BRAVO: A Gaming Environment for the Treatment of ADHD

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Abstract. Attention-deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder that is expressed through different symptoms belonging to three different dimensions: inattention, impulsivity and motor hyperactivity, each of which contributes to the learning and adaptation problems within the different contexts of life. ADHD children have to focus on three main elements: learn to self-control, make and keep friends and feel good about themselves. The BRAVO (Beyond the tReatment of the Attention deficit hyperactiVity disOrder) project aims to realize an immersive therapeutic game context, based on an innovative ICT system, with which improving the relationship between young patients and therapies (administered by means of serious games and gamification). By using wearable equipment and Virtual and Augmented Reality devices, new personalized processes of therapy will be implemented. Such processes will be able to dynamically change in order to follow the patients evolution and support the therapists in the rehabilitation program management.

Keywords: ADHD · Serious game · Virtual reality · Augmented reality · Adaptive gamification · Avatar

1 Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a behavioural and developmental disorder that affects children and teens and includes symptoms such as inattentiveness, hyperactivity and impulsiveness. It has a particularly disruptive effect in daily life activities: affected children have difficulties in planning their homework, estimating time for assignment completion, staying focused on assigned tasks and managing social relationships [1]. Moreover, they have no

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self-esteem and do not have positive thoughts, causing discouragement and emotional explosiveness, poor school achievement, social rejection, and interpersonal relationship problems.

1.1 The Main Challenges

A proper assessment of the child is essential for ADHD treatment planning, which should meet the patient requirements and allow monitoring the symptomatology evolution. From the analysis of the therapeutic needs related to ADHD, it is clear that the therapy should focus on three core elements: learning self-control, making and keeping friends, feeling good about yourself [2]. The acquisition of these macro-skills is the main way to allow the child with ADHD for a quiet life, without the distress and the frustrations due to an underperform in school or a not satisfying social life.

1.2 Serious Games and Gamification for the Treatment of ADHD

Serious games [3] are interactive computer applications that have a challenging goal and an explicit and carefully thought out educational purpose; they are defined as games that are designed to entertain players as they educate, train, or change behaviour. It is clear that the learning function is mixed with the gaming nature of the application; playing a serious game must excite and involve user while ensuring the acquisition of knowledge [4,5].

Recently, new methods have been investigated to improve the daily functional life of a child with ADHD by using a game-based approach to support behavior change [6,7].

Children with ADHD have a motivational deficit and react differently to the gratifications compared to their peers not affected by the same disorder. The playful approach helps to balance motivation and learning; video games are able to motivate children and involve them in the therapeutic process.

Although the literature is full of evidence that these training programs give only near-transfer effects, there is no convincing evidence that even such near-transfer effects are durable [8]. It is advisable, therefore, to work on video games that are able to have a real impact on the life of the child affected by ADHD [9].

1.3 Theoretical Bases

Recent trends are oriented to the use of serious games in supporting the learning of rules and behavioural strategies in everyday life, such as time management, planning/organization, and social skills [10]. These behavioural goals should be translated into appropriate psychological theories in order to have a theoretical reference framework. Indeed, several studies in literature show that serious games based on a psychological framework tend to be more effective than others [11].

The most widespread frameworks for the above mentioned abilities are the self regulation model, the social cognitive theory, and the learning theory [12].

The self-regulation model focuses on how individuals direct and control their activities and emotions in order to achieve their goals. Children with ADHD often have no self-regulation: this prevents them from acquiring all their cognitive and behavioural skills and makes them feel incompetent and insecure in situations where these skills must be used. For this reason, it is important that serious games include components (or game dynamics) that can help children in directing and monitoring their activities, adjusting their actions and emotions, and practicing until the skill has been acquired.

The social cognitive theory argues that children's learning is influenced by interactions with the environment, as well as by personal and behavioural factors. The environment should support the child in behavioural learning by providing reference and gratification models whenever a correct behaviour is shown. Indirect learning, emotional support, and experiential learning are key factors that should be implemented within a successful game design.

According to the learning theory, behaviour is the result of a process of acquiring information from other individuals. Children with ADHD are less sensitive to negative feedback and learn much more if encouraged with repeated positive stimuli. A serious game for children with ADHD should always and immediately reward positive behaviors.

1.4 The BRAVO Project

This paper presents the first results of the BRAVO (Beyond the tReatment of the Attention deficit hyperactiVity disOrder) project, which consists in the development of an immersive serious game aimed at improving the relationship between young patients affected by ADHD and therapies. The rest of the paper is structured as follows. Starting from the goals and the theoretical bases presented so far, in Sect. 2 we will review the technical literature referencing the use of serious game as a therapeutic method for the treatment of ADHD. In Sect. 3, we will discuss the BRAVO project, exploring the functionalities of the system, its hardware and software architecture, and the various choices made. The workflow of the therapeutic process will be described, following the path of the patient in the various interaction steps with the system. Also, the serious games developed for therapeutic purposes will be reviewed. Section 4 describes the project assessment procedure. Finally, Sect. 5 will conclude the paper by describing in detail the already-planned experimentation phase: a final, necessary step for an objective evaluation of the benefits introduced by the system.

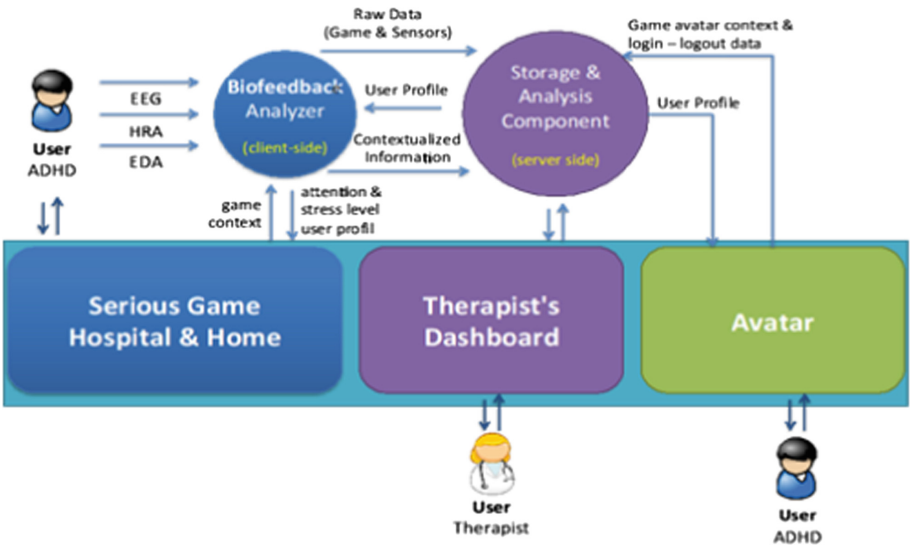

Fig. 1. The BRAVO architecture

2 Related Work

Several works in literature deal with the use of serious games for taking care of children with special educational needs (SEN) and in particular of children affected by ADHD. The fascinating effects of digital games can greatly increase their engagement and concentration, even though the generalization of skills in gamified training to daily life situations is often a challenging issue [13,14]. Serious games have a different impact based on ADHD subcategories, severity of inattention/hyperactivity problems, age and gender of the involved subjects. In a recent experiment [15], girls showed a greater benefit in planning/organizing skills, while among boys those with lower hyperactivity levels and higher levels of Conduct Disorder showed better improvements in planning/organizing skills. Serious games developed for ADHD children can be classified according to the following basic goals:

- general self-regulation skills concerning organizational problems [16], behaviour control [17], and the inhibition of impulsive behaviours [18];
- social and communication skills are stimulated in several games such as the adventures of Pico [19], Alien Health [20], Jumpido Games [21], Little Magic Stories [22], and also in the training platform described in [17];
- academic and cognitive skills such as mathematics, spelling, and pattern matching are stimulated in Games4Learning [23], Jumpido Games [21], and Kaplan Early Learning [24]; moreover, an iPad game [25] was developed to improve the reading quality in terms of attention and comprehension;
- daily life skills are promoted by Alien Health [20] and Pictogram Room [26].

The general structure of serious games for ADHD children includes a mission game, a social community (preferably closed with interaction restrictions) and a game guide that can accommodate, guide or motivate the player during his educational journey [21].

The mission game is a game environment that presents some missions the players should complete and the game actions they should perform to reach such final goals. This system allows also viewing the skills that the child should acquire. Game actions should have increasing difficulty that should be adapted to the child's level of performance. In [22] some examples of games are proposed (Labyrinth, Space Travel Trainer, Explorobot) that have proven effectiveness in teaching behaviour and in their transfer into everyday life.

The ATHYNOS system [27] combines serious games with Augmented Reality to better capture the attention of ADHD children and stimulate cognitive skills related to hand-eye coordination and problem solving. It exploits the Kinect natural user interface [28] to detect body movements as input commands.

The Kinect device is used also by the Kinems gaming suite [29], which was developed to improve the motoric skills of children with special educational needs.

Another type of input used to control or influence games is biofeedback, which consists of data about several aspects of the user physiological state. Moreover, such data usually allow to track the mental state of the children and infer their mood [30].

The ChillFish [31] game exploits the player's breath to control a fish in a 2D underwater environment. The aim is to reduce the stress levels that typically affect ADHD children.

The cognitive behaviour training platform described in [17] exploits Brain Computer Interfaces (BCIs) and the Kinect device to register both the children's brainwaves and their motion during gaming activities. The collected data are stored in a cloud platform to perform both a real-time and an offline analysis. The former allows to control the game flow and train the children's behaviours according to an adaptive intervention scheme. The latter allows evaluating the player's behaviour during the whole session and the treatment effectiveness.

Some research efforts have addressed also the design of tools allowing a classification of ADHD children. In particular, four variables have been proposed to identify children affected by attention deficit [32]: omission error (denoting missing responses to target stimuli), commission error (expressing impulsivity, i.e. the attitude of responding to non-target stimuli), response time, and standard deviation of the response time (as a measure of the irregularity in providing responses).

In more recent research [33–35], electroencephalogram (EEG) signals have been combined with serious games to detect patients affected by ADHD. Neurofeedback data collected during game sessions are analyzed and classified by means of machine learning techniques to detect any ADHD pattern.

Fig. 2. The avatar

3 Materials and Methods

The BRAVO project aims at achieving a therapeutic game environment, based on an innovative ICT system, by:

1. improving the relationship of young patients with therapies;
2. implementing customized therapy processes, able to change dynamically in order to follow the evolution of the patient's attentional levels;
3. supporting therapists in the management of the rehabilitation program.

Behind the project, there is a new generation of serious games able to monitor the patient's behavior by means of wearable sensors, in order to adapt the intervention of the system to the therapy outcomes. The data acquired through a series of devices (Kinect [28], HTC Vive [36] and controller with reference to gaming performance, EEG helmet and bracelet with reference to biofeedback data) allow to draw a user profile useful for evaluating the therapeutic trends. Based on such data, together with child's individual performance and his/her emotional state, the system will suggest to the therapist the most suitable therapeutic game and level difficulty.

By simulating realistic situations, virtual reality-mediated cognitive training is an innovative methodology able to immerse the child affected by behavior disorder, activate one or more sensorial stimulations, and provide a strong sense of presence in the virtual environment. This enables the transfer of acquired or rehabilitated skills during training to the real (non-simulated) environment.

3.1 System Architecture

In the designed platform, therapists and patients have clearly separated roles and tasks. Therefore, there are distinct applications: one to be used by therapists

(therapist's dashboard), the other ones reserved for patients/children (serious games, gamification apps, avatar). The former consists of a control interface that allows the monitoring of therapy and the customization of the video games; the other applications consist of a collection of rehabilitative exercises in the form of video games (serious games), which will be performed by the child at the rehabilitation facility during the scheduled therapeutic sessions by using virtual or augmented reality devices or, alternatively, at home (by means of an app) by using mobile device (tablet, pc, smartphone etc).

The avatar is developed for the interaction with the child and will have the task of recognizing and welcoming him on his arrival at the clinic, putting him at ease, and stimulating him to face the therapy exercises.

The interaction among the therapist control interface, the serious games, and the avatar is never direct: in the BRAVO platform all the data exchanged among these components are first transmitted to a server and then analyzed and used.

As shown in Fig. 1, the architecture consists of the modules described in the following subsections.

Storage and Analysis Component. Centralized system for storing patient data. It collects the user interaction data coming from the wearable sensors, the game and the avatar and then it analyzes them.

Biofeedback Analyzer. Module with the specific task of:

- collecting data from sensors (EEG helmet and wristband to detect the stress level) and game performance;
- processing the user emotional state based on the specific context;
- sharing data with other system components.

Serious Game Hospital & Home. Module with the specific task of giving the therapy in two distinct and independent ways: at the clinic, via serious game, connected to the sensors and at home, via the gaming app accessible via tablets and PCs.

Avatar. Module with the task of welcoming and entertaining the child at the entrance and exit of the therapy room and interacting in a personalized way according to the user profile information. The avatar (Fig. 2) represents a virtual friend who will walk the child during the therapeutic process, creating the conditions for a pleasant experience.

Therapist's Dashboard. Module representing the informational dashboard available to the therapist, which can be used to monitor the therapy and receive suggestions regarding the game and level of difficulty for the child. Furthermore, the dashboard allows the therapist to mediate the interaction between avatar and child, just as a puppeteer would do with a virtual puppet (by controlling emotional expressions, non-verbal communication, gestures and dialogues).

3.2 Therapy Workflow

The patient is the main user of the developed system. He/she will be provided with a customized therapy service, which will be able to evolve in a smart way according to the therapy progress.

Once the child/patient is in front of the treatment room, following an automatic face recognition procedure which triggers an authentication in the system, he/she will meet his personal virtual avatar. The avatar will be always consistent with the patient's psychological profile and therapeutic trend; in this way, the child will always feel recognized and welcomed by a familiar figure.

The avatar customization takes place from two independent points of view: an aesthetic one and a behavioural one. The former allows the child to define the avatar look: to this aim, he can choose among several features (physical features, accessories, etc.) available in an avatar creator tool through a touchscreen. The latter allows the therapist to modulate poses, attitudes and voice tones of the avatar by means of a dashboard in accordance with some features highlighted in the child profile. Besides being visualized on a screen at the entrance and at the exit of the therapeutic room, the avatar accompanies the child also during the therapy session in the form of holographic agent. The concept of holographic avatar refers to both the virtual character leading every augmented reality scenario (visualized through Microsoft Hololens [37]) and the hologram displayed through a projection system used as an alternative to the headset.

The main interaction phase consists in a gaming activity through a series of serious games that can be classified into three different categories: topology, attention and respect for rules, action planning.

3.3 Therapeutic Serious Games

BRAVO's game environment consists of some serious games that will be used with a wide range of sensors and actuators, such as EEG headset, VR headset, and wristband, in order to detect and store the patient emotional states, contributing to real-time game adaptation. Serious games were implemented according to well-defined therapeutic goals dealing both with educational/logopedic issues (such as the definition of topological concepts and semantic categories) and with behavioural issues (such as respect for the rules, improvement of the attention span, ability to predict the effect of the actions, improvement of social skills, and so on).

Topological Categories. It is a 7-levels game that aims at supporting the improvement of patient's topological categories skills (e.g. over - under, inside - outside, back - forth, close - far, left - right). The game has been designed to be played in a clinic through an HTC Vive [36] and a controller, allowing the user to move in a virtual environment just like it would move in a real one.

Within the game, the user will explore three different environments (a classroom, a bedroom, and a garden), in which he will be asked to accomplish specific tasks, for example, positioning items or himself in relation to (e.g. near, far, above, under, etc.) other items.

As the levels' difficulty increase, new elements will be added to the level's tasks, such as a countdown or a semaphore. Furthermore, the question complexity will increase too (e.g. multiple topological concepts are expressed in the same question), as well as the complexity of the game scene (Fig. 3).

Fig. 3. Topological categories

Infinite Runner. It is a 8-levels game whose goal is to teach the respect for rules (and how to stand still), the active listening and the awareness of the player's limits. The game will be played by means of a Kinect device [28], which allows to move the game avatar simply by using the human body: in fact, the player's movements are decoded without the need for any additional tool to be worn or linked to the body. Within the game, the user is immersed in a virtual environment depicting a country or a city road, where he is requested to follow a path by running on the spot. As the game goes on, the player has to move in the right direction to avoid several obstacles or collect any requested object. As the levels move forward, the levels' complexity increases, introducing further difficulty elements (such as a flock crossing the road, a traffic light or crosswalks), that will require the player's ability to wait and to improve the attention

span. For each level, the therapist can set different parameters, according to the patient's needs: indeed, a specific game mode has been created in order to allow children with motor skills problems to play anyway without running, by simply standing and moving to the right or to the left to accomplish the task (Fig. 4).

Fig. 4. Infinite runner

Space Travel Trainer. It is a 7-levels game that has the educational goal of teaching the patients to plan their actions and manage social relationships.

The game is controlled through the Kinect device [28], which allows detecting the player's hand movements, through which s/he will perform and accomplish the requested tasks. Within the game, the player acts as an astronaut who has the goal to take the spaceship to his friends' planet. During his journey, s/he has to face different tests: in order to pass them, s/he has to learn how to solve complex problem, how to take the right decision at the right moment (improving his decision-making ability), but most of all how to interact with his team members (in order to defeat the enemy) (Fig. 5).

4 Project Assessment

The final phase of BRAVO will include a 27-weeks trial aimed at evaluating its benefits. To such purpose, 60 young patients will be involved, divided into the following age groups:

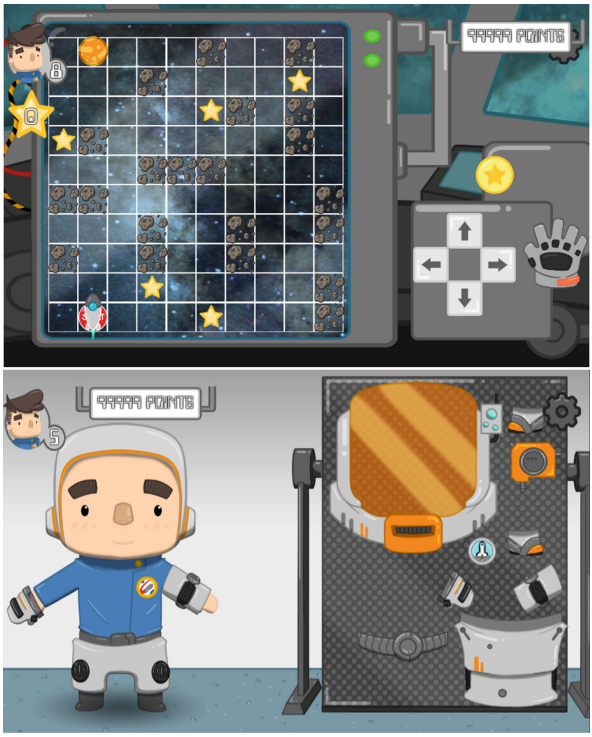

Fig. 5. Space travel trainer

1. Preschoolers: 3–6 years;
2. Primary school age: 6–9 years;
3. Secondary school children: 9–12 years.

Patients will be divided in two groups, equally numerous, randomly. The first group will be used as a control group and will be submitted to the traditional therapy currently used in the clinic. The second group will be instead the active group of the test, receiving therefore the new treatment in the developed game environment. During the therapies administration, both groups will be evaluated in three phases: before the beginning of the test, during, and at the end. In order to assess the real impact of the BRAVO system, usability and effectiveness tests will be implemented. Usability is the degree to which a product can be used by specified consumers to achieve specific objectives with effectiveness, efficiency, and satisfaction in a particular context of use.

The implemented usability tests are based on the expert inspection carried out with Nielsen heuristics. Therefore, these tests will be carried out with target users by means of standardized questionnaires, identified in scientific literature.

To evaluate the system effectiveness on patients, specific tests will be created and implemented before, during and after the administration of therapies: the comparison of the obtained results will allow therapists to determine changes

or improvements found in patients. At the beginning of the experimental phase, the users-serious game interaction aspects will be evaluated, in order to consider possible bias (in the clinical results obtained) deriving from system usability defects or from a user experience not fully in line with its expectations.

5 Conclusions and Future Work

In this paper we have described the BRAVO project, which aims at realizing an immersive therapeutic game context to support an alternative modality for the treatment of ADHD. BRAVO is based on an innovative ICT system, whose goal is to improve the relationship between young patients and therapies.

BRAVO aims at achieving its goal through the combined use of ad-hoc educational games and entertaining personalized avatars. Children/patients will be monitored using on-body sensors.

Through an analysis of the gathered sensor data and gaming scores, the impact of the BRAVO system will be evaluated in terms of clinical improvements, speed of improvement, patient involvement and empowerment.

The first results already show a great potential of serious games in attracting young patients even compared to standard therapy.

At the end of the experimental phase it will be evaluated how to improve the performance of the system compared to the defined KPIs.

References

1. Abikoff, H., et al.: Remediating organizational functioning in children with ADHD: immediate and long-term effects from a randomized controlled trial. J. Consult. Clin. Psychol. **81**, 113 (2013)
2. Shapiro, L.: ADHD: il mio libro di esercizi: Attività per sviluppare la fiducia in se stessi, le abilità sociali e l'autocontrollo. No. v. 6–12 in I materiali Erickson. Strumenti per la didattica, l'educazione, la riabilitazione, il recupero e il sostegno, Erickson (2015). https://books.google.it/books?id=5HPmDAAAQBAJ
3. Bergeron, B.: Developing Serious Games (Game Development Series) (2006)
4. De Paolis, L.T., Aloisio, G., Celentano, M.G., Oliva, L., Vecchio, P.: MediaEvo project: a serious game for the edutainment. In: ICCRD2011 - 2011 3rd International Conference on Computer Research and Development (2011)
5. De Paolis, L.T., Aloisio, G., Celentano, M.G., Oliva, L., Vecchio, P.: Experiencing a town of the middle ages: an application for the edutainment in cultural heritage. In: 2011 IEEE 3rd International Conference on Communication Software and Networks, ICCSN 2011 (2011)
6. Luman, M., Oosterlaan, J., Sergeant, J.A.: The impact of reinforcement contingencies on AD/HD: a review and theoretical appraisal. Clin. Psychol. Rev. **25**, 183–213 (2005)
7. Sagvolden, T., Aase, H., Zeiner, P., Berger, D.: Altered reinforcement mechanisms in attention-deficit/hyperactivity disorder. Behav. Brain Res. **94**, 61–71 (1998)
8. Melby-Lervåg, M., Hulme, C.: Is working memory training effective? A meta-analytic review. Dev. Psychol. **49**, 270 (2013)

9. DeSmet, A., et al.: A meta-analysis of serious digital games for healthy lifestyle promotion. Prev. Med. **69**, 95–107 (2014)
10. Ricciardi, F., De Paolis, L.T.: A comprehensive review of serious games in health professions. Int. J. Comput. Technol. **2014**, 11 (2014)
11. Baranowski, T., Buday, R., Thompson, D.I., Baranowski, J.: Playing for real: video games and stories for health-related behavior change. Am. J. Prev. Med. **34**, 74–82 (2008)
12. Bandura, A., National Institute of Mental Health: Social Foundations of Thought and Action: A Social Cognitive Theory. Prentice-Hall Series in Social Learning Theory (1986)
13. Bul, K.C., et al.: Development and user satisfaction of "Plan-It Commander", a serious game for children with ADHD. Games Health J. **4**, 502–512 (2015)
14. Bul, K.C., et al.: Behavioral outcome effects of serious gaming as an adjunct to treatment for children with attention-deficit/hyperactivity disorder: a randomized controlled trial. J. Med. Internet Res. **18**, e26 (2016)
15. Bul, K.C., Doove, L.L., Franken, I.H., Van Der Oord, S., Kato, P.M., Maras, A.: A serious game for children with attention deficit hyperactivity disorder: who benefits the most? PLoS ONE **13**, e0193681 (2018)
16. Frutos-Pascual, M., Zapirain, B., Zorrilla, A.: Adaptive tele-therapies based on serious games for health for people with time-management and organisational problems: preliminary results. Int. J. Environ. Res. Public Health **11**, 749–772 (2014)
17. Park, K., Kihl, T., Park, S., Kim, M.J., Chang, J.: Narratives and sensor driven cognitive behavior training game platform. In: 2016 IEEE 14th International Conference on Software Engineering Research, Management and Applications (SERA) (2016)
18. Colombo, V., Baldassini, D., Mottura, S., Sacco, M., Crepaldi, M., Antonietti, A.: Antonyms: a serious game for enhancing inhibition mechanisms in children with Attention Deficit/Hyperactivity Disorder (ADHD). In: International Conference on Virtual Rehabilitation, ICVR (2017)
19. Malinverni, L., Mora-Guiard, J., Padillo, V., Valero, L., Hervás, A., Pares, N.: An inclusive design approach for developing video games for children with autism spectrum disorder. Comput. Hum. Behav. **71**, 535–549 (2017)
20. Johnson-Glenberg, M.C., Savio-Ramos, C., Henry, H.: "Alien Health": a nutrition instruction exergame using the Kinect sensor. Games Health J. **3**, 241–251 (2014)
21. Jumpido: Educational games for Kinect (2019). http://www.jumpido.com/en
22. Little Magic Stories (2019). http://www.chrisoshea.org/little-magic-stories
23. Games 4 Learning (2019). http://games4learning.com
24. Kaplan Early Learning (2019). https://www.kaplanco.com
25. Wrońska, N., Garcia-Zapirain, B., Mendez-Zorrilla, A.: An iPad-based tool for improving the skills of children with attention deficit disorder. Int. J. Environ. Res. Public Health **12**, 6261–6280 (2015)
26. Pictogram Room (2019). https://autismodiario.org/2012/03/12/ya-esta-disponible-pictogram-room
27. Avila-Pesantez, D., Rivera, L.A., Vaca-Cardenas, L., Aguayo, S., Zuniga, L.: Towards the improvement of ADHD children through augmented reality serious games: preliminary results. In: IEEE Global Engineering Education Conference, EDUCON (2018)
28. Microsoft Kinect (2019). http://www.xbox.com/kinect

29. Kourakli, M., Altanis, I., Retalis, S., Boloudakis, M., Zbainos, D., Antonopoulou, K.: Towards the improvement of the cognitive, motoric and academic skills of students with special educational needs using Kinect learning games. Int. J. Child-Comput. Interact. **11**, 28–39 (2017)
30. Bodolai, D., Gazdi, L., Forstner, B., Szegletes, L.: Supervising biofeedback-based serious games. In: Proceedings of 6th IEEE Conference on Cognitive Infocommunications, CogInfoCom 2015 (2016)
31. Sonne, T., Jensen, M.M.: ChillFish: a respiration game for children with ADHD. In: Proceedings of the TEI 2016: Tenth International Conference on Tangible, Embedded, and Embodied Interaction (2016)
32. Roh, C.H., Lee, W.B.: A study of the attention measurement variables of a serious game as a treatment for ADHD. Wirel. Pers. Commun. **79**, 2485–2498 (2014)
33. Alchalabi, A.E., Shirmohammadi, S., Eddin, A.N., Elsharnouby, M.: FOCUS: detecting ADHD patients by an EEG-based serious game. IEEE Trans. Instrum. Meas. **67**, 1512–1520 (2018)
34. Alchalabi, A.E., Elsharnouby, M., Shirmohammadi, S., Eddin, A.N.: Feasibility of detecting ADHD patients' attention levels by classifying their EEG signals. In: Proceedings of 2017 IEEE International Symposium on Medical Measurements and Applications, MeMeA 2017 (2017)
35. Alchalcabi, A.E., Eddin, A.N., Shirmohammadi, S.: More attention, less deficit: wearable EEG-based serious game for focus improvement. In: 2017 IEEE 5th International Conference on Serious Games and Applications for Health, SeGAH 2017 (2017)
36. HTC VIVE (2019). https://www.vive.com
37. Microsoft Hololens (2019). https://www.microsoft.com/it-it/hololens