FocusVR: A Video Game Designed to Enhance Concentration in Children with ADHD through Sustained and Selective Attention Techniques

Abstract:

Attention Deficit Hyperactivity Disorder (ADHD) affects 5% of children worldwide, generating difficulties in education and social interaction. In this sense, this paper presents the development of FocusVR, a virtual reality video game designed to improve attention in children with ADHD through sustained and selective attention techniques. To evaluate its effectiveness, FocusVR was tested with twelve children diagnosed with ADHD, using Oculus Quest 3 goggles in 30-minute sessions. The results show that sustained attention improved by an average of 77.24% of correctly found objects. As for selective attention, children were able to correctly filter 55.66% of objects, with a standard deviation of 0.1676, suggesting greater variability among participants. In addition, some players showed significant improvements: the player with the greatest progress in sustained attention increased by 44%, while in selective attention the best player increased by 24%. These findings prove that FocusVR is an invaluable addition to the treatment of ADHD. It offers an engaging, interactive experience that can be seamlessly integrated with traditional methods such as cognitive-behavioral therapy and medication.

Keywords: ADHD, Neurodevelopment, Sustained Attention, Virtual Reality.

1 Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is defined by the DSM-5 [1] as a neuropsychiatric disorder that affects 5% of children worldwide according to WHO data. In Mexico, the health sector has identified 4.5% of the infant population. Children with ADHD face difficulties in concentrating, paying attention, and controlling their behavior, which negatively affects their academic performance and social interactions. Although effective treatments such as cognitive-behavioral therapy and medication exist, many children do not respond adequately or experience unwanted side effects[2].

In recent years, there has been growing interest in the use of video games as a treatment tool for ADHD, as they provide an interactive and stimulating environment capable of effectively capturing and maintaining attention. Garcia et al [3] suggest that certain video games can improve attention, concentration, cognitive training, and visual-motor coordination in individuals with ADHD.

This paper presents FocusVR, a virtual reality video game designed to improve attention in children with ADHD through sustained attention techniques. The structure of the article is as follows: Section 2 presents the state of the art and related work on the identification and treatment of ADHD; Section 3 describes the architecture of FocusVR; Section 4 details the gameplay of the video game; Section 5 presents the case studies of FocusVR; Section 5 presents the game's design; and section 6 presents the game's design.

2 Related Works

This section presents the most outstanding works related to video games as an alternative to improving the level of attention in children with ADHD.

Lagos-Hernández et al.[4] explored ADHD in children, offering a cognitive and motor development program. Using metrics such as the Stroop test and sustained attention, improvements in cognitive skills were evidenced, supporting the effectiveness of the program in improving selective and sustained attention in children with ADHD. Kefalis et al.[5] analyzed how video games can improve memory and attention, proposing their use to train Visual Working Memory. With 41 citations and a significant impact factor, the efficacy of video games in cognitive development is confirmed, supporting their relevance in academic research. Serrano-Barroso et al.[6] conducted a study to detect attention levels in children with ADHD using EEG-BCI and the GokEvolution application. In their proposal, they used these methods as biomarkers of attention. The results show significant differences in the variability of attention between groups, which could allow early detection of inattentive traits.

Samson et al. [7] explored how exposure to video games may influence the development of cognitive skills, specifically selective attention in young children. Finding a significant positive association between video game exposure and selective attention, they provide studies on the impact of video games on children's cognitive development. Alava-S et al [8] identified differences in attention between children with ADHD and learning disorders, using tests such as CPT-II (Continuous Performance Test) and

CSAT (Children Sustained Attention Task). Children with ADHD were found to have significant difficulties in selective attention. These findings, based on a sample of 437 children, support the importance of accurate differential diagnosis. Doulou et al.[9]analyzed skills in children with ADHD using electronic games. Using games such as “ATHYNOS”, a significant improvement in social and time management skills was recorded, and validated by metrics such as game time, performance in the activities, score obtained in each exercise, and evaluation of the usability of the system through the questionnaire by analysis.

Sújar A. et al [10] implemented the development of therapeutic video games to treat ADHD in children. It proposes personalized and motivating solutions, using technologies such as virtual reality. The results show a good usability of the TSTM game, supported by metrics of effectiveness and user satisfaction. Gallardo et al [11] presented the improvement of attention in children with ADHD using Serious Games. Progress was compared between this format and pencil and paper. Thirty children aged 8 to 10 years participated. Results showed that the Serious Games group had fewer commission errors ($p = .02$) and significant improvements in the D2 test ($p < .001$) compared to the pencil and paper group. Lavalle A et al [12] designed an improvement in ADHD assessment using gamification. They proposed a digital game that collects biometric data to accurately detect ADHD. With a cohort of 58 subjects, a positive correlation was established between the game assessment and the D2 test, validating the efficacy of the approach. Martin-Morantinos et al.[13] implemented a protocol addressing the effectiveness of a serious video game, MOON, in the treatment of ADHD in patients aged 7 to 18 years. Improvement in emotional regulation is assessed by a 3- to 4-point decrease in the overall SDQ (Strengths and Difficulties Questionnaire) score. Clinical scales and objective tests are used to measure change.

Teruel M. et al [14] addressed the measurement of attention in ADHD patients using a computer game. The proposed solution is to use bio-metrics to assess symptoms. The results show correlations between the game and standard attention tests. Metrics such as the Pearson Correlation Coefficient and a sample of 80 participants are included.

The literature review demonstrates that video games can significantly improve attention in children with ADHD, especially sustained and selective attention. However, personalized assessments and further research are needed to optimize these programs. In this context, FocusVR presents itself as an innovative and promising tool.

3 FocusVR Architecture

Figure 1 shows the FocusVR working architecture and workflow organized into four main layers that interact with each other to provide a complete and efficient virtual reality (VR) experience. The following is a detailed description of each of these layers, their internal components and their interactions.

Presentation Layer is responsible for the user interface (GUI). This layer facilitates the interaction between the user and the system by providing a graphical interface that allows users to navigate and control the options available within the virtual environment.

Video Game Engine Layer is subdivided into three main components: Virtual Reality, Motion Control, and Unity Functions.

- Virtual reality (VR) is a technology that enables users to interact with computer-generated environments and content in a manner that simulates physical presence in a real-world setting. The term encompasses both VR controllers and VR hardware. Controllers permit the user to engage in physical interaction with the virtual environment, whereas hardware encompasses devices such as helmets and sensors.
- Motion control is a component that interprets the user's physical movements and translates them into actions within the virtual environment. This component is responsible for interpreting the user's physical movements and translating them into actions within the virtual environment.
- The Unity functions are as follows: The Unity software is responsible for rendering graphics, animations, and sounds, thereby creating the visual and auditory environment of the game.

Game Logic Layer handles the mechanics and internal rules of the video game. It is composed of:

- Scripts: code fragments that dictate the rules and behaviors of the game.
- Events: Events within the game that affect its development, such as collisions and achievements.
- Game Scripts: Specific scripts that dictate the logic of the game, ensuring the correct execution of the rules.
- Character Control: Scripts that allow you to manipulate the actions and movements of the main character.

Management Layer is responsible for managing the data necessary for the operation of the game. This includes the Levels data, which is the information about the structure and characteristics of the different levels of the game. This data is crucial for the initialization and configuration of each level.

Figure 1 illustrates the specific roles and collaborative functions of each layer in ensuring the proper functioning of the game. The presentation layer is responsible for displaying the game to the player. The engine layer oversees the technical aspects of the game. The logic layer defines the rules and behaviour of the game. Finally, the management layer manages the resources and services. It is of paramount importance that there is effective communication and coordination between these layers if the video game is to be a success.

The workflow in the FocusVR architecture is not linear; rather, it involves a continuous and dynamic interaction between the layers in order to ensure an optimal user experience. The startup process commences with the verification of the minimum requirements of the VR device, followed by the calibration of the tracking system. The

Video Game Engine Layer initiates the system components, including the video game engine and user interface. Concurrently, the VR application loads the game data, including character models, objects and environments. Once the game logic layer has been loaded, it initiates the process of setting up the main character and loading the video game programming.

Events are initiated and held in a state of readiness, poised to be triggered by user actions. Setup scripts are executed to prepare the game environment, while the Management Layer queries user information such as progress and metrics. During gameplay, the VR application is continuously updated in accordance with the player's actions. This update encompasses the spatial positioning of characters, objects, and the environment, which is managed by the Video Game Engine Layer through motion control and Unity functions. The player interacts with the virtual world through the use of VR controllers, which transmit signals to the computer in real-time to reflect any changes. Finally, the VR application renders the virtual world graphics and transmits them to the VR viewer screens, thus completing the interaction loop.

The following section outlines the procedure in relation to the virtual reality goggles and the FocusVR software.

1. FocusVR initializes VR through device drivers.
2. System checks ensure minimum requirements and upload relevant data.
3. VR device calibrates tracking.
4. Game engine, user interface, and game data (characters, objects, environments) are loaded.
5. Main character logic and configuration are loaded..
6. The game logic is loaded from the main character, including its configuration set.
7. FocusVR programming is then loaded.
8. The events are initiated and maintained in a waiting process.
9. The configuration scripts are then executed.
10. VR application updates game state based on player actions (character, object, environment positions).
11. FocusVR modifies the state of the game in accordance with the player's actions. This process entails the updating of the positions of characters, objects and the environment.
12. The player engages with the virtual world through the use of virtual reality controllers. The virtual reality controllers transmit signals to the computer, which utilises them to update the state of the game. At this juncture, the storage of the attained objectives is initiated. This is accomplished by establishing a connection to an online database.
13. The VR application utilizes the game engine to render the visual components of the virtual world. These rendered graphics are then transmitted to the display screens of the VR headset for the user to experience.

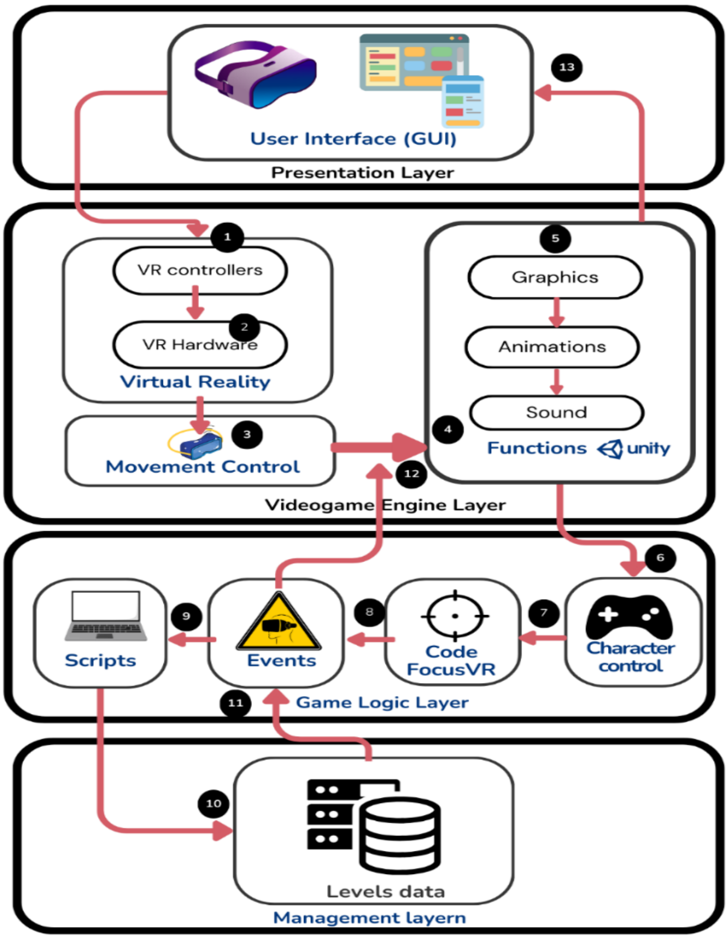

Fig. 1. Architecture of FocusVR

4 FocusVR playability

This section outlines the player's interaction with FocusVR, encompassing elements such as controls, game mechanics, difficulty level, action flow and immersion.

In FocusVR, gameplay commences when the user moves their head to pull down the menu. Once the user has logged in, the available levels are presented. As the game is structured around a progression system, certain levels will remain inaccessible until the preceding sublevels have been completed. For example, Figure 2 illustrates a layout of sublevels. Each FocusVR level is divided into several sublevels, presenting scenarios such as rooms or interiors of a house. The scenarios are designed to be comfortable and familiar, thus facilitating a fun and immersive gaming experience.

Fig. 2. Levels and sub-levels of FocusVR

The rules for completing each sublevel include finding a series of objects within a time limit. Each level contains 18 objects, distributed incrementally across the sublevels: 3 objects in the first sublevel, 6 in the second and 9 in the third, as detailed in Table 1. To advance, the player must find at least 75% of the objects in the established time. Full success is achieved by finding all the objects within the time.

Table 1. Objects to be found in the levels

Level	SubLevel	Environment	Objects to be Found	Main Objective
1	Pink room	Indoor	3	Find all the toys
	Playroom	Indoor	6	Collect all the books and toys
	Bathroom	Indoor	9	Find hygiene items
2	Clothing Store	Commercial	3	Locate specific garments
	Living Room	Indoor	6	Collect lost and found items
	Laundry	Interior	9	Picking up laundry
3	Kitchen	Indoor	3	Find the ingredients
	Guy Room	Indoor	6	Collect personal items
	Classroom	Educational	9	Find school supplies

The smoothness of the action in FocusVR is guaranteed by the rapid response of the controls and the seamless transitions between menus and levels. During gameplay, the elapsed time is displayed at the top of the screen, while a list of objects to be searched for is displayed on the right side, as illustrated in Figure 3. The user interface has been designed with the intention of being clear and efficient, with the objective of allowing the player to concentrate on the game without distractions.

The immersive experience offered by FocusVR is enhanced by the use of sound and visual effects. Upon selecting the correct object, a clapping sound and the message "object found" are emitted, whereas an error sound is played when the incorrect object is selected. As the allotted time draws to a close, a countdown sound is emitted to alert the player. Should the requisite number of objects not be identified within the allotted time, the player is afforded the option of restarting the sublevel. Should the player fail to complete 75% of the objects in level one, they will be required to restart the entire level from sublevel one, accompanied by a corresponding message. The use of friendly and familiar scenarios, accompanied by auditory feedback, ensures that the player remains immersed in the virtual environment.

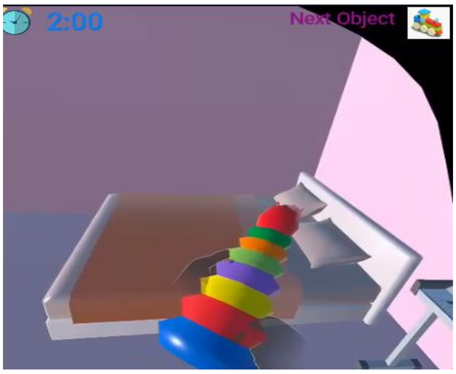

Fig. 3. Video game operation mode.

In successful cases, the time spent by the player to find the objects is recorded, and congratulatory messages are generated. These records allow progress and errors to be evaluated, providing useful feedback to improve the game experience.

5 Case Studies

This section describes the development of a case study using FocusVR. A total of twelve children diagnosed with ADHD consisting of four girls and eight boys, with an average age of 11 years (range: 9-13 years). The participants were selected through an exhaustive evaluation process carried out by psychologists from the Child Development Psychological Center “Cree Cimientos”. Written informed consent was obtained from the parents or legal guardians of the participants before starting the study.

5.1 Development of the Study

The Oculus Quest 3 virtual reality goggles were employed for the purposes of testing. Four sessions were conducted during which participants were permitted to explore the FocusVR environment. Prior to commencing the experiment, a brief introduction to the Oculus Meta Quest 3 goggles was provided to all participants. This explained that, upon leaving the designated area, the game would be observed in a dim light and the interface would be disrupted. Subsequently, a tutorial of the video game was presented, outlining the rules of the game and the challenges encountered at each level. The sessions were conducted in a "Crecimientos Foundations" classroom, which was equipped with a one-square-meter work area to facilitate the mobility required by the device. The Oculus Quest 3 goggles, which were preloaded with the game, constituted the sole resource utilized. Each session lasted 30 minutes, during which each participant engaged with the game under the supervision of a therapist and their parents. This ensured the children's safety and provided emotional and technical support if necessary.

At the conclusion of each session, participants and their parents were invited to provide feedback on their experience with FocusVR.

5.2 Assessment process

To evaluate the impact of FocusVR on the care of children with ADHD, a detailed analysis of key variables and metrics was conducted. This analysis was based on a review of specialized literature, consultation with experts in the field, and consideration of metrics relevant to ADHD, as illustrated in Figure 4.

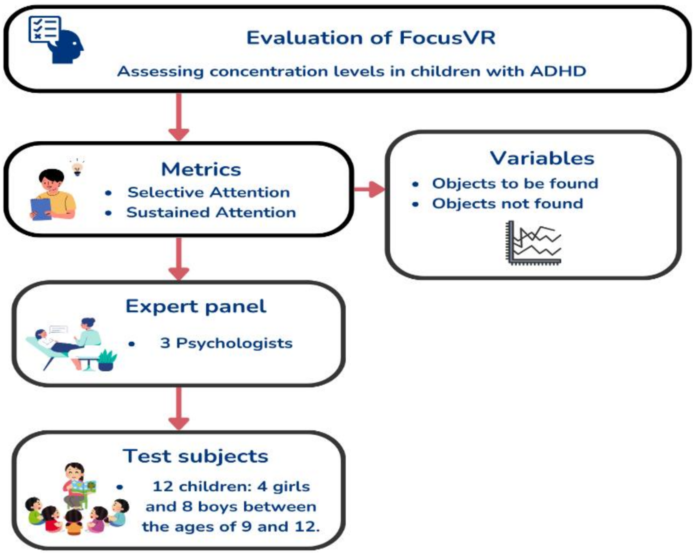

Fig. 4. Assessment process

FocusVR uses two main metrics extracted from NESPLORA AULA SCHOOL [15] to assess participants' performance in selective attention and sustained attention. These metrics are based on specific variables that allow a detailed analysis of patient attention in the context of the video game. Sustained attention is defined as the ability to maintain concentration on a stimulus or activity for a prolonged period. This ability is critical for learning, memory, and academic performance. The metrics selected to assess sustained attention in FocusVR are as follows:

- Total number of objects correctly found: Indicates the number of objects the participant found correctly in the scenario. A higher number of correctly classified objects reflects a better capacity for sustained attention.
- Total number of objects: Represents the total number of objects present in the game, regardless of whether they are found or not.

$$\text{Sustained attention} = \frac{\text{Total number of objects correctly found}}{\text{Total number of objects}}$$

Selective attention is defined as the ability to focus on a specific stimulus while ignoring irrelevant information or distractions. This ability is crucial for performance on tasks that require concentration and selection of relevant information. The additional metric used in this evaluation is:

- Total number of incorrectly found objects: Indicates the number of objects that the participant found incorrectly in the scenarios. A lower number of incorrectly encountered objects reflects better selective attention ability.

The equation used to calculate selective attention is:

$$\text{Selective attention} = \frac{\begin{array}{c}\text{Total number of objects correctly found} - \\ \text{Total number of incorrectly found objects}\end{array}}{\text{Total number of objects}}$$

5.3 Results

Table 2 presents the average sustained attention and selective attention scores collected from twelve players. These data are averages of the three levels and sublevels of the FocusVR video game, applying the previous formulas.

Table 2. Average of the twelve FocusVR players over four sesions

Player	Sustained attention	Selective atttentión
1	0.6667	0.3334
2	0.8380	0.6759
3	0.8611	0.7222
4	0.8843	0.7686
5	0.6944	0.3889
6	0.7963	0.5926
7	0.7824	0.5648
8	0.7685	0.5370
9	0.6158	0.2315
10	0.7546	0.5093
11	0.8195	0.6389
12	0.8380	0.6759

The results of each session are presented graphically, which facilitates the visualization of improvements in the sustained and selective attention of the players over time. Figures 5 and 6 illustrate the improvement trends for each player.

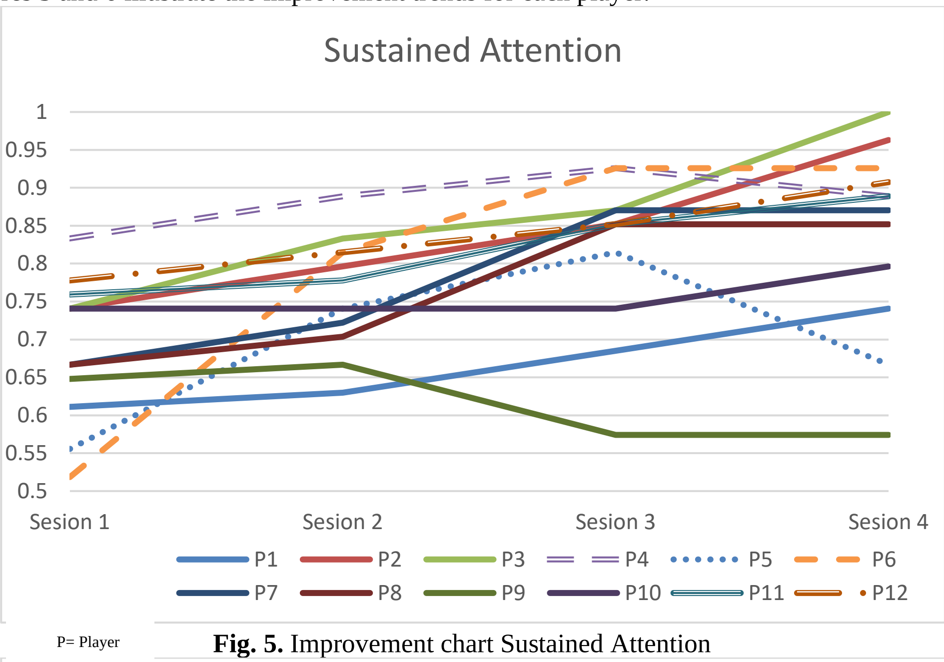

Fig. 5. Improvement chart Sustained Attention

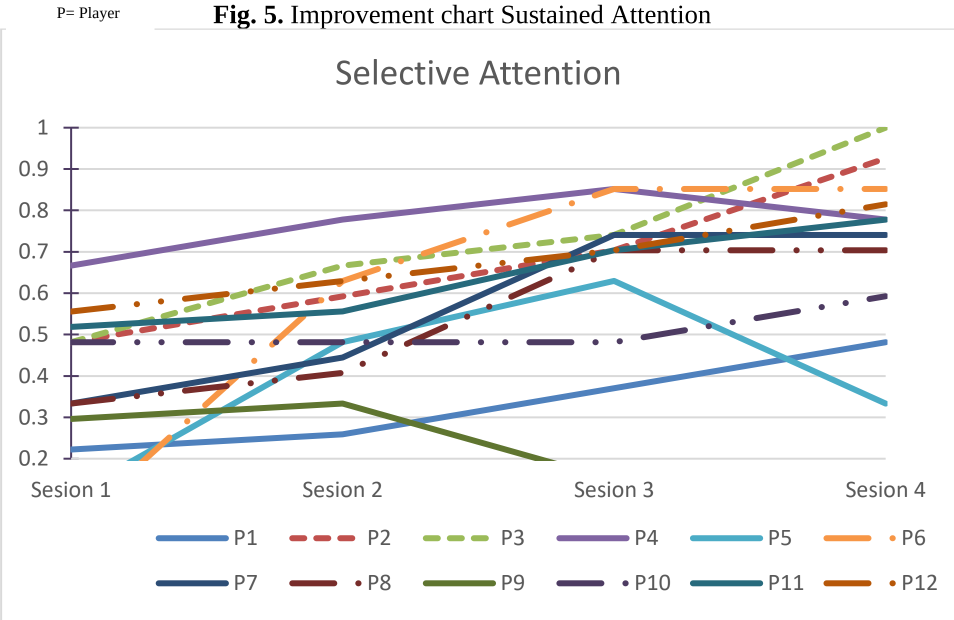

Fig. 6. Improvement chart Selective Attention

The graphs show that all players experienced improvements in selective and sustained attention throughout the sessions. The variability in the degree of improvement among players suggests individual differences in learning and adaptability. Specifically:

- **Selective Attention:** Player 11 showed the greatest progress with a 24% improvement, followed by Player 2 with a 19% increase. This indicates that these players were able to filter out distractions and focus better on relevant stimuli as they progressed through the sessions.
- **Sustained Attention**: Player 9 made the most progress in this area, with an improvement of 44%, indicating a greater hability to maintain concentration for prolonged periods. In contrast, player 1 presented a 22% improvement, suggesting a more gradual progress in maintaining sustained attention.

For the sustained attention data, we have

- Mean ($\overline{x}_{Attention\ \mathrm{sustained}}$)= 0.7766
- Standard deviation ($\sigma_{attention\ sustained}$)= = 0.08189

The mean sustained attention indicates that players were able to co-find 77.66% of the objects correctly. This high mean suggests that FocusVR is effective in maintaining players' attention during game periods. The low variability, with a standard deviation of 0.08189, suggests that players perform relatively consistently in terms of sustained attention. This can be interpreted as a sign that the game is uniformly challenging and manages to maintain players' focus homogeneously. The consistency in the results could also indicate that the game mechanics and the stimuli provided are equally effective for most players.

The coefficient of variation is calculated as:

$$CV_{Sustained\ Attenion} = \frac{0.08189}{0.7766} \approx 0.105$$

A CV of 10.4% indicates a low relative variability. This means that the sustained attention scores are closely clustered around the mean, suggesting a consistency in the players' ability to maintain concentration during the game.
On the other hand, the mean of selective attention is $\overline{x}_{Selective\ Attention}$= 0.5532. This implies that the players were able to correctly filter 55.32% of the objects, ignoring the irrelevant ones. The standard deviation ($\sigma_{Selective\ Attention} = 0.1637$)=) is higher compared to sustained attention, suggesting greater dispersion in the data.

For the coefficient of variation of selective attention:

$$CV_{Selective\ Attention} = \frac{0.1637}{0.5532} \approx 0.296$$

A CV of approximately 29.6% indicates greater relative variability in selective attention, reflecting more significant individual differences in players' ability to filter out distractions.

Looking at individual scores, it can be noted that some players, such as Player 9, have lower sustained attention scores (0.6158), indicating a lower ability to maintain concentration during the game. On the other hand, players such as Player 4 have very high scores (0.8843), showing an outstanding ability to sustain attention. These individual differences suggest that, although the game is generally effective, there is variability in how players respond to it. Factors such as individual predisposition, initial level of attention, and game strategies may influence these differences.

It is interesting to note the relationship between sustained and selective attention in players. In many cases, players who showed high sustained attention also showed good selective attention. For example, Player 4 not only had high sustained attention (0.8843) but also high selective attention (0.7686). This suggests that the skills of sustaining attention and filtering distractions are correlated, although they are not completely dependent on each other.

These results have several important implications for the education and therapy of children with ADHD. The high consistency in improving sustained attention suggests that FocusVR could be an effective tool for helping these children maintain concentration on prolonged tasks, which is crucial for their academic performance and daily activities. The variability in selective attention highlights the need for personalized approaches. Given that some children improved significantly while others showed less progress, training programs should be tailored to individual needs. This could include adjustments in-game difficulty, different types of feedback, and specific strategies to help players filter out distractions more effectively.

6 Conclusions

The present study has demonstrated that FocusVR, a virtual reality video game, is a promising tool for improving attention in children with ADHD. Using sustained and selective attention techniques, FocusVR showed significant improvements in participants' attentional skills. On average, sustained attention increased by 77.24%, reflecting a high ability of the children to maintain concentration on specific tasks throughout the sessions. On the other hand, selective attention improved by 55.66%, albeit with greater variability among participants, suggesting the need for personalized approaches to maximize the benefits of the game.

The individual differences observed in players progress indicate that, although the game is generally effective, there is variability in how children respond to the intervention. Factors such as individual predisposition, initial level of attention, and play strategies may influence these results. The findings suggest that FocusVR can complement traditional treatments such as cognitive-behavioral therapy and medication, providing an interactive and stimulating alternative that can be integrated into existing therapeutic programs. In addition, the immersive and friendly environment of the video game contributes to a positive and engaging gaming experience for children, which could improve their treatment adherence**.** For future research, it is recommended to expand the sample of participants to validate the results obtained and explore the effectiveness of FocusVR in different demographic and age groups. It would be beneficial to conduct longitudinal studies to assess the long-term effects of video game use on attention and other cognitive skills in children with ADHD.

Another aspect to consider is the customization of the game to better suit the individual needs of each child. This could include adjustments in game difficulty, different types of feedback, and specific strategies to help players filter out distractions more effectively. It would also be valuable to explore the use of biometrics and other objective data to measure and monitor players' progress, which would allow for a more accurate and personalized assessment of their performance.

Finally, future research could focus on the implementation of FocusVR in educational and therapeutic settings, evaluating its acceptance and usability by both children and healthcare professionals. The goal is to develop a comprehensive and sustainable approach that maximizes the benefits of video gaming in the treatment of ADHD and other neuropsychiatric conditions.

7 Acknowledgments

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