Smart Learning Environments

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Gameful strategies in the education of autistic children: a systematic literature review, scientometric analysis, and future research roadmap

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Abstract

The education of autistic children presents significant challenges, compelling various educational stakeholders to seek solutions that can enhance teaching and learning experiences for these individuals. Among the most promising strategies are gameful approaches, including gamification, card games, and simulators. Despite recent efforts, understanding the development and application (i.e., the state of the art) of these approaches in the education of autistic children remains a complex task. To address this issue, we conducted a thorough systematic literature review and scientometric analysis to explore the design and implementation of gameful approaches for the education of children with autism. Our findings highlight the predominant use of 2D games designed for personal computers, focusing on natural, home, and urban settings. Additionally, we observed that the studies were primarily qualitative. Based on these results, we proposed a research agenda. We offer a comprehensive overview and a research agenda for the design, use, and assessment of gameful approaches in the education of children with autism.

Keywords: Special needs education, Early years education, Gameful approaches, Teaching/learning strategies, Systematic review

Introduction

Autism Spectrum Disorder (ASD) is a syndrome that causes neurobiological interference in people (Chmielewski & Beste, 2015; Hodges et al., 2020b; Marotta et al., 2020). ASD affects cognitive aspects and can usually be diagnosed in children while they are still in their early years of life and training (Kas et al., 2014; Khaleghi et al., 2020; Al-Mazidi, 2023). People diagnosed need support from professionals and family members in specialized treatments and follow-ups to reduce the impact on the quality of life of these children (Rosenberg et al., 2009; Daniels & Mandell, 2014; van't Hof et al., 2021). Thus, in the last few years, different methods and tools for monitoring the learning process of children with autism have been developed (Accardo & Finnegan, 2019; Hsiao &

Sorensen Petersen, 2019; Dynia et al., 2020). Especially, recent research suggests that the school environment is particularly challenging for young people with autism spectrum disorder, where many of them experience bullying from typically developing peers, leading to poor academic performance, low self-esteem, and mental health difficulties (Hodges et al., 2020a; O'Hagan et al., 2021; Hill et al., 2023).

Gameful approaches are one of the technologies with promising potential for this purpose, playing an essential role in stimulating children's cognitive aspects of learning processes (Kim, 2019; Arzone et al., 2020; Simões-Silva et al., 2022). Through gameful approaches such as gamification, card games, and simulators, it is possible to stimulate the cognition of autistic children (Wang et al., 2022). However, it is still unknown to the community how gameful approaches have been designed and used in the educational process of autistic children (Silva et al., 2021; Valenciaet al., 2019; Hassan et al., 2021).

Facing this challenge, we conducted a systematic literature review to understand how gameful approaches are used in the education of children with autism. As secondary goals, we defined:

- To identify strategies for gameful approaches designed for children with ADS.
- To identify how researchers have interacted with children's parents and professionals on the studies.
- To propose challenges for research direction using gameful approaches for ASD children.

To achieve this goal, we answered five different research questions: (i) What visual approaches have been used to present gameful approaches for autistic children? (ii) What platforms have been used to present gameful approaches for autistic children? (iii) What environmental contexts have been used in the gameful approaches for autistic children? (iv) What graphic elements have been used in the gameful approaches for autistic children? and (v) Which professionals and people (in general) are involved in the application of gameful approaches with autistic children? We raised these questions focusing on mapping and identifying further directions related to game utilization for children with ASD. The proposed questions are associated with the cognitive aspects and game technologies.

For this work, we used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), which provides a guide composed of a flow and a checklist for authors to give a minimum necessary for systematic review. We chose PRISMA because it is a well-recognized protocol and an officially indicated method of some publication venues. From an initial range of 375 studies, we analyzed 32 based on the defined inclusion and exclusion criteria. The main results indicate that (i) digital 2D gameful approaches are the most common for the education of autistic children, (ii) the personal computer is the most common platform used in the education of autistic children, (iii) nature, house, and city are the most common environmental contexts and graphic elements implemented in the studies, and (iv) in most of the studies, only teachers accompanied autistic children.

In the end, based on the results found, we also proposed an agenda for future studies with recommendations related to the design, use, and assessment of gameful approaches in the education of children with autism. With that, we aim to help the community to evolve studies in the area over the next few years. Thus, we contribute especially to the fields of educational technologies and mental health, through a series of discoveries, insights, and recommendations into the use of gameful approaches for the education of autistic children.

Background

This section describes the concepts discussed in this article (i.e., gameful approaches, and autism in children). We also present and compare some recent related publications.

Gameful approaches

Gameful approaches (e.g., gamification, game-based learning, and serious games) are becoming one of the main tools for motivating people, providing support for a range of individual and collective beneficial behaviors (Sendra et al., 2021; Sailer & Homner, 2020; Aura et al., 2022). Especially, gamification (i.e., the process in which services, activities, and systems are transfigured to promote comparable motivational benefits as those found in games) is one of the widely used and effective methods, that in turn promotes intrinsic motivation through the use of various game design elements beyond fully functional games (Hamari, 2019; Koivisto & Hamari, 2019).

Gamification research has been conducted in a wide range of fields that eventually adopt it to their function, such as health care, marketing, advertising, government services, and education (Hamari & Koivisto, 2015; Mubin et al., 2020). Gamification has grown steadily over the past decade (Mubin et al., 2020). At the same time, game design covers the gradual embedding of proven intrinsic motivators while considering different aspects of successful games, thereby applying them to these principles in the educational process (Aguilar et al., 2018).

Recently, there has been a significant increase in the development of gameful approaches for use in education (Koivisto & Hamari, 2019). Using card games and gamified applications, for instance, contributes to raising awareness of users as well as positive changes in their behavior (Boncu et al., 2022). Gameful approaches also have attracted increased research interest due to their potential to increase engagement in health interventions and motivate behavior change (Cheng et al., 2019; Johnson et al., 2016). Gameful approaches also demonstrate the highest productivity in specific fields of application, one of which is health care, where numerous experiments have yielded positive results (Bellotti et al., 2013).

Different gameful approaches for the intensive treatment of children with autism have now been developed (Constain et al., 2019; Mubin et al., 2020; Jiménez-Muñoz et al., 2022). These approaches are based on the finding that children with autism perceive visual information better and also show an interest in digital and video games (Malinverni et al., 2017; Constain et al., 2019; Zhang et al., 2022; Camargo et al., 2019; Jiménez-Muñoz et al. 2022; Soltiyeva et al., 2023). These studies demonstrate the community's recognition of the possibility of using gameful approaches in the education of autistic children.

Autism in children

Autism is a specific disability of the nervous system that makes it difficult for an individual to form emotional contact with the outside world, especially with people (Lauritsen, 2013; WHO, 2023). The official criteria for autism are defined in the major diagnostic classification system Diagnostic and Statistical Manual of Mental Disorders (DSM-V) (Lord et al., 2018). Diagnosis requires obvious impairments in social interaction and communication, as well as the presence of two or more limited, repetitive, stereotypical behavioral responses or interests (Kulage et al., 2014; Lord et al., 2018).

Autism occurs in all social classes and all nations with equal frequency (WHO, 2023). Also, the overall ratio of boys to girls is the same (i.e., 4:1). Globally, it is estimated that about 1 child in 100 has autism (WHO, 2023; Lord et al., 2018). In the absence of timely diagnosis and adequate psychological and pedagogical correction, many of these children become unteachable and unadapted to life in society (WHO, 2023). Otherwise, if modification is started properly, most autistic children can attend school, often showing giftedness in some fields of knowledge, art, and others (Rogers, 2000).

The behavior of an autistic individual is characterized by strong stereotypes and monotony (Volkmar et al., 2014; Lord et al., 2018). First of all, it is the desire to maintain the usual consistency in the environment: eating the same food, wearing the same clothes, having household items constantly in the same places, walking the same route, repeating the same movements, words, phrases, receiving the same impressions, focusing on the same interests, the tendency to make contact with the environment and interact with people in the same habitual way (Johnson & Myers, 2007). Attempts to break these stereotypical conditions of life of the child cause him or her to diffuse anxiety, aggression, or self-aggression (Matson & Nebel-Schwalm, 2007).

Children with autism are better at perceiving visual information and also interact well with technology, however, they have difficulty interacting with the real environment (Grossard et al., 2017; Soltiyeva et al., 2023). Consequently, researchers have developed multiple teaching methods using gameful approaches such as games, gamification, Virtual and Augmented Reality, serious games, and others (Silva et al., 2021; Valenciaet al., 2019; Hassan et al., 2021). The results of these studies provided evidence showing that the use of gameful approaches can promote progression and skill development in children with autism (Zakari et al., 2014; Cheng et al., 2019; Jiménez-Muñoz et al., 2022).

Related work

The primary motivation of this review is to understand the practical aspects of using games for learning for children with autism. As a result, we expect a classification of the profile of technologies, playful contexts that are close to children's daily lives, and which professionals are generally involved in the experiments reported in the literature. Similar recent literature reviews were found.

Silva et al. (2021) classified the conditions worked on with children through games. The authors identified that social skills are the main category addressed when technology is a serious game or an entertainment game. The other types specified were affective and behavioral aspects, cognitive functions, and emotional recognition. The authors also presented how the child interacts with the games. According to the authors, kids can

play alone, interact with peers, or even interact with virtual agents in the game (Silva et al., 2021).

Valenciaet al. (2019) analyzed how technology contributes to people with autism, elements, methods of usability, and experience that are applied, and which game elements are considered. Although the study revealed exciting aspects, the approach followed by the authors is broader than the one proposed in this paper, as they consider children, adults, and adolescents as their audience.

Finally, Hassan et al. (2021) focused on a review of aspects of the design of serious games to improve the social behaviors of people with autism. The work brings an approach focused on just one of the aspects and does not discuss technologies and professional participation, with a contribution focused on game design.

While these studies advance the literature by providing insights concerning the use of specific game-based technologies for the education and treatment of autistic people, the gap remains open regarding understanding the state of the art of using gameful approaches for the education of autistic children. Thus, to the best of our knowledge, we are the pioneers in investigating the use of gameful approaches (in general) for the education of autistic children through a secondary study (i.e., a systematic literature review).

Protocol

This systematic review was conducted based on the PRISMA protocol[1] that allows the conduction of a systematic process, from the collection of data to the writing of the results (Page et al., 2021).

Objectives and research questions

We carried out this systematic literature review with the main goal of identifying which gameful approaches have been used to stimulate the cognitive process of autistic children. To reach the purpose of the study, the following research questions (RQs) were defined:

- *RQ1: What visual approaches have been used to present gameful approaches for autistic children?*
  - With this question, we aim to understand the kind of visualization used in the gameful approaches.
- *RQ2: What platforms have been used to present gameful approaches for autistic children?*
  - With this question, we aim to understand the platforms used to present gameful approaches for autistic children and correlate the visual approach with the most common technological platforms for user interaction.
- *RQ3: What environmental contexts have been used in the gameful approaches for autistic children?*
  - With this question, we aim to understand the most common environments from which an ASD child's routines have been considered for correlation with the gameful approaches.

[1] https://prisma-statement.org/.

- *RQ4: What graphic elements have been used in the gameful approaches for autistic children?*
  - With this question, we aim to understand which elements, such as objects, animals, and characters, are used in the gameful approaches.
- *RQ5: Which professionals and people (in general) are involved during the application of gameful approaches with autistic children?*
  - Finally, with this question, we aim to understand the professionals involved in the experiments with children.

In this study, we refer to graphical elements as symbols used to represent real-world objects. Examples include dogs, flowers, or trees, which serve as components in games. We use the term "visualization" to denote the dimension (2D or 3D) of these graphical elements, along with the type of device used for their projection. For instance, 2D and 3D graphical elements can be projected onto planned surfaces (e.g., monitors, mobile devices) or spatial environments, such as Virtual and Augmented Reality devices. Combining 2D and 3D graphical elements with planned or spatial visualization devices presents a feasible option.

It's important to note that even when a virtual or augmented reality application is projected onto a planned surface, such as a mobile device, it can still provide a sense of immersion by integrating virtual elements with the real world (as facilitated by Augmented Reality technology). Similarly, virtual reality applications can utilize planned surfaces for projecting digital elements. However, this technology can also be combined with optical devices to enhance users' sense of presence and immersion.

Lastly, we define "environmental contexts" as the real-world settings chosen to represent the daily routines of individuals with ASD. Examples of such contexts include houses, schools, and forests.

Eligibility criteria

Next, following the PRISMA protocol, the eligibility criteria were defined to filter the studies:

- *Inclusion criteria*
  - Primary empirical studies published since 2017 presenting the use of screen-mediated gameful approaches for the teaching of autistic children.
- *Exclusion criteria*
  - Out-of-scope studies (i.e., unrelated to the review's objectives);
  - Gray literature (i.e., studies without verified peer review, such as book chapters and prefaces);
  - Redundant studies (i.e., similar belonging to the same group of authors). In these cases, we retained the most recent study;
  - Studies in languages other than English;
  - Duplicate studies;
  - Secondary or tertiary studies (e.g., literature reviews, scoping reviews, and scientometric analysis).

Specially, choosing to select primary studies from 2017 onward, we aim to have a more faithful landscape of the most recent advances in the area.

Sources and search strategy

For data collection, we chose to use the database Scopus,[2] as it is a base that encompasses all other bases in the area (e.g., ACM, IEEE Xplore e Springer) and is widely used as a single source in recent secondary studies of different areas (e.g., (Cosio et al., 2023; Mattinen et al., 2023; Oliveira & Hamari, 2024)).

Following the PRISMA protocol, after defining the data source, we define the search strategies (i.e., the keywords used to assemble the search string). The query/search string used was: TITLE-ABS-KEY (autism*) AND TITLE-ABS-KEY ("game-based") OR TITLE-ABS-KEY ("serious game*") OR TITLE-ABS-KEY ("simulation game*") OR TITLE-ABS-KEY (games-with-a-purpose) OR TITLE-ABS-KEY ("educational game*") OR TITLE-ABS-KEY ("learning game*") OR TITLE-ABS-KEY ("gamif*").

Selection process and data collection

The system Parsif.al[3] was used to remove duplicate studies, as well as to organize the selection process. Initially, the title and abstract were read to define whether a study met the inclusion criteria of the review. The process was conducted by three researchers who read the titles and abstracts. We divided the studies for each researcher for a first classification, and a second researcher should double-check. In the end, a meeting between three researchers was conducted to discuss divergent points. The meetings focused on remaining doubts after double-checking or a final decision in case two researchers disagreed with a paper evaluation. The data collection followed the parameters previously defined.

Methods of synthesis and selection of studies

The query returned 375 studies, of which 10 duplicate studies were removed by the Parsif.al platform. At the beginning of the screening step, 310 studies were rejected by the researchers for not meeting one of the inclusion criteria and 55 were accepted for the reading and data extraction stage. In this step, 13 studies were removed for not being available (even after a formal request to the authors). Five of them were identified as redundant and five were removed as they were identified as out of scope during the full read. Finally, 32 studies were included in the review. Figure 1 presents the PRISMA diagram summarizing the whole process. The initial search took place on November 25, 2021, and the review process lasted 1 year. The protocol and dataset were registered in the OSF.[4]

Results

Initially, Appendix presents the Id, Title, and Citation of the 32 studies included in this review. To highlight the studies more clearly, the Ids are identified with the letter "S" followed by the corresponding number and the name of the study. For example

[2] https://www.scopus.com/home.uri.
[3] https://parsif.al/.
[4] https://osf.io/ev86q.

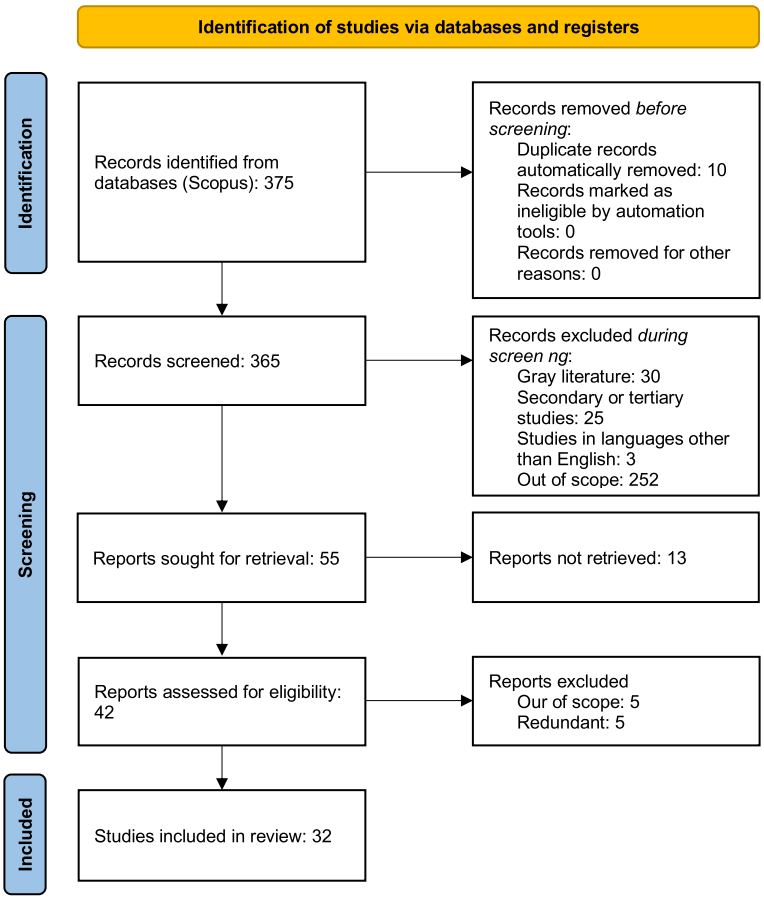

Fig. 1 PRISMA diagram (adapted from Page et al. (2021))

S01, S02, S03, and so on and up to S32. Next, we present the results of our study, separated by RQ, starting with the scientometric analysis.

Scientometric analysis

Table 1 presents the number of publications per country. Spain is the country with the highest number of studies in the area (i.e., four studies), followed by Brazil and Canada (three studies each). This result shows that no country has dominated research related to the use of gameful approaches to the education of autistic children.

Table 2 presents the number of publications per author. Only five authors published more than one work in the area. At the same time, we counted another 144 authors participating in an article. Thus, it is also possible to note that no one author or research group dominates research on the use of gameful approaches in the education of autistic children.

RQ 1: What visual approaches have been used to present gameful approaches for autistic children?

This RQ aims to understand the technological aspects of gameful approaches for children with autism. Understanding the main visual approaches and platforms can help

Table 1 Publications per country

Countries	N
Spain	4
Brazil, Canada	3
Japan, Malaysia, Netherlands, Portugal, United Kingdom	2
Belgium, Ecuador, Egypt, Finland, France, India, Israel, Morocco, Poland, Serbia, Taiwan, United Kingdom, United States	1

Number of publications per country

Table 2 Publications per author

Authors names	N
Esteves, J.S.; Ghosh, A.; Pereira, A.P.; Silva, V.; Soares, F.	2
Aboelnaga, K.; Abreu, L.C.D.; Ahami, A.O.T; Al Osman, H.; Alami, N.; Al-Thani, D.; Ananta, G.P.; Antão, J.Y.F.D.L.; Antunes, T.P.C.; Arifin, A.; Askenazy, F; Baldassarri, S.; Barajas, A.O.; Barbosa, R.T.D.A.; Baron-Cohen, S.; Ben-Zur, S.; Berggren, S.; Bogdanovi?, Z.; Bölte, S.; Bourgeois, J.; Bourreau, B.; Cabãero, M.D.M.; Cai, Y.; Carlier, S.; Chan, S.; Costa, P.; Crocetta, T.B.; De Backere, F.; de Barbosa, C.R.S.C.; de Mira Gobbo, M.R.; De Turck, F; Dillenburger, K.; ?or?evi?, M.; Drissi, M.M.; ?uri? Jovi?i?, M; Elhaddadi, M.; Elshahawy, M.; Fatoni, M.H.; Freitas, H.; Fridenson-Hayo, S.; Garcia-Garcia, J.M.; Ghanouni, P.; Glumbi?, N.; Goei, S.L; Golan, O; Gomez, J.; Goodman, L; Guarnieri, R.; Gupta, N; Halimah Baki, S.; Hervás, A.; Hsiao, I.Y.T.; Huang, L.; Hulusic, V; Hun, S.; Hutchison, M; Jaccheri, L.; Jarus, T.; Kapoor, R.; Kärnä, E; Karthic, P.; Kerns, K.A.; Khowaja, K.; Kitahara, I.; Korhonen, V.; Kuipers, D.; Laffey, J.M; Lan, Y.-J.; Lassalle, A.; Latifi, M.; Lozano, M.D; Lu, A.; Lucyshyn, J; Maazouz, H.; Macoun, S.; MacSween, J.; Mafort, F.; Mairena, M.Á.; Malinverni, L.; Massetti, T.; Meir-Goren, N.; Mènon, C.S.; Mioni, J.L.V.M; Mirocha, J.; Mohd, C.K.N.C.K.; Monteiro, C.B.D.M; Montoro, G; Mora-Guiard, J.; Morandini, M., M.; Nay, Z.T.; Noor, H.A.M.; O'Reilly, H.; Oki, M.; Ongenae, F.; Padillo, V.; Paillacho Chiluiza, D.F.; Paillacho Corredores, J.S; Pares, N; Passerino, L.; Patil, K.; Pei, J.; Penichet, V.M.R.; Perales, F.J; Pervaiz, T.; Pierie, J.P.E.N; Pierron, P.; Pigat, D.; Pistoljevic, N.; Prins, J.T.; Rahmadiva, M.; Ramis, S.; Raposo, A.B.; Räty, H.; Riquelme, I.; Salim, S.S; Santos, A.; Sedek, M; Serret, S.; Shahbodin, F.; Sharaf, N; Shih, M.-F; Shirmohammadi, S; Silva-Calpa, G.F.M.; Sochocka, A.; Solorzano Alcivar, N.I.; Starypan, R; Suplino, M; Suzuki, K; Takahashi, I.; Tal, S.; Terlouw, G.; Thümmler, S.; Tonks, J.; Torrado, J.C.; Valero, L.; Van der Paelt, S.; Van't Veer, J.; Vuki?evi?, S.; Wagle, S.; Wang, X.; Watanabe, T; Xing, W.; Yakkundi, A.; Zwicker, J.G.	1

Number of publications per authors

researchers and professionals develop games to support the teaching of children with autism. The 2D view is the most common, presented in 18 studies (S01, S02 S05, S06, S07, S08, S09, S10, S12, S14, S16, S17, S19, S20, S22, S24, S25, S26, S27, S30, S32) with publications in all years. The 2D and 3D label corresponds to a system that uses both visualizations on the same platform (used only in the study S15). Although 3D is the second most common form of visualization, it is less explored, being contemplated in seven studies (S03, S11, S13, S18, S21, S28, S29).

We did not focus on finding specific reasons why authors chose to use 2D games. However, there may be clues related to computational processing power since, in general, 2D games require fewer resources than 3D games. Another aspect is that 2D games may be more suitable for children, especially children with ASD, for attention purposes (Ip et al., 2017). A disadvantage of 2D games is the difficulty of working with spatial perception since these games operate in two dimensions. On the other hand, it is important to consider that 3D applications, especially in VR and AR, can help the autistic in the spatial and dimensional recognition of artifacts. One study used a robot (S31) and in two studies (i.e., S04 and S23), it was not possible to identify the visual approach used in the study. Figure 2 presents a summary of the use of the identified interfaces and their applications over time.

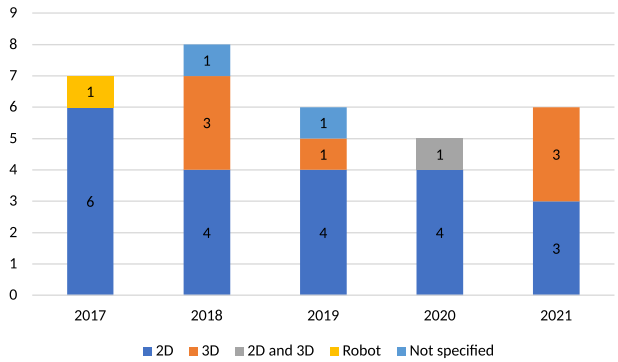

Fig. 2 Visual approaches distribution over the years

Table 3 Relationship between visual approaches and platforms

	PC	Mobile	VR/AR	e-book	II	Console
2D	11	7	1	1	1	1
3D	4	–	3	–	–	–
2D and 3D	1	–	–	–	-	–
Not Specified	1	1	–	–	-	–

PC: personal computer; VR: virtual reality; AR: augmented reality; II: interactive installation

RQ 2: What platforms have been used to present gameful approaches for autistic children?

Regarding the RQ 2, the personal computer (PC) is the most common platform used in 16 studies (S01, S02, S04, S06, S07, S10, S11, S12, S13, S15, S16, S17, S18, S25, S26, S27, S29), the mobile platform (e.g., smartphones, tablets, and others) is the second most common described in eight studies (S08, S10, S19, S20, S22, S23, S25, S32), followed by virtual reality or augmented reality (VR/AR) platforms with four occurrences (S03, S21, S28, S30). One occurrence was identified for interactive installation, e-book, video game console, embedded device, and robot. In one of the studies, it was not possible to identify the platform. Some of the solutions presented merge more than one platform. Therefore, the number of platforms found is superior to the number of analyzed papers.

Table 3 presents the relation between the three leading platforms and the visual approaches found. 2D visualization is present on all platforms. VR/AR platforms mainly use the 3D interface. It is important to note that VR/AR platforms can be processed on PCs or mobile devices, depending on the choice of gadget. It was not possible to identify this aspect in the reviewed works. Meanwhile, mobile platforms make use of 2D. This is probably because mobile devices have less computational power for graphics processing, although this has changed over the years.

AR and VR platforms have the potential to be explored in further studies. This technology has become more popular and less expensive in recent years. Currently, a VR gadget is similar in price to a popular smartphone. Meanwhile, AR can be experimented with on smartphone screens. We have the opportunity for massive use by ASD children in several contexts, such as school, therapy, and a home, with the supervision of professionals and parents. Otherwise, more AR and VR efficacy studies should be developed and better explored. Furthermore, AR and other mobile technologies allow researchers

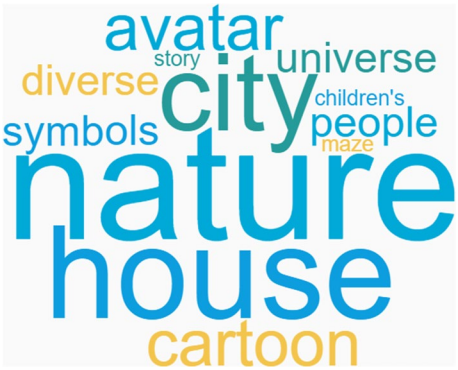

Fig. 3 Used environments words cloud

and practitioners to design technologies for integration with real-world environments, which can benefit ASD people for therapy and education purposes.

RQ 3: What environmental contexts have been used in the gameful approaches for autistic children?

The identification of environments is important to understand the children's correlation of the game with the real world. The three most common environments were Nature (S01, S02, S04, S05, S07, S09, S12, S13, S20, S21, S23, S32), House (S11, S15, S18, S22, S25, S28), and City (S03, S13, S14, S18, S29). These may be the most chosen because they usually portray environments in which children with autism are inserted into their routines. The other contexts were Universe (S10, S20), Cartoons (S07, S08, S24), presentation of people (S19, S26), symbol (S06, S30), diverse (S16, S27), avatar (S31), maze (S29) and children's story (S17). Figure 3 shows a word cloud with the most common environment identified.

RQ 4: What graphic elements have been used in the gameful approaches for autistic children?

We also related the graphic elements of the three primary environments, representing 66% of the analyzed studies. Figure 4 shows the three sets, Nature, House, and City, and the identified cognitive elements. The font size represents the proportion of occurrence of terms, with the least frequent one appearance and the most frequent nine appearances. Some elements are found in more than one context as presented. We identified a lack of common gameful elements in the context of "Nature" and "City". Concerning the cognitive aspects, we identified several elements in the considered articles. Emotions, Learning, and literacy were the most common. Figure 5 shows a word cloud with the identified aspects.

RQ 5: Which professionals and people (in general) are involved in the application of gameful approaches with autistic children?

In nine studies (S07, S08, S13, S16, S17, S21, S22, S27, and S29), only teachers accompanied autistic children. In five studies (S01, S06, S20, S26, and S04) only parents accompanied the children. In four studies (S03, S09, S12, and S18), children

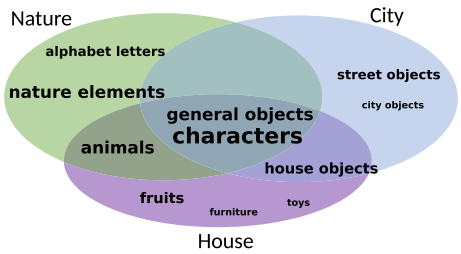

Fig. 4 Distribution gameful elements into most common environments

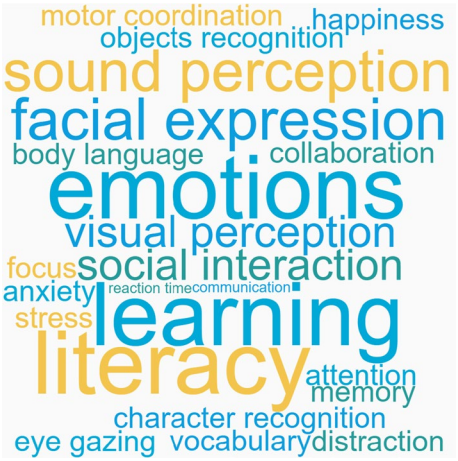

Fig. 5 Used Environments words cloud

were accompanied by parents and teachers, while in two studies (S10 and S25) children were accompanied by parents and therapists. In one study (S11), parents and clinicians accompanied the children. In the study (S32), parents and educators accompanied the children. In research (S28), psychologists and educators accompanied the children. In a different study (S05), adults (not specified) accompanied the children. In an alternate study (S02), educators accompanied the children. Finally, in another study (S14), therapists accompanied the children. In six studies (S15, S23, S24, S30, S31, and S19), it was not possible to identify if/who accompanied the children (Fig. 6).

Discussion

Below, we present a discussion of the results of this systematic review. Our objective is to bring some possibilities regarding each result and reflect on how future studies can advance the state of the art. We conducted a systematic review of the literature to identify gameful approaches used to improve the cognitive performance of autistic children. Our study focused on important aspects, such as visual approaches, platforms, environment, professionals, and people involved in the use of gameful approaches with children with autism.

In another review, researchers focused on game elements, user-centered design techniques, and emerging technologies such as artificial intelligence, virtual reality,

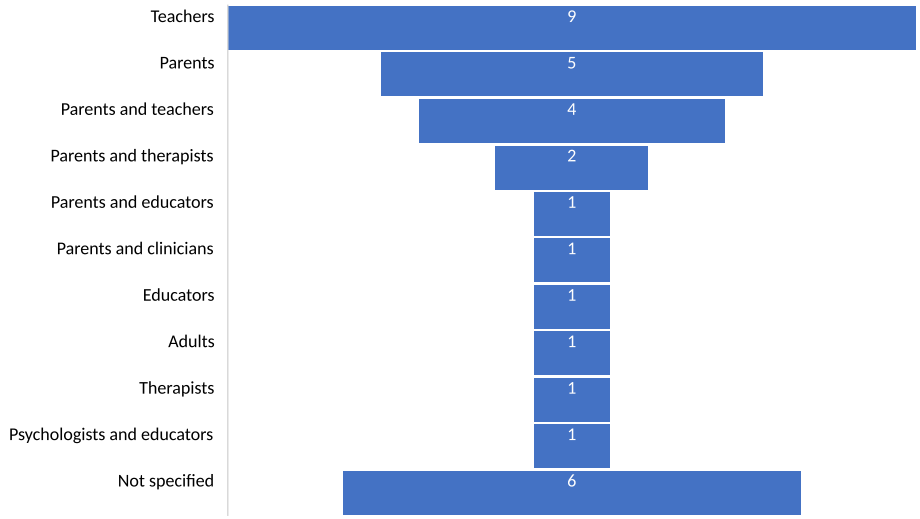

Fig. 6 Professionals involved in the studies

and educational robotics for the education of children with disabilities, providing evidence that collaboration among educators, game developers, researchers, and parents is essential to ensure that gamification initiatives are inclusive and address the diverse needs of students (Jadán-Guerrero et al., 2023). Camargo et al. (2019) delved into gamification resources for autistic individuals, specifically focusing on gamification elements and User Interface design. They also discovered that numerous studies utilize strategies to customize learning outcomes and offer parental control. Synchronizing devices for both the child and parent, as well as the child and teacher, enables educators, therapists, or parents to oversee their children's progress. This facilitates the selection of individualized learning goals based on the child's specific cognitive responses (Camargo et al., 2019).

Visual approaches used to present gameful approaches for autistic children

In the first research question of our study, we answered "What visual approaches have been used to present gameful approaches for autistic children?", aiming to understand the technological aspects of gameful approaches for children with autism. Understanding the main visual approaches can help researchers and professionals in the development of gameful approaches to support the teaching of children with autism. The main results indicate that 2D is the most common visual approach, presented in 18 studies with publications in all analyzed years.

The "2D and 3D" category corresponds to a game that uses both views on the same platform (used only in one study). Although 3D visualization is the second most common form, it is less explored, and contemplated in only seven studies. This can be attributed to the need for graphics processing capabilities and the fact that 2D application development is generally simpler. On the other hand, it is important to consider that 3D applications, especially in VR (virtual reality) and AR (augmented reality), can help autistic people in the spatial and dimensional recognition of artifacts.

The predominance of the use of 2D approaches in gamified interventions for autistic children presents both benefits and potential harm. Using 2D visuals offers several advantages. First, 2D graphics are generally simpler to develop and require less computational resources than 3D graphics, making them more accessible and cost-effective. Additionally, 2D visuals provide a clear, familiar representation that can facilitate understanding and engagement for autistic children, who often prefer structured and predictable environments. The simplicity of 2D visuals can also help minimize sensory overload, as excessive visual stimuli can overwhelm individuals with autism.

However, the predominance of 2D approaches also has potential harm and limitations. One limitation is that relying solely on 2D visual aids can restrict the range of experiences and interactions available to autistic children. Three-dimensional representations, especially in virtual reality (VR) or augmented reality (AR) environments, have the potential to offer a more immersive and multisensory experience, promoting spatial awareness and increasing engagement (Mota et al., 2020). By focusing primarily on 2D visuals, researchers and developers may miss out on the unique benefits that 3D technologies can offer in terms of promoting learning, social skills, and sensory integration.

It is crucial to strike a balance between the benefits and limitations of 2D approaches in gamified interventions for autistic children. In particular, AR, VR, and 3D gaming approaches can offer an immersive and interactive environment, allowing for greater user participation and engagement (Mota et al., 2020). In addition, the use of robots is also an interesting alternative, promoting the physical and social interaction of autistic children (Panceri et al., 2021). At the same time, the analysis of visual approaches in games for autistic children can contribute to advancing knowledge in cognitive psychology and inclusive education (Pereira et al., 2023). Understanding how different views impact the experience of autistic users can support theories and explanatory models about visual processing, selective attention, and social interaction in this specific context (López-Bouzas et al., 2023).

2D, 3D, and AR/VR visual approaches have similarities. Firstly, they are flexible for building elements that work on playful and cognitive aspects. All approaches can be used for gamification and composing abstract real-world components into concrete visualizations in the form of visual elements that enhance understanding and learning. Furthermore, the interfaces allow game elements to have cartoonish visual aspects. This perspective is interesting because although games can stimulate emotions, people can realize that the game is not part of the real world. On the other hand, 3D games differ from 2D in that they allow spatial visualization in 3 dimensions (x, y, z). For people who want this spatial aspect, these scenarios are more suitable.

Augmented and virtual reality games increase people's immersion, especially if combined with 3D elements. It is essential to highlight that virtual reality aims to immerse the person in a context different from what they are experiencing in the real world. For example, a person using a roller coaster application has the visual and audible stimuli of that experience in a virtual world. In the real world, the person may sit in an armchair with the necessary physical security to avoid getting hurt. Meanwhile, augmented reality aims to integrate real-world elements with virtual elements. The interaction occurs by physically integrating virtual components with real-world components. For example, a virtual character might walk across a (real) table in a

study room. This happens because, in general, virtual reality equipment has sensors to capture and digitize surfaces in the real world and allow this integration.

AR and VR can make user behavior more realistic through interaction with space because these devices have immersion at 6 degrees of freedom, unlike 2D and 3D games that play on flat surfaces, such as monitor screens and mobile devices, among others. Interaction with the 6 degrees of freedom can benefit autistic people who use the ABA (Applied Behavior Analysis) process as a therapy. ABA operates along the lines of behavior, and virtual and augmented reality enable more realistic behavioral actions for people, promoting better options for evaluation.

ABA is a scientific approach currently considered one of the most effective behavioral intervention methods for individuals with autism and other developmental disabilities. This methodology involves analyzing environmental factors influencing human behavior. ABA proves highly effective in teaching fundamental skills such as communication, enhancing attention, concentration, social skills, memory, and academic performance, while also reducing problem behaviors (Ithriyah, 2018; Eckes et al., 2023). ABA therapy can be adapted to cater to the individual needs of each person. The positive impact of ABA is rooted in the principle of conditioned reflex, wherein the child is guided to develop essential skills, and each action is reinforced with a specific reward (Portnova et al., 2020).

In addition, the insights obtained can inform pedagogical and therapeutic practices, helping educators, therapists, and game developers to design more effective and personalized interventions, adapted to the individual needs of autistic children. The theoretical and practical implications of these results are relevant for researchers, professionals, and game developers. By knowing the visual approaches used in games aimed at autistic children, it is possible to base the creation of new proposals, considering aspects such as accessibility, usability, and therapeutic potential. In addition, the research highlights the need to further explore 3D applications and the use of technologies such as VR, AR, and robotics in the context of autism, expanding the possibilities of intervention and support for children.

Platforms used to present gameful approaches for autistic children

The dominance of the PC as the most common platform for gameful approaches in the education of autistic children (see Table 3). These results can be explained by the widespread availability of PCs in educational settings and households, which makes them a convenient and accessible tool for implementing game-based interventions. The versatility of PCs allows for a diverse range of game designs and applications, catering to the diverse needs and preferences of autistic children. Moreover, the familiarity of educators and parents with PC technology may contribute to its prevalence, as it reduces barriers to adoption and implementation.

The second most common platform identified in the literature is the mobile platform, encompassing smartphones, tablets, and other portable devices. The popularity of mobile platforms in gameful approaches for autism education may stem from their portability and tactile nature (Ahmad Lawan et al., 2023). Autistic children often benefit from hands-on and interactive learning experiences, and mobile devices provide a tangible interface for engaging with educational games. Additionally, the ubiquity of mobile

devices in contemporary society makes them easily integrated into everyday learning environments, facilitating seamless transitions between formal and informal educational contexts (Al-Rashaida et al., 2022).

The relatively lower frequency of VR/AR platforms in the reviewed studies could be attributed to practical constraints and the evolving nature of VR/AR technology. While these platforms offer immersive and interactive experiences that can be highly engaging for autistic children (Ahmad Lawan et al., 2023; Dechsling & Nordahl-Hansen, 2023), they may require specialized equipment and expertise for implementation. The cost and complexity associated with VR/AR setups could limit their widespread adoption, especially in resource-constrained educational settings. Future research may explore strategies to overcome these challenges and enhance the feasibility of integrating VR/AR technologies into autism education.

The limited occurrences of interactive installations, e-books, video game consoles, embedded devices, and robots suggest a less prevalent but potentially impactful role of these technologies in gameful approaches to autistic education (Derbali et al., 2023; Santhanam, 2023). Interactive installations and robots, for instance, may offer unique opportunities for social interaction and tailored interventions (Ahmad Lawan et al., 2023). However, their limited presence in the literature may reflect the nascent stage of research in these areas, signaling avenues for further exploration and innovation. Understanding the specific contexts and scenarios where these platforms excel could inform the development of targeted interventions for specific needs within the autistic spectrum.

The diverse range of platforms identified in the literature highlights the dynamic landscape of gameful approaches to the education of autistic children. The prevalence of PCs and mobile devices underscores their practicality and accessibility, while the emerging role of VR/AR and other platforms suggests ongoing exploration and potential advancements in technology-assisted interventions. As the field continues to evolve, researchers and practitioners should consider the nuanced strengths and limitations of each platform to optimize the design and implementation of gameful approaches for the diverse needs of autistic learners.

Environmental contexts used in the gameful approaches for autistic children

Individuals with ASD often experience heightened sensitivity to their surroundings due to sensory processing deficits, as sensory processing deficits, such as sensitivity in eyesight or hearing, can render the environment distracting and potentially frightening (Ip et al., 2017). Design professionals, educators, and parents should be mindful of the sensory challenges encountered by individuals with autism. This awareness is crucial for crafting suitable learning environments (Gaines et al., 2016). Research demonstrates that utilizing Nature as a therapeutic environment for individuals with ASD yields therapeutic benefits, including enhanced self-confidence, improved self-esteem, positive effects on personality and development, and a reduction in certain sensory problems (Anas, 2023; Barakat et al., 2019). Environmental factors, which are more challenging for individuals with ASD to perceive, are minimized during Home therapy as the patient is in familiar surroundings. Therefore, therapeutic interventions in House settings are particularly crucial. Additionally, the active involvement of the family promotes

the development of interpersonal relationships and enhances social and communication skills (Chistol et al., 2023). Studies have shown that autistic children often experience social isolation from both peers and teachers. Consequently, many parents prefer to educate their autistic children in a Home environment (O'Hagan et al., 2021).

The prevalence of Nature, House, and City environments in the design and application of gameful approaches for the education of autistic children suggests a deliberate emphasis on contextual relevance and familiarity. The prominence of Nature settings, with 12 studies focusing on this environment, aligns with research highlighting the therapeutic benefits of nature exposure for individuals with autism. Nature environments may offer a calming and sensory-rich backdrop for educational games, potentially contributing to enhanced engagement and learning outcomes. Moreover, these settings likely resonate with the everyday experiences of autistic children, reflecting the importance of aligning game content with their familiar surroundings to optimize the effectiveness of educational interventions.

The prominence of House settings in six studies and City settings in five studies further underscores the emphasis on integrating gameful approaches into the daily routines and environments of autistic children. The home and urban environments are integral parts of a child's life, and leveraging these settings in educational games can enhance the transferability of skills learned in the virtual context to real-world situations. Designing gameful approaches that simulate home and city environments may facilitate a smoother transition between the virtual and physical worlds, promoting the generalization of skills acquired during gameplay to practical, everyday scenarios. This alignment with familiar settings could enhance the overall effectiveness and applicability of gameful interventions for children with autism.

The inclusion of diverse contexts such as Universe, Cartoons, presentation of people, symbols, diverse, avatars, mazes, and children's stories, each in varying frequencies, suggests a recognition of the need for diversity in game design to cater to the heterogeneous preferences and needs of autistic children. While Nature, House, and City environments dominate, the incorporation of varied contexts reflects a nuanced understanding of the diverse interests and sensory preferences within the autistic spectrum. Game designers and educators can draw on this insight to tailor interventions to individual preferences, ensuring a more personalized and effective learning experience. As the field progresses, further exploration of the unique benefits associated with each context may guide the development of targeted gameful approaches for specific subsets of the autistic population, promoting inclusivity and individualized support.

Professionals and people (in general) involved in the application of gameful approaches with autistic children

Effective communication between parents, teachers, and therapists is crucial in enhancing special education services and fostering the development of academic, social-emotional, and behavioral skills in children diagnosed with ASD (Azad et al., 2021). The ASD Inclusion Collaboration Model comprises five elements: implementing suitable environmental and curricular adjustments, offering support and employing instructional methods in general education classrooms, providing attitudinal and social support, fostering a committed and coordinated team approach, regularly assessing inclusion procedures,

and promoting collaboration between home and school (Anthony & Campbell, 2020). Interprofessional collaboration enhances communication among parents, special educators, and social workers, thereby assisting the child in enhancing, sustaining, adjusting, and functioning within the learning environment (Anthony & Campbell, 2020).

The diverse patterns of adult accompaniment in the education of autistic children underscore the importance of considering the collaborative involvement of various stakeholders in the educational process. The prevalence of teachers as the sole companions in nine studies and parents in five studies reflects the pivotal roles these primary caregivers play in the educational journey of autistic children. Teachers, with their expertise in pedagogy, are well-positioned to integrate gameful approaches into structured learning environments, ensuring alignment with educational objectives. On the other hand, parents, being intimately acquainted with the daily lives and routines of their children, offer a unique perspective that can inform the development of gameful interventions tailored to the individual needs and preferences of autistic learners. This highlights the need for collaborative efforts between educators and parents to create holistic and well-rounded game-based educational strategies.

The occurrence of studies where children were accompanied by both parents and teachers (four studies) or parents and therapists (two studies) suggests the potential benefits of interdisciplinary collaboration. The collaboration between parents and educators allows for a seamless integration of learning experiences across home and school environments, fostering continuity in the application of educational interventions. The involvement of therapists alongside parents acknowledges the specialized support required by some autistic children, emphasizing the importance of integrating therapeutic expertise into the design and implementation of gameful approaches. This collaborative approach aligns with the holistic nature of autism education, recognizing that the support network for autistic children extends beyond the classroom and involves a multidisciplinary team.

The inclusion of diverse combinations such as parents and clinicians, parents and educators, psychologists and educators, adults (not specified), educators, and therapists in the accompaniment of autistic children in various studies highlights the necessity of flexibility in educational strategies. Each combination likely brings a unique set of perspectives, skills, and expertise to the table. The challenge lies in understanding and harnessing the synergies between these diverse stakeholders to create a cohesive and comprehensive educational environment. Moving forward, educators and researchers should explore frameworks that facilitate effective collaboration among teachers, parents, therapists, and other professionals, ensuring that gameful approaches are not only well-designed but also seamlessly integrated into the broader educational support system for autistic children.

Threats to validity and limitations

Initially, access to 13 studies was not possible as they were not publicly available. To mitigate this limitation, we attempted to acquire these studies by contacting their respective authors via email. However, due to a lack of responses, these 13 studies were ultimately excluded from the review process. Additionally, the initial search was conducted in November 2021, resulting in the exclusion of studies published in 2022. To mitigate this

limitation, we ensured that studies published within the last five years were included in our review. Nonetheless, some important information may have been inadvertently overlooked in our review results.

Given that this analysis was conducted by humans, there is a possibility of data collection errors, which could lead to inconsistencies in the results. To mitigate this limitation, we implemented strict analysis criteria enforced by three researchers. It's worth noting that certain studies on the subject may not have been captured either because they were not identified by the search string or because they were not present in the database utilized. To mitigate this limitation, we meticulously crafted the search string through collaborative discussions among three researchers. Additionally, we conducted several tests using different search strings and ultimately selected the one that yielded the most comprehensive results. Furthermore, our search was conducted using a database (i.e., Scopus) that encompasses the primary repositories in the field.

Research agenda for future studies

Initially, there is a predominance in the use of a specific visual approach (i.e., 2D), as well as a predominance concerning the use of personal computers for using the approaches. At the same time, it is known that independent approaches have used VR and AR individually. Given this, **we suggest that future studies can add gameful approaches and technologies such as VR and AR**. These novel approaches can enhance the teaching of autistic children by integrating two types of resources that are typically employed independently.

The results of our review demonstrate a predominance of studies involving nature, home, and city environments. On the one hand, this demonstrates a concern on the part of researchers in the area to work on fundamental aspects of the daily life of autistic children. On the other hand, there is a lack of studies that develop applications considering aspects of learning in general, such as school. Given this, **we suggest that future studies seek to go beyond conventional environments, proposing approaches that involve other types of environments**. These studies and interventions can broaden the perspectives of autistic children, fostering greater engagement with their surroundings and potentially enhancing their social skills.

Our study also shows that there is a predominance of those who accompany the children during the studies. In most studies, only teachers and parents accompany children. If, on the one hand, this is important and demonstrates a concern on the part of parents and teachers (who are primarily responsible for the intellectual development of children), on the other hand, it also demonstrates that few studies have sought collaboration with health professionals, such as psychologists, neurologists, and therapists, who are also fundamental to understanding how gameful approaches affect children's intellectual development. **We suggest that future studies involve other professionals in observing children using gameful approaches**. Incorporating diverse professionals into studies and interventions can enhance understanding of autistic children's behavior, thereby facilitating the development of effective approaches.

Conclusion

In the past few years, there has been a growing focus on the education of autistic children across various academic disciplines. Among the strategies employed in their educational journey is the integration of gameful approaches. To gain insights into the evolving landscape of community knowledge in this area, we undertook a systematic literature review to uncover the design and application of gameful approaches aimed at enhancing the educational experiences of autistic children. As part of our future research agenda, we aspire to broaden the review's scope, address diverse research questions, and undertake a meta-analysis to provide a more comprehensive understanding of the impact of gameful approaches on the learning outcomes of autistic children.

Notes

During the preparation of this work, the authors utilized Microsoft Copilot to enhance readability and language. After the utilization of this tool/service, the authors diligently reviewed and edited the content as necessary, assuming full responsibility for the publication's content.

This article is an extension of the conference paper conducted by Honorato et al. (2023).

Appendix

List of studies

See Table 4.

Table 4 List of studies

Id	Title	Reference
S01	"Emotiplay": a serious game for learning about emotions in children with autism: results of a cross-cultural	Fridenson-Hayo et al. (2017)
S02	A Demonstration Project for the Utility of Kinect-Based Educational Games to Benefit Motor Skills of Children with ASD	Vukićević et al. (2019)
S03	A Design of Multipurpose Virtual Reality Game for Children with Autism Spectrum Disorder	Rahmadiva et al. (2019)
S04	A full-body interactive videogame used as a tool to foster social initiation conducts in children with Autism Spectrum Disorders	Mairena et al. (2019)
S05	A pilot study: a computer game-based assessment of visual perspective taking of four children with autism with high support needs	Korhonen et al. (2017)
S06	A Serious Game for children with Autism Spectrum Disorder as a tool for play therapy	Barajas et al. (2017)
S07	A Vocabulary learning of children with autism spectrum disorder (Asd): From the development to an evaluation of serious game prototype	Khowaja et al. (2018)
S08	ACA game for individuals with Autism Spectrum Disorder	de Mira Gobbo et al. (2021)
S09	An empathic design approach to an augmented gymnasium in a special needs school setting	Takahashi et al. (2018)
S10	An inclusive reading programme for individuals with autism and intellectual disability using multi-media: Application of behaviour analysis and Headsprout early reading programme	Yakkundi et al. (2017)
S11	An interactive serious game to Target perspective taking skills among children with ASD: A usability testing	Ghanouni et al. (2021)
S12	Attention and working memory training: A feasibility study in children with neurodevelopmental disorders	Kerns et al. (2017)

Table 4 (continued)

Id	Title	Reference
S13	Autistic youth in 3D game-based collaborative virtual learning: Associating avatar interaction patterns with embodied social presence	Wang et al. (2018)
S14	CoASD: A tabletop game to support the collaborative work of users with autism spectrum disorder	Silva-Calpa et al. (2018)
S15	CodaRoutine: A serious game for introducing sequential programming concepts to children with autism	Elshahawy et al. (2020)
S16	Development and testing of a game-based digital intervention for working memory training in autism spectrum disorder	Wagle et al. (2021)
S17	Educational e-book for children with and without developmental disorders	Pistoljevic and Hulusic (2019)
S18	Effective learning design of game-based 3D virtual language learning environments for special education students	Lan et al. (2018)
S19	EmoTEA: Teaching children with autism spectrum disorder to identify and express emotions	Garcia-Garcia et al. (2019)
S20	Empowering children with ASD and their parents: Design of a serious game for anxiety and stress reduction	Carlier et al. (2020)
S21	Learning through VR gaming with virtual pink dolphins for children with ASD	Lu et al. (2018)
S22	Leo con Lula, introducing global reading methods to children with ASD	Gomez et al. (2018)
S23	LOLY 1.0: A Proposed Human-Robot-Game Platform Architecture for the Engagement of Children with Autism in the Learning Process	Paillacho et al. (2020)
S24	PlayCube: Designing a Tangible Playware Module for Human-Robot Interaction	Silva et al. (2018)
S25	Serious games as an aid in the development of people with intellectual disabilities	Sochocka et al. (2020)
S26	Serious games to teach emotion recognition to children with autism spectrum disorders (Asd)	Elhaddadi et al. (2021)
S27	Teaching literacy skills to French minimally verbal school-aged children with autism spectrum disorders with the serious game SEMA-TIC: An exploratory study	Serret et al. (2017)
S28	The development of an escape room-based serious game to trigger social interaction and communication between high-functioning children with autism and their peers: Iterative design approach	Terlouw et al. (2021)
S29	Toward emotional interactive videogames for children with autism spectrum disorder	Baldassarri et al. (2021)
S30	Use of Augmented Reality with a Motion-Controlled Game Utilizing Alphabet Letters and Numbers to Improve Performance and Reaction Time Skills for People with Autism Spectrum Disorder	Antão et al. (2020)
S31	Using a humanoid robot as the promoter of the interaction with children in the context of educational games	Freitas et al. (2017)
S32	Using interactive games to engage children with autism on visual impairment	Che Ku Mohd et al.(2019)

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Noemi Honorato: Conceptualization, Data curation, Formal analysis, Investigation, Writing—original draft; Aiganym Soltiyeva: Writing—original draft; Wilk Oliveira: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Validation, Writing—original draft, Writing—review and editing; Saul Emanuel Delabrida: Funding acquisition, Conceptualization, Formal analysis, Methodology, Project administration, Supervision, Writing - original draft, Writing—review and editing; Juho Hamari: Funding acquisition, Writing—review and editing; Madina Alimanova: Supervision.

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Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
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Competing interests
We declare that we do not have any financial or non-financial Conflict of interest.

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