The application of serious games in educational intervention for children with autism

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Abstract

Background *Games have gradually become the main means of educational intervention for children with autism. Allowing children with autism to participate in games suitable for their developmental age and engage in safe, non-threatening, and personalized situational exercises in a private environment plays an important role in helping children observe, imitate, demonstrate, and ultimately develop social interaction skills. A serious game is not a purely recreational electronic game that requires the embedding of teaching elements in the game, aiming to clearly enhance certain abilities or skills. Its characteristics are educational and entertaining, which helps players obtain personalized, interactive, and entertaining learning experiences, thereby stimulating their learning potential.*

Method and Content: *This article uses a literature search method to systematically review domestic and foreign literature on the application of serious games in educational interventions for children with autism, showcasing its research status, analyzing its research trends, and emphasizing its theoretical basis, technical carriers, and intervention directions.*

Conclusion: *Serious play provides a new perspective for educational intervention in children with autism, involving aspects such as cognition, emotion, and skills. However, there are still certain limitations in current related research. Future research should improve the design of game programs, optimize the design of experimental processes, deeply explore the application channels, accelerate the localization, and strengthen the application of serious games in ASD children's teaching practice.*

Keywords: *Game, Serious game, Behavior expression, Autism*

I.   Introduction

Games are a form of behavior with specific behavioral patterns and rules that can entertain the mind and body or determine the outcome. Simply put, it means having a certain amount of physical and intellectual content, according to specific rules, and ultimately providing participants with certain entertainment or rewards.

Serious game is not a purely recreational electronic game commonly used for learning or problem-solving in fields such as education and medicine [1]. Serious games emphasize the embedding of teaching elements in the game, with the aim of clearly enhancing certain abilities or skills. Similar to traditional electronic games, it has attributes such as simulation, human-computer interaction, infinite trial and error, freedom, immersion, and regularity. It also has important characteristics such as scientific, multimodal, narrative, and exploratory. European and American countries have extensively explored the application of serious games in children with ASD intervention, and developed corresponding serious games based on the intervention goals, such as "Circus in Motion" to improve vestibular nerve dysfunction [2], "Life is Game" based on iPad to improve facial emotion recognition ability [3], and "Tobias in the Zoo" combined with virtual reality technology (VR) to enhance attention and social motivation [4]. Scholars in China have also attempted to use somatosensory games to improve attention [5], social skills [6], motor skills [7], and daily life skills [8], as well as VR games to enhance interpersonal interaction skills in children with ASD [9]. However, these studies focus on the effectiveness of serious games in intervention for children with ASD, without exploring the intervention advantages, shortcomings, and development directions of serious games themselves.

II.   Research Status of the Application of Serious Games in Intervention for Children with ASD
2.1 The Theoretical Basis

Implicit Learning Theory, Reinforcement Theory, Flow Theory, and Zone of Proximal Development Theory are the theoretical foundations for applying serious games to intervention in children with ASD. Based on Implicit Learning Theory, implicit motor learning is much more effective for children with ASD than explicit

motor learning, especially in improving social interaction skills, identifying and regulating emotions, improving cognitive level, and acquiring motor skills. ASD children do not need mechanical cognition and memory in serious games, but rather experience the knowledge and emotions contained in the game from the first perspective, and acquire target skills through subtle influence [10]. Based on Reinforcement Theory, most of human behavior is operational, and any learned behavior is related to timely reinforcement [11]. Upgrading, rewarding, scoring high, and praising children with ASD in serious games can trigger a sense of achievement. Moreover, providing immediate feedback on the game behavior of ASD children through feedback mechanisms during the game can increase the frequency of correct behavioral responses. For example, when children complete games, they can receive rewards in gold coins or virtual currencies for their good performance. Gold coins can also be used for further personalized decorations, which can continuously stimulate children's interest and give them a sense of achievement.

The Flow Theory and Zone of Proximal Development Theory are the theoretical foundations for skill challenge design in serious games. Based on the Flow Theory [12], when people focus on an activity, they unconsciously filter out the influence of interfering factors and enter a state of immersion. Most of the existing mainstream VR devices have fully enclosed headsets, which are sufficient to completely isolate players from the real world. Once players immerse themselves in VR serious games, they can gain the same experience as solving practical problems in a real environment, rather than completing textbook style learning in a fictional scenario, such as visiting the Palace of Versailles in "VersailesVR | The Palace is yours", experiencing the lives of homeless people in "Becoming Homeless: A Human Experience", overcoming fear of insects in "Fearless", and so on. In games, people often voluntarily try to complete a difficult and valuable task, and maximize their physical and mental potential. The "Zone of Proximal Development Theory" was proposed by Vygotsky, who believed that children have two levels of problem-solving in teaching activities: first, the zone of proximal development refers to the level of problem-solving that children can achieve with the support of people with more knowledge (i.e. "knowledgeable others"). The second is the existing development zone. It refers to the level of problem-solving that children can achieve in independent activities. The proximal development zone and existing development zone of children can be transformed. If children are in the zone of proximal development and have difficulty completing tasks independently, they can solve problems and complete tasks independently through guidance and assistance from teachers, cooperation with peers, or imitation of others' behavior. In this way, the "proximal development zone" can be transformed into an existing development zone"[13]. Based on the Zone of Proximal Development Theory, the difficulty of the serious games can be gradually increased according to the abilities of ASD children, based on the evaluation and calibration of the starting point and difficulty of the game. Therefore, there will be no situation where the game is too difficult/easy to give up. Moreover, through goal resolution and difficulty stratification, ASD children can not only successfully complete the game, but also gradually acquire target skills.

2.2 Application Carriers

The carriers of serious games are gradually diversifying, from mobile devices such as computers, smartphones, and tablets to virtual reality technology, sensory gaming devices, robotics technology, and more. Among them, the use of mobile terminals alone is the most common, followed by the use of virtual reality technology and sensory gaming devices. The joint use of two or three carriers is a new trend in research.

Most mobile devices such as computers, smartphones, and tablets have the characteristics of small screen sizes and good touch screen functions, which can provide more intuitive interactive forms for ASD children. Electronic games based on the various applications they carry are popular among ASD children and are also the most commonly used carrier by researchers. Virtual reality (VR) technology provides ASD children with a dynamic and realistic social scene platform, enabling them to actively explore and experience in virtual situations [14]. Sensational games cater to the visual information preferences of ASD children, providing rich dynamic visual stimuli, while also offering a variety of forms and strong fun. Robot technology can create a simple interactive environment to interact with ASD children as peers in games. Combining serious games with robotics technology can effectively compensate for the shortcomings caused by ASD children being excluded in peer games.

2.3 Intervention Effect of Serious Games on Children with Autism

Serious games can be used to intervene in the following 3 aspects like cognitive (perception, attention, language), emotional (emotion recognition and expression), and skills (social communication, society, knowledge, and exercise) of children with autism.

2.3.1 Enhancing Cognitive Abilities in Children with ASD

serious games are mainly used in the intervention of three aspects of the cognitive ability: sensory and perception, attention, and language ability of ASD children.

Approximately 45% to 95% of ASD children have abnormal sensory and perception, with clinical symptoms mainly including sensory delay or allergies, special sensory preferences, etc. [15]. The current interventions mainly include several aspects: improving vestibular nerve dysfunction [2], auditory hypersensitivity [16], eye gaze [17], and social attention to the face [18].

D. Johnston et al. [16] utilized VR based serious games to improve auditory hypersensitivity symptoms in children with ASD. The audio rendering technology of VR in the game realistically simulated the motion state and normal sound environment of aversive stimuli, and transmitted target auditory stimuli to players through dual channel audio to help ASD children gradually reduce anxiety levels related to aversive stimuli. After a period of intervention, the tolerance of ASD children to target stimuli increased, and the anxiety caused by target stimuli also decreased.

Common attention deficit is one of the core disorders in children with ASD, with clinical symptoms manifested as excessive attachment to minor aspects of things while neglecting important parts. The improvement or not is an important indicator for evaluating the effectiveness of intervention [17]. Researchers have used a game called Caribbean Quest to improve the attention of children with ASD, which includes key intervention components such as attractive images and gameplay, adaptive level progression, etc. The early stages of the game are more focused on training selective attention, inhibitory control, and visual memory, while the later stages are focused on training auditory memory [19].

There are significant differences in vocabulary development between children with autism and normal children, as they face certain difficulties in vocabulary expression, comprehension, and combination [20]. About 30% of ASD children still have poor language ability after receiving early intervention [21]. In addition to affecting social and communication abilities, language deficits can also lead to "underestimation" of cognitive skills and other assessments in ASD children. Compared to traditional teacher teaching, serious games can help ASD children learn more vocabulary and promote near transfer of learned words. S. Serret et al. [22] invented a game that uses visual cues to help ASD children learn vocabulary. The game includes ten stages, from word recognition to sentence association, with increasing difficulty to help children master the target vocabulary and learn how to make sentences. Ultimately, ASD children have greatly improved their vocabulary. Bosseler et al. [23] used interactive computer serious games to teach vocabulary to 9 children with autism aged 7-12. The game based elements included individualized treatment goals (12 words that children do not know), and providing feedback and rewards for achieving short-term goals. After one month of intervention, these children were able to remember 80% of the words taught in the game. Whalen et al. [24] conducted an innovative intervention that mixed on-site learning and serious game intervention to teach vocabulary learning to ASD children. The TechTown software he used included the following game elements: a test that rewarded success (including praise and image prizes), an increase in personalized word markers and difficulty levels, and also provided face-to-face generalization activities that children could complete alone or with the teacher in a group. The research results indicate that there is a near transfer effect of learning.

Overall, serious games have achieved certain results in terms of perception, attention, and language skill intervention, due to the following three reasons: First, serious games emphasize user centeredness, and by evaluating and calibrating individual differences among ASD children, match the starting point and difficulty of the game with their actual cognitive level, helping them better choose cognitive goals; Second, serious games can obtain game data for ASD children through the backend statistical function, and the game's peripherals can also capture and record the intervention status in real-time, facilitating researchers to adjust the intervention progress in a timely manner; Final, the diverse elements contained in serious games can meet the limited interests of ASD children, combining intervention goals with items of interest to ASD children, effectively helping them improve attention, reduce stereotypical behavior, and master target skills. However, previous research has the following shortcomings: on one hand, the focus on indicators is too few, and the game content is monotonous and lacks interest. For example, language training mostly focuses on expanding the vocabulary of children with ASD. Although it has achieved certain therapeutic and near transfer effects, there is limited or no use of narrative storylines, or no long-term goals set, and there are few tests for far transfer (i.e. daily generalization) of language ability. On the other hand, previous experiments have mainly focused on single subject experiments which refer to analyzing and inferring the effectiveness of experimental treatments based on one or several subjects' behavioral changes during the baseline period and expectations [25]. Due to the limited sample size of a single subject experimental design and the difficulty in ensuring external validity, some researchers have attempted to supplement this method with different types of multi baseline experimental design, which has to some extent improved the experimental validity.

2.3.2 Enhancing the Emotional Recognition and Expression Abilities

Compared with ordinary children, ASD children have difficulty recognizing the emotions of others and expressing their own emotions in a reasonable manner [26], which is related to their facial emotion recognition ability and emotional recognition deficiencies [27]. Serious games not only help ASD children recognize emotions, but also help them learn to express and improve emotions. Researchers [28] used a serious game called "Emotiplay" to teach emotion recognition to children with high functioning autism aged 6-9 from three countries (i.e. UK, Israel, Switzerland) for 8-12 weeks. In the game, children were asked to play the role of explorers in international research camps in the jungle, studying human behavior and emotional expression. The game consists of four parts. The first part introduces what emotions are, the second part introduces basic emotions (such as happiness, sadness, fear, anger, disgust), the third part introduces the joys and sorrows of school life (such as surprise, interest, boredom, shame, and pride), and the fourth part introduces friendly and unfriendly emotions in social relationships. In the end, the improvement in emotional recognition indicators in the experimental group was significantly higher than that in the control group. The serious game "Face Emotions" designed by Dantas et al. [29] uses animation and 3D elements to attract participants' attention, increase interest, and provide corresponding cultural backgrounds based on the nationality of the participants. It teaches children how to generate facial expressions and uses a camera to capture the player's facial expressions in real time, improving children's emotional expression ability through a multimodal combination of facial expressions, vocal rhythm, and body language. Ultimately, it not only improves the emotional expression ability of ASD children, but also enhances their enthusiasm and interest in game learning.

Serious games can effectively help ASD children improve their emotional recognition and expression abilities for three reasons. First is that this type of game focuses on identifying emotions in photos, drawings, audio or video recordings in the game. The attractive images, characters, and dynamic interfaces in the game are deeply loved by ASD children. Second, serious games using computers, mobile phones, tablets, and other technology carriers can effectively showcase the dynamic nature of facial expressions and character emotions. Third, the various modes in the game provide a large number of opportunities for ASD children to participate, experience, and create, allowing them to consolidate the learning content personally on the scene and enhance their participation and interactivity.

2.3. 3 For Skill Enhancement

Serious games can help improve the social communication skills, social skills, knowledge skills, and motor skills of children with ASD.

Social communication disorder is one of the core defects of ASD children, manifested as inability to spontaneously interact with peers, difficulty in making eye contact, and being more likely to be rejected by peers, and even being harassed by peers. The intervention of serious games mainly involves learning communication and peer communication skills. Researchers [29] used ComFit games to intervene in the interactive communication skills of four children with severe ASD. Participants first interact with virtual characters in single player mode to establish player knowledge, and then use the knowledge gained in single player mode to communicate with another human player in multiplayer game mode. In multiplayer mode, the teacher will provide varying degrees of encouragement and assistance based on the participants' familiarity with the rules. The experimental results showed that the peer communication skills of ASD children who participated in the game were significantly improved.

The intervention of serious games on social skills of ASD children is mainly reflected in vocational skills, daily life skills, and other aspects. Kang et al. [27] gamified "bathing" using Kinect sensors to train six ASD children with independent bathing skills. The game divides the bathing process into 25 steps. Children can choose their own cartoon models according to their personal preferences, and then follow the prompts in the game to gradually complete the bathing task and earn points. There are also many interesting aspects added to the game to enhance the fun of the intervention, such as: an animated bacterial demon will mark the head of the model that needs to be cleaned, children need to activate the hair washing tool through real bathing actions to wash the model's hair, and the system will score based on the degree of washing. After a period of intervention, the accuracy of the bathing steps in all 6 ASD children was significantly improved, and their motivation to participate was also improved. Parents reported that their children's proactive and independent bathing behavior at home had also been significantly improved. This intervention method of embedding serious games into somatosensory gaming devices is not only beneficial for enhancing the active interest of ASD children, but also can to some extent improve the generalization of target skills in real situations.

ASD children exhibit passivity in learning and often have poor adaptation, manifested by the frequent occurrence and long duration of such behaviors, and most activities require appropriate reminders and assistance [17]. Serious games can attract the attention of ASD children, enhance their learning interest, and help them master cultural knowledge. B. Bossavit et al. [30] designed a serious game for high-performance ASD teenagers to help them learn geography knowledge. The confrontation and reinforcement during the game effectively

increased the interest of ASD teenagers and promoted their mastery of geography knowledge.

ASD Children often suffer from motor developmental disorders, mainly manifested as delayed development of gross movements, insufficient fine motor skills, and abnormal morphological development [31]. Serious games can improve motor skills in ASD children, such as object control skills [32], large muscle motor skills [33], hand eye coordination skills [34], and walking skills [35]. Researchers [36] have effectively improved the motor skills of ASD children using Kinect based visual motor games. In this game, four sections were designed to enhance the classification, capture, imitation, and search abilities of ASD children. After the children's motor ability reaches a certain standard, a "racket" mini game combining AR technology was used to examine the comprehensive application ability of the above four motor skills. However, some studies have pointed out that the intervention effect of serious games on motor skills in children with ASD needs further verification. The study by J. Edwards et al. [31] confirmed that a serious game based on virtual reality did not effectively improve the object control ability of ASD children in sports, but it effectively enhanced their motivation to participate in sports activities.

Serious games can enhance the social and learning skills of ASD children, for the following reasons: First, the immersive storyline in serious games is one of the most effective elements to enhance ASD children's learning motivation. By combining the storyline with the learning objectives, the narrative approach can increase players' learning pleasure, motivation, and engagement, allowing them to acquire corresponding skills in the story or life context, while helping them generalize the acquired skills into real life scenarios; Second, continuous performance feedback and progress rewards in serious games are also beneficial for motivating ASD children to overcome learning difficulties. Final, serious games allow ASD children to try again in the event of failure or wanting to achieve better results, effectively avoiding situations where they stop playing due to frustration.

III.   Prospect
3.1 The Advantages of Serious Games to ASD Children

Serious games are designed based on the learning characteristics of ASD children, enabling them to stimulate learning motivation, increase interest, and maintain attention through game intervention. The main goal is to enhance game motivation and generalize the knowledge or skills learned in games into daily life, improving their real life situation. The important features of serious games are their immersive storylines, specific skill goals, rewards and feedback for goal progress, gradual increase in difficulty levels, personalized training, and providing choices. First, by creating a storyline or scenario narrative, effectively contextualize the skills and goals that need to be learned. The integration of storyline and target learning can increase interest and immersion in learning situations, allowing individuals to experience learning content in meaningful situations, thereby improving learning motivation and enhancing the comprehensibility and transferability of learning content [37]. Second, guide participants to achieve specific skill goals, including basic end goals (marked by completing the game) and progressive goals that currently provide challenges and reflect progress. Midterm goals include narrative goals driven by completing story tasks or earning sufficient scores through tests (within minutes or hours) to reach a higher level. The organic combination of mid-term goals, long-term goals, and narrative storylines (such as overcoming difficulties or solving problems) can provide learning opportunities for various skills, and as the difficulty increases, it can also enhance the intrinsic motivation to continue playing the game [38]. Third, guide participants to achieve challenging goals through continuous feedback and rewards for progress. When designing rewards and feedback, both internal and external motivations need to be carefully considered. Entertainment games focus almost exclusively on visual or auditory feedback, providing instant external rewards through a points system and a competitive ranking that displays players' total scores. The impact of this method on behavior cannot be sustained, and once the reward is removed, reinforcement will immediately disappear. In contrast, serious games can provide continuous accumulation of progress information related to primary learning goals, thereby providing feedback related to long-term goals and enhancing internal learning motivation. Fourth, serious games increase difficulty in a personalized and proportional manner, providing challenging and achievable goals that make players less susceptible to setbacks, thereby improving their specific skill levels [39-40]. Fifth, in serious games, options are provided that are related to teaching, but the number is appropriately limited, which can help participants maintain autonomy and control during the learning process, avoid fatigue, and improve their intrinsic motivation and sense of fun [41-42]. Final, adopt cooperative multiplayer games, where there are two or more cooperative or competitive players. Compared to single player games and games that encourage competition, games that encourage individual participation in collaboration can lead to an increase in prosocial behavior [43], which may be related to promoting multiplayer communication in collaborative games, providing individuals with autism with unique and safe opportunities for communication and collaborative practice to achieve goals.

3.2 The Shortcomings of Serious Games to ASD Children

The use of serious games provides a new technology for intervention and education of ASD children, effectively helping them improve their cognitive function and enhance their skill. However, overall, there are still some shortcomings in current research.

3.2.1 The Design of Serious Games Needs Improvement

There are not many serious games specifically designed for ASD children, and the content has many flaws. Firstly, the target ASD group has limitations. This article involves 677 children with ASD, with 447 children reporting lineage related characteristics, including 331 children with high functional ASD or Asperger's disease (as diagnosed before DSM-5), indicating that current serious game design may be more focused on ASD children with higher cognitive levels. For example, EMOTIPLAY is only applicable to children with high functional ASD and not to children with poor abilities. There are also studies that have found that the same serious game intervention has better effects on ASD children with good cognitive compared to those with poor cognitive. Secondly, the design of serious games did not fully consider the preferences of children with different ASDs. From a gender perspective, the content of serious games currently generally lacks a female ASD perspective, mostly based on a male perspective, which may affect the gaming experience of female ASD patients. At the same time, individual differences in ASD children's preferences should also be taken into account in game design. For example, some serious games are only limited to individuals with autism who have high expression and communication abilities, without considering those who are not suitable for group discussions or have limited language abilities. Thirdly, in the design of serious games, the learning characteristics of ASD children should be fully considered, emphasizing the personalization of game content. For example, the rewards and transition scenes of some serious games are based on text, causing confusion or frustration for children who cannot read. Therefore, the content of the game should be presented more using visual or auditory stimuli. In future serious game design, attention should be paid to ASD children with different abilities and gender characteristics. The design should be closely linked to learning goals and ASD children's characteristics. At the same time, industry standards should be formulated to promote the development of serious game norms.

3.2.2 Experimental Design Needs Optimization

Firstly, previous studies have generally encountered issues with small sample sizes and short experimental cycles in experimental design. Therefore, in order to generalize the results to other ASD patients, long-term, traceable, and repeatable experiments need to be conducted in a larger population to obtain more reliable statistical significance. Secondly, most existing studies have used single group pre and posttest programs without considering the control of unrelated variables, such as interference caused by children's previous gaming experience, school courses, and interventions received by children after class, which can have different effects on the experimental results. Therefore, in the process of experimental design, irrelevant variables should be strictly controlled. Thirdly, there was no control group set up in the experimental arrangement, which resulted in the inability to answer the superiority of this intervention method. For example, compared to robot assisted intervention, would it be more effective for a human therapist to perform the same scenario. Finally, the researchers did not consider factors such as whether children with autism are interested in the game, whether interest gradually decreases, and whether fatigue effects occur. For example, in a study using serious games to provide music education for ASD children, participants were found to be impatient and uncooperative due to certain melodies being too long, resulting in fatigue effects.

3.2.3 The Development Efforts of Localized Serious Games Need to Be Increased

Although there have been many studies abroad using serious games to intervene in ASD children, at the macro level, there are still many technical issues. On one hand, the development of serious gaming technology requires a significant amount of manpower and material resources, requiring continuous testing and adjustment of newly developed technologies. On the other hand, the serious games involved in the study are mainly Western games that are adapted to Western culture. Compared to Western, the development of serious games in China is backward and lacks localized games. Therefore, it is necessary to accelerate the development of localized serious games. From the perspective of game form, strengthen the combination of Chinese style games and serious games, including pretend games and serious games, performance games and serious games, music games and serious games, and develop diversified serious games; From the perspective of game background, we will vigorously develop serious games based on China's excellent traditional culture, combine traditional Chinese festivals, customs, and other elements, and promote and develop serious games with Chinese characteristics in combination with Chinese pronunciation and text; From the perspective of local culture, based on the living environment and cognitive experience of ASD children, select games suitable for ASD children and integrate them into serious games.

3.2.4 Application Pathways Need to Be Expanded

Most existing interventions are based on school environments and professional institutions, with few being able to be implemented in family settings. The reason is that, firstly, the intervention of serious games is carried out through electronic technology and requires corresponding technical equipment. For example, in serious games, physical or virtual reality games, physical or VR devices are required. However, these devices are often expensive, highly technical, and lack portability, making it difficult for families to purchase, use, and maintain them; Secondly, different serious games require different intervention environments, such as the size of the space and the strength of the interfering factors. Not all families with disable children have the necessary environment for serious game intervention; Thirdly, some parents are unable to distinguish between serious games and regular electronic games, and simply define serious games as "playing on the phone" and refuse to use them due to concerns about affecting the child's learning.

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