

*Short review**Open access*

# Novel Attention Training in Children with Attention Deficit/Hyperactivity Disorder

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**ABSTRACT**

Attention Deficit Hyperactivity Disorder (ADHD) is a common neurodevelopmental disorder marked by an ongoing inattention and/or hyperactivity-impulsivity pattern. Traditional treatments targeting attentional aspects are associated with drug side effects, costly expenses, and poor compliance. This review aims to present novel approaches to attention training, such as using digital interventions to improve cognitive function mediated by video games, eye trackers, and gesture recognition sensors. The merit and shortages of these novel approaches and some new ideas of attention training in ADHD are discussed.

**KEYWORDS**

ADHD, attention training; Video games; Eye-tracking

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ADHD is a neurodevelopmental disorder that is characterized by inattention and/or hyperactivity-impulsivity, with an estimated prevalence at 5% worldwide (1). The front-line interventions for ADHD include pharmacological medications (e.g., methylphenidate, amphetamines, atomoxetine, guanfacine, clonidine) and non-pharmacological treatments such as psychological therapies (e.g., neurofeedback, cognitive therapy, sensory integration, behavioral therapy) and dietary supplements. (2-4). While these interventions had short-term or inconsistent efficacy (5), they tend to have drug side effects, are costly, and are associated with poor compliance, which may affect the treatment efficacy (2, 6-8). Children with ADHD have been indicated with abnormalities in brain structures and functions associated with the neurocognitive function (9), which have been considered key therapeutic targets. With rapid advances in digital communication and computational technology, digital interventions for ADHD have

emerged and developed rapidly. Digital interventions can target potential neural mechanisms or functions for therapeutic purposes to improve cognitive dysfunction.

In this review, we provide a brief overview of some novel attention training to improve cognitive functions through the use of digital interventions mediated by video games (10-15), eye trackers (15), or gesture recognition sensors (14). In addition, we discussed these new methods of attention training in ADHD, which may make ADHD treatment more accessible and less expensive. The playful approach increases children's compliance and ensures the effectiveness of the training.

**VIDEO GAMES**

Studies have shown that patients with ADHD can focus on their favorite activities for long periods, a phenomenon

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that is sometimes referred to as "hyperfocus" (11). Because of appealing to children, video games seem promising as a mediator of therapeutic interventions for ADHD.

Current theory addressing cognitive training is based on neuroplasticity and the possibility of reorganizing neurological functions (16). In children with ADHD, impairments related to attention and cognitive control are associated with lower activation of ventral attention and frontoparietal networks. At the same time, hyperactivation of ADHD was indicated in multiple neural networks, including the default, ventral attention, and somatomotor (17). By linking these brain systems with specific digital interventions and optimizing their design, video games can activate regional brain patterns, increase the volume of grey matter, and increase blood flow to the cerebral cortex by changing the interaction of the brain network. These altered regional brain regions induced by video games can alter brain structure and improve cognitive functioning (18) to achieve the cognitive repair.

The emerging field of digital medicine was a breakthrough. Two computer programs have been approved or are under clinical evaluation. "EndeavorRx" is a game-based digital therapy delivered through a mobile device for children 8-12. It has been approved by the US Food and Drug Administration (FDA) to treat inattention in children with ADHD (10, 13). This is the first digital therapy designed to improve symptoms associated with ADHD and the first digital medical treatment that received FDA approval for a game-based cure for any condition. It uses sensory stimuli and simultaneous motor challenges to target brain areas that play a key role in attention function and requires healthcare professionals to prescribe. However, it is not intended to be a stand-alone therapeutic. A cognitive computer program called "ACTIVAGE" (12) has been developed to improve different cognitive functions and tested for training children with ADHD. It requires children to focus during the game to score as many points as possible.

A randomized controlled trial of novel digital intervention has shown that the video game "EndeavorRx" improve objectively measured inattention in pediatric patients with ADHD (10). EndeavorRx is a video game and the first, and so far, the only FDA-approved digital medication. Based on the primary outcome - mean change in the Test of Variables of Attention (TOVA) Attention Performance Index (API) score from the baseline; the trial study found treatment group significantly improved compared to the active control group. The mean (SD) change from baseline on the TOVA-API scores was 0.93 (3.15) in the video game group and 0.03 (3.16) in the control group. No serious adverse events or discontinuations were reported, and some mild adverse reactions, including frustration (3%) and headache (2%).

To ensure that children are motivated to participate in treatment and to increase adherence, these games share several standard features: advanced mobile digital intervention platforms, modern video game interfaces, engaging reward loops, and real-time adaptive mechan-

isms that dynamically personalize difficulty based on user's ability. Not only does a game-based approach to attention training provides a greater degree of focus and optimize treatment outcomes for children with ADHD, but also the treatment is convenient. It does not require the real-time involvement of a physician. However, game addiction might be a problem that should consider.

## EYE-TRACKING ATTENTION TRAINING

Eye-tracking attention training can isolate specific aspects of visual attention uniquely. Research has shown a link between oculomotor dysfunctions and attention (19); it is more difficult to suppress saccadic eye movements when fixation is required for children with ADHD (20, 21). While training eye-hopping movements by using an eye tracker during games can increase inhibitory control in the prefrontal cortex, suppressing saccadic eye movements and improving attention (15).

RECOGNeyes is a computer program used for attention training (15) and played using the eyes as the game controller. Unlike the traditional mouse, the eye tracker captures the eye's movement to manipulate the game. Moreover, in the game training, eye-hopping exercises will be trained using an eye tracker to improve visual attention.

The other game-based dual system application adds gesture recognition sensors to video games and eye trackers, which has been developed using the "NET framework." In the game training (14), an ADHD child uses the eye tracker to control and target the calculation object with their eyes and then uses gestures to show the calculation results. At the same time, the application uses the gesture recognition sensor to recognize the child's calculation results and presents the corresponding result on the screen. This counting game promotes hand-eye coordination and gesture-based learning, thus helping to improve children's attention and learning skills.

A randomized controlled trial found that the eye-tracking attention training game "RECOGNeyes" improved the visual attention system in patients with ADHD (15). After three weeks of eye-tracking attention training, participants showed decreases in impulsivity, reaction time, and the number of fixations. Still, increases in the duration of fixations compared to the baseline. However, there was no change in the mouse control group.

However, this computation-based game model is relatively simple and should be considered in practical applications for compliance with long-term treatment for children with ADHD. Besides, one should consider the accuracy of the operating range of sensors using eye trackers and gesture recognition.

## VISUAL TRACKING INTERVENTIONS

Visual tracking interventions are based on similar principles to the aforementioned eye-tracking inter-

ventions. Research has shown that the oculomotor system mediates the motor and cognitive functions (22) and that there is a strong correlation between eye movements and attention (23, 24). Some specific visual training based on eye-tracking and visual fixation has been reported to reduce the rate of inattention (25). In contrast, in this visual tracking intervention training, an engaging game format was used to perform eye movement training to improve attention.

During the training, children follow the trainers instructions to train their eye movements according to the tasks presented, such as moving their eyes with the laser pointer and looking for objects in the classroom while their heads are fixed. Fundamental components of the exercise focused on the duration of fixation (gaze), the range of eye movement in focal and ambient visual processing, a Go-No go task involving orientation and direction of eye pursuit, and eye-hand coordination.

A randomized controlled trial was conducted to study the effect of the eye-tracking intervention on children with ADHD (26). They were evaluated using Conner's Parent Rating Scale, the Continuous Performance Task-2, and the Test of Visual-Motor Skills-Revised before and after the intervention. After five weeks of visual tracking intervention, cognitive problems decreased, coping behavior reduced, and hyperactivity reduced significantly than the control group. Besides, In the Continuous Performance Test scores, detectability score, omission errors, commission errors, reaction time, variability, and preservation showed significant differences between the control and experimental groups. Still, considering the interference of the external environment during the treatment process, virtual reality (VR) technology (27-30) to simulate the natural environment for visual tracking interventions is a possible direction to consider.

The attention training method mentioned in this review makes full use of a product that is becoming popular in life - video games - and allows ADHD patients to be treated in the process of playing games through the optimal design of digital interventions. It promotes hand-eye coordination through the training of eye-hopping movements in children with ADHD. Besides, eye-tracking and gesture-recognition sensors allow for more effective and targeted attention training. Some empirical studies of these methods have yielded promising results (10, 14, 15, 26). However, there is a need to continue to refine them, considering issues such as compliance in actual treatment, addiction in children during game training, and the accuracy of the operating range of sensors using eye trackers and gesture recognition.

#### CONFLICT OF INTERESTS

Authors have no conflicts of interest to declare.

#### ARTICLE INFORMATION

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