieve it has to be clear	The necessity of planning the work and concentrating on the successive objectives must be emphasized to the children
G3. The game should help the children be aware of the time	The educator has to control the duration of each activity, allowing rest periods and activity breaks if needed
G5. The game should be controllable by the educator	They should assist the children in completing tasks so that they can feel competent
	It is also important to consider the children's interests and hobbies when defining and allocating the activities
G4. The manipulative possibilities of the tabletop should be potentiated	The designed game should profit from the tangible possibilities offered by the tabletop. The fabrication of physical toys should be one of the activities to be performed by the children
G6. The game should promote the search for information and the identification of alternatives	The educator should promote the search for alternatives to the preliminary proposals. All of the recommendations should be thought about and discussed. Any suggestions from the children themselves should be given appropriate consideration
G7. Positive and encouraging feedback must always be given	Provide a high-reinforcement environment. Besides direct positive feedback, an effort has to be made to incorporate proposals coming from all the participants in the final design
G8. Interest and motivation should be maintained through several stimuli	The session should contain short activities with a clear objective to help children focus on it and maintain interest. This will help to control impulses
G9. Games should enhance selective attention	The necessity of planning the work and concentrating on the successive objectives must be emphasized to the children
G10. The game should promote collaboration to solve problems	The concept of a design team is formed by members with different but complementary roles that share a common and discuss their design decisions with the rest. Some of the activities should be performed in-group

Fig. 5 Personalized letters. Left: girls. Right: boys

help us complete a previously prepared game called *Greetings* using the KitVision Graphic Assistant. This gave them a preliminary idea of how it worked. The game's background shows five empty picture frames, each with the name of one of the children written on it (see Fig. 7). Each child also has a personalized object with their name on it.

The idea of the game was for the children to place their objects on the frame with their names on it. A picture of them would then appear, and they would hear audio saying "hello." The audio was pre-recorded, but the pictures had to

Fig. 6 Sessions of the experience

Table 4 Session 1 activities

Activity	Description
Presentations	Talking about hobbies and interests
Design team and planning schedule	How design teams work/the result we are looking for/ how to achieve it
NIKVision	Playing with the tabletop and reflecting on the structure and characteristics of the games
KitVision	Developing the greetings game
Recap	What we have done/what remains for the next session

be taken during the sessions. The children used the Graphic Assistant to add their images and objects.

The children took the pictures using a mobile phone provided by one of the experts attending the session. The idea was to help them feel relaxed with each other as they would be working and playing together. Four of the children agreed to take pictures of themselves, while the eldest, F, preferred to do a drawing of himself and take a picture of it (see Fig. 8).

Session 2: brainstorming In the second session, the children were asked to think of ideas for possible games. To do this, they had the help of the therapist and two experts. First, the experts reviewed some past games with the children, encouraging them to say what they liked or did not like about them and to identify the principal components (for example, the toys or the characters used in the game). The children were each given a template on which they had to write or draw two ideas (see Fig. 9).

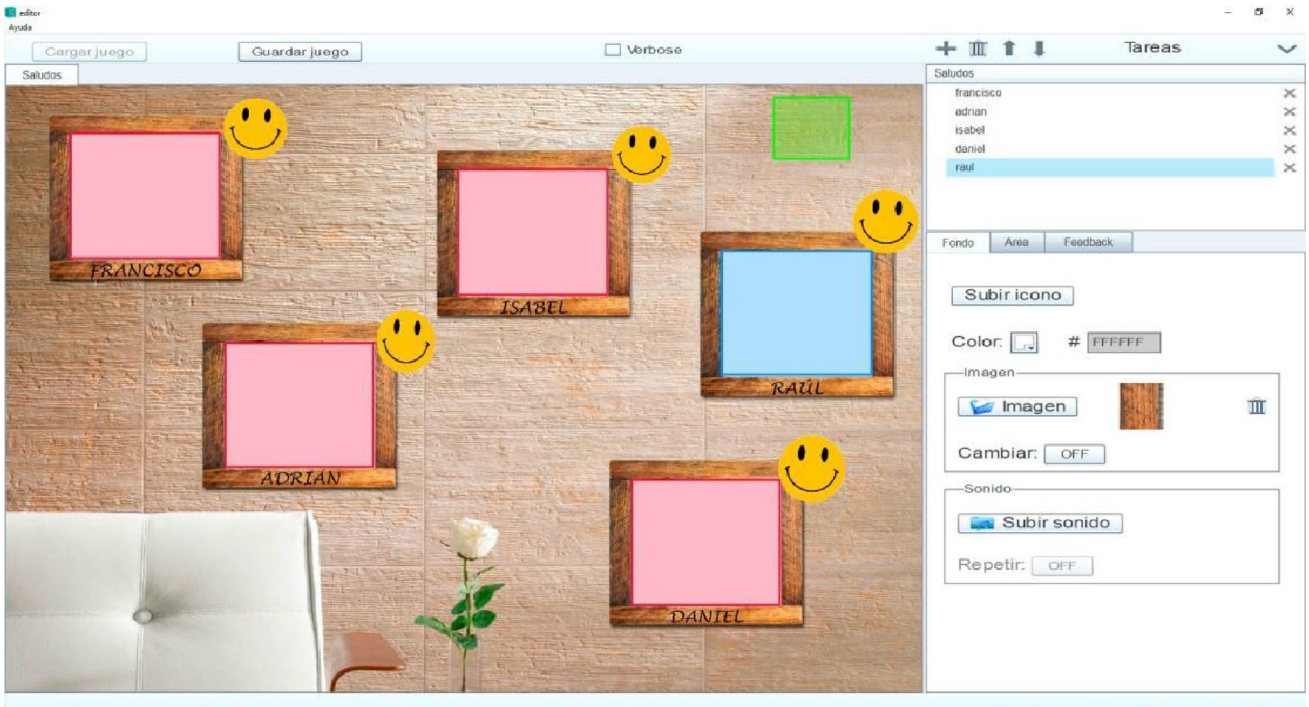

Fig. 7 KitVision graphic assistant loaded with the *Greetings* game

Fig. 8 Background with the children's pictures

Unlike the other children, the two brothers, R and A, did not produce any ideas in the brainstorming session. They merely drew characters and situations taken from the last game they had played (*Cuphead*). They were frequently distracted, talking about the old game rather than trying to think of ideas for a new one. However, the other three children came up with various ideas:

– D thought of a game featuring a spaceship;
– I put forward two different ideas. The first was a rhythm-based game, while the second was a treasure hunt using a map, during which several mini-games had to be played;
– F also had two ideas for games. The first was a game based on the rhythm of a song, similar to I's first idea.

Fig. 9 Brainstorming game ideas

The second involved helping a character to cross a road with much fast traffic.

In the end, ideas from the three children were used to design a game set in space. The players would use spaceships to interact (D). It was not possible to use the rhythm-based games (I and F) because KitVision is limited to placing objects in areas. Nevertheless, it was possible to use I's idea of completing different mini-games to progress through the principal game. It was also possible to adapt F's idea of avoiding cars on the road by substituting it with spaceships having to avoid meteorites. Although R and A had not produced any new ideas, it was decided to adapt elements of the game they liked. In the *Cuphead* game, various weapons were used to achieve the objective, and this idea was incorporated into the new game.

Session 3: designing the game The first two sessions concentrated on the game as a whole. The third session was devoted to planning the mini-games, which made up the game's various stages. Four mini-games were designed, which players accessed through different planets visited by the spaceship. On completing each mini-game, the players were rewarded with a prize: a weapon required to complete the subsequent stages of the game (Fig. 10).

Below we provide a brief description of the components of the game:

– *Meteorites*: the first mini-game is based on F's suggestion in session 2. The players attempt to avoid colliding with meteorites while moving the spaceship toy on the tabletop. F was tasked with creating animations of the meteorites since he enjoyed programming animations

Fig. 10 Activities in the third session. Left: drawing the Final Boss and some of the weapons. Right: building spaceships with Lego

and had already made up some games on his own. *Prize: Power Blade. Toys involved*: *Spaceships.*

– *Riddles*: this second mini-game was prepared by the authors before the sessions. This was because it was considered too ambitious to design and make new toys for four games within the two-hour time limit of the session, and we wanted to take advantage of some toys made previously. During the session, the children chose their two preferred space-related riddles from several we had prepared in advance—prize*: "The Reaper" Axe. Toys involved*: *Letters.*

– *Quiz questions*: this mini-game was based on suggestions by R, A, and D. The authors prepared several questions about space which the children selected two for the game. *Prize: Galactic Shotgun. Toys involved*: *Spaceships.*

– *Maze*: the fourth mini-game was based on a suggestion by I for escaping from a maze. F proposed that it should be made more difficult by asking the players to memorize the directions for getting out of the maze. The rules, for example, "right-up-right-down-left," appear on the screen for 5 s before the player can move. *Prize*: *rocket launcher. Toys involved*: *Spaceships.*

– *Final Boss*: this final stage of the game is played after the four mini-games have been completed. The players then travel by spaceship to the last planet to try to defeat the evil Mr. Meeseeks using the weapons won in the mini-games. Mr. Meeseeks is a character selected by the children, taken from the "Rick and Morty" animated science fiction sitcom. *Toys involved*: *The four weapons.*

Once the mini-games were planned, we divided the children into two groups, each with a task. R and F had to draw the Final Boss and the four weapons (see Fig. 10, left). I, D, and A made the spaceships using Lego (see Fig. 10, right).

On completion of these tasks, we were asked by D to produce a script of the game, narrating the story and explaining the mini-games.

After R and F finished their drawings, I and A adapted the weapons so that the tabletop could recognize them. They were supplied with previously prepared foam bases to glue the corresponding fiducial markers, the weapons, and the spaceships (see Fig. 11).

Session 4: implementing the game The graphic resources required for implementing the game were prepared before the session.

I could not attend this session, so the four remaining boys were divided into pairs (see Fig. 12). It was considered advisable to separate the brothers so they would be less distracted. This also had the advantage of pairing R, the youngest child, with F, the oldest and, therefore the most likely to be able to keep the more youthful boy focused on the game.

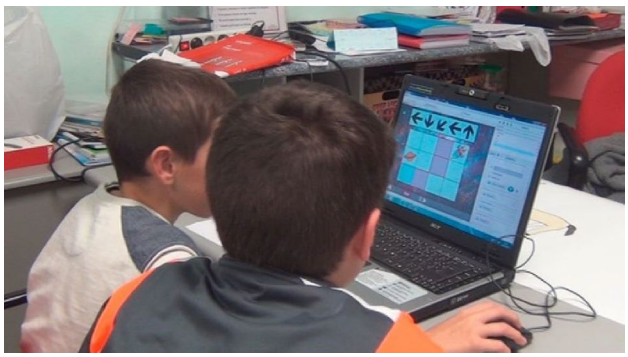

Fig. 12 Using the KitVision graphic assistant to complete the game

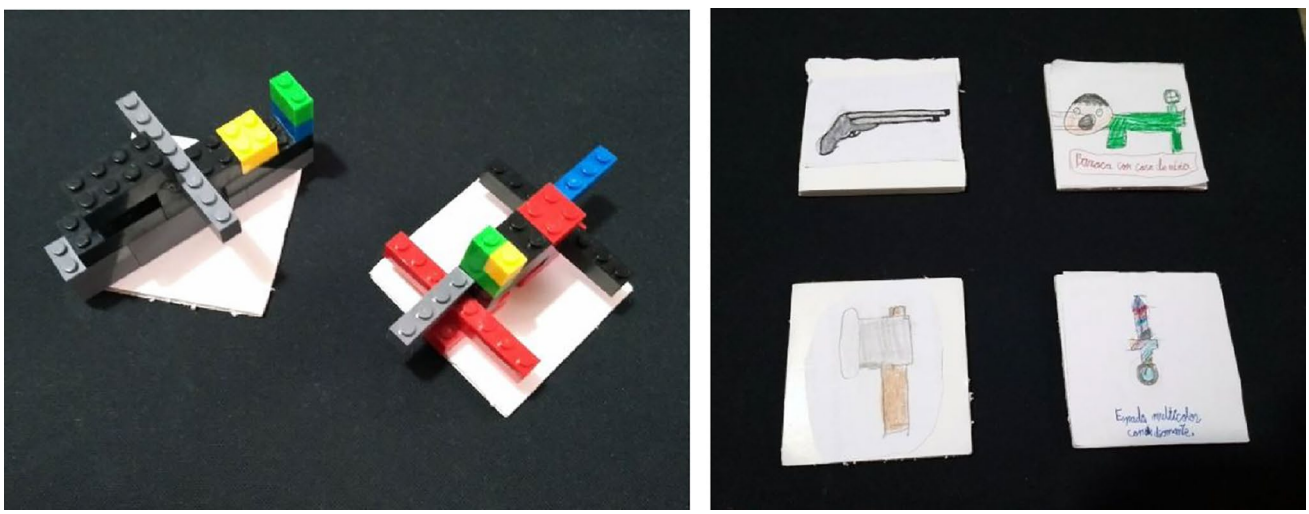

Fig. 11 Toys created during the session. Left: spaceships. Right: weapons for the mini-games

– *Meteorites*: to implement this first mini-game, the children only had to select the animation and establish the background (see Fig. 13, top left). After creating the background covering the whole the surface, they placed the fiducial markers corresponding to the spaceships (1 and 2) on the defined area;
– *Riddles*: in the second mini-game, a riddle is shown in the background, with the answer missing most of the letters. The children's task was to create the areas corresponding to the missing letters and to assign their fiducial markers (A = 0, B = 1, C = 2, …, Z = 26) (see Fig. 13, top right);
– *Quiz questions*: this mini-game consisted of questions with four possible answers. The children had the choice of creating the four areas relating to the answers (only one of which was correct) or simply the area corresponding to the right answer. R and F chose the first option, while D and A chose the second (see Fig. 13, bottom left). Again, the children had to assign the appropriate fiducial markers, this time to the spaceships;
– Maze: in this final mini-game, the spaceships had to escape from the maze by visiting the correct squares in sequence. Here, the children had to create the areas for the squares. They then had to assign the fiducial markers to the spaceships (see Fig. 13, bottom right).

The final stage of the game, defeating the Final Boss, was completed by the authors after the sessions had finished. This was because F, responsible for the design, could not finish in time. We, therefore, completed it after he sent us his drawings (see Fig. 14).

Session 5: testing the game The families attended the final session so the children could explain the game to them (see Fig. 15).

Once the children had explained their game, both parents and children were asked to complete a questionnaire, as discussed below.

3.3.3 Data collection and results

We used a reduced version of the PTD Engagement Checklist concerning the soft skills and their evaluation (Table 5). As mentioned in Sect. 2.3, PTD's key behaviors are related to intrapersonal skills (content creation, creativity, and choices of conduct) and interpersonal skills (communication,

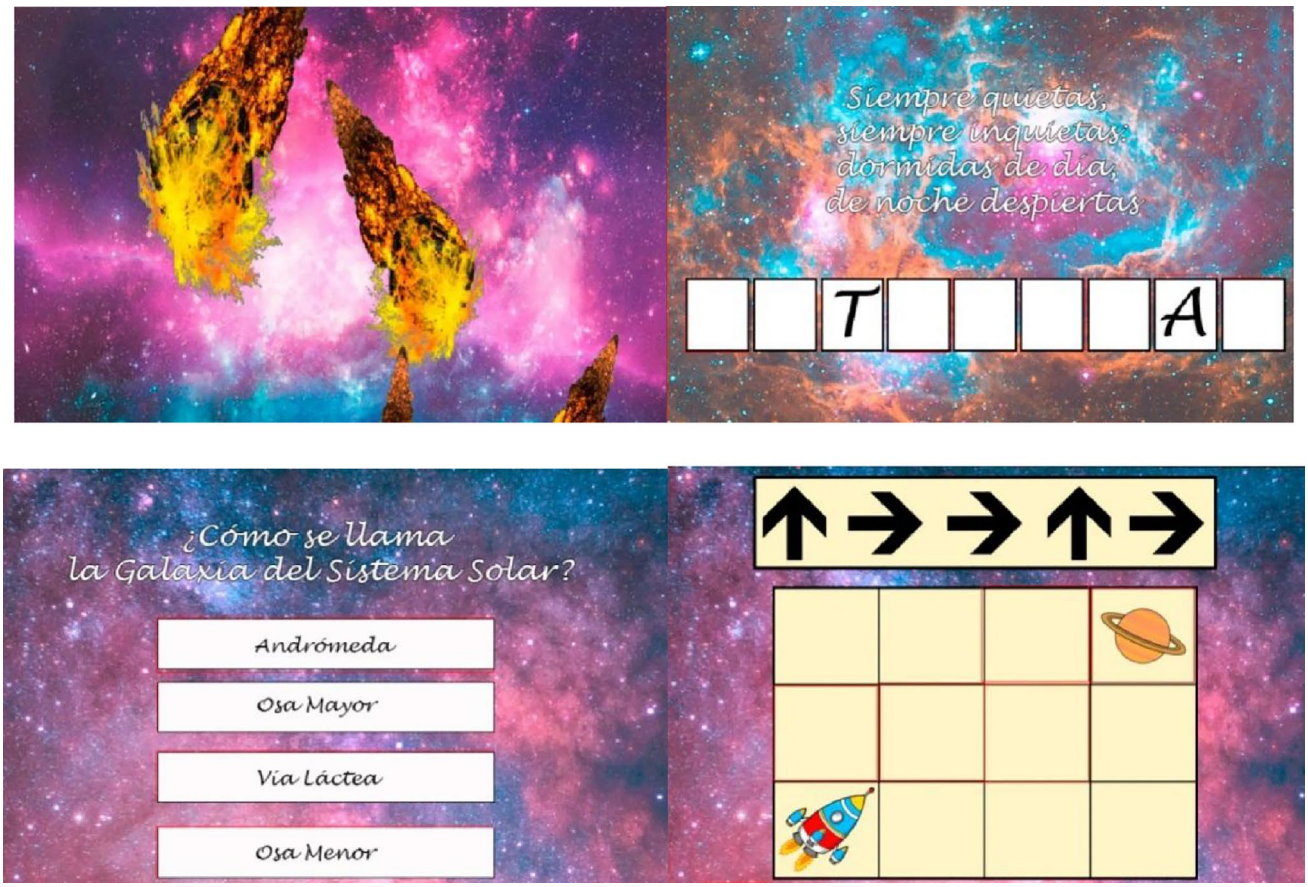

Fig. 13 Mini-games. Top left: meteorites. Top right: riddles. Bottom left: Quiz. Bottom right: Maze

Fig. 14 Final Boss. Left: Mr. Meeseek about to fight. Right: Mr. Meeseek defeated

Fig. 15 Testing the game

collaboration, and community building). So, by observing these behaviors, we can observe the soft skills developed during the sessions, like creativity and social skills. Table 5 shows the occurrence of positive behaviors observed during the session organized by type.

As particular examples of these observed behaviors, we can cite the following:

- Communication
    - Talking about their interests and, above all, playing the NIKVSION table. It encourages communication (observing each other, playing with adults) (Session 1);
    - Their ideas are shared and discussed with adults and among themselves (Session 2);
    - the work was divided (some using Lego, others doing drawings), but everyone looked at and shares the work of others. Within each group, ideas are shared (Session 3);
    - work was divided, but everyone looked at and shares the work of others. Within each group, ideas are shared (Session 4).
- Collaboration
    - using KitVision to make a collaboration game. They must take pictures of everyone and upload them to the template. Together they must complete it. They share a cell phone to take pictures; they share the computer to define the game screen (pictures) (Session 1);
    - they work on the idea of a common game (Session 2);
    - materials are shared within each group (Lego, paints) (Session 3);
    - they must take turns using the materials; the pairs must agree on the texts (Session 4).
- Community building
    - Once the ideas have been worked on individually, they are together in common. Everyone works/shares their favorite games (Session 2);
    - what is created is made available to the group. Everything is brought to the common table (Session 3);
    - everything that is created is for the group (Session 4).
- Content creation
    - Everything is placed on a shelf next to the table. They are left alone to create and are only assisted if they have doubts (Session 3).
- Creativity

Table 5 Positive behaviors were observed and worked during the five sessions

Positive behaviors/sessions	S1	S2	S3	S4	S5
Communication	X	X	X	X	X
• Students exchange ideas with others					
• Students feel comfortable seeking help and asking questions with adults					
• Students feel comfortable seeking help and asking questions with peers					
• Students are eager to share ideas with others					
Collaboration	X	X	X	X	X
• Students exchange ideas with others					
• Students feel comfortable seeking help and asking questions with adults					
• Students feel comfortable seeking help and asking questions with peers					
• Students are eager to share ideas with others					
Community building		X	X	X	
• Students volunteer to share work with others					
• Students volunteer to share their work with families, therapists, etc.					
• Students participate in community-related tasks					
Content creation		X	X	X	
• Students know how to use technology to do a project					
• Students are interested and enthusiastic about their projects					
• Students persist despite obstacles or setbacks					
• Students know how to debug their programs					
Creativity		X	X		
• Students unexpectedly use technology					
• Students exhibit confidence and can initiate and complete tasks with little coaching					
• The students brainstorm ideas for their projects					
• The projects are introduced to students as open-ended; there is more than one way to create a project					
• Students are given basic guidelines for their projects, but there is also an opportunity for them to expand beyond them					
• Students are having fun as they work on their projects					
Choices of conduct	X	X	X	X	X
• Students focus on the activity and choose to be engaged with it					
• Students follow classroom rules					
• Students are using materials and resources responsibly					
• Students are showing respectful behaviors to peers and adults					

  - Although some ideas are inspired by children's favorite games, they are original game ideas (children's drawings can be shown) (Session 2);
  - they decide the games and their questions. They are given materials (to make weapons, for example), and they make them as they want. Lego pieces are left for them to make the type of spaceships they want (Session 3).

- Choices of conduct
  - The table and the toys are fragile (they look inside the table with the camera, and the mirror…), so they must be treated with care. The computer is not personal; they have to take care of it. Also, they must take turns playing (Session 1);
  - everyone's ideas are discussed and accepted (Session 2);
  - materials (pencils, Lego pieces) are collected at the end of the task. Handling the camera and scissors has to be done carefully (Session 3);
  - handling the camera, tape recorder, and laptop with care also, the toys are created so as not to break them (Session 4).

At the end of each session, the therapist was asked about the experience and behaviors observed. The therapist also reported back on any observations made by the parents.

Following the first session, the therapist felt that the children were highly motivated and keen to participate, although worried about the possibility of failing (D in particular). In the second session, I, who was normally

quite reticent, became actively involved and tried hard to integrate the ideas put forward by the other children. D continued to be shy, but he did begin to work. His parents reported a change of attitude, pointing out that he agreed to participate in a school project which he had earlier refused to do. He also got good marks in a school exam, which was unusual as he normally received poor marks due to his lack of motivation.

The children were all quite active in the third session, talking together and helping each other to complete their tasks. After this session, F's parents reported that he had agreed to join a football team, which surprised them. All the families felt that their children were happy and keen to participate in the following sessions.

Table 6 Questions of the final kids' questionnaire

Question	Average
I felt nervous during the workshop	1.4
I think I did well during the workshop	4
I have learned things during the workshop	4.4
I would like to learn more	4.8
The workshop has been fun	4.6
I think my colleagues did well	4.6
My ideas for the game were taken into account	3.8
I could not do some of the ideas I had for the game	2.6
During the workshop, I was thinking about other things	2.2
I would like to participate in another similar workshop	4.6
I felt at ease while doing the workshop	4.6
I felt comfortable with my colleagues	4.2
The sessions were long	3.6
I would recommend the workshop to my friends	4.6
I am satisfied with the final result of the game	4.6

Two questionnaires were completed at the end of game testing (one for kids and the other for parents) to evaluate the co-creation experience. The children's questionnaire comprised 15 questions covering different aspects of the co-creation experience. In Table6 and Fig. 16, questions and results are shown. As can be seen, kids felt comfortable during the experience, and with their mates, they felt that their suggestions had been accepted, they would recommend the experience to others, and they would be willing to participate in similar experiences in the future.

The parents were asked five questions and their level of agreement with them recorded on the Likert scale was as follows (1—not agree, 5—totally agree):

1. My child has told me things about the sessions (3, 25);
2. My child went motivated to the sessions (4, 75);
3. My child came back happy from the sessions (5);
4. I have noticed a positive change in my child's behavior (3, 25);
5. I think the experience has been positive for my child (5).

In their additional comments (open question), they pointed out, *"More workshops for children with ADHD needed," "I would increase complexity and time. Great," and "Longer workshop, they are left wanting more."*

The therapist was asked about the experience. She categorized it as very positive for the children: *"Creating a videogame was the main motivation; being able to do it daily has made it possible for them to be involved actively in all the steps. The changes in activity allowed them not to get bored and distracted. All the proposals were accepted and included in the game; there was not any direct criticism of them, nor between the group members, which gave them a sense of belonging to the group. Seeing the advances in each*

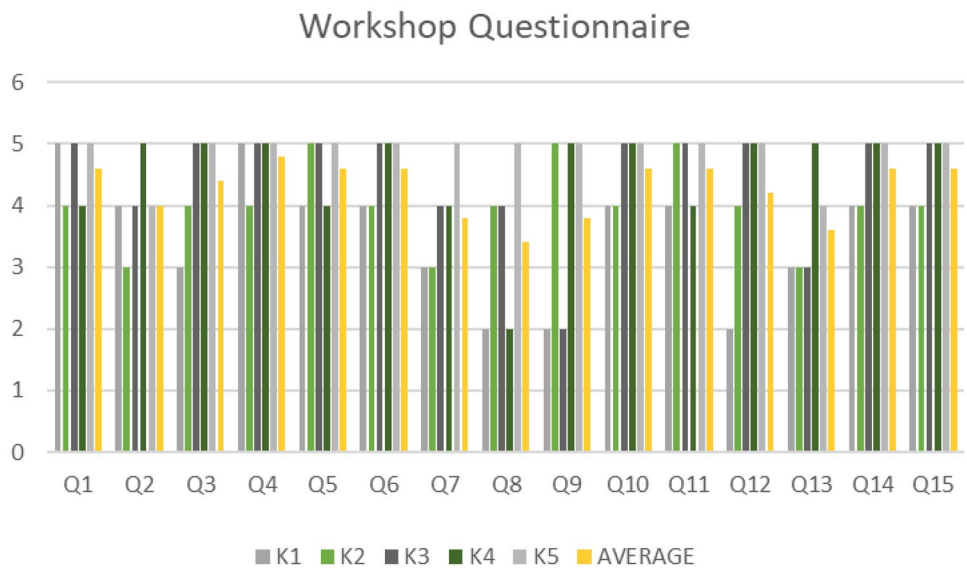

Fig. 16 Kid's questionnaire results. The questions are those in Table 6. A Likert scale (1—not agree, 5—totally agree) was used. Note that answers 1, 8, and 9 have been reversed so that the higher the punctuation, the more positive assessment

session made them aware of what they were creating, which enhanced their imagination, attitude, and effort." After the sessions, she highlighted the children's motivation and willingness to participate in the activities (the children had been chosen mainly because of their lack of motivation and engagement with regular activities). Besides, she emphasized the good atmosphere during the sessions and the positive mood he observed when they came out of the room.

3.3.4 Reflections

Everyone assessed the experience very positively. Children reported they felt comfortable during the workshops and with their mates and would recommend it to other kids. Families observed a positive change in their kids during the weeks of the activity regarding motivation to therapy and even to other school activities. They also asked for more duration of the activity and/or doing more of such activities. The therapist liked the activities and said they enhanced the children's imagination, attitude, and effort. Researchers observed that kids were actively involved in all the proposed activities, and a playable game was obtained.

However, some aspects deserve a reflection. Regarding technological restrictions, technology imposes some restrictions on the type of game to be designed; in our case, the hardware (tabletop) and software (the graphic assistant) make the game based on putting/manipulating objects/toys onto the tabletop. The children must be aware of the possibilities and restrictions imposed by the technology from the beginning (our first session was intended for that) so they do not get disappointed. Also, during the initial brainstorming, we made an effort to give alternatives to each of the proposals that escape from the real possibilities of the tabletop. Besides, it was explicitly stated that real design teams had also to adapt themselves to technology, time, or staff constraints.

Regarding the scalability of such an activity, we indeed had to do some work between the sessions to continue with the plan (collecting graphics and sound resources to be used, ending an animation to be included in the game…). The children's inability to complete the tasks was not due to their lack of capability but rather due to the constraints of time. We were limited to just four working sessions, each lasting two hours. If we had more time at our disposal, the children would have been fully capable of completing all the work independently. Notably, even the task of "programming" the games did not require real programming skills, as a graphic assistant provided assistance.

About the difficulties encountered, the main difficulty was, as stated before, the time shortage (low number of sessions): scheduling sessions taking school/center timetables and families and children availability is difficult. Also, anther reflection is related with the team's small size: if one or two kids could not come to one session, the teamwork suffers. A balance between control and size must be achieved.

Concerning the use of tangible tabletops as supporting technology, despite the restrictions already mentioned (in terms of the kind of activities and interactions supported), we still think that they are an optimal option to support this kind of co-creation activities; tangible interaction, based on the manipulation of physical toys to be created by the children open the door to manual activities (drawing, constructing) that children love. Moreover, integrating the physical toys with the graphics projected on the tabletop and the sounds makes the activities engaging for the children. This digital / physical integration with the children playing afterward altogether around the table, sharing space and time, is especially attractive from the educative point of view, as it merges the best of two worlds: videogames and traditional manipulative games.

Regarding the creation process and its results, it is crucial to take the ideas of all children somehow into account so that every child feels that they are contributing in all the stages and that the product/result is his/hers. The children were all satisfied with the final game, and except for one of them, they liked their game more than the previous ones.

Regarding the skills, we think that such an activity, with many different tasks, some of them digital, some of them physical, makes up an ideal context to work on creative and social skills not only with children with ADHD but with all kinds of children, including mixed neurodiverse teams as well as intergenerational teams as we plan to explore next.

Finally, in relation to the overall impact on the participating children, the therapist that have been working daily with the children reported an increase in motivation and a change of attitude that the families confirmed. Families communicated a positive change in children's general attitude beyond sessions. As researchers, when proposing the enrollment of users in our research experiences, the benefit for participants is an (ethical) key point to be considered: what are they going to gain with their participation in our study? Even if limited, we have to ensure a positive impact on participants.

4 Limitations

It is also important to address the limitations of the study. Regarding the total number of participants, we did one workshop with five kids participating. As commented before, the therapist considered it a good number, making it possible to control the sessions and make careful observations of each kid. Therefore, we propose keeping the number of participants low and replicating the workshops to increase the information gathered. Another possibility that would be very interesting is to have mixed groups combining special needs

children with children that require less supervision. This would imply carrying out the workshops in schools (which, as commented is complicated due to their tight schedules and time restrictions) or in social places, a good option for this kind of experience [33] the selection of the kids: was made by the therapist; she selected the ones that she thought needed more as they were quite unmotivated and had difficulties to get them involved in their activities. This is why we are optimistic when trying to extrapolate the results to other participants with ADHD.

About the *characteristics* of the kids, all of them had been diagnosed with ADHD but also had other disorders (dyslexia, Asperger). This makes it necessary to be prudent with the results and their relationship with ADHD, but it just reflects reality: ADHD is a common neuro-developmental disorder that is accompanied by several comorbid conditions [34]. Comorbidity of ADHD and reading disorder (RD) is frequent [35]. Autism Spectrum Disorder (ASD) and ADHD have frequently been identified as having strong connections: ASD and ADHD "co-occurrence" studies yielded estimates ranging from a low of 37% to a high of 85% in clinic samples [36].

Concerning the *gender* imbalance, we note that only one girl participated in the workshop. As already noted, recruitment was made by the therapist among the children attending the association. Nevertheless, the small number of girls shows the reality: research has consistently shown that boys are more likely to be diagnosed and treated for ADHD-related symptoms than girls [37]. Male-to-female ratios of ADHD diagnosis range from 2:1 to 10:1, with higher male-to-female ratios found in clinical vs. population-based samples. Research on gender differences suggests that girls may be misdiagnosed due to differences in the expression of the disorder between boys and girls. The DSM-V diagnostic criteria are fixed and categorical, independent of age and gender and were drawn from male-dominated samples. Moreover, the manifestations of ADHD are certainly different in a boy than in a girl [38]: girls with ADHD tend to have more inattention than hyperactivity, so they manifest less problematic behaviors and learning difficulties than boys. Several studies show fewer referrals to specialists for girls than for boys. We have to be aware that many girls with ADHD are likely to remain unidentified and untreated, with implications for long-term social, educational, and mental health outcomes [38]. From that point of view, it is essential to reach girls with ADHD so that our studies do not perpetuate this gender-imbalanced situation.

5 Conclusions

Despite the prevalence of ADHD, specific activities, recommendations, games, or co-design and participatory experiences for children with ADHD are lacking in the human–computer interaction literature. Like other neurodiverse children, ADHD kids also have strengths and may feel comfortable in participatory teams if their rhythms and characteristics are considered. Activities different from academic and therapeutic ones can become strongly motivating events for them. The possibility of getting results and showing them to their friends and families helps them strengthen their competence. Besides, co-design activities help them develop soft skills, such as social and creative capabilities.

We can answer R.Q.1 regarding the principles and strategies appropriate to design co-creation activities with children with ADHD, through the proposal of adapting the D4D framework to children with ADHD. In this paper, we have proposed specific recommendations and activities showing how to promote soft skills in children with ADHD through co-design.

Regarding R.Q.2 as to what soft skills are developed by children with ADHD in a co-creation experience adapted to their needs, we have observed through the PTD checklist six positive behaviors acquired during the co-design sessions. This observation shows that the co-creation design experience has promoted soft skills such as communication, collaboration, and creativity.

The co-creation experience may impact other tasks and contexts, as remarked by the children's families during our study. Nevertheless, as commented in the reflections, the experience should be replicated with more time and children to make further progress. Besides, it would also be interesting to compare the acceptance by the children's ADHD mates of the activities they designed with those designed by their therapists. In the future, it would be interesting to open the experience not only to other kids but also to their families in an intergenerational activity that would open the door to work on social skills in intergenerational teams.

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Declarations

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Institutional review board statement The study was conducted in accordance with the Declaration of Helsinki.

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