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ADHD Dog: A Virtual Reality Intervention Incorporating Behavioral and Sociocultural Theories with Gamification for Enhanced Regulation in Individuals with Attention Deficit Hyperactivity Disorder

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Abstract: The need for effective cognitive training methodologies has increased, particularly for individuals dealing with Attention Deficit Hyperactivity Disorder (ADHD). In response to this demand, Virtual Reality (VR) technology emerges as a promising tool to support cognitive functions. Addressing this imperative, our paper introduces ADHD Dog, a VR game designed to aid individuals with ADHD by harnessing the advancements in VR technology and cognitive science. Our approach integrates behavioral and sociocultural theories, alongside gamification, to foster player engagement and reinforce cognitive functions. The theories employed, including operant conditioning and social constructivism, are specifically chosen for their relevance to ADHD's cognitive aspects and their potential to promote active and context-based engagement. ADHD Dog, grounded in the principles of neuroplasticity and behaviorist methods, distinguishes itself by utilizing technology to amplify cognitive functions, like impulse control, attention, and short-term memory. An evaluation by individuals with ADHD, psychologists and computer scientists yielded promising results, underscoring the significant contribution of blending narrative-driven gameplay with behavioral and sociocultural theories, along with gamification, to ADHD cognitive training.

Keywords: Attention Deficit Hyperactivity Disorder (ADHD); cognitive training; executive functions; focus; game design; gamification; impulsiveness; memory; operant conditioning; Sociocultural Theory of Cognitive Development; skill development; unity; virtual reality; VR game

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1. Introduction

The need for effective cognitive training methodologies has taken on new urgency, particularly for individuals with Attention Deficit Hyperactivity Disorder (ADHD). ADHD is a neurodevelopmental condition characterized by persistent challenges in maintaining attention, managing impulsivity, and/or displaying hyperactive behaviors [1]. It requires attention due to its prevalence, affecting individuals across lifespans. Traditional interventions have ranged from pharmacological solutions to behavioral therapy, yet each comes with its own set of limitations [2]. Theoretical perspectives on neuroplasticity and cognitive development suggest that the brain's adaptability can be harnessed through targeted training, indicating the potential of technology-assisted interventions [3]. Cognitive training methodologies have garnered interest as potential interventions, aiming to enhance executive functions and mitigate ADHD symptoms. While research is ongoing, these methodologies hold promise in offering alternative approaches to manage and support individuals with ADHD, complementing traditional treatments. Within this context, Virtual Reality (VR) technology emerges as a promising tool, supported by numerous studies

indicating benefits for cognitive functions such as working memory, executive function, and attention [4–8]. These findings suggest the potential for VR to offer interesting and effective experiences [9]. VR is described as an interactive computer-generated 3D environment in which users can immerse themselves. VR uses computer graphics, sounds, and images to reproduce electronic versions of real-life situations. The term was first introduced by Jaron Lanier in 1989, who is considered the father of VR [10]. There are various input and output devices that are used to create immersion in the virtual world, evoking various sensations in the user. One of the most well-known is the VR headset, which is placed on the user's head and is used to isolate the user from their external environment. Last but not least, the key features that assess the quality of a VR application are immersion, interaction, and imagination [11]

VR also revolutionizes experiences by providing immersive and interactive simulations, transforming abstract concepts into realistic scenarios. The advantages of employing VR from a diverse perspective, as outlined in [12], encompass the following:

- It simulates and creates a simulated environment that enhances a person's understanding of an object or process.
- It encourages active learner participation, providing the learner with the opportunity to interact with the realistic environment.
- It provides a multi-sensory experience that combines vision, hearing, and interaction.
- It provides training in objects or processes that are dangerous, inappropriate, or uncomfortable in the real world.
- It visualizes and represents data and concepts for easier understanding.
- It involves active exploration with its own flow and independent time frame.

In conclusion, VR allows for a hands-on approach to education, where people can engage with their subject matter in a multi-sensory environment, gaining a deeper understanding through active participation. This technology is particularly valuable for safely exploring scenarios that would be too dangerous or impractical to experience in real life. By providing a flexible platform for independent, self-paced exploration and empowering individuals to absorb complex information more effectively, VR emerges as a powerful tool for various applications [13].

This study introduces ADHD Dog, a VR game designed to support individuals with ADHD, by leveraging the latest advances in VR technology and cognitive science. The game aims to enhance critical cognitive functions, such as impulse control, attention, and short-term memory, through interactive and immersive gameplay. Drawing upon behaviorist methods and neuroplasticity concepts, it combines unpredictability with realistic scenarios to mirror real-life challenges, thereby enhancing engagement and overall effectiveness. The game's design is informed by operant conditioning [14], social constructivism (Vygotsky), and gamification—selected for their relevance to ADHD's cognitive aspects and for their ability to promote active, context-based engagement. This approach ensures that the game is not only therapeutic, but also enjoyable, aiding in player engagement and cognitive function reinforcement. The narrative of "Luna", the Dalmatian dog, provides a coherent and engaging context that aligns gameplay with educational objectives. The motivation and novelty of ADHD Dog lie in its inventive approach to aiding individuals with ADHD. This VR game, informed by the principles of neuroplasticity and behaviorist methods, stands out for its use of technology to enhance cognitive functions. By integrating randomness and realistic scenarios, it offers an engaging, interactive experience that goes beyond traditional therapies. This blend of narrative-driven gameplay and multiple cognitive function training marks a significant contribution to ADHD cognitive training, as also discussed in [15].

2. Related Work

The design of the ADHD Dog application was based on known behavioral and sociocultural theories used in Information and Communications Technology (ICT) and features of educational software. The design aimed to support players within the game with a pedagogically sound approach, especially school-aged players. In addition, VR technology

was chosen for the development of ADHD Dog because research suggests that VR can be used for physical and cognitive training [16]. It is a safe and controlled environment where the user can watch and interact with activities represented in 3D models. Recent research has shown that the use of VR can have benefits for adult patients with deficits in executive functions [17]. With the help of virtual environments, patients can improve their cognitive functions such as visuospatial attention, executive function, and memory. The design of these VR applications is based on clinical findings and protocols for physical and cognitive training, tailored to the requirements of VR, and creates a friendly and familiar environment for the user. Similar research has been conducted on the restoration of executive functions using VR applications in children [18] and individuals with ADHD [19]. VR applications have been developed by the Virtual Environments Laboratory at the University of Southern California with the goal of studying and rehabilitating cognitive and functional processes for individuals with ADHD and other attention disorders. One of them replicates an online environment in which the player can experience both visual and auditory distractions in a safe environment while their hand and leg movements are being tracked. The candidates' response times to the visual and 3D audio attention tasks are the application's outputs. This degree of immersion, involving head-mounted displays, provides an immersive layer of a realistic classroom simulation and makes it possible to create attention assessment tasks that are more representative of real-world situations, leading to an enhanced ecological validity of measurement and treatment in the cognitive improvement domain [7].

Building on this concept, 'The Secret Trail of Moon' is a VR game specifically engineered for cognitive training, targeting the core symptoms of ADHD and representing a significant advancement in its treatment [20]. Designed to capitalize on the immersive and engaging potential of VR technology, the game enhances attention, concentration, and executive functioning in individuals with ADHD. The purpose of the application goes beyond traditional therapeutic approaches by offering an experience that is not only interactive, but also therapeutically beneficial. In a survey of 56 mental health and education professionals, including psychologists, neuropsychologists, teachers, pedagogues, and counselors, a notable 71% (40 out of 56) have had experience with students who have ADHD. Impressively, 87% (49 out of 56) indicated that they would use "The Secret Trail of Moon" as a therapeutic and educational tool, while 91% (51 out of 56) believed that a serious video game could be beneficial in this context.

Another development in this field is the "Virtual Human Benchmark" (VHB) [21], which is a digital adaptation of the BATAK light board game, developed to function in a VR environment, specifically tailored for the Oculus Rift and Quest platforms. The BATAK game, known for its potential in enhancing physical reflexes and hand–eye coordination, served as a foundational inspiration for VHB. The VR version is segmented into three distinct modes: reaction, accumulator, and sequence. In the first one, the users respond to randomly illuminated targets, testing their visual processing and reflexes. In the second mode, users hit a series of illuminated targets within a time frame, assessing their motor agility and dexterity, mirroring the traditional BATAK game, while in the third mode, users replicate a series of illuminated patterns with increasing complexity. Twenty participants evaluated the first version, VHB v1, against the conventional BATAK setting. Refinements based on feedback from this assessment resulted in the creation of VHB v2. An additional twenty participants in a follow-up assessment of this revised version attested to the improved use and engagement of the design. Furthermore, VHB's capacity to record and show performance indicators makes it a useful tool for experts working in the therapeutic and sports training fields.

Further research in the field of VR and cognitive training has underscored the versatility of VR applications in addressing various aspects of ADHD. For instance, "MindOfMine" [22] introduces a brain-based serious game approach for supporting cognitive deficits in mental disorders, including ADHD. This application utilizes engaging, game-like elements, aligning with the gamification theory by providing an interactive platform for cognitive improvement. Similarly, "PANDAS" [23] is a tablet-based game developed for

screening ADHD, gathering real-time user data during gameplay. Although it utilizes a support vector machine (SVM) for classification, the abstract does not explicitly indicate the use of operant conditioning principles unless the feedback provided to users is specifically designed to reinforce certain behaviors. Nonetheless, the use of gamified elements in "PANDAS" also contributes to gamification, offering a more engaging and interactive diagnostic approach. Both applications demonstrate innovative uses of technology in the field of ADHD management, highlighting the growing trend of incorporating digital gaming and interactive elements for cognitive enhancement and diagnostic purposes.

Moreover, the mobile application discussed in [24] aims to enhance social skills in students with ADHD through educational games, paralleling ADHD Dog's use of engaging narratives and gameplay. Similarly, "Antonyms" [25] and neurorehabilitation games using neurofeedback [26] highlight the effectiveness of game-based strategies in enhancing attention and social skills. The EmoGalaxy video game [27], focusing on social skills, also emphasizes the use of interactive digital environments. These approaches resonate with aspects of Vygotsky's Sociocultural Theory, as they foster social interaction within a cultural context.

Shifting focus to the integration of brain–computer interface (BCI) technology, the 3D learning playground [28] and other BCI-based systems like those in [29–31] underscore the role of advanced technology in ADHD management. These systems, which combine immersive VR environments with BCI, align with ADHD Dog's approach in using VR for cognitive training. They demonstrate the potential of technology not only to engage users, but also to provide novel methods for cognitive enhancement and attention training in ADHD therapy.

In contrast to the individual studies and applications referenced above, the ADHD Dog application distinguishes itself by comprehensively integrating a range of educational theories and methods. While the aforementioned VR tools and games, such as those discussed in IEEE Documents [24–26] and others, primarily focus on specific aspects of ADHD management or selectively apply one or two educational theories, ADHD Dog seamlessly blends operant conditioning (Skinner), Sociocultural Theory (Vygotsky), and gamification into a cohesive framework. By combining these diverse educational approaches, ADHD Dog emerges as a holistic and versatile educational resource, uniquely equipped to address the multifaceted needs of individuals with ADHD.

3. Materials and Methods

In terms of the research methodology, quantitative research was conducted using a sampling technique, with data collected through questionnaires [32].

Initially, a literature review was conducted, and existing research in the field of VR application development and, more specifically, in their uses for educational and therapeutic purposes related to the enhancement of executive functions were studied. The literature review was conducted on Google Scholar, Scopus, Science Direct (Elsevier), ADHD Information Library, and in the advanced search of the MITOS (Hellenic Academic Libraries Link Integrated Library Catalog) and the National Documentation Center digital library using sources from the past decade. A manual search was performed for the selection of studies. In addition, physical bibliographic resources were searched in the University of West Attica's Library.

The keywords used in the combined search were as follows: ADHD, Attention Deficit, Hyperactivity, Special Education, Attention Deficit Hyperactivity Disorder, Learning Disabilities, VR, VR Applications, Serious Games, Educational Games, Educational Software, Behavioral and Sociocultural Theories, Educational Use of VR, VR for Cognitive Rehabilitation, Cognitive Functions, Educational Neuroscience, and Executive Functions Training. The initial search was conducted in February 2023 and repeated in July 2023. In total, the search returned thousands of studies, and initially, the titles and whether they were relevant to the topic of the literature review were examined. Based on the titles, about 120 sources from the literature were identified, and after reading the corresponding abstracts, 30 of

them were selected according to the inclusion criteria. The main criteria for the inclusion of the bibliography were the publication of the research in scientific journals, conference proceedings, academic books, or in digital libraries of accredited universities. The date of publication plays an important role, and therefore, research older than 10 years was excluded. Finally, the criteria for literature type allowed no primary empirical research (quantitative or qualitative), and therefore, literature, theoretical, systematic reviews or meta-analyses, as well as theses and dissertations, were not excluded.

Then, the hypothesis was formulated, and the ADHD Dog application was created. Then, the basic research process was carried out by testing ADHD Dog on a sample of the population by distributing the questionnaires in electronic form (google forms) and collecting the data (responses). The experimental testing of the ADHD Dog application and the sampling of data for the study were carried out in accordance with the European Code of Conduct for Research Integrity [33]. Regarding the materials, Quest 2, a VR headset developed by Facebook Reality Labs, featuring the graphic performance of the Qualcomm Snapdragon XR2 Gen 2 [34], along with its Oculus Touch controllers, was utilized to conduct tests on the sample population and to gather data. Last but not least, after data collection, statistical processing and an analysis of the results were carried out [35].

Figure 1 briefly presents the steps of this research and how it was organized. Firstly, the research problem was formulated and the study objectives were determined. Then, a very thorough literature review was conducted. Formulating the research hypothesis and selecting the research approach were the next and very important steps for beginning ADHD Dog's development. After specifying the population of interest (individuals positively diagnosed with ADHD over ten years old), the development of the app finally began, and the ethical consideration was established. A study about ADHD Dog was then conducted by selecting the sample, collecting the data needed, and preparing them for analysis. Those data were analyzed and interpreted appropriately. Finally, the research findings were disseminated, and they are presented in this paper.

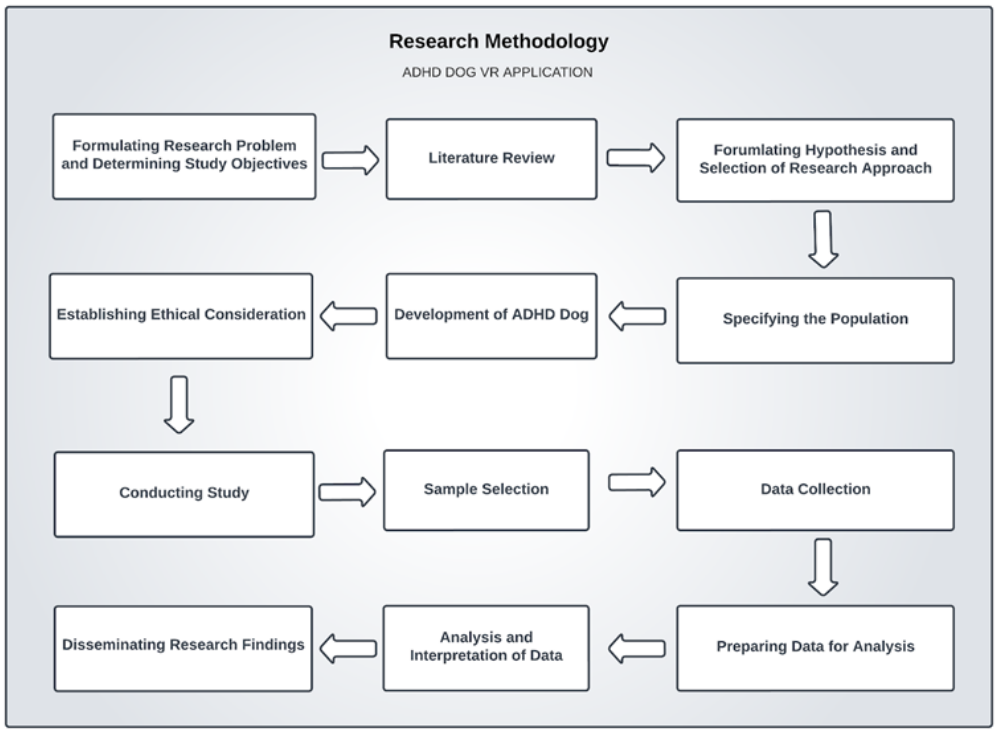


Figure 1. Research methodology of ADHD Dog.

This study involved a sample size of 7 individuals, specifically selected based on the criterion of being over 10 years old, which is in line with the age recommendation provided

by Meta (formerly Facebook) for the use of VR headsets. This age group, along with their positive diagnoses of ADHD, was chosen to assess the effectiveness of the ADHD Dog application within a demographic that is both relevant to the study and within the safe usage guidelines for VR technology.

It was observed that most participants were not familiar with VR technology, which could potentially influence their judgments regarding the effectiveness of the mini-games due to their initial interactions with the VR hardware (headset and controllers). This lack of familiarity might have implications on the study's findings, particularly in assessing the intuitive usability and adaptation curve of the VR application.

The Quest 2 VR headset was chosen for its advanced graphical capabilities, haptic feedback, and degrees of freedom, which were crucial for aligning with the research objectives, as they provide a more immersive and interactive experience, which is essential for the study's focus on cognitive and executive function enhancement through VR. Also, due to its processing power, the game did not freeze, and the overall motion sickness effect was reduced. This study aimed to test the hypothesis that the ADHD Dog VR application could effectively enhance cognitive and executive functions in individuals with ADHD. The objective was to determine if the interactive and immersive nature of VR, combined with game-based strategies, could offer a beneficial alternative to traditional ADHD interventions.

4. ADHD Dog Overview

This section presents an in-depth exploration of the logical architecture and educational design of the ADHD Dog virtual reality game, focusing on its three mini-games: Cross The Road, Park Attention Shooter, and Memory Market. Each game is meticulously crafted to address specific cognitive skills, such as impulsivity control, attention focus, and memory retention, leveraging behaviorist and social constructivist theories. The games incorporate both positive and negative reinforcements, aligning with strategies that promote active engagement through VR.

4.1. Logical Architecture

The presented diagram (Figure 2) encapsulates the interactive relationship among various elements designed to create a comprehensive VR experience. At the start, a representation of a user is shown, symbolized by a "person" icon, which directly connects to a VR headset, specifically "Quest 2". This headset interacts bidirectionally with Unity API. Unity API serves as a central hub in this system, as it facilitates interactions across multiple modules. One key module is the "Player prefs file", which manages user credentials, primarily handling the username. From Unity API [36,37], there is a direct interaction with several game and support modules. The "Helping Module" directs users to a suite of main games: "Cross the Road" (targeting impulsiveness), "Attention Shooter" (designed for focus and attention training), and "Mini Market" (tailored for memory enhancement). These games' performance metrics are integrated into the "Statistics Module", where data like the total time and scores are stored. Based on performance, specifically, if a player finishes the easy mode in less than four minutes, they unlock an achievement represented by the "Red Dog Collar". This achievement is an actual interactable 3D object model that the player can place on Luna in order to be able to experience a more challenging version of the ADHD Dog game. Lastly, overarching all of these modules is the "Game Manager", which seamlessly integrates and manages all components for an immersive experience, such as scene management, fade in/out mechanism, and the player's data handling.

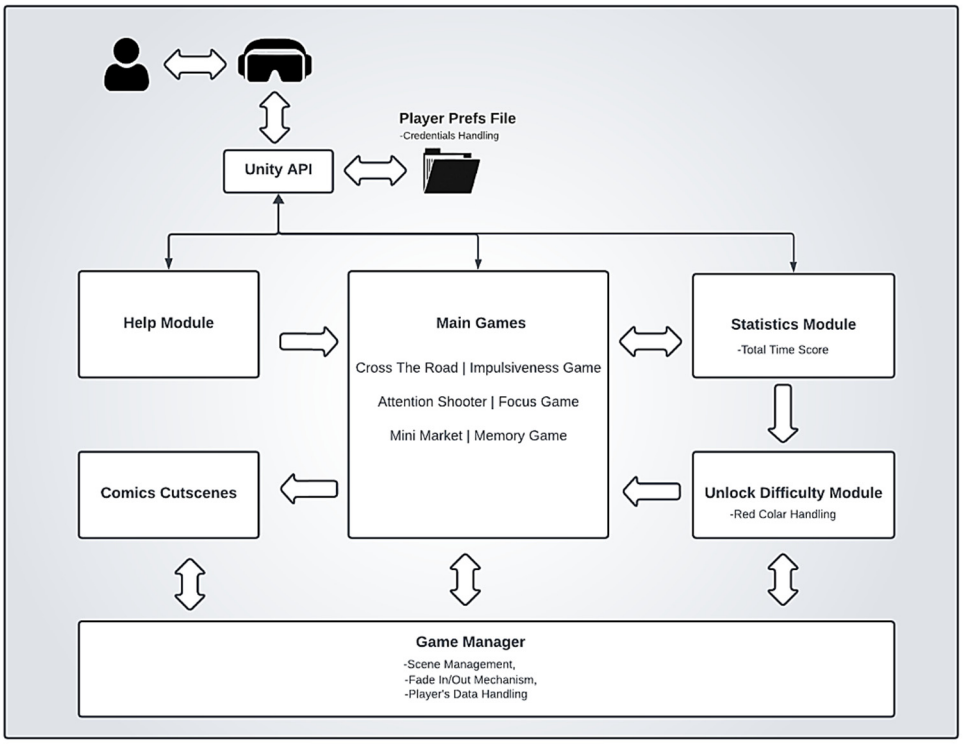


Figure 2. Logical architecture of ADHD Dog.

4.2. Overview of the Three Mini-Games

The game is structured into three mini-games. Each mini-game has three levels of difficulty with differences in logic and the addition of both visual and auditory distractions that make completing each mini-game more difficult. Lastly, it is important to note that, to access the hard level, players must successfully complete the easy level within a specified time threshold. Also, each of these mini-games was created with the scientific support of a special educator and an occupational therapist.

The core design of the game is based on behavioral and sociocultural theories, such as behaviorism and constructivism, primarily evolving reinforcement theories and social constructivism [38]. Players are continually exposed to external stimuli in the impulsivity game. Their reactions to these stimuli yield either positive reinforcements (rewards) for desired behaviors or negative feedback for undesirable ones, as presented in Table 1. This immediate feedback mechanism ensures that the players continually adapt their behaviors in the direction of better impulsiveness management. The game also taps into the idea of engaging and entertaining educational activities, employing a VR environment as an immersive medium [38]. Such a medium, when combined with the main points of behaviorist theories, creates a rich, reactive environment where players can safely learn and adapt. Furthermore, there are elements of social constructivism theory (Lev Vygotsky's Sociocultural Theory of cognitive development) in a lot of ADHD Dog's mini-games. According to Vygotsky, an individual in the process of skill acquisition is not a passive recipient but an active subject who shapes their cognitive reality through their actions [38]. The present VR game is designed for active participation and engagement by individuals, emphasizing hands-on experience to shape experiences. Moreover, social constructivism is currently highly valued for the importance it gives to social and cultural elements. The present game uses real-life situations with real social and cultural elements (Western world daily life scenario, a realistic storyline about a lost pet, street crossing, nature, and shopping at a supermarket). The sociocultural educational software category includes simulations, other virtual environments, online games, etc. [38]. Thus, ADHD Dog also belongs to this category of educational software [39].

Table 1. Mini-games: positive and negative reinforcements.

Mini-Game Title	Reward	Punishment
Cross The Road	Crossing turns green when player is at the correct spot	Player moves back one crossing, negative sound plays
Park Attention Shooter	Butterfly leaves Butterfly disappears	Flower becomes smaller, level restarts after 3 mistakes
Memory Market	Positive face appears	Sad face appears, one life heart vanishes

4.2.1. The Impulsiveness Game

The player must navigate five traffic light crossings in the first task (Figure 3). Each traffic light begins at a random number within a certain range, decreasing every second. This change causes the traffic light to switch from green to red or vice versa when it reaches zero. The player must control their impulsiveness; if they cross the road on red, they move one crossing back from where they were and hear an error sound. This provides real-time feedback, instructing the player to comply with the game's rules to complete it.



Figure 3. Cross The Road/impulsivity game.

The spark behind the creation of the "Cross the Road | Impulsiveness Game" was the case of Yannis, a child with ADHD, who displayed impulsive behavior, as described in [40]. The book in [40] delves into individual cases, such as that of Yannis, to elucidate the behaviors of children with ADHD. Yannis, as described in [40], was always on the move, as if he had an internal engine propelling him forward. His inability to focus on a task for more than a few minutes was evident. However, the most concerning observation was his lack of danger awareness. A vivid description from the book depicts a shopping trip where Yannis, upon the release of his hand, would instinctively run towards the opposite sidewalk without considering the potential perils.

The "Cross the Road | Impulsiveness Game" game, inspired by the comprehensive content of the book, serves as an interactive platform aiming to hone impulse control in children. By simulating real-life situations, the game pushes children to think before they act, helping them better manage their impulsiveness.

4.2.2. The Focus Game

In the second activity, the player must focus on particular moving objects in space, butterflies, which are trying to hide a flower from the player while the player tries to cut it (Figure 4). The butterflies come in two varieties: regular butterflies and red butterflies. Their lives diminish while the player concentrates on them, and the red butterflies require more concentration time to defeat. The player must continuously avoid the butterflies until the timer ends.

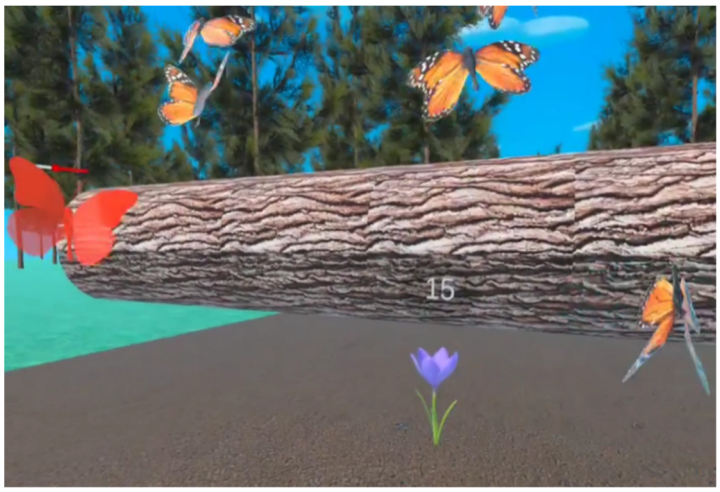


Figure 4. Park Attention Shooter/focus game. The number 15 indicates the remaining seconds for user action.

The inspiration for this focus game is deeply rooted in empirical studies emphasizing the intersection of executive functions and motivational components, especially in the realm of ADHD. The work of [41] sheds light on how visual–spatial working memory, a crucial executive function, is notably impaired in children with ADHD. This research showed that while children with ADHD performed sub-optimally in a working memory task with only feedback as reinforcement, introducing stronger incentives like monetary rewards or a game-based version of the task led to significant improvements. Notably, gaming emerged as an equally powerful motivator as monetary reinforcement, underlining the potential of game environments in enhancing attention and persistence. This empirical insight highlighted the promising role of game-based interventions, serving as a pivotal cornerstone in the development of our focus-driven game.

The behaviorist training in the Park Attention Shooter/Focus Game draws inspiration from the principles of behaviorist psychology, particularly those articulated by B.F. Skinner. In this game, players are tasked with concentrating on moving targets, represented by butterflies, that they must deter from a flower they aim to cut. Aligning with Skinner's theories of operant conditioning, as detailed in his work *The Behavior of Organisms: An Experimental Analysis* [14], the game offers immediate feedback to players, reinforcing desired behaviors and discouraging undesirable ones. Positive reinforcement is evident when a player's attention successfully zeroes in on a butterfly; the butterfly then changes its color to green and retreats, signaling to the player their correct action. In contrast, negative reinforcement occurs when players fail to target the butterflies with their gaze. The flower shrinks in size with each unattended butterfly's touch, and after three such instances, the game level restarts. Through this continuous cycle of positive and negative reinforcement, central to Skinner's behaviorist theories, players are encouraged to refine their focus and attention strategies based on immediate feedback. Skinner stated that schools should look for available positive reinforcers and activities that entertain students. Skinner also referred to teaching machines, which can currently be described as computers with educational software. VR headsets with corresponding educational applications, like

ADHD Dog, could potentially be future teaching machines. In fact, the game could possibly be described as a training and practice program or a closed behavioral-type simulation, as it has many similarities with these types of behavioral educational software (different teaching materials based on level of difficulty, direct feedback to the player, and rewards and positive reinforcement of correct actions/behaviors and negative stimuli accordingly, following a linear organization pattern) [39].

4.2.3. The Memory Game

The third and final activity finds Luna entering an area of a local convenience store where, as indicated, only staff are allowed (Figure 5). The player agrees to take the cashier's place until they find her and brings her back to the owner. This activity is designed to practice short-term memory as it presents the player with four random items that can be found in a memory market on the store's main screen, which the player must retain in memory within a given time in order to obtain them and place them in the shopping cart. Consequently, when the player makes a correct decision about an item, a random face displaying a positive emotion, such as happiness or excitement, is shown as positive feedback. Conversely, when the decision is incorrect, a random face expressing a negative emotion, such as sadness, anger, or frustration, appears. This final challenge tests the player's memory and encourages them to practice retaining and recalling information accurately.



Figure 5. Memory Market/short-term memory game.

The inspiration for Memory Market is taken from one publication in the *Scientific Reports* journal where some memory-based games for individuals with autism spectrum disorder were created. One of them suggested a game with three colored baskets [42]. In the gameplay, a colored fruit is imprisoned inside a bubble that travels above those variously colored baskets in a zigzag pattern. When the player taps the bubble to pop it, the fruit drops into one of the baskets, and a visual reinforcement of a girl laughing and clapping is given when the fruit's color matches the color of the basket, followed by a particle scattering effect. The progression of the game is that the baskets gradually descend and disappear from the screen, hiding their colored components entirely at last, making the game more difficult to finish [42].

4.3. Educational Design of ADHD Dog

The objectives of the ADHD Dog mini-games were structured based on Mager's theory of goal setting [32] encompassing a subject, outcome, action, conditions, and degree of achievement.

First Game:

The player of the game should be able to restrain their impulsivity to pass the game passages without errors within 10 min.

The player needs to exercise inhibitory control within a realistic time frame through game-based interactions.

Second Game:

The player of the game must be able to keep their attention on the butterflies without distracting themselves until they defeat them all.

The player practices maintaining attention and concentration within a digital simulation environment that captures the player's interest.

Third Game:

The game player should be able to recall specific products from memory with absolute accuracy a few seconds after having seen them.

The player enhances their working memory by recalling images, seen a few moments ago, through gamification.

As stated before, the educational design of ADHD Dog is based on behavioral and sociocultural theories, such as behaviorism, primarily evolving reinforcement theories and social constructivism, which are presented in Table 2 in more detail. It also features characteristics of primary educational software categories, like behavioral educational software (training and practice program and closed behavioral simulation) and sociocultural educational software (simulations, virtual environments, and a leaderboard with the players' names and scores). The final game of ADHD Dog has indeed been designed according to the pedagogical features mentioned above (positive reinforcements, direct feedback, and real-life situations with familiar social and cultural elements). It also contains elements of gamification (e.g., difficulty levels, lives, leaderboard, time, etc.). It is a VR game after all. At the same time, it uses game-based training because players actually improve their skills by playing a game. Modern approaches to education were chosen for the development of ADHD Dog due to the type of application (VR game) and their scientific significance and positive outcomes in today's education. Gamification has been shown to be beneficial for teaching and training, and game-based practices are considered important and useful in the current teaching landscape [13].

Table 2. Overview of behavioral and sociocultural theories applied in mini-games.

Mini-Game Title	Operant Conditioning (Skinner)	Sociocultural Theory of Cognitive Development (Vygotsky)	Gamification
Cross The Road	✓	✓	
Park Attention Shooter	✓		✓
Memory Market	✓	✓	✓

The featured behavioral and sociocultural theories were selected because of their adaptability to unique aspects of ADHD and their impact on therapeutic interventions for it. Firstly, operant conditioning, as proposed by Skinner, emphasizes the impact of consequences on behavior. This theory is particularly pertinent to ADHD, where immediate and consistent feedback can significantly influence behavior modification, catering to the often shorter attention spans associated with ADHD. Skinner's theories provided the foundation for a therapeutic technique known as behavior modification, which is used in ADHD interventions [43]. Vygotsky's Sociocultural Theory, as elucidated in Shabani's work [44], underscores the importance of mediation and social interactions, which are concepts that can be highly beneficial for individuals with ADHD. The ADHD Dog game leverages these ideas by incorporating features like leaderboards to foster community and motivation, aligning with the theory's emphasis on social interaction as a fundamental basis of development. Additionally, the app's design includes visual aids and structured instructions in each mini-game, supporting the concept of scaffolding within the Zone of

Proximal Development (ZPD). This is crucial for ADHD learners, assisting them in focusing and understanding tasks. The game's varying difficulty levels also allow for progression at a personalized pace, reflecting the adaptive experience within the ZPD, a key aspect of Vygotsky's theory. Lastly, the integration of gamification in serious games represents a significant development in addressing ADHD [1]. This method is especially suited to ADHD learners because it merges game elements with educational content, enhancing engagement and attention regulation. Crucial features like immediate feedback, rewards, and dynamic environments are key to capturing the attention of these learners ([45,46]). These elements not only maintain motivation and interest through a sense of achievement and progression, but also cater to the varied needs and attention spans of individuals with ADHD. The interactive nature and engaging design of serious games make challenging tasks seem more manageable and enjoyable. This approach helps develop problem-solving skills and resilience, as learners are more inclined to engage with and overcome difficulties presented in a game-like format.

The development of each of these mini-games was facilitated by the interdisciplinary collaboration of a special educator and an occupational therapist, both of whom provided scientific expertise and guidance. The special educator brought her specialized expertise to focus on important information about ADHD, variations in ADHD symptoms, teaching intervention strategies, and behavioral and sociocultural theories that are compatible and suited for individuals with ADHD. Sharing her professional experience from teaching and assessing students with ADHD and providing feedback was a part of her contribution, too. She helped guide the development of the mini-games so that each of them meets the unique challenges of people with ADHD and helps them improve their skills, according to her experience and the newest relevant research findings from the field of special education. Taking into consideration the complexity and the cognitive, emotional, and behavioral aspects of ADHD, she also contributed by spotting the potential challenges surrounding the direct involvement of individuals with ADHD in the evaluation of the ADHD Dog game and by suggesting specific ethical considerations to avoid exposing them during this process, as well as good practices for creating an appropriate and pedagogically correct environment for people with ADHD during the evaluation.

Regarding the contribution of the occupational therapist, she provided scientific support about executive functions and how they are affected by ADHD. Moreover, she proposed how the mostly affected executive functions can be trained and improved using therapeutic interventions in individuals with ADHD, and she also recognized potential feelings of distress or discomfort that could be experienced by individuals with ADHD while playing the mini-games and provided meaningful feedback to the developer.

5. Incorporating ADHD Dog in Health Education

Health education refers to the interdisciplinary activity that promotes the well-being of an individual, combining both the physical and psychological dimensions of health. It focuses on prevention and education so that individuals develop the necessary skills and knowledge to enable them to make responsible and informed decisions about their health [47]. In addition, it aims to reduce school failure and to prevent the social marginalization of young people and the early drop-out of compulsory education. In today's society, where environmental, social, and psychological factors are progressively affecting the physical and mental health of individuals, health education is a central pillar. Through this process, students are encouraged to develop self-awareness about healthy habits, nutrition, movement, and mental health [48].

The ADHD Dog game is an innovative approach to health education, respecting the needs of players with ADHD, as it aims to help them practice critical executive functions in which they often have deficits, such as impulse control, attention concentration, and working memory. Through its procedures and direct feedback, it enables players to practice self-regulation. A child, for example, who finds it difficult to concentrate can be trained to maintain concentration for longer periods of time through the game. Also, children

who react impulsively to various situations can practice regulating their behaviors while sharpening their working memories through the scenarios offered by play.

In the context of exercising executive functions, ADHD Dog provides a structured platform for practicing elements such as organization, planning, decision making, and adapting to new situations. These functions, which are vital to everyday life, are practiced and possibly enhanced through constant practice and friction with this game. Thus, ADHD Dog could be used effectively in several content areas proposed by the Ministry of Education for health education, providing added value to the overall process compared to traditional teaching, e.g., to promote the inclusion and visibility of pupils with deficits in specific educational functions due to a disorder (ADHD, etc.) or disability in the "Interpersonal Relationships-Mental Health" and "Social Exclusion-Equal Opportunities" axes. Another example is the use of the first sub-game of ADHD Dog in the "Traffic Education-Accidents" and "Pedestrian behavior of pupils" axis or in the "Emergency Response" axis, as its games develop relevant skills [48].

In summary, ADHD Dog is not only an entertaining game, but also a multi-faceted tool that combines fun with educational value and the practice of the user's executive functions in a safe virtual environment, thus supporting health education, the integration of ICT in the implementation of Health Education programs, and the integrated cognitive development of players.

6. Use of ADHD Dog in Teaching and Therapeutic Interventions for Attention Deficit Hyperactivity Disorder

This section discusses the game's design, which is rooted in behaviorist and cognitive teaching methods, and its connection to ADHD. The mini-games, which were developed based on characteristics commonly found in children with ADHD, are presented to illustrate this alignment and their purpose.

6.1. Characteristics of ADHD in Individuals

Attention deficit and hyperactivity disorder is one of the developmental disorders that occur in children before the age of 7 years and can extend into adolescence and even into adulthood, with significant effects on behavior, social adjustment, and school performance [49]. According to DSM-5, the diagnostic criteria for ADHD are attention deficit/distraction, hyperactivity, and impulsivity [50]. Recent studies confirm the efficacy of VR in supporting individuals' development [15].

The in-depth exploration of individuals' behaviors, as highlighted in studies on individuals with ADHD [40], encapsulates various characteristics in these individuals, including the following:

- A heightened sense of enthusiasm and arousal;
- An incessant need to talk and move;
- The inability to filter out insignificant stimuli;
- Frequent shifts in activities without a break;
- A sense of regret after carrying out impulsive actions.

6.2. Enhancing Cognitive Executive Functions in ADHD through Gamified Interventions

While the behaviorist approach provides immediate external feedback to players, the cognitive aspect of the game immerses players in situations that require them to introspect, reflect upon, and modify their inherent thought processes. Cognitive training goes beyond the mere reaction to stimuli; it fosters a deeper understanding of why certain impulsive behaviors arise and how one's thought patterns can be realigned. By merging both the reactive learning of behaviorism and the reflective learning of cognitive training [51], the game aims to provide a comprehensive experience that combines real-time feedback with opportunities for introspective growth while using gamification that makes learning more enjoyable [52]. It seeks to enhance not only immediate reactions but also long-term cognitive processes.

The impulsiveness game offers a holistic approach to understanding and managing impulsiveness that showcases how traditional educational theories can be revitalized in the contemporary digital age. By combining the principles of behaviorist and cognitive teaching methods, it equips players with the insights and resources to comprehend, manage, and ultimately mitigate their impulsive tendencies. In this specific game, the player is required to effectively utilize their inhibition executive function to stay stationary until the traffic light turns green, essentially overcoming their impulsiveness [53]. Particularly in the difficult mode, the player must maintain focus on the traffic light, sidelining distractions from the environment such as car horns and butterflies, in an attempt to timely cross to the other side of the road. This gamified approach aligns with the findings from a study conducted by the authors of [45]. Their research, published in *Entertainment Computing*, identified that serious games have a positive impact, enhancing executive functions among individuals with ADHD [54].

The "Park Attention Shooter | Focus Game" hones various executive functions. Players employ attentional control as they constantly shift and refocus their gaze, adjusting to the ever-changing targets present in the game's environment. Working memory comes into play as, with game progression, players need to store and recall specific characteristics and behaviors of different targets, such as the butterflies' movement patterns. The challenge of time management arises as players must judiciously allocate their time to different in-game tasks. This ensures that they address immediate threats while also strategizing for forthcoming challenges. Further depth is added with the requirement for strategic planning and prioritization [55]. Players are called to make decisions on which targets to emphasize based on their significance. The introduction of "Boss butterflies", which demand a longer span of attention, exemplifies the necessity for setting priorities within the gameplay. Additionally, the game environment, especially in advanced levels, necessitates adept task-switching as players need to swiftly transition between tasks, like altering their focus among different butterfly types or game elements [56]. Through these mechanisms, the game serves as a dynamic platform to refine these critical cognitive processes.

The third game in the levels is designed to enhance working memory, specifically through visual memory. However, in addition to this, other various visual perception skills are stimulated: First of all, visual figure–ground, which is the ability of an individual to concentrate on a particular visual stimulus while ignoring the rest (e.g., a symbol or shape is presented among other similar or different ones), is stimulated [16]. Then, visual constancy, the ability of an individual to recognize the shape itself presented in another form (different size, orientation, direction), is stimulated. And finally, visual discrimination, meaning the ability to recognize key features of visual stimuli, such as shape, size, color, or orientation, is stimulated. In addition, the executive function of planning is used since the player needs to choose from the many products given to them at the beginning and put them in the basket. That is, the player must organize their movements in order to achieve the goal.

7. Evaluation Results and Discussion

In this evaluation, the impact and effectiveness of ADHD Dog are addressed across three distinct populations. The first group (G1) comprises individuals diagnosed with ADHD. By engaging this target population, we seek to evaluate ADHD Dog's potential in addressing the unique challenges associated with ADHD and enhancing regulatory skills. The participants of G1 were categorized into two groups: G1-A, comprising 40 individuals who used ADHD Dog for six months, and G1-B, consisting of 40 individuals who used a conventional version of ADHD Dog for the same period. The conventional version shares the same user interface but lacks the integration of behavioral and sociocultural theories.

The second group (G2) involves psychologists who specialize in neurodevelopmental disorders and behavioral interventions. Leveraging their expertise, we aim to gain valuable insights into ADHD Dog's alignment with established therapeutic principles and cognitive theories and its potential contribution to the field of ADHD interventions.

The third group (G3) consists of computer science experts, bringing a technical perspective to the evaluation. Their assessment will focus on the technological aspects of the ADHD Dog VR intervention, including usability, user experience, and the integration of gamification elements.

In adherence to ethical principles concerning the involvement of individuals diagnosed with ADHD, it is crucial to highlight that they have provided their full and informed consent to participate in the study. All participants in this subgroup are over the age of 18, ensuring that they possess the legal capacity to provide consent for their involvement in the evaluation.

Prior to their inclusion in the study, participants with ADHD received clear and comprehensive information about the nature, purpose, and potential outcomes of this research. This includes details about the virtual reality gamified intervention, its objectives, and any potential risks or benefits associated with participation. Additionally, the participants were assured of their right to withdraw from the study at any point without facing any negative consequences. The evaluation of G1 was conducted under the control and continuous monitoring of G2.

To safeguard the well-being and privacy of individuals with ADHD, confidentiality measures were implemented; all data collected from this population have been anonymized, and all personal information has been handled with care.

The characteristics of the participating population are shown in Table 3.

Table 3. Characteristics of the participants.

Characteristics	G1 (Individuals with ADHD)	G2 (Psychologists)	G3 (Computer Science Experts)
Number	80	20	20
Mean Age	25	38	42
Gender	36 females 44 males	13 females 7 males	5 females 15 males
Educational background	Secondary education diplomas, bachelor's or master's degrees in diverse fields	At least a master's degree in their field	A PhD degree in their field
Origin background	Equal percentage of individuals with urban and rural origins.		
Computer skills	Adequate proficiency in computer usage.	Adequate proficiency in computer usage.	Advanced proficiency in computer usage.
Motivation	Contribute to developing innovative solutions for managing ADHD symptoms through engaging virtual reality experiences.	Evaluate the effectiveness of a novel intervention, merging psychological theories with technology, to enhance ADHD regulation.	Assess the technological aspects of a gamified virtual reality intervention, contributing to the intersection of technology and cognitive health.

After the six-month period, the participants in G1-A were asked to respond to the following questions on a Likert scale ranging from 5 ("Very much") to 1 ("Not at all"):

- To what extent did you find the ADHD Dog intervention engaging and enjoyable in addressing challenges related to ADHD symptoms? (Q1-I)
- How effective do you believe the ADHD Dog intervention was in enhancing your ability to focus and regulate attention? (Q2-I)
- To what degree did the ADHD Dog intervention contribute to a sense of accomplishment and self-efficacy in managing ADHD-related difficulties? (Q3-I)
- How comfortable were you navigating and interacting with the virtual reality environment in the ADHD Dog intervention? (Q4-I)

- To what extent do you believe the ADHD Dog intervention has positively impacted your daily life and activities outside of the virtual environment? (Q5-I)

  The results are presented in Figure 6.

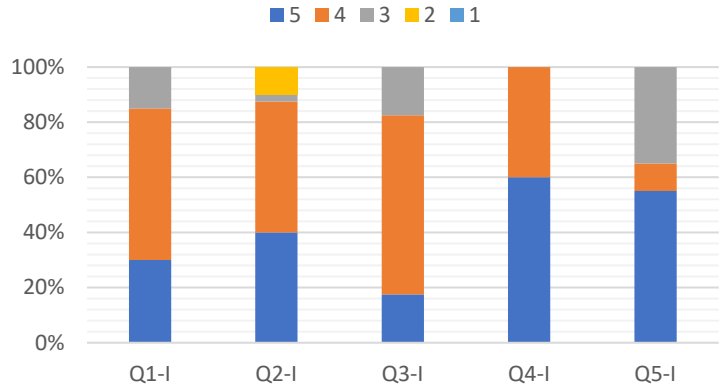


Figure 6. Questionnaire results from individuals with ADHD.

The results of the survey reveal significant insights into the participants' experiences with ADHD Dog. Firstly, a substantial number of participants found the intervention engaging and enjoyable, suggesting its potential as an attractive tool for addressing challenges associated with ADHD symptoms (Q1-I). Additionally, the respondents perceived the intervention as effective in enhancing their ability to focus and regulate attention, emphasizing its positive impact on cognitive aspects related to ADHD (Q2-I). The intervention also contributed to a sense of accomplishment and self-efficacy in managing ADHD-related difficulties, reflecting its potential to improve users' confidence and coping mechanisms (Q3-I). Furthermore, the participants expressed a comfortable experience navigating and interacting within the virtual reality environment, highlighting the user-friendly nature of the intervention (Q4-I). Lastly, the positive impact of the ADHD Dog intervention extended beyond the virtual environment, as indicated by participants who believed that it positively influenced their daily lives and activities (Q5-I). Overall, these findings underscore the potential efficacy and versatility of the ADHD Dog intervention in addressing various aspects of ADHD-related challenges.

In this study, a *t*-test on the participants of G1 was employed to assess the statistical significance of the results and address the research questions regarding the ADHD Dog intervention.

Comparisons between the two groups, namely G1-A and G1-B, enabled a thorough investigation into the effectiveness of integrating behavioral and sociocultural theories in enhancing user engagement, immersion, and understanding of the ADHD Dog content. Both groups completed a Likert scale questionnaire (Q1-I, Q2-I, Q3-I, Q4-I, Q5-I) post-VR experience, providing valuable insights into their perceptions. This study's null hypothesis posited equal means for both groups, while the alternative hypothesis suggested differences. The chosen significance level for the *t*-test was alpha = 0.05 (Table 4).

Table 4. *t*-test results.

	Q1		**Q2**		**Q3**		**Q4**		**Q5**	
	G1-A	**G1-B**	**G1-A**	**G1-B**	**G1-A**	**G1-B**	**G1-A**	**G1-B**	**G1-A**	**G1-B**
Mean	4.15	3.475	4.175	3.65	4	3.1	4.6	3.925	4.2	2.675
Variance	0.438462	1.178846	0.814744	0.387179	0.358974	0.246154	0.246154	2.686538	0.882051	2.122436
Observations	40	40	40	40	40	40	40	40	40	40
Pooled variance	0.808654		0.600962		0.302564		1.466346		1.502244	
Hypothesized mean difference	0		0		0		0		0	
df	78		78		78		78		78	
t Stat	3.356893		3.028663		7.317265		2.492875		5.564353	
P(T $\leq$ t) one-tail	0.00061		0.001665		9.75×10^{-11}		0.007395		1.79×10^{-7}	
t Critical one-tail	1.664625		1.664625		1.664625		1.664625		1.664625	
P(T $\leq$ t) two-tail	0.001221		0.00333		1.95×10^{-10}		0.01479		3.57×10^{-7}	
t Critical two-tail	1.990847		1.990847		1.990847		1.990847		1.990847	

In Q1-I, the findings revealed that the 40 participants who utilized ADHD Dog (mean = 4.15, variance ≈ 0.43) exhibited significantly better peak flow scores compared to the 40 participants in the control group (mean ≈ 3.47, variance ≈ 1.17), with $p < 0.05$ (Table 4). The results revealed a high level of engagement and enjoyment in addressing challenges related to ADHD symptoms (Q1-I), indicating that ADHD Dog successfully captured their interest. Similarly, in Q2-I, the 40 participants in the experimental group (mean ≈ 4.17, variance ≈ 0.81) demonstrated notably higher peak flow scores than the participants in G1-B (mean = 3.65, variance ≈ 0.38), with $p < 0.05$ (Table 4). ADHD Dog demonstrated a significant positive impact on the participants' ability to focus and regulate attention (Q2-I), showcasing its effectiveness in addressing cognitive aspects associated with ADHD. Moving to Q3-I, the participants of G1-A (mean = 4.00, variance ≈ 0.35) showed considerably higher peak flow scores compared to the participants of G1-B (mean = 3.1, variance ≈ 0.24), with $p < 0.05$ (Table 4). ADHD Dog contributed significantly to a sense of accomplishment and self-efficacy in managing ADHD-related difficulties (Q3-I), suggesting that the participants felt empowered and successful in navigating the intervention. Q4-I revealed that the participants of the experimental group (mean = 4.6, variance ≈ 0.24) also demonstrated significantly better peak flow scores than the participants of the control group (mean ≈ 3.92, variance ≈ 2.68), with $p < 0.05$ (Table 4). The results highlighted the participants' comfort in interacting with the virtual reality environment (Q4-I), emphasizing the user-friendly nature of the intervention. Finally, in Q5-I, the participants in the experimental group exhibited notably superior outcomes with a mean of 4.2 and a variance of around 0.88, surpassing the control group's participants with a mean of approximately 2.67 and a variance of about 2.12, achieving statistical significance with $p < 0.05$ (Table 4). The perceived positive impact of ADHD Dog on participants' daily lives and activities outside of the virtual environment (Q5-I) underscores its potential for meaningful, real-world application and improvement in individuals' overall well-being.

The *t*-test results provided compelling evidence to reject the null hypothesis, indicating significant differences in the outcomes between the two groups. The distinctive incorporation of behavioral and sociocultural theories in the experimental group led to noticeably better results across all five questions compared to the control group.

The statistically significant difference in the mean effectiveness ratings further supports the conclusion that the presented approach, integrating behavioral and sociocultural theories with gamification, contributed to a more intuitive and effective experience for the participants in the experimental group. This resulted in enhanced regulation in individuals with ADHD compared to the control group.

The favorable *t*-test results can be attributed to the strategic incorporation of behavioral and sociocultural theories within the design of ADHD Dog. By integrating behavioral theories, the intervention taps into principles such as operant conditioning, fostering a structured environment that reinforces positive behaviors and regulates impulsive tendencies associated with ADHD. This behavioral approach enhances engagement and provides a systematic framework for users to develop and reinforce desirable cognitive patterns. Additionally, the inclusion of sociocultural theories, such as Vygotsky's Sociocultural Theory of Cognitive Development, introduces a social context to the learning experience. This social interaction aspect promotes collaborative learning, allowing individuals with ADHD to navigate challenges within a supportive virtual environment. The combination of these theories, coupled with gamification elements, ensures a holistic and effective approach to regulation enhancement in individuals with ADHD. The diverse and integrated theoretical foundations provide a multifaceted strategy, addressing the unique cognitive and social aspects of ADHD, and ultimately contributing to the positive outcomes observed in the *t*-test results.

In summary, this study's findings illuminate the effectiveness of incorporating behavioral and sociocultural theories in tailoring a virtual reality intervention for individuals with ADHD. These insights contribute to a deeper understanding of how such targeted approaches positively impact regulation and engagement in individuals with ADHD.

Transitioning to G2, our focus shifts towards evaluating ADHD Dog through the expert lenses of psychologists. In this context, G2, comprising psychologists, underwent a one-month engagement with ADHD Dog. The objective was to assess the quality of the virtual reality intervention specifically in terms of its impact on psychological aspects related to ADHD. This evaluation from the perspective of psychology professionals provides valuable insights into the intervention's efficacy and potential contributions to psychological well-being in individuals with ADHD. The questions posed to G2 are on a Likert scale ranging from "Very much" (5) to "Not at all" (1) and are as follows:

- To what extent do you believe the ADHD Dog game positively impacts the cognitive, emotional, and behavioral aspects of individuals with ADHD? (Q1-P)
- How strongly do you agree that the game demonstrates observable changes or improvements in attention regulation and overall psychological well-being during the evaluation? (Q2-P)
- Indicate your level of agreement regarding the potential benefits and challenges associated with integrating ADHD Dog into therapeutic strategies for individuals with ADHD. (Q3-P)
- How effective do you think the incorporation of behavioral and sociocultural theories is in enhancing cognitive skills in individuals with ADHD through ADHD Dog? (Q4-P)
- To what degree do you believe the ADHD Dog intervention has the potential to complement traditional therapeutic methods for individuals with ADHD? (Q5-P)

As illustrated in Figure 7, the psychologist perspective (of G2) on ADHD Dog revealed consistent positive evaluations across various dimensions. The participants expressed their agreement regarding the game's positive impact on the cognitive, emotional, and behavioral aspects of individuals with ADHD, indicating its potential to address the multifaceted challenges associated with the disorder. The psychologists also noted observable changes and improvements in attention regulation and overall psychological well-being, aligning with the intervention's intended goals. While recognizing the benefits, the psychologists also acknowledged potential challenges in integrating ADHD Dog into therapeutic strategies, emphasizing the need for careful consideration. The incorporation of behavioral and sociocultural theories was positively assessed for its effectiveness in enhancing cognitive skills related to ADHD. Moreover, the psychologists believed in the complementary potential of ADHD Dog compared to traditional therapeutic methods, positioning it as a valuable adjunct for comprehensive ADHD management. Overall, the psychologist perspective provides a clear understanding of the intervention's positive impact and considerations for its integration into therapeutic practices.

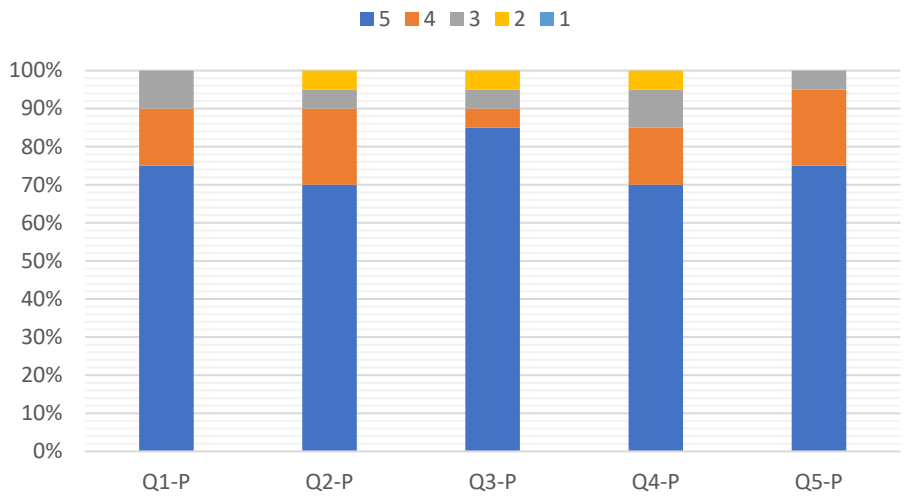


Figure 7. Questionnaire results from psychologists.

Transitioning to the G3 population, our focus shifts towards the evaluation of ADHD Dog through the expertise of computer science experts. In this context, G3 participants, comprising computer science experts, engaged with ADHD Dog for one month. The objective was to assess the quality of the virtual reality intervention from the standpoint of computer science principles. This evaluation aimed to glean insights into the technological aspects of ADHD Dog, including usability, user experience, and the integration of gamification elements, providing a thorough examination of the intervention's adherence to computer science principles and its overall quality in the realm of technology and software design. The questions presented to G3 are rated on a Likert scale, spanning from "Very much" (5) to "Not at all" (1), and include the following:

- To what extent do you find the technological aspects, such as the virtual reality, of the ADHD Dog effective and user-friendly in promoting engagement and interaction? (Q1-C).
- How would you rate the integration of gamification elements in ADHD Dog in terms of enhancing user engagement and interaction? (Q2-C).
- In your professional opinion, how well does ADHD Dog leverage technological advancements to create an immersive and effective experience? (Q3-C).
- Considering the potential scalability and adaptability of the technological components in ADHD Dog, how confident are you in its applicability to a broader audience? (Q4-C).
- To what degree do you believe the technological components of ADHD Dog contribute to a positive user experience, considering factors such as accessibility, responsiveness, and overall usability? (Q5-C).

The examination of the results from the computer science expert perspective (G3) sheds light on critical aspects of ADHD Dog's technological features, as shown in Figure 8. Responding to the extent of effectiveness and user-friendliness of the virtual reality aspects (Q1-C), the computer science experts recognized the significance of these elements in promoting engagement and interaction. The evaluation of the gamification elements (Q2-C) showcased positive ratings, emphasizing their role in enhancing user engagement. In their professional opinion regarding the leveraging of technological advancements (Q3-C), the experts acknowledged ADHD Dog's success in creating an immersive and effective experience, attesting to its alignment with contemporary technological standards. Considerations of scalability and adaptability (Q4-C) yielded a confident outlook, indicating that the technological components are applicable to a broader audience. The assessment of the technological components' contribution to a positive user experience (Q5-C) encompassed factors such as accessibility, responsiveness, and overall usability, revealing an overall positive reception among the computer science experts. These findings collectively underscore the effectiveness of ADHD Dog in leveraging technological principles to create a robust, engaging, and user-friendly virtual reality intervention.

The comparison of ADHD Dog with existing systems in the literature reveals distinct advantages and novel contributions. While several VR applications and games, such as those presented in [20–22], have focused on enhancing cognitive functions in individuals with ADHD, ADHD Dog stands out for its comprehensive integration of behavioral and sociocultural theories with gamification. Unlike other applications that may emphasize specific aspects of ADHD management or selectively apply one or two behavioral and sociocultural theories, ADHD Dog blends operant conditioning (Skinner), the Sociocultural Theory (Vygotsky), and gamification into a cohesive framework.

The application of known behavioral and sociocultural theories in ICT and educational software design informed the psychologically sound approach adopted in ADHD Dog. By leveraging VR technology for its potential benefits in physical and cognitive training, ADHD Dog provides a safe and controlled environment where users can interact with 3D models, fostering improvements in cognitive functions. The game's design, rooted in operant conditioning and social constructivism, contributes to its therapeutic and enjoyable nature, enhancing player engagement and cognitive reinforcement.

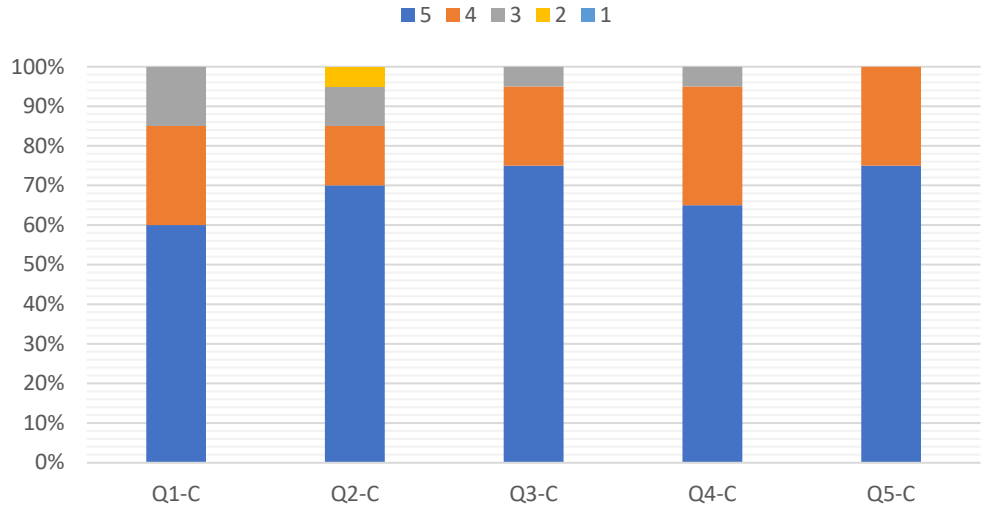


Figure 8. Questionnaire results from computer science experts.

Comparatively, other VR applications in the literature have explored specific aspects of ADHD, such as attention regulation, executive function, and memory. For example, the work in [28] and BCI-based systems (e.g., [29–31]) combine immersive VR environments with advanced technology, aligning with ADHD Dog's approach in using VR for cognitive training. However, ADHD Dog distinguishes itself by encompassing a broader spectrum of theories, offering a holistic and versatile resource that addresses the multifaceted needs of individuals with ADHD.

In contrast to individual studies and applications that focus on specific cognitive aspects or therapeutic approaches, ADHD Dog's incorporation of diverse theories contributes to a more comprehensive and nuanced intervention. The integration of operant conditioning, the Sociocultural Theory, and gamification positions ADHD Dog as a unique and promising tool for enhancing regulation in individuals with ADHD.

8. Conclusions

In conclusion, this paper presents a significant advancement in cognitive training for ADHD. This study showcases the potential of VR as an effective tool in addressing the challenges faced by individuals with ADHD. By integrating behaviorist methods with innovative VR elements, ADHD Dog offers an engaging and effective approach to cognitive training. The game not only exercises multiple cognitive functions, but also introduces an element of unpredictability, enhancing its therapeutic impact. The integration of technology in ADHD Dog aligns with current educational trends, making it a pioneering tool in the field. The research methodology, combining inputs from psychologists and computer scientists, ensures a holistic evaluation, addressing both psychological and technical aspects.

While ADHD Dog shows promise in assisting individuals with ADHD, it is important to acknowledge a few considerations. Its effectiveness may vary based on individual experiences, and relying on self-reporting could introduce subjective elements. Additionally, continuous updates and user feedback incorporation are key to addressing evolving needs and ensuring that the application remains a valuable support tool.

The results indicate positive impacts on cognitive, emotional, and behavioral aspects in individuals with ADHD, validating the game's effectiveness as a therapeutic and educational tool. Future developments and research could explore more personalized designs, multiplayer modes, and further interdisciplinary collaboration, enhancing its applicability and efficacy.

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Institutional Review Board Statement: Ethical review and approval are not required for this study, as it exclusively involves the analysis of properly anonymized datasets obtained from past research studies through voluntary participation. This research does not pose a risk of harm to the subjects. All data are handled with the utmost confidentiality and in compliance with ethical standards.

Informed Consent Statement: Informed consent was obtained from all subjects at the time of original data collection.

Data Availability Statement: The data supporting the findings of this study are available upon request from the corresponding author. The data are not publicly available as they contain information that could compromise the privacy of the research participants.

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