

## Working Memory (WM) training to improve ADHD in children, theory and the role of digital technologies

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### Abstract

Working Memory (WM) is a cognitive system that is strongly related to a person's ability to reason new information and funnel their attention to information that is relevant to the goal at hand. Because of its key role in general knowledge, it has become the focus of a rapidly growing literature. Recent studies have shown that the effects of Working Memory (WM) training extend to both attentional control and reduction of ADHD symptoms. The findings indicate that Working Memory might be viewed as a key component in how children with ADHD acquire their academic skills, and that interventions to enhance Working Memory may aid them in becoming more adept at school environments.

**Keywords:** Working Memory (WM); Working Memory Training; ADHD

### 1. Introduction

Working Memory (WM) issues are widespread in a variety of conditions, including developmental and learning difficulties such as dyslexia, specific language impairment, trouble reading or math, and ADHD (Attention Deficit Hyperactivity Disorder) (10). Students face severe pressure and high demands in the present educational environment, which demands good levels of memory to complete assignments and activities. As a result, it is not unexpected that students with poor Working Memory (WM) perform poorly in school (10). Learning is a process of gradual mastery and effective completion of actions and activities that lead to in the collection of knowledge. Therefore, children with Working Memory issues frequently fail in school because the workloads required exceed their capacity. When these children's Working Memory (WM) system fails, they withdraw, forget the activity they are involved in, and as a result, they tend to led to deviant actions. Ultimately, the outcome is a combination of missed learning opportunities and poor rates of progress (10). Children who have been diagnosed with ADHD fall into this category to a considerable extent. Attention Deficit Hyperactivity Disorder (ADHD) is a major psychiatric illness that can be diagnosed as early as childhood and is becoming increasingly widespread (7). Its main characteristic is the lack of attention due to severe difficulty in concentration, combined with impulsivity and hyperactivity (23). For these reasons, it is considered particularly essential to examine and deal with this specific set of children, namely kids diagnosed with ADHD, as well as the methods that can improve their Working Memory. When we understand how Working Memory training improves ADHD symptoms and the best ways to practice it, we will have optimized the best techniques for utilizing this strategy in conjunction with other strategies.

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## 2. ADHD

### 2.1. Historical Background of ADHD

Dr. Heinrich Hoffman initially characterized the features of what is now recognized as Attention Deficit Hyperactivity Disorder (ADHD) in 1845. Then, in 1902, Sir George F. Still talked about "weak-willed individuals with little capacity for moral control of their behavior" basically youngsters with impulsive behavior and other management issues. Later, in 1947 the "brain damage theory" (12) appeared, which was termed as a "minimal brain dysfunction" (12). Much later, there was the term "childhood hyperactivity disorder" in the DSM-2 (Diagnostic and Statistical Manual of Mental Disorders), while the "attention deficit disorder" emerged in the DSM-3 in 1980. Indeed, various studies on this disease were conducted between the late 1970s and the late 1980s. The majority of them stated that it is a condition with a neurodevelopmental base, possibly genetic origins, and environmental factors that contribute to its occurrence (7). Unfortunately, how these elements interact is yet unknown (7).

### 2.2. Definition

In simple terms, Attention Deficit Hyperactivity condition (ADHD) is a significant mental condition that is evident as early as infancy (26). Its fundamental characteristic is a loss of attention as a result of extreme difficulties concentrating, along with impulsivity and hyperactivity (23).

The American Psychiatric Association's DSM-3 (American Psychiatric Association, 1980) classifies the disease as "Attention-Deficit Disorder with or without Hyperactivity." However, the more recent and revised DSM-5 (American Psychiatric Association, 2000) refers to it as "Attention-Deficit Hyperactivity Disorder" (ADHD), highlighting both the attention component as well as the issue of hyperactivity and impulsivity (13). Inattention, on the other hand, is regarded an essential requirement for ADHD symptoms by the ICD-10 (International Classification of Diseases) diagnosis tool (3).

### 2.3. Diagnosis

The diagnosis of ADHD constitutes a process concerning exclusively trained and specialized scientists. Specifically, this task belongs to clinical or school psychologists and psychiatrists, who lead to the diagnosis through clinical interview and observation (7).

Based on the DSM-5 criteria, ADHD can be distinguished into three forms:

- ADHD with a dominant inattentive type, and is seen in both boys and girls (22). Children with this diagnosis have difficulty staying focused, even though, at their age, they should be able to (44).
- ADHD with the main type of hyperactive-impulsive and is more common in boys (22). These children are exceptionally energetic and talkative compared to children of the same age and act spontaneously and thoughtlessly (44).
- Finally, the combined-mixed type, in which children are both hyperactive and inattentive (44). Children in this group exhibit all of the aforementioned behaviors (44).

Additionally, in accordance with the DSM-5, symptoms in children must appear before the age of seven in two or more contexts, and they must influence their functioning in at least two aspects of their daily life, such as social or educational functioning (18). Furthermore, they must have had six or more signs of inattention, hyperactivity-impulsivity, or a combination of the two, and the behaviors must have been regarded inappropriate for the child's age and developmental level for at least six months previous to the evaluation (18). Finally, the combined-mixed type, in which children are both hyperactive and inattentive (44). In this group, children combine all the above behaviors (44).

Furthermore, as stated by the DSM-5, symptoms in children must appear before the age of seven in two or more settings, and these must affect their functioning in at least two areas of their daily life, such as their social or school functioning (18). Also, six or more symptoms of inattention or hyperactivity-impulsivity or combined must appear. The behaviors are considered inappropriate for the child's age and developmental level for more than six months before the examination. Finally, no other disorder should explain any of the symptoms (13).

## **2.4. Characteristics / Symptoms**

The three key features of the disorder are inattention, hyperactivity, and impulsivity, as cited by (22), which exhibit to a degree disproportionate to the children's age (13). Clinical signs of the disorder are likely to occur as early as infancy, although are generally discovered later.

In infants, the symptoms usually include hypersensitivity to stimuli, such as noise, darkness, and temperature, accompanied by intense crying and increased motor activity. Sometimes the symptoms are defined by excessive comfort in stimuli paired with a long sleep time (21).

When kids reach school age, they may demonstrate a significant interest in hobbies but rapidly quit them. Their behavior in the classroom includes inappropriate posture, they talk without authorization and get out of their seats. Regarding their attitude towards the family and home, these children are characterized as lively and impatient. They are irritable, cause mishaps, and have extreme mood swings (21).

At the same time, ADHD manifests itself in the form of hyperactivity, "generalized dysregulation of muscle coordination," impaired perceptual and motor skills, difficulty recalling knowledge, rapid switching of emotions, lack of attention, obsessions, and failure to complete tasks (21).

In addition, these children avoid tasks, exhibit impulsive and rebellious behavior, and fail to comply with directions. (3). Finally, there is a possibility that they may display aggressive or challenging behavior (21) and struggle to form relationships with their peers (18). These difficulties continue during adolescence.

According to studies, 50-70% of children who have been diagnosed will face social adjustment problems or even psychiatric problems (22). Even as adults, children that have been diagnosed with ADHD continue to struggle, with only around 22% of them attending college and just 5% finishing their studies and later on, they get into conflicts with their coworkers at work. (2).

The good news is that just 4% of people with ADHD show all symptoms, which is encouraging (22).

## **2.5. Methods of Addressing, Managing, and Improving ADHD Symptoms**

Unfortunately, no treatment for ADHD has been discovered as of yet. However, some types of interventions can help children improve their symptoms. These interventions can be carried out successfully either in the context of the school or at home. There are three major categories: 1. Pharmaceutical, 2. Behavioral, and 3. Educational (with cognitive approaches, mainly through memory training) (12). There are even studies that deal with the positive contribution of nutrition, biofeedback, and self-management behavior in dealing with ADHD symptoms.

### **2.6. Pharmaceutical Intervention**

One of the most widespread methods for dealing with the symptoms of ADHD is the pharmaceutical approach. At the same time, it is also the most controversial method. Medicines are administered exclusively by the attending physician. Medicines include active ingredients such as methylphenidate and dextroamphetamine, which are regarded safe for the treatment of ADHD and are used more often (25), as well as amphetamine and atomoxetine, which increase dopamine and norepinephrine release (19).

### **2.7. Behavioral approach**

Behavioral approach refers to interventions aimed at modifying behavior. The intended result is the reduction of undesirable behaviors and at the same time the increase of desirable and functional ones (12). Given that ADHD is a chronic disorder, the interventions of the behavioral approach must be long-term to achieve the desired effect.

### **2.8. Dietary Supplements**

Other studies concern nutritional supplements. It is supported that children diagnosed with ADHD show lower levels of fatty acids (EFA), Omega 3 and Omega 6 (20) and red blood cells (24) in their blood. Therefore, the administration of specific supplements will benefit these children. Compared to medication, supplementation appears to show similar levels of improvement in attention and self-control (11).

## **2.9. Biofeedback**

Another way of management can be considered the intervention through biofeedback. According to the AAPB (Association for Applied Psychophysiology and Biofeedback) Biofeedback is defined as a procedure that tries to supply the individual with the information needed to manage the body's autonomous functioning. It enhances and suppresses the frequencies associated with relaxed attention and hyper-arousal through the scalp (14). According to research (16), this intervention led to an increase of 9 points in the IQ of children with ADHD and significantly reduced inattention, but not aggression and hyperactivity. Additionally, (15) claim that biofeedback improves attentional performance, whereas (17) claim higher gains in attention and less improvement in hyperactivity.

## **2.10. Behavioral Self-Management**

Another way to manage ADHD symptoms can be considered behavioral self-management. It is conducted in the context of the school environment with the help of the teacher, who records the desired objectives, divides the teaching time into three parts and grades each of them on a five-point scale with 0-not good at all and 5-excellent. The child also rates himself with the aim of comparing results and improving the student's self-awareness. The teacher gives feedback that encourages the student, and the process is repeated by gradually reducing the frequency of comparisons and reinforcements (9).

## **2.11. Working Memory (WM) Training**

The term "Working Memory" (WM) refers to an individual's capacity to store and simultaneously process information for a short period of time. On top of that, is defined as a system that temporarily stores and manages the information needed to perform complex cognitive processes, but also refers to the collection, initiation and termination of functional information processing. Based on the above, we can understand the significance it plays in daily life. According to studies, the ability to retain and process information at the same time with the goal of quick application is also critical in the school context, since issues with Working Memory might have an impact on a child's academic performance (1).

Children diagnosed with ADHD perform poorly on audiovisual short-term memory activities (4) as well as verbal and audiovisual Working Memory tasks. It is possible that the inattention and disruptive behavior that characterize ADHD are caused by Working Memory issues, as task completion involves the preservation of task objectives and constant mental activity. As a result, inadequate Working Memory (WM) function may be responsible for insufficient attention and, as a result, failed completion of tasks and activities. Therefore, exercising and strengthening Working Memory via cognitive training or computer programs may result in a decrease in ADHD symptoms (5, 6, 8).

## **2.12. The Role of ICTs**

There are many methods and ways to intervene and support the children with ADHD, as we aforementioned, but the most efficient that are used in the recent years are those that are based on digital technologies. We emphasize the significance of all digital technologies in the field of education and in ADHD training, which is highly effective and productive and facilitates and improves assessment, intervention, and educational procedures via mobile devices that bring educational activities everywhere [27-30], various ICTs applications that are the main supporters of education [31-50], and AI, STEM, and ROBOTICS that raise educational procedures to new performance levers [51-59]. Additionally, the development and integration of ICTs with theories and models of metacognition, mindfulness, meditation, and the cultivation of emotional intelligence [60-86], accelerates and improves more than educational practices and results, especially in children with ADHD, treating domain and its practices like assessment and intervention.

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## **3. Conclusions**

Concluding we have to highlight that all the intervention methods for improving ADHD, including Behavioral approach, Dietary Supplements, Biofeedback, Behavioral Self-Management, Working Memory (WM) Training, and digital technologies based interventions, have results, but the combination of more than one method is the crucial factor for more positive results, especially in the cases when we combine and exploit the power of ICTs.

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## Compliance with ethical standards

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### *Disclosure of conflict of interest*

The Authors proclaim no conflict of interest.

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