



Design and Validation of an Eye-Tracker-Based Software to Improve Attention in Attention Deficit Hyperactivity Disorder (ADHD): A Validation Study

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Original Article

Abstract

Introduction: Attention Deficit Hyperactivity Disorder (ADHD) is a common neurobiological disorder affecting school-age children. One of the main symptoms is short attention span, which is a key factor of poor academic performance, especially in tasks requiring long-term concentration. Children with ADHD often jump from task to task without finishing any of them. They feel trapped by any task that takes longer than the time they are able to stay focused. Improving this skill usually requires breaking tasks into smaller segments while working to increase the child's attention span. The goal of this research was to design and validation of a software package based on Eye-Tracker technology to improve attention in children with ADHD.

Materials and Methods: The population of this validation study consists of psychologists, who are expert in the field of learning and cognitive deficits in children and adolescents, as well as educational technologists; among them, ten people were selected on purpose. The tools used in this research included a video game developed in Unity, and Tobii Eye Tracker 4C device, and a researcher-made questionnaire for content validation. Software validity was calculated using the Kappa coefficient.

Results: After applying requested revisions, the Kappa coefficient was calculated as 93.4%.

Conclusion: The software seems to have appropriate content validity, and may be advised to be used to improve attention in children with ADHD.

Keywords: Attention deficit hyperactivity disorder; Eye tracker; Attention

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Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a childhood and adulthood disorder characterized by a pattern of severe, persistent, and debilitating pervasive attention deficit. ADHD is one of the most common reasons for referring to family physicians, psychologists, pediatric neurologists, and child and adolescent psychiatrists (1). Although ADHD was initially thought to decrease at the end of childhood,

several studies have shown that this disorder is often chronic, with one-third to one-half of those experiencing it, would retain its symptoms during adolescence and adulthood (1-3). Various studies have reported varying incidence rates of about 1% to nearly 20% of ADHD among school-age children worldwide (2,3). This disorder affects the children in many areas of normal growth and function.

Children with ADHD are more likely than their

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peers to experience social isolation, academic failure, and antisocial behaviors during their school years, and to face major problems in the after-school period (1). The disorder is one of the most common neurological and developmental disorders in childhood, and its global prevalence in children under the age of 18 has been reported to be 5.3% based on 102 systematic studies, most of whom found in North America and Europe (2).

ADHD is divided into three different types: "inattentive, hyperactive-impulsive, combination". Moreover, the three common symptoms of this disorder include inattention (being easily distressed, lack of concentration, and poor organizational skills), impulsivity (ignoring risks), and hyperactivity (restlessness and unremitting speaking) (4). It is important to know that ADHD is a neurological disorder, and subjects with this disorder have undeveloped frontal lobes in their brains that are responsible for programming, controlling impulses, attention, reasoning, and working memory (5).

According to the Diagnostic and Statistical Manual of Mental Disorders-4th Edition (DSM-IV), ADHD is characterized by pervasive and disruptive symptoms of inattention, hyperactivity, and impulsivity (4) and is one of the most important issues in schools, that sometimes leads to making mistakes and misunderstandings in diagnosing children with this disorder and other children (5). It is estimated that 3 to 5% of children definitely have some forms of attention deficit and hyperactivity disorders; however, this figure has a much higher percentage in some schools (6). Some students with ADHD are not identified. There are several reasons why a student may have an attention deficit or hyperactivity disorder but not actually have the ADHD disorder. Labeling this disorder is the first answer a teacher can give to abusive students (7). Lack of discipline can make behaviors that seem like attention deficit or hyperactivity disorder too serious. A student with low learning speed may not pay enough attention to the content due to the large volume of content (8) or a gifted student may be inattentive; because the material is very easy for him and the student may have already learned the concepts and does not want the teacher to explain it again (7). Anxiety or depression can also lead to attention deficit (8). It is very difficult to diagnose these factors to prove ADHD (6). During their academic and social life, children and adolescents with ADHD experience weaknesses in academic performance, repetition of materials, difficult relationships with family and peers, and low tolerance for frustration (8). The results of studies show that children with ADHD have

poorer performance in terms of verbal cognition, perceptual reasoning, working memory, and processing speed compared to normal children (9,10). Early attention deficits appear as programming problems. Failure to do homework often causes serious problems for children at school (11).

Decision-making is very difficult for children with ADHD in schools, most of who have attention deficit and hyperactivity characteristics, and even school counselors refuse to prescribe medication as the first line of treatment for these children (12). Medication has its side effects and often persists for a long time with its own problems (13). Acceptable treatment around the world is a combination of medication, behavioral management, and parental education (9,11). Although the overall performance of children with attention deficits is lower than that of the normal children, these children perform well in some situations (10). According to Berkeley, "the problem is not that they cannot do the task, but that they cannot maintain the level of performance as most children can." The fluctuations in symptoms are so dramatic that physicians believe that ADHD is described not only as an attention deficit but also as an attention incoordination (12). At present, short-term changes in attention deficit symptoms are not properly identified, and few studies have been conducted to detect the pattern of these changes (13). A detailed description of the time and cause of emergence of the deficit can lead to an insight into the disorder and help resolve the challenge of these short-term fluctuations for an accurate diagnosis (12).

Attention Restoration Theory (ART) states that being in nature can affect individuals' attention and concentration (14). Three principles of ART provide potential insights into the nature of ADHD. The first principle of ART is based on the work by William James. Accordingly, attention is explained by two main mechanisms; In the first mechanism, the person tries to focus on the subject directly and purposefully, and in the second mechanism, attention to the subject is performed without any effort by the person and indirectly and unconsciously. This concept explains why people with ADHD focus so well on their favorite topics; while they are reluctant to pay attention to other issues. The second principle is fatigue and recovery (13), which illustrates why the performance of individuals with ADHD generally worsens throughout the day, and this performance varies as a function of the quality and quantity of sleep (13). In the third principle, ART states that different environments have different effects on attention; that is, environments that attract more

attention are tedious, and prolonged exposure to such environments leads to poor performance in tasks that require intentional attention (13). Two recent studies on children with ADHD suggest that attention deficit symptoms may decrease after activity in more natural or greener environments. In surveys on the impact of after-school activities on children with ADHD symptoms, consistent parental ratings show that symptoms of attention deficit after activity in the natural environment improve more compared to the activity in outdoor settings (14). Treating ADHD is not just about taking medication. There are many other effective treatments that can help children with ADHD to improve self-attention, control stimulating behaviors, and inhibit hyperactivity. Nutritious meals, play and exercise, learning new coping skills, and improving social skills are all part of a balanced treatment plan that can improve children's performance at school, strengthen their relationships with others, and reduce stress and frustration among them. Many of the systems applied to track treatment outcomes are based on parental reports through interviews and questionnaires or clinical evaluations by the specialist.

There is a new treatment for children with ADHD that uses the eye tracking technology. Eye tracking is a new technology for evaluating eye movements (15). In general, an infrared light projector is employed using some mathematical algorithms to determine the user's eyes position and determine the points he looks at. Eye tracking technology enables non-invasive quantitative and objective evaluation of eye movements that can be used in neuroscience research to assess cognitive function or disorders such as brain damage, autism spectrum disorder (ASD), and neurological diseases (16). Only a small number of studies have been performed using the eye tracking technology (17). Eye tracking has been one of the main research methods in recent years to gain insight into advances in the field of cognitive science (18).

Researchers have concluded that the selection of visual information (19) or face detection in infants (20) and their visual environment (21) can be performed by tracking the eye movements (22). Investigations indicate that tracking attention and social sensitivity using eye movements may predict the response to treatment in ASD (23). Other studies have also found that eye movements can predict memory impairment in patients with dementia (24). Therefore, taking into account the above issues and studies, the present study is conducted aiming to design a video game based on eye-tracking technology to improve attention deficit in children with ADHD.

Materials and Methods

The objective of this study is to determine the content validity of the eye-tracking based software package developed to improve the attention problems of children with ADHD. The study was of design and validation type that was conducted in 2019 in the Serious Entertainment Laboratory, Entertainment Industry Innovation Center, University of Isfahan, Isfahan, Iran. The statistical population of the study included all specialists in the fields of educational technology and psychological disorders of children and adolescents in Isfahan. From the statistical population, 10 people were selected by the purposive sampling method. It should be noted that the sample size was determined based on the Krejcie and Morgan table (25).

The study tools included a Tobii Eye Tracker 4C device, a video game developed using the Unity game engine, and a researcher-made questionnaire designed to perform a content validation on the software package.

Game scenario: The designed game consisted of 9 treatment sessions. At the beginning of each session, the main menu of the game was displayed with the settings option, used for initial calibration. Before starting the game, the therapist could set a time for the eye to rest to prevent its fatigue and loss of function. The gameplay was such that a character was running on a road, controlled with the user's eye movements. There were obstacles and bonuses in the path of the character that the subject needed to cross in order to gain the necessary scores, and if he could not successfully overcome these obstacles, he would fail and had to do that step again.

The treatment sessions were based on a specific structure. In this way, the difficulty of the game varied based on the indicators of the character's speed, obstacles and the enemy, distraction factors, and the type of scores in each stage. The first session was dedicated only to familiarizing the subject with the game environment and how to act in the game. From the second to the fourth sessions, the character's speed gradually increased and a limited number of obstacles were placed in his path. From the fifth to the ninth sessions, distraction factors were observed in the game that the subject had to pay full attention to the game in order to be successful in each stage. A scene of the game is demonstrated in figure 1.

Eye movement tracking using the Tobii Eye Tracker 4C: Eye Tracker is a device that enables the computer to detect the position of the user's eyes and includes a camera, a projector, and several processing algorithms. The projector creates a pattern of infrared waves on the eye, and the camera embedded in the device captures images of the user's eyes and their

surface pattern. Then, the image processing algorithms draw maps of the user’s eye position and its reflection patterns, and then, based on the data, the exact position of the eyes and the point of stare are determined using computational algorithms.

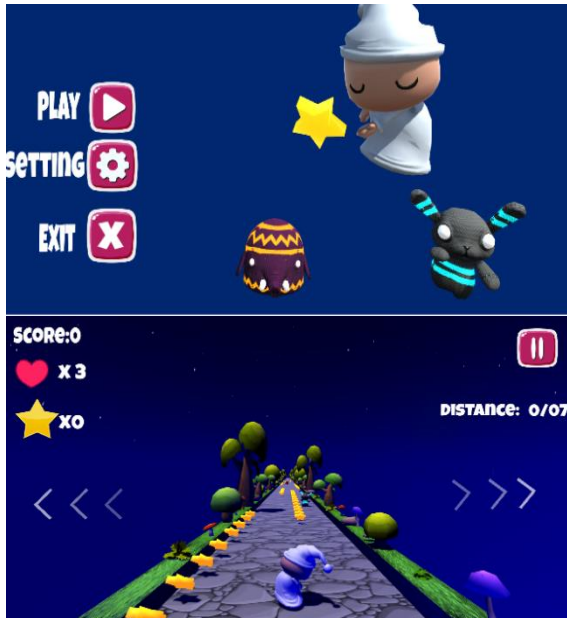


Figure 1. View of the designed game

Researcher-made questionnaire: To validate the software, a special questionnaire was designed with 6 different items, with a Likert scoring scale and options from “Strongly agree to strongly disagree”. The questionnaire items were about the difficulty of the game, the content of the game, the number and order of sessions, the distraction factors used in the game, the duration of each stage, and the efficiency of the game to improve attention. The software and the video of the software development process and its pilot test, along with the eye tracking device, were presented to the relevant experts individually. They first watched the video of the software development process and the sample test of the software, and then completed the questionnaire. Some professors commented on the improvement of the software and after their desired changes were made, they reran the modified software and completed the questionnaire again.

Method of implementation: The game was designed

in nine stages based on common methods in children and adolescent clinics. In the present study, two teams of psychologists and technicians collaborated. Based on the psychological approaches in the treatment of children with ADHD, the stages were developed by the psychology team and provided to the technical team for design. After designing the game and solving the specialized problems, for the pilot test, the software was tested on six primary school girls and their feedback was recorded. After reviewing the results of the pilot test and solving the technical and specialized problems, the final software package was provided to the experts for validation. In this way, the stages were run for each specialist and they were asked to answer the researcher-made questionnaire. An example of the pilot test is shown in figure 2.



Figure 2. Software pilot execution

The revisory comments of the experts were applied to the software, and then provided to them for the final review. Finally, the assessment agreement coefficient was evaluated using the Kappa coefficient in SPSS software (version 20, IBM Corporation, Armonk, NY, USA).

Results

Table 1 represents the demographic characteristics of the study participants.

The responses of the experts to the questionnaire and the scoring of each item are presented in Table 2.

The Kappa coefficient in the present study was obtained as 93.4%. Therefore, the prepared treatment package had the necessary content validity.

Table 1. Demographic characteristics of specialists participating in the study

Field of study	n	Job experience (year)	Age (year)	Academic degree
Educational sciences	3	10 ± 2	40 ± 5	Phd
Primary schools counseling	4	10 ± 3	50 ± 5	Phd
Psychology of Exceptional Children	3	20 ± 5	50 ± 5	Phd

Data were reported based on mean ± standard deviation (SD).

Table 2. Responses of the experts to the questionnaire

Items	Strongly agree	Agree	No comment	Disagree	Strongly disagree
The game content is suitable for increasing children's attention and concentration.	8 (80)	1 (10)	1 (10)		
Given the game therapy protocol provided, the arrangement of sessions is appropriate to increase the attention and concentration of children with ADHD.	9 (90)	1 (10)			
Given the game therapy protocol provided, the number of sessions is appropriate to increase attention and focus of children with ADHD.	9 (90)	1 (10)			
The disturbing factors used in the game change the level of children's attention and affect their performance.	10 (100)				
The duration of each session is appropriate.	10 (100)				
The difficulty of the game is commensurate with the characteristics of the children with ADHD	8 (80)	1 (10)	1 (10)		

Data were reported by n (%).

ADHD: Attention deficit hyperactivity disorder

Discussion

The aim of this study was to design a video game controlled by user's eye movements to improve attention problems in children with ADHD. The findings revealed that from the perspective of the experts, the software package prepared could be used to improve attention in children with ADHD. According to studies, there is a relationship between eye movements and cognitive processes such as reading and visual perception (25). Additionally, the results suggested that the use of the game environment in the treatment of children with attention problems is useful. By eye-tracking, one can understand how the user focuses on the target and ignores distraction factors. Compared to conventional methods, the eye-tracking technology is more accurate and reliable. The spatial coordinates of the user's eyes are recorded in the game every second and stored on the computer. These data are then used to assess the subject's progress at each stage and throughout the treatment. Moreover, using this technology, special steps can be designed based on the individual characteristics of the subject. The previously designed games were mostly puzzles that were performed using an eye-tracking device, however, a game in this style and taking into account the new treatment protocol was designed for the first time.

Given the advancement of technology and its role in human life, it is necessary to reconsider the current treatment and rehabilitation methods. The application of the eye-tracking technology to diagnose and treat psychological disorders has been investigated in studies. It is recommended that the effectiveness of the software package designed in the present study be tested and its effectiveness be compared with other attention deficit therapy methods, and if successful,

be provided to counseling centers, schools, education departments, families, and organizations which deal with children with ADHD.

Limitations

Since no study has been conducted in this field in Iran so far, and also, the number of studies conducted in other countries in this regard is limited, it was not possible to compare the results. Besides, due to the unfamiliarity of the children with English, the software was prepared in Persian and non-Persian speaking children cannot use it.

Recommendations

Studies on the effectiveness of this treatment on a large community of children with ADHD can help upgrade the software and determine its true clinical value. It is also recommended that this software be developed and reviewed for other languages and dialects. The use of eye-tracking to diagnose and treat other related disorders could be considered in future studies.

Conclusion

According to the experts, the designed software seems to be of sufficient validity and can be employed to improve attention in children with ADHD.

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Authors' Contribution

Javad Rasti: Study design and ideation, attracting financial resources for the study, supportive, executive, and scientific study services, providing study equipment and samples, analysis and interpretation of results, manuscript preparation, specialized evaluation of the manuscript in terms of scientific concepts, approval of the final manuscript to be submitted to the journal office, the responsibility of maintaining the integrity of the study process from the beginning to the publication, and responding to the referees' comments; Amirhasan Torabi: Study design and ideation, supportive, executive, and scientific study services, data collection, analysis and interpretation of results, specialized statistics services, manuscript preparation, specialized evaluation of the manuscript in terms of scientific concepts, approval of the final manuscript to be submitted to the journal office, the responsibility of maintaining the integrity of the study process from the beginning to the publication, and responding to the referees' comments; Nasibeh Sarrami-Foroushani: Study design and ideation, attracting financial resources for the study, supportive, executive, and scientific study services, providing study equipment and samples, data collection, analysis and interpretation of results, specialized statistics services, manuscript preparation, specialized evaluation of the manuscript in terms of scientific concepts, approval of the final manuscript

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Conflict of Interest

The authors declare no conflict of interest.

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