

## THE EFFECTS OF AI-DRIVEN SERIOUS VIDEO GAMES ON FACIAL EXPRESSION ABILITIES AND ACADEMIC PERFORMANCE OF CHILDREN WITH AUTISM SPECTRUM DISORDER: AN EMPIRICAL STUDY

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### Abstract

**Background:** Children with autism spectrum disorder (ASD) often face challenges in creating facial expressions that appropriately respond to social cues, which can affect both their social interactions and academic performance. While many serious games have been designed to assist players with facial expression identification, fewer have focused on training children to generate facial expressions suited to specific social settings. This study explores an AI-driven, gamified approach aimed at enhancing both facial expression abilities and academic outcomes for children with ASD.

**Method:** A video game was developed featuring a 3D virtual world that presents social scenarios in which the player must express emotions such as happiness, anger, or sadness. The game includes real-time feedback through an integrated AI-powered facial expression detection system, which allows players to assess and improve their facial expressions. The AI-driven system utilizes advanced facial recognition technology to analyze and provide immediate, individualized feedback to the player, enhancing the learning experience. Special attention was given to the aesthetic and motivational elements of the game's design, incorporating gamified features such as levels, rewards, and challenges to maintain player engagement. A brief feasibility study involving autistic children (N = 25) was conducted to evaluate their perceptions of the game, the effectiveness of real-time AI feedback, and the impact of the game on academic performance.

**Results:** Participants showed significant improvements in producing facial expressions in response to the AI algorithm's real-time feedback during the training sessions. This suggests that children were able to comprehend the complexity of creating appropriate facial expressions and that the feedback provided by the AI algorithm was effective in aiding this learning process. The AI-driven nature of the game provided tailored feedback that adapted to each player's performance, allowing for more targeted learning. Participants also reported positive subjective experiences regarding the game's playability, motivation, aesthetic appeal, and ergonomics, emphasizing the effectiveness of the gamified elements such as progression through levels and the achievement of rewards. Moreover, results revealed that 60% of the participants demonstrated an increase in their academic performance after engaging with the serious game, indicating a potential link between improved emotional intelligence and academic success.

**Conclusion:** The beta version of the game appears to hold promising potential, and further research is recommended to develop additional games and scenarios to enhance the learning experience. Extending gameplay duration could allow for comprehensive clinical validation, thereby better supporting children with ASD in both social and academic aspects of their lives. Future studies should focus on refining the AI algorithms and expanding the gamified elements to create a more robust, immersive, and clinically validated intervention for children with ASD.

### 1. Introduction

The ability to accurately interpret facial expressions is fundamental to social interaction and communication, serving as a cornerstone of both personal relationships and academic success. This skill, which develops from infancy to adulthood, is influenced by a range of genetic, neurological, and environmental factors. The developmental trajectory of these abilities is critical for typical social functioning, as noted by Hudepohl et al. (2015). When development is atypical, particularly in cases of neurological or developmental disorders such as autism spectrum disorder (ASD) or schizophrenia, significant impairments in social interactions can occur, leading to profound challenges in personal relationships and community integration (Kohler et al., 2010).

ASD is a neurodevelopmental disorder that significantly impacts verbal and nonverbal communication, as well as social interactions. Other characteristics of ASD include restricted interests, resistance to change in daily routines, repetitive behaviors, and unusual sensory responses. Such characteristics appear before the age of three and can also impact academic performance (American Psychiatric Association, 2013). The Diagnostic and Statistical Manual of Mental Disorders (DSM-5) classifies ASD as a condition that typically presents between the ages of 12 to 14 months (Licari et al., 2020). Recent data from the Centers for Disease Control and Prevention (CDC) estimated that 1 in 44 American children are diagnosed with ASD, with males being four times more

likely to be diagnosed than females (Maenner et al., 2020; Bilder et al., 2016). The growing prevalence of ASD highlights the urgent need for effective, specialized therapeutic and educational interventions tailored to this population (Zhang et al., 2023).

Despite the recognized importance of facial expression recognition, existing interventions often fall short of addressing the unique needs of individuals with ASD. Traditional therapeutic approaches are frequently grounded in neurotypical developmental patterns and fail to accommodate the distinctive cognitive processing characteristics associated with ASD, such as differences in executive function, attention, and social cognition (Rezayi et al., 2023). Furthermore, cultural and contextual variations in facial expressions can pose additional challenges, as individuals with ASD may struggle with expressions that are subtle or culturally specific, leading to increased social isolation and misunderstandings (Grossard et al., 2018).

Research has consistently shown that children with ASD have notable differences compared to typically developing (TD) peers in areas such as executive function, cognitive flexibility, and behavioral control (Felipe et al., 2020; Golshan et al., 2019). Executive function, a group of higher-level cognitive skills that include planning, working memory, and organization, is often impaired in children with ASD, leading to uneven cognitive development and challenges in daily functioning. Such impairments extend to facial expression (FE) recognition, which is essential for social communication. Deficits in FE recognition have long been recognized as markers for ASD (Loth et al., 2018), and these deficits are associated with significant challenges in social and academic settings. The inability to infer others' emotions through facial expressions significantly hampers social communication, which is particularly important during early development stages. Facial expressions such as happiness, sadness, anger, and surprise form the basis of nonverbal interpersonal communication, and difficulties in interpreting these expressions can interfere with personal relationships and social upbringing (Barrett et al., 2019; Hudepohl et al., 2015).

In response to these challenges, this study proposes to investigate the efficacy of gamified interventions, specifically "serious" games, which integrate learning objectives with engaging game mechanics. Serious games offer a dynamic platform for teaching complex social skills, such as facial expression recognition, in an interactive and controlled environment. These games are particularly beneficial for children with ASD, providing a motivating and safe space to practice social interactions and receive immediate feedback (Marsman et al., 2018). Research has shown that instructional software, including serious video games, can support the development of facial expression skills in children with ASD (Wagenmakers et al., 2018).

The increased reliance on digital learning tools during the COVID-19 pandemic further underscored the potential of video-based and interactive learning to maintain educational engagement, especially for children with ASD. Findings indicate that autistic children engage more effectively with educational content that includes clear emotional expressions, suggesting that visual cues are integral to their learning processes (Zhang et al., 2023). Building on these insights, the current research aims to evaluate the effectiveness of AI-powered gamified learning environments in improving facial expression recognition skills in children with ASD. Furthermore, this study will compare the performance of children with ASD to that of their neurotypical peers in recognizing various emotional intensities in facial expressions, using AI-powered tools for real-time feedback.

The findings are expected to inform the development of more effective educational tools and therapeutic strategies, enhancing social integration and overall quality of life for individuals with ASD (Griffiths et al., 2019). By focusing on innovative, technology-driven solutions, this research not only addresses immediate challenges faced by individuals with ASD but also contributes to the broader dialogue on how digital tools can be harnessed to support diverse learning needs in our evolving educational landscape.

## 2. Literature Review

Numerous research studies have explored the use of technologies targeting individuals with ASD, focusing on various aspects of assessment, treatment, and therapeutic interventions. According to Lopez-Herrejon et al. (2020), technology can assist with ASD assessment in children (Dahiya et al., 2021) and be used to support interventions (Tsikinas & Xinogalos, 2019). Researchers have also investigated how computer-based technologies can be customized for ASD users, with recent research emphasizing the use of serious video games as tools for ASD therapy. Serious games are defined as video games designed to teach players skills beyond mere entertainment (Ritterfeld et al., 2009; Susi et al., 2007). Studies have shown that playing serious video games can be beneficial in helping individuals with ASD receive therapy (García-Redondo et al., 2019; Hassan et al., 2021; Tsikinas & Xinogalos, 2019). For example, Tsikinas and Xinogalos (2019) conducted a literature review of fifty-four studies on the effects of serious video games on people with ASD or intellectual disabilities and found that most yielded positive outcomes.

The deficits in emotion recognition and social skills among individuals with ASD have been thoroughly studied by multiple researchers. For instance, Leung et al. (2019) investigated the neural mechanisms underlying emotional face processing in children with ASD. Their study revealed differences in emotional processing between children with ASD and control groups, suggesting abnormal emotional information processing among ASD participants. Griffiths et al. (2017) also reported that young individuals with ASD experience greater impairments in recognizing even subtle facial expressions compared to their neurotypical peers.

Several studies have thus proposed interventions to improve emotion recognition and social skills in individuals with ASD, with serious video games being a proven effective method. Hassan et al. (2021) conducted a systematic review of forty serious video games designed for individuals with ASD and concluded that these games contribute to improving emotional and social skills. One notable example is the "Junior Detective" game (Beaumont & Sofronoff, 2008), part of a 7-week training program for children with Asperger Syndrome and ASD. This game involved children taking on detective roles, identifying emotions through facial expressions and gestures. Significant improvements in social functioning were observed among participants following the intervention, with progress maintained during a follow-up evaluation.

Other notable interventions include Dantas & Nascimento's (2022) software, which uses digital image processing techniques to help children with ASD recognize six basic facial expressions—joy, sadness, anger, disgust, surprise, and fear. Experiments demonstrated the software's effectiveness in improving emotional skills. Fridenson-Hayo et al. (2017) conducted a cross-cultural evaluation using the "Emotiplay" game, which teaches facial expression and gesture recognition in an interactive and motivational manner. Results showed improvements in emotion recognition, adaptive socialization, and reduced ASD symptoms, proving the effectiveness of serious games as psycho-educational interventions.

The literature also highlights the impact of serious video games on academic performance. Studies have suggested that the integration of inclusive technologies like serious video games in educational settings can enhance students' academic performance (Arockiyasamy et al., 2016; Weis & Cerankosky, 2010; Wright, 2011). Games used as motivational tools have been found to have positive effects on academic engagement without negatively impacting core school subjects like reading or mathematics (Drummond & Sauer, 2014; Rosas et al., 2003). Moreover, games can improve working memory, cognitive performance, and social interactions, all of which are crucial for students with ASD (Thatikonda et al., 2023).

The COVID-19 pandemic has also emphasized the importance of video resources for students with ASD. For instance, Zhang et al. (2023) studied the effects of teacher facial expressions in video lessons and found that the use of positive expressions, such as smiling, improved motor learning fidelity and engagement among ASD students.

The role of artificial intelligence (AI) in video gaming for ASD therapy has gained considerable attention in recent years. AI facilitates the creation of adaptive and personalized gaming environments, enhancing player engagement through dynamic difficulty adjustments and realistic non-player character interactions. AI technologies allow for customized feedback, providing ASD players with individualized learning experiences tailored to their progress and challenges (Yannakakis & Togelius, 2018). The ethical considerations surrounding AI use, such as data privacy and player manipulation, are also important aspects that must be addressed to ensure responsible use in educational and therapeutic settings.

The literature review reveals the significant impact of serious video games on cognitive development, social skills, and academic performance, particularly for children with ASD. Video games offer a controlled and engaging environment for improving social communication, emotional recognition, and executive functions, making them valuable tools in therapy and education for children with ASD. At the same time, excessive gaming or exposure to non-educational content can pose risks, including reduced academic performance and increased aggression. The integration of AI in video games offers promising opportunities for personalized learning, though it raises ethical concerns that need careful consideration.

This research aims to answer key questions related to the role of emotion type, duration of gameplay, and the effectiveness of AI-powered video games in improving facial expression accuracy and overall outcomes for children with ASD. The findings will help inform the development of more effective educational and therapeutic tools for supporting diverse learning needs in children with ASD.

### 3 Method and Materials

This research is based on one group quasi- experimental design.

#### 3.1. Participants

The final sample included sixteen boys and nine girls, aged between six and fourteen years (mean age: 10.5 years, SD = 1.5). All participants with autism had been clinically diagnosed using either the Autism Diagnostic Interview-Revised (ADI-R) or the Autism Diagnostic Observation Schedule (ADOS). Cognitive abilities were assessed using the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV), with an average IQ of 87.46 (SD = 15.51). Parental consent was obtained for all participants to engage in the intervention procedures of this study.



Figure 1. Example of game interface selecting the his suitable avatar

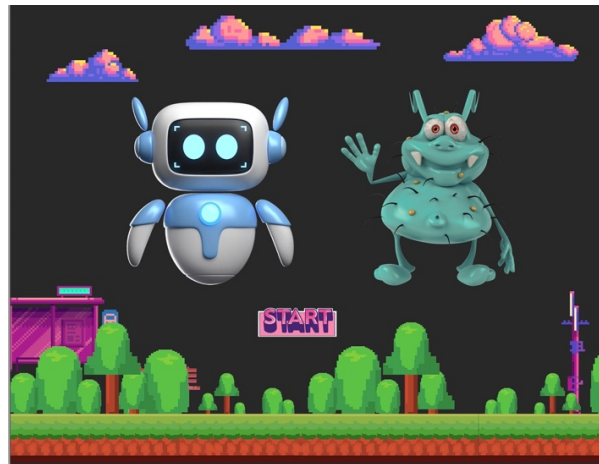


Figure 2. The player can choose one of the robot or a monster as his/her companion



Figure 3. An avatar expressing emotions that was used in the game

### 3.2 Procedures:

The evaluation, which lasted approximately 80 minutes, proceeded as follows. The child was seated at a PC equipped with a camera and joysticks to record their actions. Once the equipment was set up, the child began interacting with the program under the supervision of a therapist. The therapist guided the child through various training games, explaining the settings and social scenarios presented during the gaming phase. Throughout the 65-minute session, a second therapist observed the child's behavior and completed a monitoring grid, while an external camera recorded the entire session for further analysis.

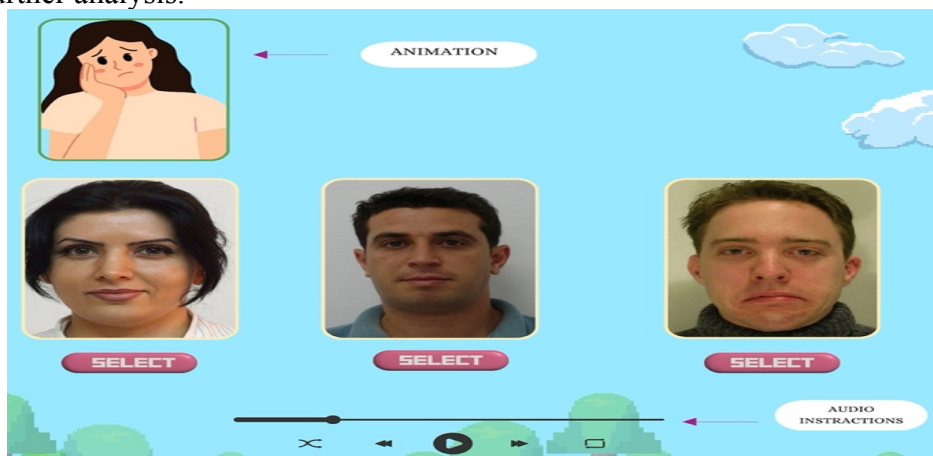


Figure 4 Game interface for evaluating basic emotions of joy, sad, surprise, anger, and disgust  
*Notes.* Game interface of planned SG: (a) user ID and Pass; (b) choosing proposed avatar; (c) basic emotions evaluation; (d) game different interactions about emotions; (e) training sessions; (f) after expressing each emotion correctly, a gift item is present that can progress game map.

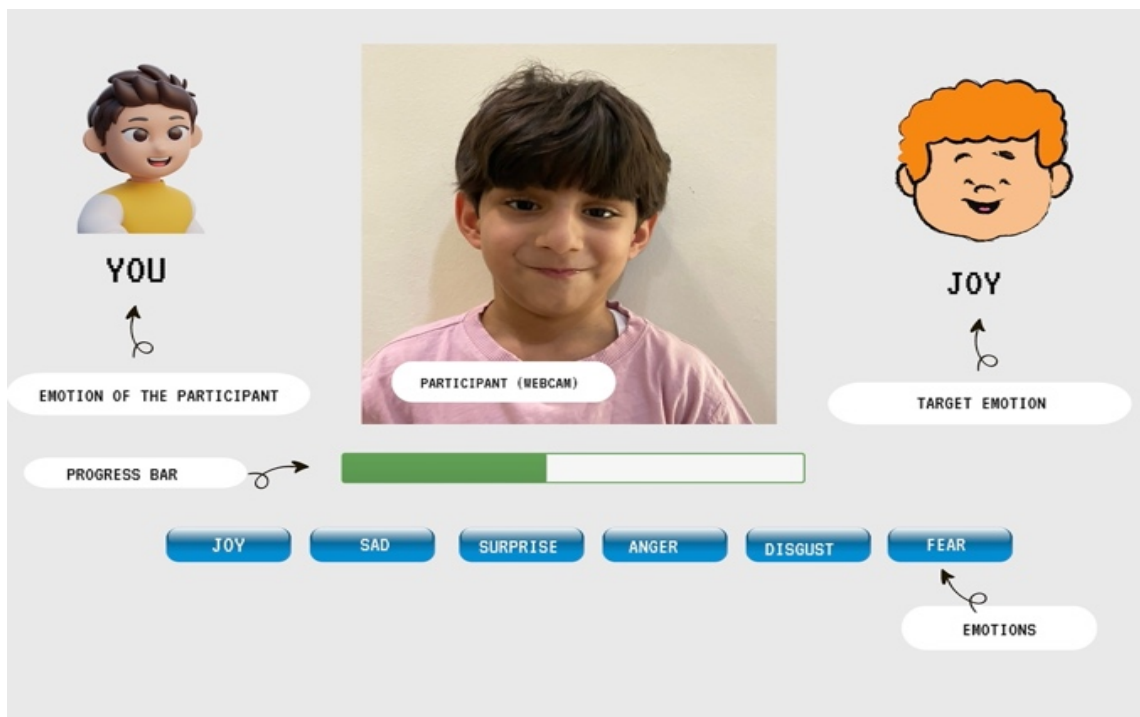


Figure 5 interface of training sessions on facial expression and functionality

#### 4. Results

The facial expression (FE) algorithm classifier integrated into the video game was designed to improve the quality of facial expressions in children with autism during the training phase. To assess the impact of factors such as age, gender, game duration, and emotion patterns on the enhancement of facial expressions, a multivariate model was employed in our analysis.

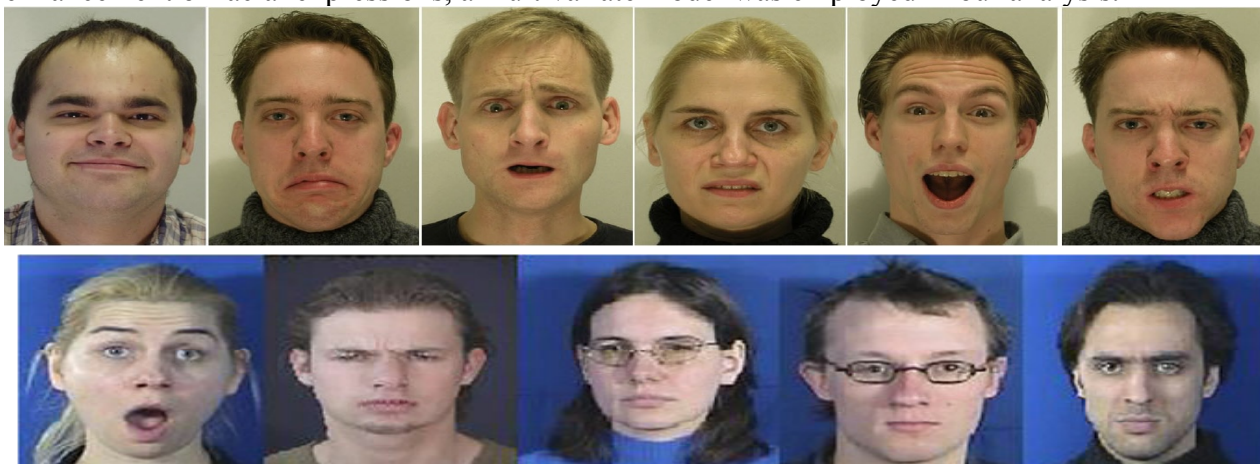


Figure 6 Images with representation of emotional expression in the MMI dataset

The study utilized logistic regression analysis through R v.3.4.0 software, with the following equation:

$$\text{issue-age+gender+game time+mood+ (1 | id\_patient)}.$$

The analysis revealed that the data did not follow a normal distribution, as indicated in Table 1. This table presents the effects of age, gender, game timing, and desired emotion on the quality of facial expressions (FE) during the training phase for 25 participants.

Table 1: Impact of player FE quality based on age, gender, game time, and emotion patterns (N = 25).

Independent Variable	df	AIC	LRT	p-values
Age	2	8.117	1.889	.168
Gender	1	9.117	1.971	.160
Game timing	2	7.123	79.733	.000
Emotion	3	1.362	195.193	.000

The observational grid used during the study provided consistent positive feedback regarding the playability of the game. For example, 92% of the children customized their avatars within two minutes, showing a high level of ease with the process. Similarly, 83% selected their gaming companion with little difficulty, averaging only 8 seconds for the selection. During the training session, all participants engaged actively with the software’s feedback mechanisms, including color gauges and video feedback. Most children easily understood these tools, with 84% understanding the gauge operation and 79% comprehending the video support. Navigation in the virtual world was smooth for all participants, with 93% effectively using the map to locate hidden objects such as candy.

Moreover, 95% of the children expressed satisfaction with the program’s functionality and design. Of the children who customized their avatars and gaming companions, 94% appreciated the customization features, with 89% particularly favoring the ability to modify their gaming buddy, with robots being the most popular choice. Seventy-eight percent of the children were pleased with the appearance of the avatars they were required to emulate or interact with in the virtual world. The visual and contextual elements used during the training phase were well-received by 85% of the participants.

In terms of the game’s design, 95% of the children were satisfied with the visual elements, navigation features, and overall production quality. Finally, 97% of the participants valued the opportunity to earn rewards based on their in-game achievements, highlighting the motivational aspect of the game’s design. The study employed a facial expression (FE) algorithm to enhance the quality of facial expressions among autistic children during gameplay, and the results were analyzed using a logistic mixed effect model.

The analysis showed that the type of emotion expressed significantly affected the quality of the children’s facial expressions, with expressions of anger and happiness being more accurately reproduced than sadness. However, neither age nor gender had a statistically significant effect on the quality of facial expressions among autistic children.

In another experiment comparing students’ academic performance before and after engaging in a video game, 60% of the 25 students showed an improvement in their grades after playing the game, 24% maintained their pre-test performance, and 16% experienced a decline in their post-test grades.

Table 2: Pre- and Post-Test Grades of Students

Student Pseudonym	Pre-Test	Post-Test
Khaled	80%	85%
Hamad	75%	88%
Ahmed	85%	88%
Yasser	90%	90%
Abdulaziz	87%	87%
Mohamed	100%	100%
Majed	80%	70%
Samir	90%	77%
Nofal	87%	87%

Abdullah	98%	98%
Fahad	76%	76%
Omar	77%	88%
Saher	88%	90%
Albaz	90%	99%
Lofty	99%	100%
Abdulsalam	89%	99%
Masoud	99%	100%
Youssef	88%	77%
Ali	88%	90%
Nora	77%	90%
Fatima	88%	80%
Shahad	50%	80%
Sara	88%	90%
Lulwa	96%	100%
Haya	92%	98%

The results indicate that 60% of the students experienced an improvement in their academic performance after engaging with video games, suggesting that video games may positively impact academic achievement. Several factors may account for this enhancement, including the development of cognitive skills, improved focus and attention, and encouragement of creative problem-solving. Certain video games require complex strategies and foster critical thinking, which can contribute to better academic outcomes. Furthermore, the immersive nature of video games may help individuals develop sharper focus and attention, positively influencing academic performance. Additionally, games that stimulate creativity and problem-solving may help students approach academic challenges with greater innovation.

However, it is important to note that these factors may not affect all individuals uniformly, as the relationship between video games and academic performance can vary depending on the type of game played and the amount of time spent gaming. While the positive correlation between video gaming and academic achievement is evident in some cases, other variables may also play a role, and caution is needed when drawing broad conclusions.

## 5. Discussion:

The primary aim of this study was to examine how the type of emotion and game duration influence the quality of facial expressions (FE) in children with autism during a video game-based training phase. The data analysis conducted using a logistic mixed-effects model that considered age, gender, game time, and emotion type, revealed several key findings.

The results revealed that emotion type significantly impacted the children's ability to produce accurate facial expressions. Specifically, expressions of anger and happiness were more accurately represented than sadness, suggesting that certain emotions may be easier for children with autism to mimic and understand. This finding underscores the importance of tailoring training programs to focus on emotions that are more easily recognized, which could enhance the overall effectiveness of such interventions.

Additionally, game duration was found to play a crucial role in the refinement of facial expressions. The longer children engaged with the game and received real-time feedback from the FE algorithm, the more they adjusted their expressions to align with the feedback. This suggests that extended gameplay and training sessions could provide greater opportunities for children to improve their emotional expression skills.

Interestingly, age and gender were not statistically significant factors in influencing the quality of facial expressions in this study. This result, though not definitive due to the small sample size,

implies that improvements in emotional expression through training are not inherently tied to a child's age or gender, reinforcing the need for targeted training to develop these skills.

In another experimental comparison of students' academic performance before and after playing video games, the results revealed that 60% of students experienced improved grades post-intervention, 24% maintained their grades, and 16% saw a decrease. This positive correlation between video game use and improved academic outcomes could be attributed to the development of cognitive skills such as attention, problem-solving, and creative thinking. Video games that involve strategic decision-making and require focus may help enhance these cognitive functions, potentially contributing to better academic performance. These results suggest that video games may enhance academic performance by improving cognitive functions such as attention, problem-solving, and creativity. However, the effects are not uniform across all students and likely depend on factors such as game type and time spent playing. As such, these findings must be interpreted with caution, recognizing that other variables, such as learning environment, individual differences, and gaming content, may also contribute to changes in academic performance.

Research supports the complex interactions between video games, emotional processing, and academic performance in children, particularly those with autism spectrum disorder (ASD). Studies by Wells et al. (2016), Diaz et al. (2016), and Miedzobrodzka et al. (2021) highlight how video games, particularly those with violent content, can affect children's ability to process facial emotions. For instance, Wells et al. (2016) found that exposure to violent video games decreased attention to positive emotions, like happiness, underscoring how video games can alter emotional recognition. This aligns with broader conclusions that video games may affect emotional processing, potentially reducing sensitivity to positive emotions in certain contexts.

The findings regarding improved academic performance in 60% of students' post-gameplay are consistent with studies showing that video games can enhance cognitive skills. For example, Granic, Lobel, and Engels (2014) argue that video games can improve critical thinking, attention, and problem-solving abilities, all of which can contribute to better academic outcomes. The variability in responses, however, emphasizes the importance of considering individual differences when evaluating the impact of gaming interventions on learning.

In the context of facial expression recognition training, research by Tanaka et al. (2010) and Rice et al. (2015) demonstrates that targeted video game interventions can significantly improve emotion recognition and social skills in children with ASD. These studies support the conclusion that video games designed to enhance emotion recognition can also improve social interactions and, in some cases, academic performance. The logistic mixed-effects model in the current study, which showed that certain emotions like anger and happiness were more accurately expressed than sadness, highlights the importance of focusing on specific emotions in training programs for children with ASD.

In summary, the results of the current study concur with the results of the reviewed studies which collectively show that video games can positively impact both emotional recognition and academic performance, particularly in children with ASD. The integration of video games into educational and therapeutic settings, especially when personalized to the individual, offers considerable potential for enhancing cognitive development and social skills. Further research is needed to optimize these interventions and address the variability in outcomes

## **6. Conclusion**

The findings revealed two key factors that influenced children's progress. Firstly, emotion type significantly impacted facial expression accuracy, with children better representing emotions like anger and happiness than sadness. This suggests that some emotions are easier for children to replicate, a critical insight for refining game-based interventions that simulate human referees' feedback on emotional accuracy. Secondly, game duration played a pivotal role in the children's ability to improve. The longer children engaged with the game, the more they aligned their facial

expressions with the algorithm's expectations, indicating the importance of sustained training for meaningful improvements.

Although the study did not observe statistically significant effects of age or gender on facial expression quality, this may be due to the small sample size, limiting the statistical power. Importantly, the absence of a strong age effect suggests that children do not naturally improve their facial expressions with age, further highlighting the necessity for targeted interventions to assist autistic children in modifying their facial expressions in social contexts.

Given the importance of early diagnosis and intervention in managing autism spectrum disorder (ASD), the study underlines the need for efficient, practical tools that can improve emotional recognition. Current treatments primarily focus on behavior management and the development of communication skills, but early interventions are crucial for optimal outcomes, as younger children display a greater capacity for change. Traditional diagnostic methods for ASD are often time-consuming and expensive, necessitating the exploration of simpler tools like observing children's responses to animated faces.

While the results highlight a beneficial connection between video gaming and academic achievement for some students, it is essential to consider the variability in these outcomes. Factors such as the type of game played, the duration of gameplay, and individual differences in learning styles all contribute to the overall effect of video games on academic performance. Therefore, caution is necessary when interpreting these results, as not all students may experience the same level of improvement. Further research with larger samples and a diverse range of game types is recommended to draw more robust conclusions about the impact of video games on academic success.

In conclusion, the findings demonstrate that both the type of emotion and game duration significantly influence the quality of facial expressions in children with autism, while the use of video games may also positively impact academic performance by fostering cognitive skills such as attention, creativity, and problem-solving. However, these benefits are not uniform, and further studies are needed to explore the broader implications of video game use in educational and therapeutic contexts.

#### **Implications:**

The study highlights the varied effects of video games on emotional processing and academic performance, stressing the need for tailored interventions. While video games can enhance social and cognitive skills for some children, particularly those with ASD, the effectiveness of these interventions depends on individual factors, such as the type of game and the duration of gameplay. Facial expression training has proven beneficial for social and academic development, but its success is highly variable based on the child's specific needs.

The observed variability in academic performance improvements and emotional processing underscores the need for personalized approaches in video game interventions. While some children benefit significantly from video games and related cognitive training, others may not experience the same level of improvement. This suggests the need for future research to refine these interventions to account for individual learning differences, emotional processing styles, and cognitive abilities.

**Limitations:** Some limitations were identified in the current study:

1. **Sample Size:** The small number of participants limited the generalizability of the findings. The lack of a statistically significant effect of age or gender may be due to the small sample size.
2. **Absence of a Control Group:** The lack of a control group prevents a direct comparison between intervention and non-intervention outcomes, which limits the study's ability to make conclusive claims.
3. **Generalizability of Findings:** The study focused on children with ASD, and while the findings provide valuable insights, they may not generalize to a broader population or to individuals with other neurodevelopmental disorders.

Addressing these limitations in future studies will enhance the applicability of the findings and the development of more effective interventions for children with ASD.

### **Ethical Issues**

This research adhered to the BERA Ethical Guidelines (2018) by ensuring that all procedures were conducted ethically and with respect for participants' rights. Informed consent was obtained from parents or guardians, and assent was sought from the children where possible. Confidentiality was maintained by anonymizing data and securely storing it. To ensure no harm, the study carefully monitored participants' well-being, especially considering their ASD diagnosis. All participants were informed of their right to withdraw without any consequences. Additionally, the research took special care to tailor interventions to the specific needs of the children, upholding principles of transparency and integrity throughout the study. This ethical framework ensured the protection and welfare of the vulnerable participants involved.

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