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The Use of Executive Function Intervention as a Treatment of ADHD

Nithya Mallavarapu

Westlake Academy

ABSTRACT

Catecholamine deregulation in the brain can cause ADHD (attention deficit hyperactivity disorder). Deregulation could lead to problems with executive functioning (impact on the prefrontal cortex). Through the analysis of studies from NIH regarding Executive function intervention and the Department of psychological studies, it was concluded that executive function intervention was effective for children who practiced rather than those who did not. It significantly helped those with poor executive functioning skills (those with ADHD). It was helpful because certain activities can optimize catecholamine action by engaging in meditation (an example of executive function international). However, the activities should be done for a long time to see long-lasting results.

INTRODUCTION

Chronic diseases are persistent health conditions throughout an individual's life. ADHD (Attention Deficit Hyperactivity Disorder) is a chronic disease that impacts millions in the US. It is a neurological development disorder within the brain's prefrontal cortex that starts in children at a very young age, and symptoms become prevalent around 12 years old. Symptoms include hyperactivity and inattentiveness. Different tests, such as the IPPDAI "Identificazione Precoce del Disturbo da Deficit di Attenzione/iperattività per Insegnanti," which can identify the symptoms of ADHD through tests on inattentiveness, working memory, and other executive functions. These symptoms are primarily deficits in executive functions. Executive functioning skills are located in the brain's prefrontal cortex and are responsible for the different cognitive processes that help attain goals. These skills include self-control, monitoring, organization, attention, emotional control, flexibility, and time management. Practicing executive functioning skills is something that is done daily. A person with ADHD struggles with those tasks, which causes them not to be successful when achieving their goals. Due to the deficits of the executive functions, they will not be able to focus on tasks appropriately, and their organization skills will also be compromised, so it would be harder to be successful when achieving their goals. However, the intervention of these functions and the development of better practices that help overcome cognitive challenges can improve the underlying mechanisms of ADHD, which cause a deficit in executive functioning skills. Through executive function interventions, the symptoms of ADHD due to its underlying mechanisms can be improved. This issue must be researched because there have been some studies regarding executive function intervention. Still, not there are not many that connect it back to the underlying mechanisms of ADHD.

MECHANISMS OF ADHD

ADHD is associated with the prefrontal cortex and catecholamine activity. The prefrontal cortex is a part of the frontal lobe, and it is responsible for cognitive and emotional processes, which allows for the regulation of impulses, language, attention, decision-making, and error correction.

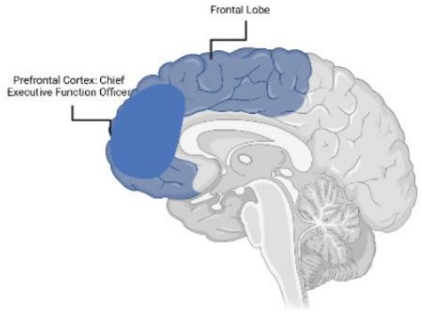

Figure 1: The image shows the location of the Prefrontal Cortex within the frontal lobe. Dark Blue: the prefrontal cortex (chief executive function officer) Blue: Frontal Lobe B&w: other parts of the brain which do not contain the executive functions.

The executive functions are working memory (imperative for decision-making), self-control, covert responses (attention), emotional control, organization, and time management. However, outside stressors(like environmental factors) cause lesions to the PFC, which causes problems in executive functioning. Additionally, the deregulation of catecholamine release can also cause ADHD.

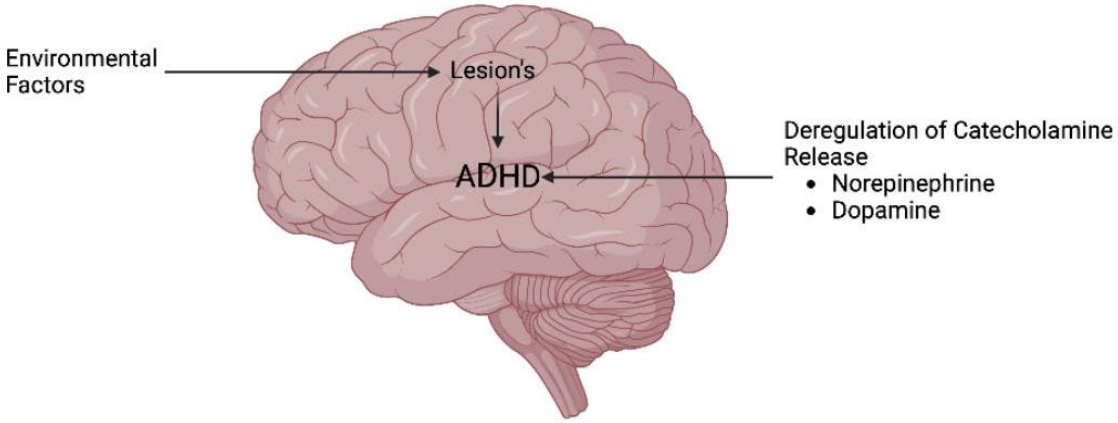

Figure 2: The image illustrates two different factors which cause ADHD, one being lesions and the other being the deregulation of catecholamine.

The catecholamine norepinephrine is responsible for sending messages (cell signaling) regarding an individual's attention and control (executive functions). At the optimum level, it improves the prefrontal cortex function. Alpha-adrenergic receptors (alpah2a receptors) regulate NE during cell signaling. This means that NE is produced by the endocrine system and carried around the bloodstream to deliver the message from one to the other cell through alpha2a receptors. The message can only be received when the NE and alpha2a receptors bind, causing proteins to be activated in the cell and displaying the message.

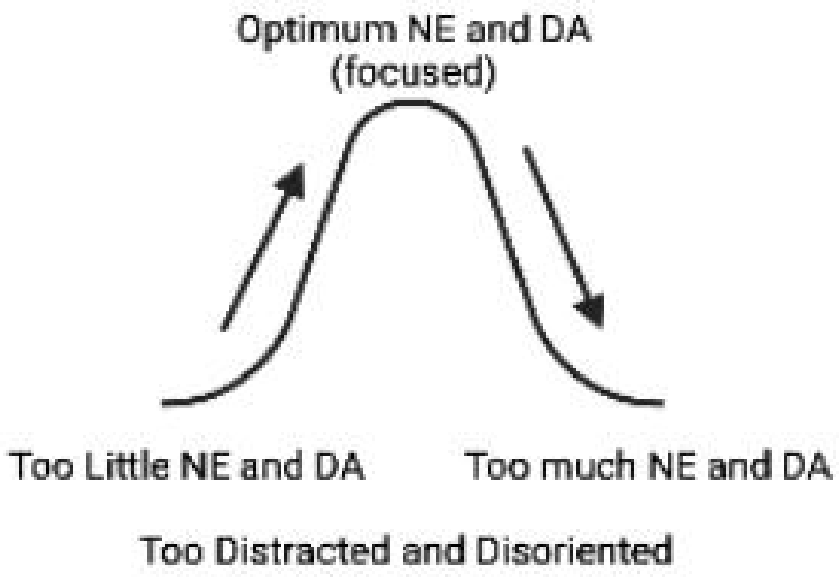

Figure 3: The image displays catecholamine deregulation when the hormones do not function at the optimal level at the receptors.

The catecholamine norepinephrine (NE) is responsible for sending messages (cell signaling) regarding an individual's attention and control (executive functions). At the optimum level, it improves the prefrontal cortex function. Alpha-adrenergic receptors (alpah2a receptors) regulate NE during cell signaling. This means that NE is produced by the endocrine system and carried around the bloodstream to deliver the message from one to the other cell through alpha2a receptors. The message can only be received when the NE and alpha2a receptors bind, causing proteins to be activated in the cell and displaying the message.

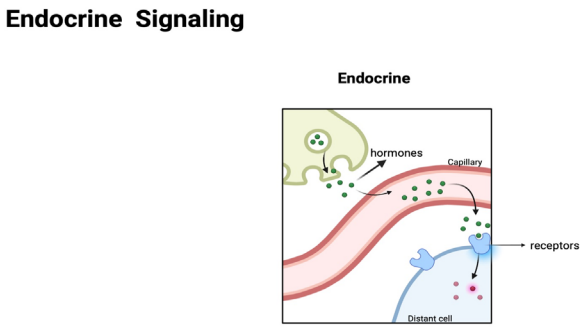

Figure 4: The image shows endocrine cell communication.

Thus, the alpha2a receptors regulate NE by controlling cell signaling. However, it was found that when yohimbine (an alpha2-adrenergic receptor antagonist) is infused into the pathway, the a2a receptors are blocked. Thus, the NE is no longer regulated, and the amount of NE used in cell signaling increases, which causes working memory and impulse control to be impaired. Thus, if the level of NE gets too high or low(not appropriately regulated by the a2a receptor,

it can impair impulse control and memory(the executive functions which are in the prefrontal cortex) and cause ADHD(deficits in executive functions). For a child with ADHD, they usually have lower levels of alpha2 receptors. Also, high levels of A1 receptors can indicate high NE levels. Dopamine pathways are responsible for working memory, attention, and self-control—the dopamine pathways project to the mesocortical pathway (area of the brain). The mesocortex is vital for the ability to attach attention and relate attention to the working memory. Dopamine projections to the neocortex mediate the prefrontal cortical processes that are responsible for executive functions such as working memory, self-regulation, and attention. Furthermore, executive functions such as planning, and organization require the activation of dorsolateral projections to the DRD2 receptors. However, when the pathways are overly activated, there are problems with executive functioning skills. Therefore, the deficits in the catecholamines cause deficits in executive functions. However, through studies, it has been proved that certain activities can optimize catecholamine action by engaging in activities such as meditation (an example of executive function intervention)

INTERVENTIONS OF ADHD

Executive function intervention aims to instill new habits in individuals to overcome cognitive challenges. To ingrain new behaviors, these individuals must practice activities that require them to perform their executive functions properly. An example of an intervention is computerized training (using CogMed©), a program that trains working memory and reasoning skills. The website provides games where children can play and level up in the games. Through the website, improve their executive functioning skills due to practice. In a study done with the help of this website, scientists gathered a group of 4-year-olds. One group of 4-year-olds was trained on working memory (using CogMed©), one on non-verbal reasoning, another on both, and a control group on both but remaining at the most manageable level. The kids who trained in working memory improved in that skill, and the kids who taught in non-verbal reasoning improved in that aspect. However, there were not any long-lasting impacts. This observation can be attributed to the length of the experiment(only a short time) or the age of the children. The combined group showed less improvement on both (having received less practice on each).

	Working Memory Training	**Non-Verbal Reasoning Training**	**Training on Both (control group)**
Improved Working Memory (short-term)	yes	no	no
Improved Non-verbal Training (short-term)	no	yes	no
Improved on both (short-term)	no	no	no
Improved Working Memory (long-term)	no	no	no
Improved Non-verbal counseling (long-term)	no	no	no
Improved on both (long-term)	no	no	no

Figure 5: Source NIH

Another example is martial arts. Martial Arts are different forms of self-defense. Traditional martial arts emphasize self-control, discipline (inhibitory control), and character development. Taekwondo is a form of martial arts. It was found in a study that children getting Tae-Kwon-Do training improved executive functions(e.g., cognitive [distractible—focused] and affective [quitting—persevering]) more than in traditional physical education on all of the executive functions studied. This was observed in a study where children 5–11 years old were randomly assigned by homeroom class to Tae-Kwon-Do (with challenge incrementing) or traditional physical education. The Tae-Kwon-Do sessions began with three questions regarding self-control: Where am I (i.e., focus on the present moment)? What am I doing? What should I be doing? The two questions guided children to select specific behaviors, compare their behavior to their goals, and make concrete improvement plans. This allowed the students to be reflective and indirectly see which executive functions they needed to improve. Additionally, the movements in Tae-Kwon-Do take self-control and focus to master. The improvements were observed by parents and teachers.

	Taekwondo	**Standard Physical Training**
Executive Functioning Skills that improved	**Yes (increase in attention and self-control)**	**no**

Figure 6. Source NIH

Another form of intervention is mindfulness training. Mindfulness training is a form of meditation whose goal is controlling attention. In a study with 7-9-year-olds, there was a group in mindfulness training and a control group that did not participate. Children who practiced mindfulness meditation and who had more significant EF improvements were found to be 7–9 year olds with initially-poor EFs than those with initially-better EFs. Both of these improved more than controls (who silently read). The mindfulness training sessions have three sections, meditation, activities to enhance sensory awareness, attention regulation, or awareness of the environment. The kids in each group were identified as having "strong executive function" or "poor executive function" Children with initially poor executive functions showed executive function improvements overall and in the components of shifting and monitoring, bringing their scores up to average. Overall, executive function intervention was able to improve the symptoms of ADHD by optimizing catecholamine activity in the children's brains. Deficits in the catecholamines cause deficits in executive functions that are present in children who have ADHD.

	Mindfulness training (initially had poor EF)	**Mindfulness Training (initially had strong EF)**	**No mindfulness training (students who read or took part in normal training-no EF intervention)**
EF improvement	**Improved in self-monitoring, control, and memory (more widespread improvements)**	**Improvements were not as prevalent**	**No improvements**

Figure 7. Source NIH

STUDY OF EXECUTIVE FUNCTION INTERVENTION WITH PRE-SCHOOLERS

A study by the Department of Development and Socialization Psychology, University of Padova, focuses on the effects of early intervention on executive functions (EFs). The study focuses on interventions on working memory, attention, responses or behaviors, and shifts from one activity to another. As it is well known through research, ADHD children have weaknesses in their EFs like attentional control, working memory, and inhibition. In particular vital meta-analyses showed impairment of ADHD children in several EF. The Department of Development and Socialization Psychology study examined the results of training the executive function. Specifically, attention/ability to control, inhibition (self-control), and working memory are carried out in the context of school activities with groups of preschoolers. There are two groups, the children who exhibit ADHD symptoms and typically developing (TD) children. It was hypothesized that group training of executive functions, impulse control/inhibition controlled attention and working memory) included in the daily routine of kindergarteners could improve executive functions and possibly reduce symptoms of ADHD. The participants have 26 children with ADHD and 26 who are typically developing (TD). It was determined if a child exhibited ADHD symptoms by collecting data from teachers and the child's rationing on the IPPDAI. An IPPDAI rating below 3 represents that the child is TD, and a rating above 3 indicates that they exhibit ADHD symptoms. The test included an attention control test (Walk-No Walk Test), a working memory test (the Dual Request Selective Task), and an impulsivity control test was administered (Matching Figures MF-14). The assessment was followed by 17 one-hour sessions distributed over nine weeks, twice a week for the training group interested in executive functions and the control group interested (in the usual school practices). One week after the end of the training, the teachers were invited to complete the IPDDAI again, and the same measures collected before the training were recollected.

The Walk–No Walk Test is a paper-and-pencil test that evaluates attention control and the impulse control of an ongoing response: "The task requires children to follow a series of directions and stop an ongoing response when a particular event (a signal) occurs. The test includes two A4 sheets of paper in which 20 stairs (one for each trial) are drawn with a little frog on the first step. The child is asked to cancel a step each time they hear the GO signal, while they have to stop every time they hear the STOP signal. The STOP signal is very similar to the GO signal but differs in its ending. Obviously, there are many GO signals for every trial and only one STOP signal. The difficulty of this task is that the STOP signal is made in two parts, and the first part has the same sound as the GO signal. Therefore, the child must wait to hear the sound before responding to understand whether it is a GO or STOP signal." (Frontiers in Psychology).

The Working Memory Dual Request Selective Task (DRST): The Dual Request Selective Task is a visual-spatial working memory task that assesses the ability to maintain information in working memory and filter out irrelevant information. The test is based on a 4 × 4 matrix (17 cm × 17 cm) divided into 16 cells. "The matrix is blank with a red square always situated in the same position. DRST requires the children to perform a double task:

(1) Remember the first position indicated by the experimenter.
(2) Clapping hands when the experimenter indicates the red square.

To make the task more attractive, a small plastic frog is shown moving into the matrix. There are ten trials in order by difficulty level. Difficulty depends on the number of cells touched by the frog (length of the pathway), from a minimum of two to a maximum of six cells. There are two trials for each length level. The child must complete the entire task. A trial is considered correct only when the child carries out both tasks correctly; in other words, clapping and remembering the first position. ” (Frontiers in Psychology).

The MF-14 test "assesses several executive components, particularly sustained attention and impulsivity control. The test consists of 14 items that include a target picture and six alternative pictures similar to the target. Among these pictures, only one is exactly like the target. The child must identify the picture that is just like the target. The pictures represent everyday life objects. For the scoring of this test, two parameters are considered: 1) Number of errors and 2) Response time (i.e., the time of the first response) that is assumed to represent a form of impulsivity" (Frontiers in Psychology).

Results

Considering the performance of children with ADHD symptoms on the Walk–No Walk Test, it was found that the training groups significantly improved in attention and impulse control(specifically, they can wait until they fully respond to something), whereas there was only a slight improvement in the control/non-training group. This was seen in their IPDAAI rankings and observations by the student's teachers. Furthermore, there were significant effects on time(impulse control). The same results were seen in the DRST and MF-14 tests.

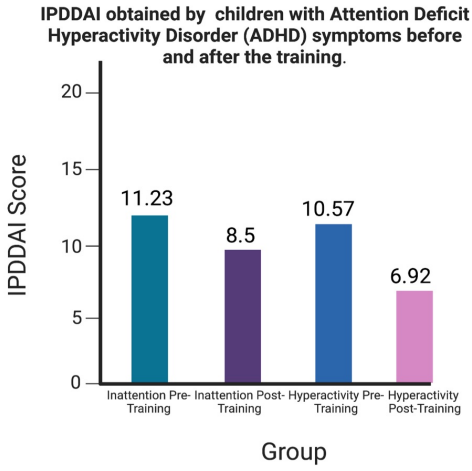

Figure 8. Source: Frontiers.org. The lower the IPDDAI Score the closer they are to a typically developing child.

CONCLUSION

This research paper aimed to see to what extent executive function intervention could be used to treat those with ADHD. The main findings were that executive function intervention was effective for children who practiced rather than those who did not. It significantly helped those with poor executive functioning skills (those with ADHD). This is because certain activities can optimize catecholamine action by engaging in meditation (an example of executive function international). However, the activities should be done for a long time to see long-lasting results. In the future, further research could be done to see which interventions are the most effective.

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