A Web serious game for children with attentive disorders: design and experiences from two trials

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Abstract

Cognitive developmental disorders are common in children and can affect various abilities. Attention Deficit/Hyperactivity Disorder (ADHD) is the most prevalent childhood psychiatric condition. This work presents PlayToPickUp, a serious game that aims to stimulate children in relevant cognitive domains (attention, planning tasks and error monitoring).

A multidisciplinary team of experts and caregivers coming from two different centres that support therapeutic activities with such children participated from the beginning to the design of the game. Depending on the characteristics and abilities of the player, the therapist can customise the game to provide training that best fits the skills and the needs of the child while maintaining the player's motivation.

After its development the game was used over two months "in the wild", by children recruited by the two centres. In one case the children played with it within the regular activities offered by the training centre. In the other one, the parents of the children were instructed by caregivers to have the children play the game at home.

In the paper we describe the experience gathered from such two studies run in parallel, discussing the aspects that worked better and those that represented difficulties, and the lesson learnt for future studies.

Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is the most common childhood psychiatric disorder. Among children, it has a worldwide prevalence of around 5% (Polanczyk et al., 2014), and its symptoms also continue into adulthood in up to half of diagnosed cases (Caye et al., 2016). There are multiple genetic and environmental risk factors that in various combinations can cause ADHD. A typical symptom of ADHD is a continuous pattern of lack of attention and/or hyperactivity/impulsiveness that interferes with functioning and also development. In particular, ADHD can be divided into subtypes—children just with attention problems, those with impulse control and hyperactivity issues, and a group with a combination of the two. Those suffering from ADHD often deviate from their tasks, lack perseverance, have difficulties in maintaining concentration, and tend to be disorganised in their activities.

Front-line treatments for ADHD include pharmacological and non-pharmacological interventions: however, while helping with symptoms, they do not cure ADHD. Pharmacological treatments have limited efficacy and may have serious side effects; in addition, improvements revert if medication is ceased. Among non-pharmacological interventions, Cognitive-Behavioural Therapy (CBT) is often used to improve control of attention and impulsivity, and to enhance self-regulation skills (Froehlich et al., 2002). Behavioural treatments for ADHD differ according to the age of the patient. For children, parents are trained to improve their method of disciplining and interacting with them; for adolescents and adults, therapy helps patients improve their own organisational skills. However, in effective CBT, patients must have several face-to-face sessions with a therapist specialised in ADHD, which may imply high costs and major time commitments. In addition, sometimes access to such services can be especially complex due to distance/displacement, or mobility issues. Finally, traditional rehabilitation exercises often require repetitive activities, which significantly challenge the usually very limited attention span of children with ADHD. Thus, there has been increasing attention to novel approaches to improve ADHD management. Digital interventions appear promising, as they can offer facilitated access and limited side effects, while providing targeted treatment options for improving cognitive functions of the target population. Recently, there has been a growing interest in how children with ADHD can use technology to improve their wellbeing, which is also reflected in the number of research contributions focused on ADHD over the last years. Cibrian et al. (2022a) show that the pieces of work focusing on ADHD and published in ACM and IEEE from 2004 to 2019 experienced an annual average growth rate of 30%, with most publications concentrated in the last five years (2015-2019).

Over the years, many digital solutions have been developed to address issues and requirements of children with ADHD, supporting different needs (i.e. diagnosing vs. treating), aimed at different goals (i.e. addressing inattention, impulsivity, working memory, executive functions, emotion regulation), and using a wide set of technologies, ranging from video games (Peñuelas-Calvo et al., 2022), to solutions based on PC (Butt et al., 2020), mobile devices (Jácome et al., 2019), web applications, AR (Avila-Pesantez et al., 2018), VR (Bernardelli et al., 2021), tangible interfaces (Cerezo et al. 2015; Spitale et al., 2019), wearables, to robots and also BCI/neurofeedback, sometimes even combined with each other.

In this regard, digital **Serious Games** offer an interesting opportunity for improving ADHD-related issues, as they are meant not only to entertain but also to educate. In (Kokol et al., 2020) there is an analysis of serious games for children with developmental disabilities, including ADHD. Although serious games share some technology with standard video games, they have completely different objectives and uses. In serious games, the objectives, content, skills and competences to develop are well defined without neglecting the aesthetic, narrative and technical resources of video games that encourage engagement and playability (Starks, 2014). One advantage of serious games is that they often offer different levels of play according to the severity of disorders, thus providing personalised support, which in turn also tries to overcome the limited available resources and facilities of traditional rehabilitation approaches. Another advantage of serious games for ADHD is that the computerization of tasks is a feature that has shown to increase ADHD children's interest and motivation, as it typically includes clear goals and objectives, highlights important information, and provides immediate feedback regarding response accuracy, all with a game-like format. Parents, teachers, and clinicians have reported that children with ADHD, when playing a computer game, can sustain attention and concentrate for longer periods of time, and behave less impulsively. Moreover, it is known that ADHD children show great sensitivity to reinforcement and rewards: since reinforcement is highly associated with motivation, adding some incentives to a potentially boring task (as it can happen in serious games) may help children with ADHD optimise their motivation and thereby improve adherence to the proposed treatment. Finally, a gaming format can use multiple sensory modalities and provides frequent, immediate feedback about accuracy of performance (via graphics, sounds, and scoring). It often includes animated characters, colourful interactive environments, and player advancement through levels, all factors that are known to be motivating for children, including those with ADHD. However, introducing game elements may distract children from the main aim of the task, so adequate design should be followed when developing such games.

With reference to serious games targeting ADHD children, the use of web-based technology can be beneficial in that it facilitates remote treatment and support for them, thanks to its ubiquity and easy access. Indeed, web-based interventions can be accessed from everywhere, can be deployed in multiple contexts (e.g. school, home, rehabilitation services), and facilitate equality in training opportunities. In spite of this, not many web-based solutions have been developed for children with ADHD till now (some examples are in Schuck et al., 2016; Bul et al., 2015). In addition, often such solutions are tested just in controlled environments i.e. laboratories (Stefanidi et al., 2022), where it is not possible to have a fully realistic interaction and experience. Finally, even though involving key stakeholders (e.g. caregivers) in the design of solutions for ADHD children should reasonably increase their adoption, not many approaches have done this: thus, contributions in this regard are highly needed.

In this paper, we describe the experience that we gathered from two trials run in parallel in two different settings, reporting the aspects that worked well and those that presented difficulties. This can be interesting for future real-life trials involving children with attentive diseases. The trials involved the use of the PlayToPickUp game, a web-based game which primarily targets ADHD children, and secondarily their main caregivers, by providing support for training ADHD children on cognitive areas such as sustained and divided/selective attention, and error monitoring. The game has various levels (and sub-levels) of difficulties that change automatically as the game proceeds. Multimodal feedback is provided to the child at the end of each sub-level in order to reward goal attainment. Different scenarios have been implemented to stimulate children's motivation toward the game and avoid repetition. Also, operators/caregivers can customise the game on behalf of the children according to their skills and abilities. The game has been developed as a web-based solution because it is suitable for use in different contexts, it has been designed in a participatory manner and deployed in two different centres in collaboration with different groups of caregivers. One of the two groups of children involved (one for each centre) used the game mainly at home, the other one used it during the activities carried out in a training centre.

In conducting the study two research approaches have been considered when designing a solution for better supporting ADHD children in the real world: research through design and grounded design. On the one hand, research through design (Zimmermann et al., 2007) stresses that the design artefacts created should facilitate the transfer of knowledge produced to community practice, potentially increasing the likelihood that this knowledge will move into products in the world. On the other hand, grounded design (Stevens et al., 2018) emphasises the importance of a research paradigm that is both design-centred and practice-oriented, also arguing that the quality of IT design is finally evaluated in its effectiveness in dealing with socially relevant problems.

The article is structured in the following manner: after introducing the work in this section, an analysis of the state of the art is presented in Section 2. Then (Section 3), the requirements that were identified are described. Section 4 presents the design of the serious game, describing how the requirements have been incorporated in the solution. In Section 5 and 6 the two trials conducted are described, also discussing some lessons learnt from this experience, which can be beneficial for future studies involving this target population. Finally, some concluding remarks are provided.

Related Work

Especially in the last decade, growing research attention has focused on people with special needs (e.g. Cena et al., 2021) and more specifically on the subgroup of children (Baykal et al., 2020). However, while a plethora of research in HCI and Child-Computer Interaction has addressed neuro-divergent populations in general or, alternatively, specific neurodevelopmental disorders (e.g. Autism Spectrum Disorder), the amount of research on ADHD is limited in comparison, even though the topic has been gaining increasing attention because ADHD is one of the most prevalent impairments among children. This need is further highlighted by Mack et al. (2021), who pointed out that accessibility research highly focuses on visual impairments (almost half of papers), while cognitive disorders (under which ADHD is located), account for less than 10%.

A recent literature review focusing on HCI contributions targeting children with ADHD (Stefanidi et al., 2022) offers interesting results on existing contributions in this area. First, the authors found that the majority of HCI contributions are systems addressing ADHD-related symptoms. Regarding the context in which the solutions are deployed, most papers do not specify them, but rather the ‘situation’ (e.g. the Chillfish breathing game should be used in any context in which the need to support relaxation occurs, see Sonne et al., 2016b). Out of the 27 papers analysed, 13 do not have a specified context of use, while two papers mention use in multiple contexts. Other identified contexts of use for solutions supporting children with ADHD are home (7/27), school/classroom (5/27) and online learning environments (1/27). The most commonly occurring situations of use include (i) self-regulation, e.g. with a focus on mood, reflection, and emotion (4/27), (ii) learning (e.g. mathematics) (3/27), and (iii) the execution of morning routines (3/27). Moreover, they found that only a few systems considered additional stakeholders (i.e. parents or caregivers) beyond children with ADHD in the design, development and user study phases of the proposed system. Also, the majority of the papers in the authors' corpus conducted one or more user studies (20/27): the most common methods are conducting lab studies (10/27), using post-experience interviews (8/27), eliciting user requirements (6/27), and performing field studies (6/27). One article reported utilising brainstorming techniques, and another reported creating personas and scenarios. Over 50% of participants in the lab studies reported are either experts, adults without ADHD, or children without ADHD, while the most commonly used method involving children with ADHD are post-experience interviews. Cerezo et al. (2019) highlight that often works targeting this group of children adopt observational or informal methods of evaluation to avoid disturbing children while they are using the system.

In (Cibrian et al., 2022a) the authors made a review of games for supporting self-regulation in children with ADHD. Even though they focused on an aspect (namely: self-regulation) not directly addressed by our work, they made an interesting analysis that provides a good overview of aspects covered by several ADHD-related contributions. In particular, they found that most projects used mobile technology (29%) or sensors (38%) to deliver interventions and/or gather data from children. Interventions were also delivered in the form of serious games (29%), robots (22%), virtual or augmented reality (13%), and computer software and the web (12%). Also, they found that most interventions were targeted for use in schools (45%) or homes (16%). Only a few were targeted or tested in a clinic setting (6%). The rest did not have a specific context, or they were too novel or complicated to deploy in the field and were therefore only tested in the research lab (42%). Most studies described the design or development of the tools (58%). The remaining papers reported evaluation studies using single case study methods (29%), lab studies (22%), deployment studies (19%), and a small number of pilot randomized controlled trials (RCT) (12%). While for web-based interventions they found that for the most part they targeted young adults, they found that serious games were mainly delivered through mobile technology (22%), personal computers (22%), sensors (22%), and robots (11%). Their topics varied, including 33% supporting children with school activities, 11% designed to be played at home or at the clinic, with the rest either being tested only in the lab or not committing to a place of use. Empirical testing sometimes included a lab (33%), deployment (11%), or case studies (11%).

Some authors noted that there are specific difficulties connected with the design and the evaluation of solutions for ADHD people. In (Powell et al., 2018) the authors highlight that there are a number of reasons why evaluating a complex intervention with the ADHD population could be challenging. To start, no ADHD diagnosis is the same. Also, ADHD is a highly comorbid condition with a large number of potential-related difficulties (at least 65% of children and young people diagnosed with

ADHD have a comorbid condition), thus participant groups involved in evaluations could not be representative of the wider ADHD population. Furthermore, the extent to which each individual is impaired by ADHD symptoms and related difficulties is also highly variable. Finally, it can be difficult to compare accurately outcomes across different studies as there is a wide variety of measures assessing ADHD-related difficulties. Cibrian et al. (2022b) highlighted that developing a solution for ADHD people can be especially difficult due to some 'interdisciplinary tensions' that can occur between design and computing on the one hand (which includes computer and information sciences, HCI, and related fields) and clinical field (which includes medical and psychological fields). Indeed, on the one hand, the "gold standard" to evaluate a system in a clinical field is represented by Randomised Controlled Trials (RCT), whose inclusion and exclusion criteria typically require participants to exhibit clinically significant symptoms of ADHD, and also require robust and well-diagnosed samples of at least 50 to 100 participants. Given that, RCTs tend to include commercially available applications and devices, and use standardised assessment with well-established validity and high reliability to assess outcomes. On the other hand, in HCI and related fields, a formative evaluation to test the usability, usefulness, acceptability, and user experience can be conducted even with a small number of participants, and sometimes "in-the-wild". However, the inclusion and exclusion criteria, despite often being as strict as clinical fields, are frequently not well-described in publications; formal diagnostic assessment is often not conducted or required for participation in these studies. These differences in approaches draw out clear tensions in digital health interventions. On the one hand, in any given research study, a focus on adoption and usability will identify approaches that end users would engage in, but may not provide as much evidence for efficacy. On the other hand, a focus on clinically verified approaches still requires that participants need to use the tools for this purpose, and they will have either been required or incentivized to do so as part of the research study. It is extremely difficult in a single research study ‒Cibrian et al. (2022b) conclude‒ to measure both whether and how people will use the tool and its effects when used properly. In this study, we have also collected quantitative data about the use of games in the two different settings considered, since we are interested in identifying the aspects that worked better when the web-based game for supporting ADHD children was deployed in real settings.

Cerezo et al. (2019) highlighted that most of the proposed digital solutions for helping ADHD children mainly aim to improve their cognitive skills (e.g. ACTIVATE™, Play Attention, ADDitude, SitCap), or help them in their daily routines (e.g. Sonne et al., 2016; Weisberg et al., 2014).

Focusing on those realised as serious games, some mobile and PC-based applications have been proposed. In particular, EmoGalaxy (Hakimirad et al., 2019) is a serious game available on Android phones and tablets, which aims to support children's emotional and social skills, by allowing players to travel virtually among four planes, referring to four emotions (happiness, sadness, fear, and anger). Each plane has a game where children can recognize, express, or regulate their emotions. A test was conducted with 20 children with ADHD, aged between 7 and 12 years, assigned to either the experimental or the control group with no intervention in a lab setting. The pilot study showed that EmoGalaxy was effective in improving children's social skills. EndeavorRx (https://www.endeavorrx.com/) is a commercial mobile app intended for use with other therapies (including medications and behavioural therapy). It targets children 8-12 years old, having specific types of ADHD. Mysterious Bones (Rijo et al., 2015) is a game developed in Portuguese for children 6–8 years old, aiming to support the development of competencies such as working memory and executive functions in clinics. So, while it has been shown that PC-based and mobile serious games could be effective in supporting improvements of cognitive skills for children with ADHD, the Web has been exploited only in a limited manner up to now in this field, in spite of having several advantages. Indeed, web-based solutions can be accessed from everywhere, thereby they can promote availability and convenience; they can use a variety of different devices (e.g. desktop, smartphone, tablets); they can support use across different contexts, and, thanks to their ubiquity, they can help individuals taking care of their training at their own pace. In this regard, a relevant work is Train Brain (Fontana et al., 2017), a web-based serious game for selective attention training, based on storing images in one or more contexts using coloured circles. It is divided into three categories of games, each category has three difficulty levels (easy, medium and hard), each level has five phases to be travelled. However, the player has also to manually select the difficulty level: thus, a limitation is that users have to control the training without specific guidance on their progression and training needs. Another work is Plan-It Commander (Bul et al., 2015), a Web-based serious game for children aged 8 to 12 years who have ADHD. The game teaches i) time management, ii) planning and organising, and iii) prosocial skills. The game dynamic consists of three mini-games: A *Labyrinth* to learn how to manage time, *Explorobot* to learn planning, and *Space Travel Trainer* to learn prosocial behaviour. In Bul et al. (2016) the authors report a 20-week Random Controlled Trial with 182 children (aged 8 to 10 years) with ADHD, to evaluate the Plan-it Commander game. It came out that Plan-it Commander is an effective adjunctive (i.e. adjunct to the usual treatment) behavioural intervention for children with ADHD in that it improves functional outcomes of time management as well as working memory and social responsibility. It has also shown that it stimulates young children to manage their impairments by offering an easy and accessible home treatment intervention. However, not many other web-based solutions have appeared to support children with ADHD.

To sum up, serious games addressing ADHD-related issues have exploited the web only in a limited manner so far, in spite of its potentiality in promoting ubiquity and convenience. Furthermore, in the past the design process of these digital solutions was not always able to involve relevant stakeholders to improve adoption. Also, not many solutions aiming to support children with ADHD reached the maturity of being evaluated outside of a lab environment, i.e. in real contexts, also due to the difficulties typically found when working with this target population. Our contribution is aiming to help in filling these gaps.

The Requirements of the Game

To identify the requirements that PlayToPickUp should satisfy, we carried out a review of relevant work in the area, including those summarised in the previous section. In addition to them, an article discussing relevant requirements for interactive games targeting ADHD children is Cerezo et al. (2019), where the authors not only propose a set of guidelines for interactive games targeting ADHD children, but they also compare their recommendations to those suggested by other authors.

Beyond this analysis of the state of the art, we also carried out some semi-structured interviews, empathy maps and personas (Angileri and Paternò, 2022). We interviewed three psychologists and a support teacher to understand children's attitude towards serious games, and the characteristics that such games should have, to be useful for them. To understand personality, motivation, needs, difficulties, and relationships with technology we created personas and empathy maps. It came out that children with ADHD feel not very competent, and they perceive to be inadequate in various situations of daily life. They also find it difficult to learn from their mistakes because of anomalous error monitoring processes that hamper them in adequately adjusting their behaviour (Groen et al., 2008). Furthermore, they have difficulty in focusing on objectives, keeping on endurance, and being alert for a long time, as they often shift focus between different topics of interest. In the following, we discuss the requirements finally identified.

R1. The game should stimulate sustained and selective attention. Some pieces of work (Bul et al., 2016; Jácome et al., 2019) emphasised the need of properly stimulating the attentional component in ADHD people, also analysed in its composing sub-processes (i.e. *sustained attention*: the ability to keep focus on a subject or activity during a long period of time; *selective attention*: the ability to stay focused on relevant stimuli and remove possible distractions in the environment, non-relevant for the current task). The need of addressing this requirement is also emphasised in (Cerezo et al., 2019), when the authors state that "Games should enhance selective attention". In our solution we judged relevant to have tasks addressing both sustained and selective attention: in particular, children had to select relevant stimuli from irrelevant ones (target items vs. distractors) over a game that in total lasts fifteen minutes (if all the levels are completed).

R2. Its exercises should target activities that are problematic for the ADHD children. To have more practical impact, and to help ADHD children improve in activities of daily life, we deemed it useful to target activities in which they encounter more difficulties, with also the ultimate goal of a better social integration. Children with ADHD often have difficulties with executive functions, which becomes evident in their difficulties to complete tasks that require planning and organisation. As it is often challenging for people with ADHD to stay organised and on task, one situation in which we judged relevant to help these people is better structuring their day, in particular some typical activities/routines. The goal of creating a daily routine is to turn desired behaviours into habits, so that these people feel like such routines are a natural part of their day, rather than a chore. For ADHD children, a part of a typical daily routine is the organisation of the material to put in the backpack of the school. This includes selecting the right items to put (thus avoiding those that are not useful or relevant) and monitor the process afterwards (i.e. to check if any wrong object has been absently included). Thus, in our work we selected the preparation of the school backpack as one of the game scenarios in which these children can practise and thereby hopefully improve over time in their real life. Additional daily activities that target people should improve were addressed as further game scenarios in the field of emotion and money management. These scenarios came up as a suggestion from one of the training centres involved in the test, as such two areas are already addressed in the activities carried out with these children in the training centre as part of their usual training programs. Thus, there was the idea that having a game that also addresses such domains can result in better integration of activities and overall improved training efficacy.

R3. The game should support some rewards for strengthening self-esteem. Children with ADHD are very sensitive to reward. As also highlighted in (Crepaldi et al., 2020) one of the key executive functions affected by ADHD is impulsivity, which occurs in actions that are taken without reflection. This is because such a target population typically has a desire for immediate reward, or an inability to delay gratification/rewards (Martinez et al., 2016). Considering the pronounced sensibility to positive and negative reinforcement that such people have, previous work has highlighted (see e.g. Luman et al., 2005) that reinforcement strategies, including reward, response cost/punishment, feedback, and their combinations, have a positive impact on task performance and motivation in both children with and without ADHD, but more prominently in children with ADHD. The need of addressing this requirement is also emphasised in (Cerezo et al., 2019), when the authors state that "Positive and encouraging feedback must always be given". In our work we considered this requirement, putting particular attention to always provide *positive* reinforcement to target users.

R4. The game should support error monitoring. Error monitoring is another important cognitive control function that allows individuals to adapt to the changing demands of their environment and regulate their behaviour. It is often conceptualised into two main components: error detection and post-error behaviour (Dhar & Pourtois, 2011). Appropriate changes in post-error behaviour require accurate error detection and appropriate adjustments to avoid future errors. Several pieces of work in the literature report insufficient or impaired error monitoring in individuals with ADHD, who appear to be limited in detecting errors thereby also slowing down in preventing further mistakes (Christensen and Lundwall., 2018). Indeed, oftentimes ADHD people tend to respond in an immediate, impulsive manner: thus, it is important for them to have the possibility, afterwards, to reflect upon the situation and check if the result of their behaviour is the expected one and, if it is not the case, have the possibility to correct their errors. Therefore, activities that allow ADHD children to practise monitoring and correction of the outcomes of their own behaviour should be pursued. In our game we supported this activity by foreseeing a game step in which the child, after having collected some items, has also the possibility to revise them and, if needed, remove those deemed non-relevant for supporting the current task.

R5. The game should support the possibility of personalising the proposed exercises. After interviewing the psychologists, we understood that the personalization of exercises represents a fundamental requirement for therapists. While some solutions just allow for modifying some parameters of games, personalisation should allow the therapists to tune the difficulty of the exercise according to the skills of children, after careful observation of their abilities. The need of addressing this requirement is also emphasised in (Cerezo et al., 2019), when the authors state that "the game should be totally controllable by the educator" and that "the level of difficulty of the game should be adaptable". In our work, beyond the possibility to allow operators to configure the game according to the characteristics of children (i.e. the initial speed of the various objects to collect can be set by the operator), the level of difficulty of the game automatically increases as soon as the user progresses through the game.

The Design of the Game

One of the goals of the PlayToPickUp game is to help children suffering from ADHD with activities of their daily life (such as preparing the school backpack), by mainly stimulating sustained and selective attention, and error monitoring. Concretely, the goal of the game is to help a character, represented as a small robot, to collect some objects relevant for the current task (e.g. "collect all the school objects"), while avoiding the irrelevant ones (distractors) that appear as well in the game. In order to do it, the user interacts with the game through touch or mouse to make the character move. The game has been implemented as a responsive web-based application, thus it can be accessed from any browser-enabled device (tablet, smartphone, PC).

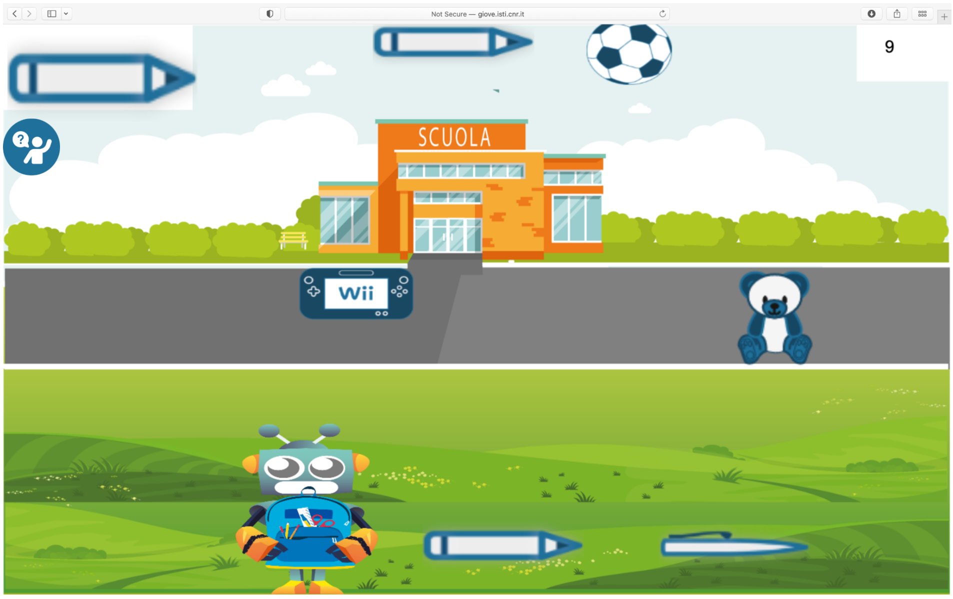


Fig.1 The first level of the PlayToPickUp game

Figure 1 shows the first level of the game. The robot is shown in the bottom part of the screen. On the top-left side, the type of target elements to collect is shown (in the first level it is a specific object: a blue pencil); just under it, a help button is shown: if the children do not remember the instructions of the game, they can select that button which pauses the game while the instructions are given by a speech synthesiser. On the top-right side the current score is visualised: as soon as the user collects some correct objects, the score is updated accordingly. In this level, the elements to collect appear as falling down from the top part of the screen, falling down along two parallel lanes.

The game has four difficulty levels that automatically increase as the game progresses. In particular, the game changes in the following way through the levels (we refer to the school scenario here):

- **First level.** In this level the user has to collect all the elements of a specific type (e.g. a blue pencil). This level is the simplest one because the task required is to collect elements of just one specific type (i.e. it is a “single request” task). The elements that appear in this level (both target and non-target ones) appear in a random manner, thus they do not follow any pattern.
- **Second level**. In this level children are asked to collect school-related objects. Thus, the request does not involve a single object, but a class of objects. Differently from the previous level, the objects that appear in this level follow a specific pattern: i) first, a pair of objects in which one is a Target (T) and the other one is a non-target (NT) element; ii) then, a pair of items in which both objects are target ones; iii) lastly, a pair of objects in which both are non-target ones. This has been done to allow the user to see first both types of objects, then to challenge them in collecting two target ones falling simultaneously, then two distractors appear.
- **Third level**. In this level children have to collect all the objects that are *not* related to school. The set of items that are shown at this level follow the same pattern as in the previous level (the second one).
- **Fourth level.** Since children with ADHD struggle in real life to manage a double request, to increase the level of task difficulty, a double request is made at this level: the children are asked to collect two specific (school-related) objects (e.g.: a red pen and a blue pencil). Such two objects are shown in the top-left part of the screen. Moreover, there is no specific pattern followed by target and non-target objects appearing in this level.

The type of *distracting* objects depends on the level: they can be school-related elements (e.g. a pen, a pencil, an eraser, a ruler) yet different from the ones requested for the current task: this for instance occurs at the first level. Alternatively, they can be non-school-related, daily life items (e.g. a ball, a Wii console, a teddy bear), as it occurs i.e. in the second level.

Each level has in turn three sublevels that differ according to the direction along which the items move (vertical vs. horizontal), and also according to the initial position from where objects appear at the beginning of each sublevel. Thus, they can move along a top-to-bottom, a left-to-right, and a right-to-left direction, depending on the current sub-level and also game configuration.

- **First sub-level.** In this sub-level the dynamic objects move vertically, and their initial positions are always the same (in the top part of the screen).

- **Second sub-level.** In this case the objects move horizontally towards right or left (depending on user's settings), thus the items appear initially in the leftmost (or the rightmost) side of the screen. Their initial positions are always the same.
- **Third sub-level.** In this case the objects move vertically. However, differently from the previous sublevels, they have non-fixed initial positions, but randomly selected ones. This was done to increase the difficulty of the task (as the children cannot foresee from where the items will appear).

In the following table we summarise the aspects that characterise the various sublevels (and levels).

Level	Request and pattern of this level	Movement and positions	Sublevel
1	- **Single** request (1 single object) - **No pattern** followed by objects that are visualised	**Vertical** movement of the objects; **Fixed** initial positions	1
		Horizontal movement of the objects; **Fixed** initial positions	2
		Vertical movement of the objects; **Random** initial positions	3
2	- **Single** request (all school-related objects) - **Pattern** followed by the objects: **T-NT; T-T; NT-NT**	**Vertical** movement of the objects; **Fixed** initial positions	1
		Horizontal movement of the objects; **Fixed** initial positions	2
		Vertical movement of the objects; **Random** initial positions	3
3	- **Single** request (all non-school -related objects) - **Pattern** followed by the objects: **T-NT; T-T; NT-NT**	**Vertical** movement of the objects; **Fixed** initial positions	1
		Horizontal movement of the objects; **Fixed** initial positions	2
		Vertical movement of the objects; **Random** initial positions	3
4	- **Double** request (2 objects) - **No pattern** followed by the objects	**Vertical** movement of the objects; **Fixed** initial positions	1
		Horizontal movement of the objects; **Fixed** initial positions	2
		Vertical movement of the objects; **Random** initial positions	3

Table1: A summary of the characteristics of the various levels and sub-levels of the game

Figure 2 shows a screenshot of the first level of the game: the goal is collecting the target elements (i.e. those associated with 7 and 8 in Fig. 2), i.e. those identical to the target element shown in the top-left part of the screen (a blue pen in this case, see 5 in Figure 2). In the main part of the screen, coming down from the top, there are the elements (both distractors (see 1, 2, 3, 4) and targets: 7, 8) that fall down.

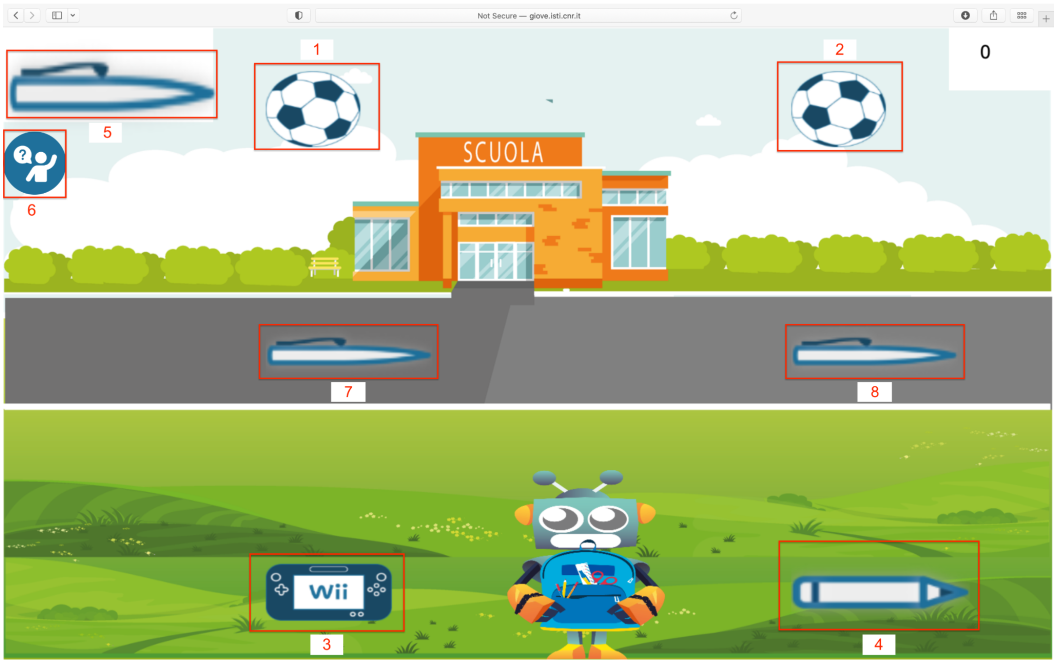


Figure 2: A screenshot of the school scenario, with various elements highlighted inside

After 75 seconds the first level ends and children can check possible errors that they might have made by dragging to the trash the elements they wrongly collected. Since one of the difficulties that children with ADHD have is planning actions, as well as monitoring -and possibly correcting- the mistakes made while reaching a specific goal, we implemented support for error monitoring and correction, so that the child can check the mistakes made and possibly correct them. In particular, at the end of each sub-level (regardless of whether the child collected or not any non-target element), all the objects (target and non-target) collected by the child are visualised, and the children can drag into a trashcan those they judge as non-target. Figure 3 shows the screen that the user visualises after having collected various items: in this case both target elements (the blue pen in this case) and distractor ones (for convenience, we highlight them in red in Figure 3) have been collected: the child has to identify the distractors and drag them to the trash can. A short sound is made to reward the user when all the distractor items reach the can.

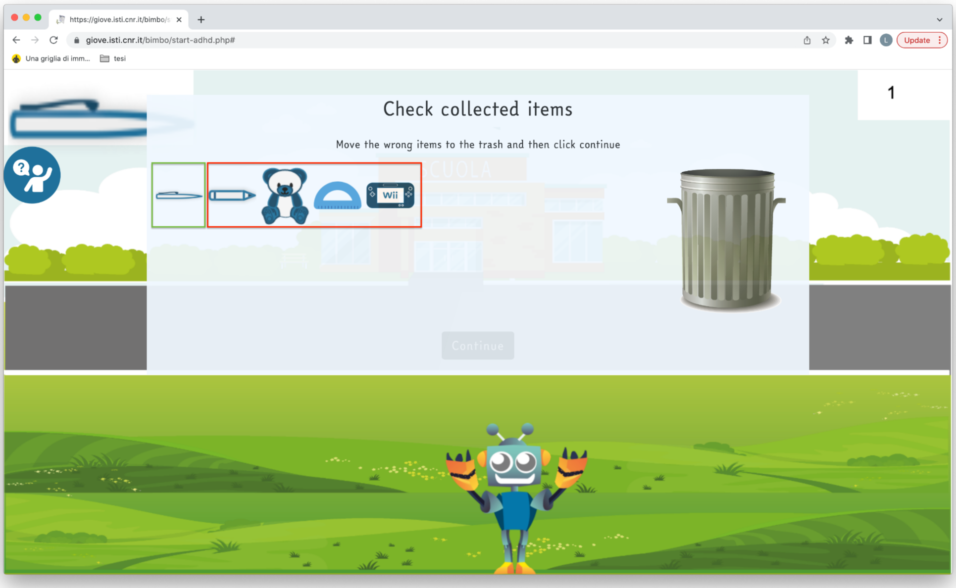


Figure 3: The window of the game for monitoring and correcting errors

PlayToPickUp also aims at stimulating sustained and selective attention. It has an overall duration of 15 minutes (if all levels are completed), as each sub-level requires 75 seconds, and there are 12 sub-levels. Since its target users (namely: children with ADHD) typically have a low degree of self-esteem, the game was designed to provide some rewards. In particular, the robot (which in the game is aimed to represent the child) transforms itself through the various levels by becoming more muscular and also provides short sounds to gratify the user at the end of each sub-level.

Customization of the Game

Caregivers and children have two different ways to access the application. While children access the web application to play the game, caregivers access a user interface that allows them to customise various aspects of the game on behalf of children, as it is shown in Figure 4.

- *Theme of the game*: using this menu, the operator can select the scenario to use in the game;
- *Speed-related aspects*: it is possible to customise the speed of the elements appearing in the game. The faster the objects appear, the greater attention the children must pay, the more challenging for them the game will be.
    - *Initial Speed*: this is the speed with which the objects to collect move at the beginning of the game (which means: in the first sublevel of the first level). Figure 4 shows the

part “Dynamic objects” | “Initial speed”. We established a range for the initial speed as [0.5-7], in which 0.5 is the lowest speed, while 7 is the highest one based on some initial preliminary tests. The possible increments in that range are 0.5.

    - *Speed Increment*: since during the game the speed will automatically increase by a specific increment, we also give operators the possibility to define this value as an additional parameter, to be configured according to the skills of the child (see in Figure 4 the part devoted to “Speed increase between levels”). The range of the speed increment is [0.5-7], in which 0.5 is the lowest increment, 7 is the highest one, and the possible increments in that range are 0.5.

- *Handedness*: we give the possibility to select the direction according to which the elements will move when their direction is horizontal. This was done to avoid, when using a touch-based mobile device, that if the users are left-handed, they might (partially) cover the screen with their hand if the objects appear from the left side of the screen.
- *Try the game.* This is not an actual parameter to set: it just allows the user to try the game by using the current parameters.

To give an idea of the number of items that appear in relation to the speed (and its increments) currently set in the game, we summarise the main aspects below:

- When the initial speed is set to 0.5 (minimum value) and the increment of the speed is set to 0.5, at the beginning of the game (namely: at level 1.1) 14 objects appear in the 75 seconds associated with the sublevel, while the last level of the game (level 4.3) shows 20 objects in the time slot. Thus, with these settings, every two sublevels there is an additional item that comes into the game (to make the game more difficult)
- When the initial speed is set to 7 (maximum) and the speed increment is set to 0.5, at the initial sublevel (level 1.1) 46 objects appear in that time slot, while in the last level (level 4.3) 52 objects will appear.

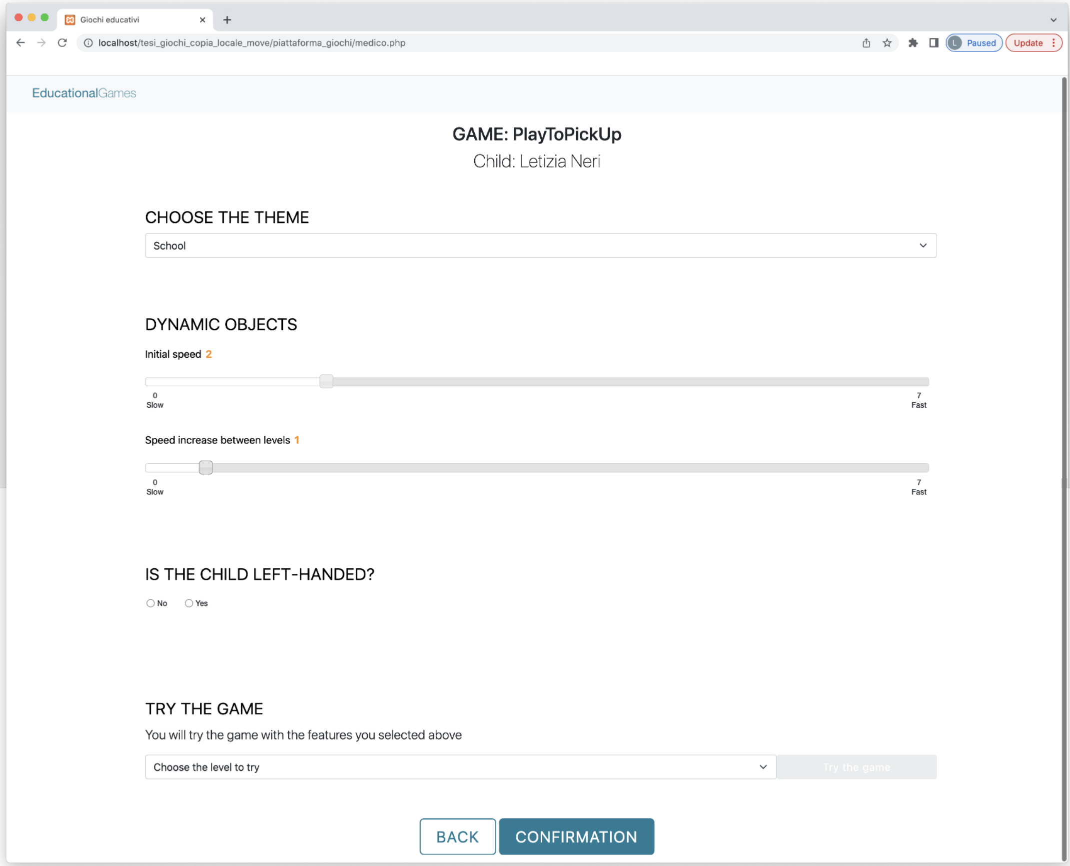


Figure 4: The window for configuring the game

The platform has also a back-end for storing data relating to children and their performance with the game, as recorded during user sessions. Therefore, based on the indications about some performance metrics that were provided to us by the psychologists, we decided to collect the following data for each subject at each sublevel: number of errors (number of wrong objects collected), speed (which can be customised by the operator based on the characteristics of the child), number of correct elements collected, date and time of the start of each sub-level.

The Trials

We conducted two trials in collaboration with two different organisations also providing support to children with cognitive disorders, to investigate whether this type of serious game can be adopted in real practice associated with supporting ADHD children.

Test Organization

The user trials went from February 2022 to April 2022. Before that, the families of the children received information regarding the aims of the research, and parents provided signed informed consent to have their children participate. In the informed consent, after providing some general information about the study and its goals, we also specified the conditions for i.e. the treatment, conservation, and access to the data that we were going to collect in the study. There was no financial or other compensation for being part of the study. Participants who agreed to take part in the study were reassured of the voluntary nature of their participation.

The trials have been carried out in collaboration with two different organisations. One organisation manages local public health (called "ASL" in Italy) in Livorno, Italy: the group involved provides psychological/psychotherapeutic services to children/young people in that area. In the other case, the organisation involved is a non-profit organisation (called "PAIM") providing various types of social and assistive services to several categories of users (i.e. children, adolescents, elderly) in Tuscany (we interacted with the group based in Pisa).

The children associated with ASL Livorno played the game autonomously, at home, while the others played it during ordinary therapy activities conducted by PAIM in one of their centres. Thus, in this case the interaction was managed by PAIM operators, who were responsible for integrating the interaction with the game within their training programme.

Four questionnaires were administered as part of the experiment:

- One questionnaire ("pre-test") was submitted to parents before the actual start. It was aimed at gathering socio-demographic information about parents and children, as well as information about children's (and parents') skills, use, and familiarity with some digital devices and applications
- The other three, "post-test" questionnaires were submitted after the use of the game: they intended to collect feedback about the use of the game during the test from different perspectives. In particular, they were directed at: i) *operators*, that is: those who guide the training; ii) *parents*: the parents of the children; and iii) *children* themselves.

  For the questionnaire directed to parents: it was filled in by the parents of the children involved in the ASL trial (as they had the opportunity to observe their sons while playing and then report their feedback) and by the operators of PAIM (since in this trial the children played the game during the activities carried out at their training centre). The parents of the children of the ASL trial were not required to fill it in as they could not see their children playing the game under their supervision.

The children questionnaire just included two questions, and it was arranged in such a way to have the children reply to them by simply selecting an emoticon among those expressing the following emotions: sad, bored, happy, excited (for the first question). For the second question the possible answers were: very easy, easy, sometimes easy and sometimes difficult, difficult, very difficult (in this case we used emoticons that expressed increasing levels of happiness or sadness depending on the level of ease.

All the questionnaires (especially the emoticons that we used for the children's questionnaire) were checked (and approved) by the psychologists before their use in the test: this was done to ensure that they were suitable for the children.

Finally, interviews were conducted with two parents (of the ASL trial) and four educators (2 PAIM, 2 ASL) who were asked some open questions (mainly selected from the questionnaires) aimed at further investigating their feelings and experience in the study (see Appendix 1 for the questions included in the various questionnaires).

Trial 1 (Home Participation)

Description of Participants and of the Test Settings/Logistics

In this trial the candidates were recruited by speech therapists and psychologists working in a local health organisation in Livorno (Tuscany), and supporting therapeutic activities with children having cognitive impairments. Once the children candidates were identified, their parents received informational letters from the therapists, allowing them to express informed consent on voluntary participation in the trial. In total, 33 parents were contacted by the therapists and informed about the goal of the study and they filled out the **pre-test questionnaire**. They were the parents of 33 children (26 males) whose average age was 7.8 years old (SD= 1.2). As for the familiarity of the children with the various devices, and their use:

- *Smartphone*: 14 children use the smartphone several times a day, 11 several times a week, 5 never, 3 once a week. In addition, 21 children out of 33 (corresponding to the 63,6% of the children) use the smartphone to play games (i.e. Roblox, Among Us), very few children (2 out of 33) use the smartphone to navigate the Internet (i.e. YouTube), 6 out of 33 use the smartphone to communicate (using WhatsApp, Messenger), 78% use the smartphone for watching cartoons (i.e. on Netflix, Disney++). One child uses the smartphone for accessing i.e. some didactical links.

- *Tablet*: 15 children use the tablet several times a week, 8 never, 5 children use several times a day, 5 once a week. 50% of the children use the tablet for playing games (i.e. educational games, Roblox, Tetris), nobody uses the tablet to navigate, just one child uses the tablet for communication; 20 children out of 33 use the tablet for watching videos/cartoons. Additional objectives for using the tablet were mentioned for two children: access to didactic links, learn a new language, use Google Classroom for the school, do some research and schoolwork
- *PC*: 13 children never use the PC, 8 once a month, 6 once a week, 4 several times a day, 2 several times a week. Only 7 children use the PC to play games, just one child uses the PC to navigate, one child uses the PC for communication, 7 out of 33 use the PC to watch video/cartoons. Additional goals for using the PC were associated with 12 children and connected to learning (i.e. learn a new language, attend online classes, help in doing schoolwork).

The second part of the pre-test questionnaire was dedicated to gathering information about the parents: 30 parents were females, 3 males. Their average age was 41.8 years old (SD=4.7). As for their education, 16 of them had high school, 7 had a secondary school level, 7 had a Master Degree, 3 had a three-year degree (i.e. Bachelor). As for their familiarity with various devices, and their use:

- *Smartphone*: all the parents use the smartphone several times per day. The smartphone is used by the parents for: entertainment (19 out of 33 replied yes, while the other do not use it for entertainment; among the comments we found TikTok app, games); work (14); to navigate (16); communication (30); online shopping (13)
- *Tablet*: 19 out of 33 parents never use the tablet, 5 use once a month, 4 use once a day, 3 several times a day, 2 once a week. The tablet is used by them for: entertainment (7 out of 33 replied yes, while the other do not use it for entertainment); work (2); to navigate (6); communication (2); online shopping (1)
- *PC*: 9 parents use the PC several times a day, 8 once a day, 7 never, 6 once a month, 3 once a week. The PC is used by them for: entertainment (2 out of 33 replied yes, while the other do not use it for entertainment); work (14); to navigate (11); communication (9); online shopping (4). Other objectives mentioned were all associated with learning tasks (i.e. for supporting children's learning)

However, it is worth noting that, in the end, the sample that was actually involved in this trial consisted of 17 children, as not all of the initial set participated in the test in the end: 16 had a diagnosis of ADHD, while one child had, beyond ADHD, also a comorbid condition of cognitive impairment. The age of the children ranged from 7 to 10 years with a mean age of 8.5 (SD=0.98).

In this trial, the children were asked to play the game a couple of times a week, and they played it at home over a period of twelve weeks. To access their game account from home, each child was given personal credentials (user id and password). The configuration of the game (i.e. setting the initial speed of the objects to collect) was done by the ASL therapists on behalf of children, according to their scores in the Erickson attention speed and concentration "3B" test (Di Nuovo, 2013). This test is meant to measure various components of concentration and attention, and involves visual recognition: the users have to press the spacebar on the keyboard as soon as they recognise a specific target element among other elements (all presented sequentially). Their performance was assessed by analysing their reaction time, which was then compared to normo-typical users' reference values (reported within the Erickson test itself) for both the mean time (M, which is 0.5 for normo-typical users) and the standard deviation (SD, which is 0.13 for normo-typical users). In particular, to assign the initial game speed according to the children's performance in the Erickson test, the ASL therapists proceeded in this way:

- They assigned the lowest speed (0.5) to two children who were not able to complete the Erickson test;
- The speed of 1 was assigned to children whose time needed for completing the Erickson test (t) was higher than the normo-typical mean time (M) plus twice a standard deviation (2SD) (that is: $t > M+2SD$, which means: $t > 0.5+0.26$, then $t > 0.76$);
- The speed of 1.5 was assigned to children whose time recorded in the Erickson test satisfied the following condition: $M+SD < t <= M+2SD$ (which means $0.63<t<=0.76$);
- The speed of 2 was assigned to children whose time recorded in the Erickson test satisfied the following condition: $M-SD <= t <= M+SD$ (which means $0.37<=t<=0.63$);
- The speed of 2.5 was assigned to children whose time needed to complete the Erickson test satisfied the following condition: $t < M-SD$ (which means $t<0.37$);

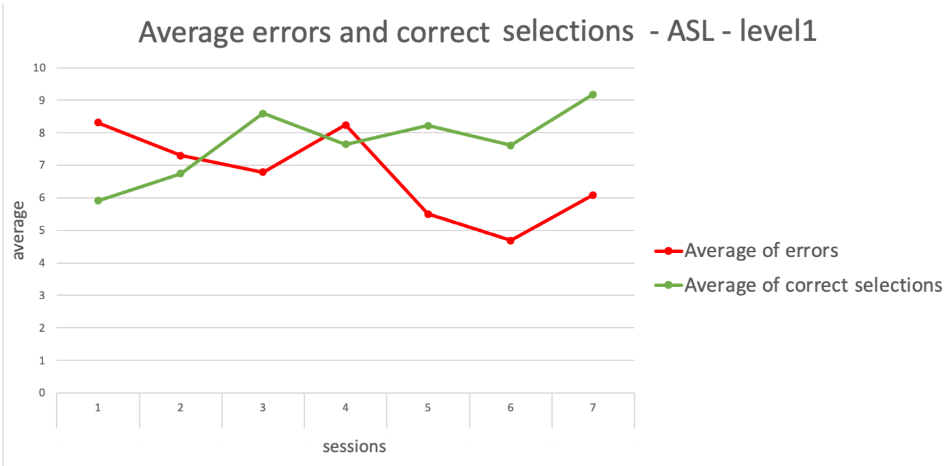
The rationale was to assign the lowest speed to the children who demonstrated the most difficulty doing the test (i.e. higher completion times). In the end, the initial speed was set for the various children in the range of [0.5- 2.5]; the most used speeds were 2.0 (assigned to eight children), 1.0 (five children) and 1.5 (five children). In all cases the increment of speed between sublevels was 0.5.

Results

Data on correct answers and errors

The children involved in this trial played in a varied manner with a minimum of 1 day and a maximum of 28 days. They generally used desktop and mobile platforms to play (the tablet was rarely used). Since after a while the children tended to play less, for the analysis we focused on those who did at least 7 sessions. For these children, we analysed the following metrics: errors made and score obtained: in the game, the score reflects the number of target items collected by the user. In particular, we considered the average of the correct selections and errors made, calculated for each level through the various sessions considered. As shown, the data of the first, second and third level highlight that errors tend overall to decrease while progressing through the levels, while the correct selections tend to increase over time.

However, the data associated with the fourth level show that both errors and corrected selections tend to increase: this was probably due to the high difficulty of the 4th level, in which a two-fold task was asked of the children.



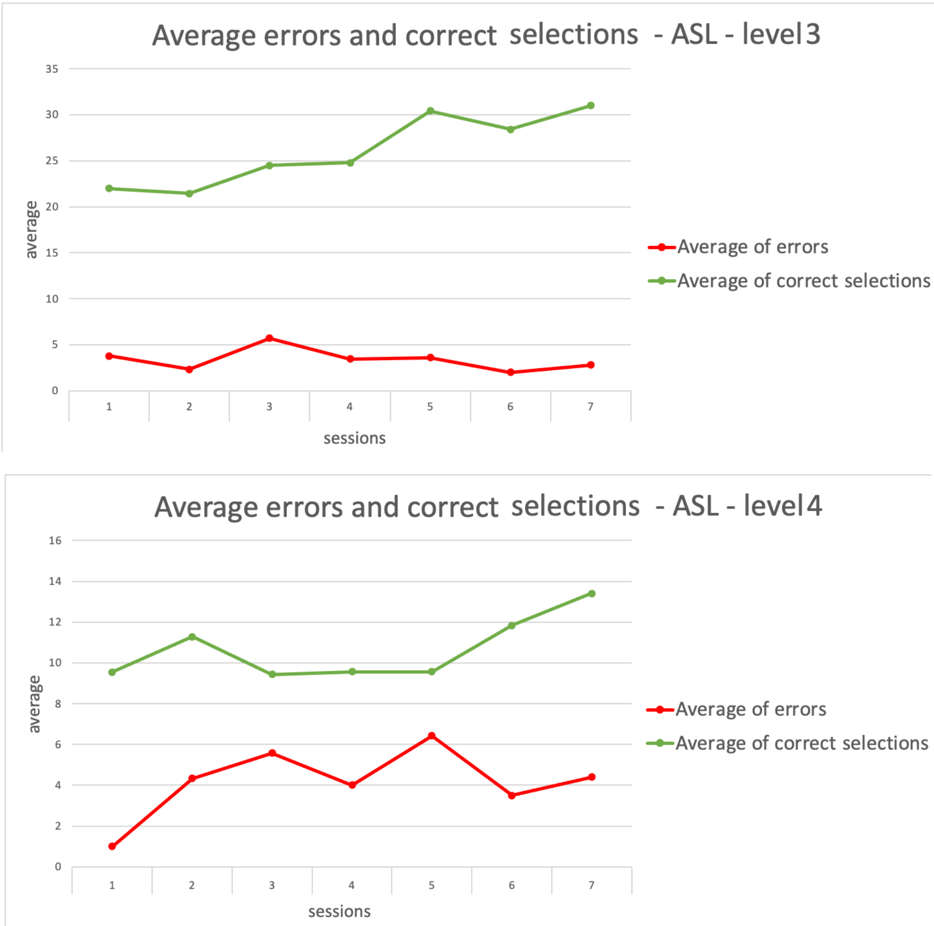


Fig. 5 Errors and corrected selection for each level (ASL trial)

Questionnaires

Questionnaires were developed for this study to assess satisfaction. Parents filled out questionnaires to measure their digital competence and that of their children (pre-test) and to measure their satisfaction with the game (post-test). At the end of the experiment, the operators also filled out questionnaires to report their feedback.

Children's Questionnaires

To the question asking how the child felt after playing the game, 7 replied feeling happy, 8 felt bored, 2 felt tired. The feedback about boredom was not particularly surprising, as children with ADHD tend to become bored more quickly than those without. In addition, the fact that they had to play at home during their spare time could have further accentuated the boredom, as the child could have devoted the same time to other activities they like more. Then, there was another question asking how easy it was for the child to play the game. For 10 children the game was very easy, for 5 it was easy, and for

2 children it was sometimes easy and sometimes difficult. Thus, overall, the game did not represent particular challenges for the children.

Parents' Questionnaires

Fifteen questionnaires were filled in by the parents of the children in the ASL trial. According to them, 14 children played the game at home, while just one played the game at the ASL centre, as part of her training activities.
When asked whether their children needed the support of another person to play, 8 parents replied that this situation occurred just for the initial accesses to the game, 5 replied that the children did not need any special help, one replied that his child needed it only when the PC froze, one parent replied that there was a need to be present all the time while the child played: actually, not for "operational" reasons (the child was able to play autonomously), rather for better motivating him to play.

When asked about the three most positive aspects of the game, the parents highlighted different aspects. The most recurrent ones were that the game was judged suitable for their children, and that it was easy to use. Other aspects mentioned were: the different levels of difficulty, the various scenarios (especially the school-related one), the fact that the game required some concentration/attention from the child, the fact that the game-playing required (as a side-effect) getting familiar with some devices (i.e. keyboard, mouse).

When asked about the aspects/features of the game that they did not like much, 9 parents reported that after a while the game might become a bit tedious, 3 reported that it was found a bit slow, 2 said that sometimes the game froze, 3 persons could not identify any negative aspects.
As for the question whether there was something they would like to add or modify in the game, 9 persons mentioned that they would like to have a more varied game (i.e. more scenarios, more objects to collect), 3 did not report anything, 2 mentioned increasing the speed, one mentioned the possibility to have some rewards also at the end of each session.

Then, there was a question about whether the parents might have recognised any specific effect in the child's life, which, to some extent, could be attributed to this training (e.g. some improvement in preparing the knapsack): only two parents replied to have seen some improvements in their child's organising the school backpack.

Operators' Questionnaires

Three operators (all females, average age= 41, standard deviation=5) answered this questionnaire. They were 2 psychologists and 1 speech therapist. When they had to indicate the three aspects they liked most in the game, they mentioned the personalization options, and the flexibility allowed by the game thanks to the fact that it can be played anytime/anywhere and therefore is suitable for being played at home, the duration of the game (which allows for improving the domain of sustained attention), and also the fact that the game forces the user to think about the answers. For instance, the task in which the child has to collect the non-school related objects is just after the task requiring collecting all the school-related objects, thereby the child has to inhibit the previous response to properly solve the current task.

As for any negative aspects of the game: it was found to be a bit repetitive, and the number of positive reinforcements was limited. In addition, educators mentioned that there were just a few changes of scenarios, and that the risk of performing incorrect actions was judged a bit too high.

When asked whether they would like to change/add anything in the game they mentioned the possibility of gathering some objects that could have some more motivational effects on the child (e.g. after collecting specific objects some new games will be unlocked).

As for the question whether they found the game as useful to improve/optimise their training activity with children, all of them replied positively. The motivations mentioned were: the possibility to play at home, and the fact that serious games are useful activities for stimulating executive functions in an entertaining manner.

Then, there was a question asking in which context/environment this game should be preferably used: two operators replied that all the environments can be suitable, to improve the generalisation of the various abilities by children. The remaining operator preferred during the therapy due to the availability of a specialised person that can support the child during the game.

Finally, there was a question asking the operators whether they would like to include this game within the training activities regularly offered in their centre to children with attention diseases. Two operators replied that they would include it especially if the mentioned modifications were added (i.e. adding further objects to collect, new scenarios/games). One operator said that the game already has the potential to be a useful tool for training.

Interviews

Some operators and parents were interviewed (one by one), in addition to filling in the questionnaires. The interviews were conducted via Skype. In particular, two parents of children were interviewed, as well as two operators.

Parent1. The parent was the mother of a child involved in the ASL trial. She reported that she liked the game as it represented a way to have some interactions with the child, as connected with the game. She particularly appreciated the possibility offered by the game to correct the mistakes made during play: this helped her encourage the child not to be afraid of making errors, and thus stimulated the child in this regard.

Parent2. She reported that her child did not show any difficulty in playing the game. The child showed some disappointment when the game froze or when he inadvertently collected wrong objects, as he was very attentive in collecting only the target ones.

Operator1. We interviewed one of the ASL operators, the only one that had the opportunity to see a child while playing the game. Indeed, differently from the other children, this child played the game at ASL premises, as part of her "cognitive strengthening", and hence she was followed by this operator while playing. The operator highlighted that the game should offer additional items representing further motivations for the child, for instance, the possibility of presenting items (such as diamonds or gems) that can unlock new scenarios. Still in regard to motivation, she reported that, in her opinion, competition among this kind of children may not work since, depending on the characteristics of the child, some may experience negative effects (e.g. getting depressed). In her opinion, the only competition suitable with these children would be competing against themselves (i.e. to see the progress over time). She also pointed out that one big advantage of this game compared to other (even commercial) tools was definitely the personalisation support. In addition, she suggested using the game in some training/therapy environments, where there should be better control over various contextual conditions. She also reported that the child, after a while, started disliking the game and therefore the operator had to mediate by, for instance allowing the child to do something she liked after finishing the game.

Operator2. Also this operator suggested improving the motivational features offered by this game, by providing some concrete objects/items that the child can understand as leading to unlocking or to achieving something that can be useful for continuing the game. Also this operator did not find it very suitable for having children play with their mates, since she emphasised that, with these children the actual competition is against themselves, rather than against the others. She also suggested introducing additional games to have the children experience different stimulating activities, which can vary over time.

Trial 2 (Participation at the Training Centre)

Description of Participants and Settings/Logistics

The participants of this trial were children followed by a social cooperative (called “PAIM") based in Pisa (Italy), whose operators provide extracurricular educational support to ADHD children with learning or social difficulties. Twenty-four children, aged between 10 and 15 years old took part in the study, as recruited by PAIM. The average age of the children is 11.65 (SD=1.57). The children involved by PAIM had rather heterogeneous diagnoses, yet the kind of training we proposed was judged by the operators as beneficial and suitable for all of them; therefore, they were included in the study. In particular, three children had been diagnosed with ADHD, five with Autism Spectrum Disorder (ASD), three with cognitive delay, four have attention disease in comorbidity with cognitive delay or ASD or global delay, three presented global delay, two had psychomotor delay, three had neuropsychic delay, one was affected by epilepsy, and one had metabolic diseases. For interacting with the game in the PAIM trial, the children used mainly some tablets provided by the PAIM centre, as well as additional devices (i.e. smartphones, tablets) that their families allowed them (exceptionally) to use for this specific study.

In the end 16 parents filled in the **pre-test questionnaire**s. They were the parents of children (13 males) whose average age was 12.6 years old (SD=1.46). As for the familiarity of the child with the various device and their use:

- *Smartphone*: 11 children use the smartphone several times a day, 3 several times a week, 1 never, 1 once a week. In addition, 7 out of 16 use the smartphone to play games, 5 use it to navigate Internet, 5 to communicate, 12 to watch cartoons. Three children use the smartphone for listening to music.
- *Tablet*: 5 children use the tablet several times a week, 5 never, 3 children use several times a day, 3 once a week. 5 children use the tablet for playing games, 4 use it to navigate, just one child uses the tablet for communication; 8 children out of 16 use the tablet for watching videos/cartoons. Additional objectives for using the tablet were: to do some activities with teachers, and to take pictures.
- *PC*: 3 children never use the PC, 3 once a month, 4 once a week, 2 several times a day, 4 several times a week. Only 2 children use the PC to play games, 4 children use the PC to navigate, no child uses the PC for communication, 4 out of 16 use the PC to watch video/cartoons. Additional goals for using the PC were associated with school/schoolwork.

The second part of the pre-test questionnaire was dedicated to gathering information about the parents themselves: 13 parents were females, 3 males. Their average age was 46.3 years old (SD=7.8). As for their education, 8 of them had high school, 2 had a secondary school level, 2 had a Master Degree, 2 had a three-year degree (i.e. Bachelor), 1 had primary school level, 1 had a post-master degree level.

As for familiarity of parents with various devices, and their use:

- *Smartphone*: the vast majority of parents (15 out of 16) use the smartphone several times per day. The smartphone is used by them for: entertainment (7 replied yes, while the other do not use it for entertainment); work (10); navigation (8); communication (11); online shopping (5);
- *Tablet*: 8 out of 16 parents never use the tablet, 3 once a week, 2 several times a day, 2 once a month, 1 once a day. The tablet is used by them for: entertainment (3 replied yes, the others do not use it for entertainment); work (5); navigation (2); nobody uses it for communication; only one uses it for online shopping;
- *PC*: 8 parents use the PC several times a day, 3 never, 2 once a month, 3 once a week. The PC is used by the parents for: entertainment (1); work (7); navigation (6); communication (4); online shopping (2). Other objectives mentioned were associated with online banking, picture taking, learning, music.

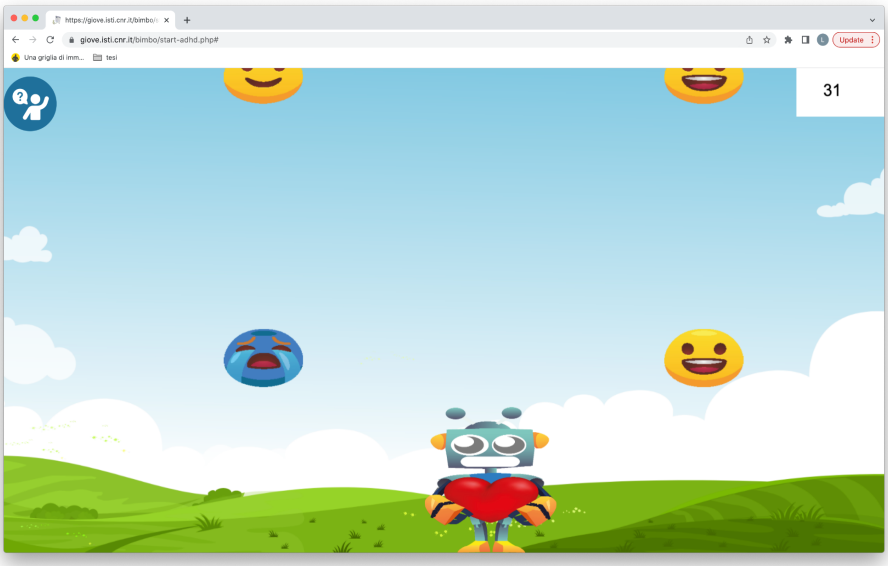


Fig 6: A screenshot connected with the scenarios of emotions

Differently from the previous trial (where the children played the game autonomously at home), in this trial the children played during the activities that they performed in the PAIM training centre; thus, their educators had the possibility to observe the children during the game sessions. In particular, the PAIM operators integrated the gameplay time within some activities of their laboratories, i.e. the money laboratory and emotions laboratory. Thus, two additional **scenarios (**emotions and money) were added to the game for the children (see Figure 6 and 7).

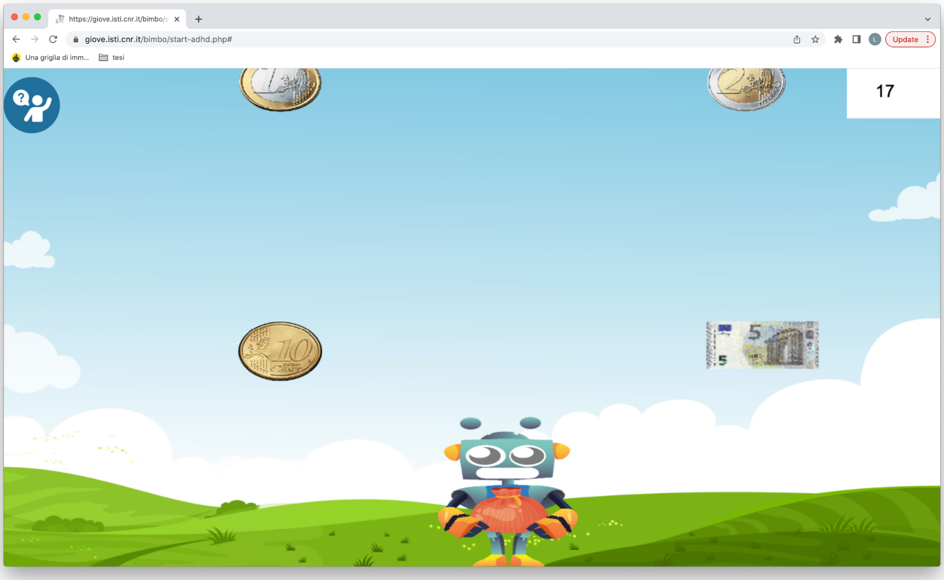


Fig 7: A screenshot of the scenario of money

In the emotion scenario the character holds a heart-shaped knapsack (see Figure 6), while in the money scenario the character holds a bag of coins (see Figure 7). The structure of the levels is the same as in the school scenario: in the first level the user has to collect a target element; in the second level, the user has to collect elements of a specific type (i.e. all the emotions of joy for the emotion scenario; all the coins for the money scenario); for the third level the user has to collect some elements different from the previous level: the emotion of sadness in the emotions scenario, the banknotes in the money scenario; in the fourth level, two-fold task is assigned, i.e. to collect two opposite emotions (in the emotion scenario), or to collect a specific coin and banknote (in the money scenario).

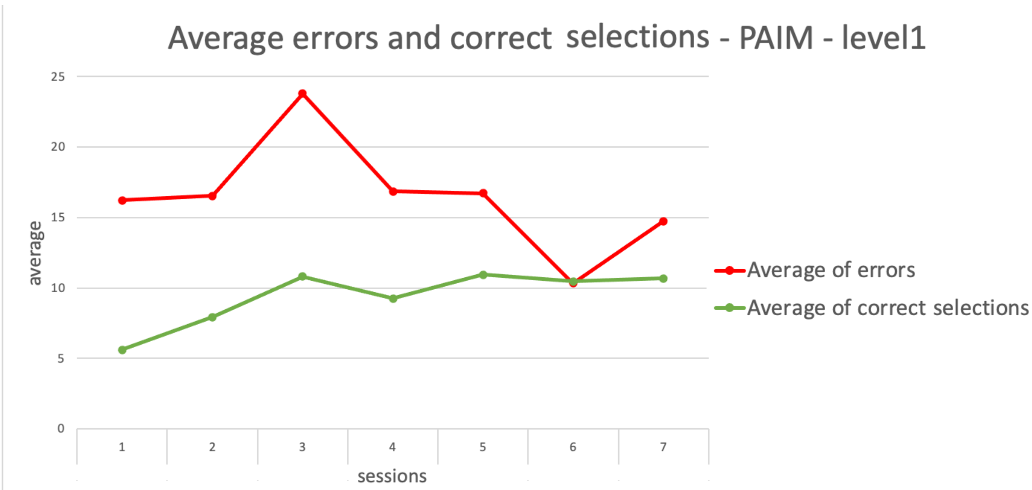
The operators of PAIM initially assigned to all the children a predefined speed (1.5) which they considered useful for starting playing. Then, after the observations in the field, they increased or decreased that speed according to what they observed during the interaction of the children with the game. In this trial the values used for the initial speed ranged between 0.5 and 6.0. The most used speed was 1.5 (5 children); 4.0 (5 children); 6.0 (4 children); the first two had a speed increment of

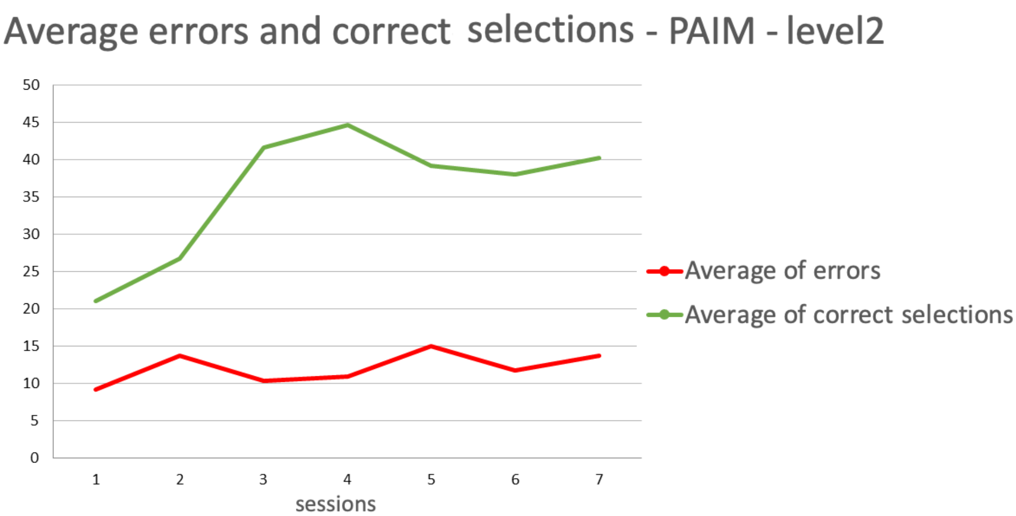
0.5, while the last had a speed increment of 6.0. Also in this case the children had their own credentials to log in the game, and they played once a week during the lab activities.

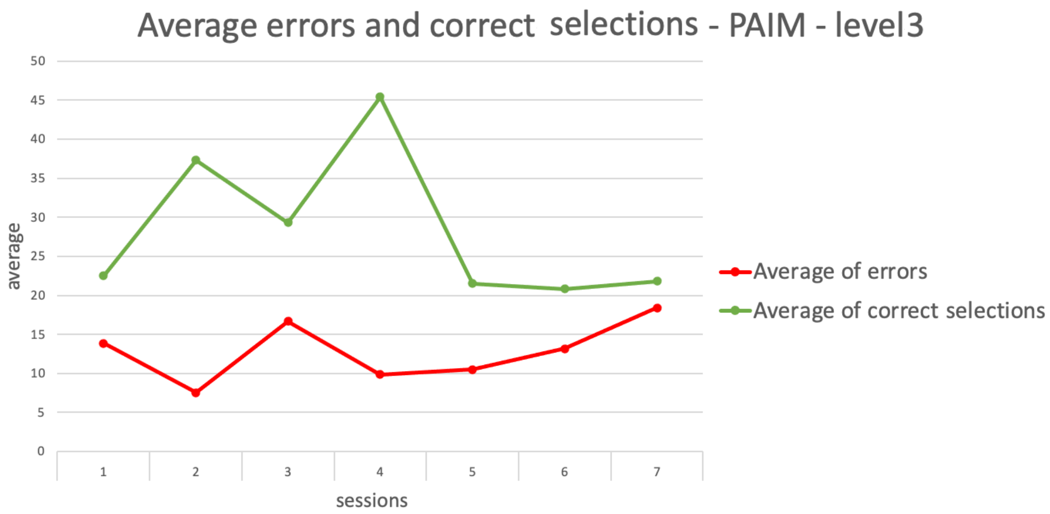
Results

Data on correct answers and errors

The children in this trial played an average of 4.5 days for 7.93 sessions, with a minimum of 1 day and a maximum of 8 days. Also in this case, we focused on the children who played at least 7 sessions, by analysing errors and scores. In particular, we calculated the average of the corrected selections done by children, as well as the errors (calculated level by level) among the 7 sessions considered. As it is possible to see from Figure 8, errors tend to decrease in level 1 and level 4, while the correct selections show a clearer trend (over the four levels they tend to increase or remain quite stable).







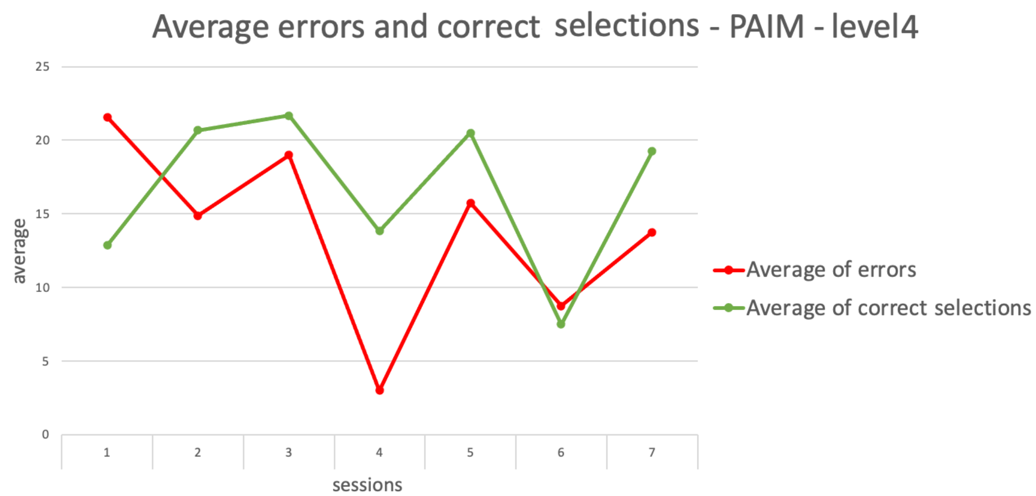


Fig.8 Errors and correct selections for each level (PAIM trial)

Questionnaires

Questionnaires were submitted aimed to collect, before the test, information about the digital competence of parents and that of their children (pre-test questionnaires); after the test, the feedback on the game from children, parents and operators (post-test questionnaires).

Children's Questionnaires

The children of this trial overall liked the game. Indeed, 8 children felt happy, 5 felt excited, 4 felt bored, 1 angry and 1 tired. When the children of this trial were asked how easy was for them to play the game, 8 answered that it was easy, while 7 replied that it was very easy; 2 replied that the game was sometimes easy and sometimes difficult, for 2 the game was very difficult. Compared to the previous trial, the children of this trial seemed to express a more positive feedback on the game.

Parents' Questionnaires

It is worth noting that, in the PAIM trial, the operators, beyond filling the questionnaire directed to them, they also filled in the questionnaire devoted to parents, as in this trial they actually supervised the children during game-playing. In this case, we slightly modified the parents' questionnaire, by adding a field where the operator could also report the pseudonym of the child to which the questionnaire was referring to. In the end, we collected 23 questionnaires, one for each of the children who actually played the game in the PAIM trial. All of them played the game at the PAIM training centre, as part of their training activities. Thus, in this questionnaire, the operators reported what the children expressed/showed/commented during the various game sessions.

When asked whether the child needed the support of another person to play the game, the results show that 6 children were always able to play the game autonomously, without any help. 12 children need some help only in the initial phases, mainly to understand the tasks to achieve at each level/sublevel, and how to play. One child needed assistance only when the game suddenly got stuck, another child needed assistance for the tasks that did not visualise all the time (by using an image displayed within the game on the top-left corner) the target objects to collect (see i.e. the levels in which the child need to collect a group of objects rather than a specific item i.e. "all the school-related material"). Two children needed some motivational support by operators to go ahead with the game, as they tended to abandon it after the initial levels. One child tried to play the game but he had troubles in proceeding with it due to his difficulties in managing anxiety: operators reported that sometimes he preferred watching what his pairs did, rather than continuing himself.

When asked about the three most positive aspects of the game, it came out that 6 children especially appreciated the scenarios: some of them liked a specific scenario (the emotion-related and the school-related ones were those appreciated most), the others liked all the scenarios. 7 children especially liked various features of the game and its look, i.e. the colours used, as well as the sounds used at the end of each sub-level. Other two aspects that were appreciated were: i) the fact that also other mates played the game at the same time (this aspect was mentioned for 3 children), and ii) the possibility of using their own device (a tablet, in this case), which was mentioned for 3 children. Two children appreciated when the game highlights that a correct item has been collected: in particular, in such cases not only the score increases, but also the robot changes its appearance (it changes its colour into green when the object is right, to red when the object is wrong). For one child the operator reported that the game, beyond providing the opportunity to concentrate, also offered to him the possibility to free his mind from other thoughts.

When asked about the aspects/features of the game that they did not like much, recurrent aspects mentioned were: i) the fact that the game, after a while, resulted a bit tedious (this was mentioned as associated with 6 children), and ii) the fact that sometimes the game got stuck (mentioned 10 times). 2 children apparently did not show any negative aspects associated with the game. One child felt as the game lasted a bit long, and one felt that the game was a bit slow. One child showed most difficulties with the money-related scenario: as reported by the operator, this was probably due to the fact that, more generally, money management is a domain that the child just started to deal with. One child did not show to like the game, overall. Another child did not show to appreciate much the game probably due to his specific difficulties in managing anxiety: in particular, his anxiety apparently increased when seeing that the tasks needed to be complete within a specific amount of time, that the objects that were falling down were somewhat "lost", the situation when a wrong object was collected. In such situations the operator reported that the child sometimes preferred to watch what his mates were doing with the game, rather doing it himself.

Then, there was a question about whether the operators recognised any specific effect in the child's behaviour, which could be brought back to the training:13 answered no, for 4 children the answer was that the children were absent to some training sessions, thereby it was not possible to see any significant effect. For one child, the operator noticed an improvement in recognising the money, especially the coins. For another child the improvement was that the child was able to correctly identify the emotions, even in real life. For two children the operators reported that the game stimulated the attention and the concentration of the child during the game, which was a good advance. One child had specific difficulties in handling his anxiety: the operator reported that the game represented an opportunity for the child to understand the playful dimension of the game itself, thereby it helped him to cope with handling some situations that could be potentially stressful for him ("*it was a good opportunity to understand the playful dimension of the game, for which he should not be anxious. Thus, it was a way to deal with him with some aspects connected with his problems*").

As a final question, there was the possibility to add further comments. Regarding five children, the operators mainly highlighted that there was a positive effect on their social dimension, due to the fact that they did the same game at the same time, thereby there was a good competitive climate between the children. It was reported that six children were happy and enthusiastic when they had to play the game, especially because they had the possibility to play using their own devices. For other three children the operators highlighted the fact that for some children it was a bit difficult to integrate the game play during their activities, also because of some heterogeneity existing in the group.

Operators' Questionnaires

6 operators filled in this questionnaire (5 females), average age= 31.7 (SD=5.4). When asked about three positive aspects of the game, they mentioned the graphical/visual look of the app (4 operators mentioned this), the easiness/intuitiveness of the game (2), the fact that it allowed for practising attention (2) and stimulating the curiosity/interest of the children (1), the scenarios (1), the possibility to customise the app by i.e. increasing/decreasing the speed (1), the sounds associated with the positive rewards at the end of each sublevel (1), the possibility to verify/correct the errors (2), the fact that the game playing had a social effect to the group in that they had a shared experience (1), the fact that the game playing required to follow the rules of using digital devices (1).

As for negative aspects, 5 mentioned that the game sometimes got stuck, and this had some negative effects on the children. In this regard, one operator added that, for this reason, the time needed for playing the game was in the end bigger than expected, and this also affected the time devoted to other training activities. Two found the game a bit tedious. One said that he would have preferred a human–like character instead of a robot-like one. One operator noted that the playing the game lasted a bit long, another found the game a bit slow. Finally, one operator said that the explanations given in the game were a bit difficult for some children because the words used were found a bit complicated for some of them. Then there was a question about whether they would change anything in the game: two suggested removing the issues that brought back the block of the game, one suggested to replace the sounds at the end of each sublevel with others having a shorter duration, one operator suggested including a music that could better stimulate the concentration of the children, one suggested to do some changes to the game (i.e. change the movements of the robot, decrease the number of levels). One operator did not report anything to change.

Then, we asked whether they found the game as useful to improve their own training activities. Four operators replied negatively. Among them, one added that he had the impression that the non-human characterization of the robot, as well as the emoticons (used in the emotion-related scenario) did not properly support children's transfer of some reflections (associated with the game) onto the real world. Two operators replied positively to this question: one found this game useful especially for children that are particularly interested in this study; another operator found especially the emotion-related scenario and the money-related one as particularly useful because, during their ordinary training activities with children at the training centre, they were addressing the same domains.

When asked about the most suitable context in which the game should be used, the operators replied in the following manner: 2 suggested the home environment as the most suitable one, as the home is a “comfort” zone where they can suitably improve some attentive skills at their own pace. Two operators suggested the contexts in which some cognitive therapy is carried out. One operator suggested the school: in this case the game could represent a “diversion” during the lessons, by proposing an attention-based activity in a game-shaped manner. The remaining operator was not able to identify a specific context where this game can be more profitably used. Finally, the operators were asked whether they would be willing to include this game as part of the ordinary activities they offer to this kind of target users. Four operators replied no: some of them explained this with the fact that it can be difficult to integrate this game within the various activities, also because the state of mind of the children need to be considered from time to time. Two operators instead recognised the potential of this game to be included within their ordinary training activities: one mentioned the scenarios of emotions and school, another one said that the game integrates well within some other ordinary activities they offer in their programs (i.e. to make the child become more autonomous).

Interviews

We interviewed two PAIM operators (at the same time), via Skype. On the one hand, they highlighted the difficulty of playing the game during the ordinary activities at the training centre, as it decreases the time that can be devoted to other activities. On the other hand, they emphasised the added value of children playing the game all together at the same time: they reported that the children felt particularly enthusiastic especially because they were allowed to use some devices that normally (i.e. at home) they cannot use. The operators reported that the game playing had positive effects on the sociality of the children, even though for this kind of children experimenting some “social” opportunities can have negative effects, they noted. For them, the most suitable context for using this game is within a training context, as adult’s supervision is needed especially for monitoring the use of a digital device by children. They also suggested adding some relaxing music to the game in order to increase the child's attention/concentration. They also provided us with further details about how they managed the scenarios of the game in the test. They sometimes directly asked the children about the most favourite scenario (smaller children appreciated the school, the others appreciated more the emotion-related and the one on money management). In other situations, the operators directly selected the scenario according to the activities they carried out with the children: for instance, after using the money-related scenario, they often also went out to actually buy something, thereby offering to the children the opportunity to experiment with the knowledge gained in a concrete, real scenario.

Lessons Learnt and Discussion

Both trials show the importance of involving the various stakeholders from the beginning of the game design, and maintaining their involvement also throughout the phases of development and evaluation. The goal is not only to enhance understanding of the game requirements and achieve a more inclusive design, but also to be able to cope in a timely manner with new requirements that might occur over time. In our study, this was especially evident with the PAIM trial, in which the availability of our customisable game implemented for the school scenario triggered the new requirement of supporting a similar game also in other domains (emotions, money) currently covered by their own training programme. This promotes both differentiating the offering provided by the training (which is especially key with children with ADHD, who tend to be easily bored), but also in the view of a better integration of activities within the regular training programme offered by training centres, as this should also be able to increase the potential adoption of the game in the longer term.

Conducting the study in the wild in two different settings provided us with the possibility of investigating the feasibility of assessing a serious game for children with ADHD in real scenarios, thus allowing us to identify advantages and drawbacks.

On the one hand, the home setting theoretically allows the most flexibility (even though an adult should anyway supervise the correct use of digital devices by the child), as children can play at their own pace, at their favourite time, in their "comfort" zone. However, if their performance and feelings are not sufficiently monitored, from time to time such children could run the risk of playing a game that is too easy or tedious (therefore they will be bored) or too difficult (and they will abandon it). The care ecosystem around such children (i.e. families, caregivers) should carefully adjust suitably and timely the fine tuning of the difficulty of the game on their behalf, by monitoring their performance over time, which is easily performed with online games such as the one presented here. In addition, the importance of personalisation appears here, as concretised in the possibility of adapting the game so that the children keep exercising, because they feel that the difficulty level is suitable for them. In this regard, especially in studies that last for weeks, it would be important that the game design provides continuous motivation for these children in the form of suitable feedback and rewards in the game (or, as suggested by some caregivers, to further emphasise the motivational features in the game by introducing additional objects that can unlock new options), to provide the children with a sense of progress, increase their self-esteem and also help them to maintain the attention to the tasks.

On the other hand, we have seen that, in training centres, there might be some difficulty in integrating the game within the various activities, as the time available with educators is limited. In such environments also the possible heterogeneity of children (with some of them presenting some co-illnesses with ADHD see i.e. the PAIM trial) could make this task even more difficult for educators. However, in this setting we found that, even though social skills are challenging for these children (as they usually feel to have little control over social contexts), the game proposed, even if it is a single player game, unexpectedly represented an opportunity for them to share a social experience, more or less in the sense of what Spiel and Gerling (2021) call "relatedness" (i.e. the need to feel belongingness and connectedness with others): the availability of operators helped in mediating and ameliorating potential negative effects of playing in these social contexts on some children, when needed. Another aspect that came out is the potential of empowering operators/educators to directly create new scenarios having references to domains that are of interest for the activities currently done in their training programmes, which can be important for more easily integrating the game in their activities: this can represent relevant work to address in the future.

Conclusions and Future work

Cognitive training through digital serious games can represent a valid complementary support for children with ADHD: they are typically positively received by both patients and caregivers that seem willing to opt for them as they are simple to prescribe, and encourage learning through their game-based features. In particular, in this paper we present PlayToPickUp, a web-based game providing support for training ADHD children on cognitive areas such as sustained and divided/selective attention, and error monitoring. It has shown to be a flexible tool for supporting the target children in different training contexts and with different groups of children. We have thus reported our experience in two trials run in parallel in two different settings, discussing the aspects that worked well and those that presented difficulties. This can be interesting for future real-life trials involving children with attentive diseases. Future work will be dedicated to extending the game with additional scenarios and features and use it in more extended studies, with larger groups of children.

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Appendix 1 The questionnaires used for parents, educators, children

Below we detail the questions included in the questionnaires.

1)Pre-test Questionnaire to parents

Info on the child (the reference parent answered to these questions, on behalf of their child)

- Genre of the child
- Age of the child
- Familiarity of the child with digital devices
- What does the child generally use the smartphone for?
- What does the child generally use the tablet for?
- What does the child generally use the PC for?

Info on the parent

- Genre of the parent
- Age of the parent
- Level of education
- Familiarity of the parent with digital devices
- What do you generally use the smartphone for?
- What do you generally use the tablet for?
- What do you generally use the PC for?

2)Post-test Questionnaire to parents (in PAIM trial, the operators answered these questions)
Use of the game

- In what environment did the child use the game?
- Did the child need adult support to play? If so, please specify why / in what situation

Parental feedback on the game

- Name three positive aspects of the game. What three things did you like most about the game?
- Name three negative aspects of the game. What three things did you like least about the game
- Is there anything you would change or add in the game?
- Have you been able to detect any effects in the child's daily life that can be traced back to what the child has learnt through play? For example, did you notice any differences in the child's ability to pack a backpack?

3)Post-test Questionnaire to operators

Info about the operator

- Genre of the operator
- Age of the operator
- Role of the operator

Educators' feedback on the game

- Name three positive aspects of the game. What three things did you like most about the game?
- Name three negative aspects of the game. What three things did you like least about the game
- Is there anything you would change or add in the game?
- Did you find play useful to improve/optimise your rehabilitation activities with children? If yes, what in particular?
- In what context do you think play should ideally be used (e.g. at home, within cognitive therapy centres, within school activities) and why?
- cognitive therapy, within school activities) and why?
- Would you include this game within the support you regularly offer to children with attention difficulties?

4)Post-test questionnaire to the children

- How do you feel after playing the game?
- How easy was it for you to play the robot game?