ADHD: Executive Functioning Complications and Treatments

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PSYC 3113: Physiological Psychology

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August 4, 2024

Introduction

Attention-Deficit Hyperactivity Disorder (ADHD) is a common neurodevelopmental disorder typically defined by symptoms of hyperactivity, lowered attention, and impulsiveness that heavily interferes with the ability for daily executive functioning (American Psychiatric Association, 2013). While ADHD symptoms vary among individuals, the disorder is known to impact an individual's executive function ability, academic performance, social interactions, and occupational functioning. Executive function is defined by cognitive processes responsible for directing and regulating cognitions, emotions, and behavior to achieve desired goals (Roselló et al., 2020). Whereas Roselló and colleagues (2020) describe occupational functioning as the ability of an individual to manage and perform work-related tasks and responsibilities. According to the Centers for Disease Control and Prevention (CDC) in 2022 it was estimated that 7 million children (11.4%) aged 3-17 in the United States were diagnosed with ADHD (CDC, 2024). In a 2024 CDC report, data demonstrated that men were more likely to be diagnosed with ADHD compared to women with men having a 15% diagnosis and women having an 8% diagnosis. Due to the high incidence of ADHD and the increasing rate of diagnosis, it is imperative to continually study the disorder in order to support those affected. Assistance for this disorder comes in various forms with the most effective therapies including pharmacological intervention and behavioral treatment.

For an individual to be diagnosed with ADHD they must exhibit a minimum of 6 symptoms within an overall 6-month period where the symptoms create great dysfunction in the patient's social, academic, or occupational functioning (APA, 2013). The listed symptoms in the Diagnostic and Statistical Manual of Mental Disorders fifth edition (DSM-5) include the inability to pay attention to details leading to errors, avoidance of activities that need significant mental

effort, and losing items for task and/or activity completion (APA, 2013). These symptoms can lead to several negative outcomes for ADHD patients including higher rates of unemployment, lowered social acceptance, and reduced academic and occupational functioning.

Symptoms of ADHD are grouped into three primary categories for ADHD inattentive-dominant, hyperactivity-impulsive-dominant, and a combination of both types. The inattentive-dominant category involves great difficulty with focus and task completion, which leads to recurrent distraction., It is typically defined by patients who tend to jump from task to task due to frequent and obstructive distractions. Common expressions of inattentive-dominant ADHD are they complete tangent tasks, which can slow down the completion of other tasks they started originally. Individuals with hyperactive-impulsive dominance express it through typically moving while talking and impulsively acting on thoughts leading to the completion of unrelated actions (APA, 2013). Hyperactive-impulsive dominant patients usually struggle with areas of physical and mental control. The third category is when a patient expresses a combination of symptoms of both inattentive-dominant and hyperactive-impulsive dominant categories of ADHD. To appropriately treat an individual with ADHD, it is necessary to understand which category of ADHD best aligns with their experiences.

The neurophysiological aspects of ADHD are not fully understood, however, research has linked genetic composition and environmental factors to the disorder's development process. Factors that play into the neurophysiological components include issues with event-related potentials because of the distinct differences in the P3 and N2 components of the brain compared to those without ADHD (Münger et al., 2021). Issues with P3 and N2 components indicate problems with attention and cognitive control elements of brain functionality. A feature found was there was variability in the reaction time an ADHD individual had to a stimulus,

demonstrating there was impairment in cognitive processing and sustained attention (Münger et al., 2021). The impairment indicates that there is dysfunction in an individual's executive functioning capability. Münger and colleagues (2021) also discovered significant differences in neural oscillations where there were higher ratios of theta and beta waves in electroencephalogram scans (EEG), illustrating cortical hyperarousal and impaired cognitive functioning.

The neurophysiological marker of unusual connectivity between the default mode network (DMN), executive control network (ECN), and salience network (SN) of ADHD was observed (Münger et al., 2021). The connectivity differences lead to issues due to the DMN's involvement during rest and mind-wandering while ECN's involvement in goal-directed activities and decision-making. SN is the key to detecting and filtering salient stimuli between the DMN and ECN. The disruptive communication between these networks leads to issues with attention, information processing consistencies, and executive function management such as planning, organizing, and regulating emotions (Münger et al., 2021).

Several regions and systems of the brain are affected by ADHD leading to problematic communication throughout the brain. A significant region of the brain that ADHD affects is the frontal-parietal region as they experience a decrease in the level of gray matter volume directly impacting features of executive functioning, attention, and working memory (Yu et al., 2023). Additionally, the prefrontal cortex and mesocorticolimbic circuits are involved in executive functioning, which has a dysfunctional dopaminergic system in ADHD patients (Mariggiò et al., 2021). The limbic system is also heavily impacted by a decreased level of gray matter volume in the anterior cingulate cortex and hippocampus, leading to deficits in emotion regulation and memory (Rolls, 2023). Altercations of the dopaminergic pathways, DRD1 and DRD2 receptor

polymorphisms can worsen the deficits by increasing disruptions of normal dopamine signaling (Mariggiò et al., 2021). Issues within the brain can be linked to problematic GABAergic neurotransmission which is crucial for the GABA system's functionality. The GABA system's proper functionality is a key area for the ability to maintain strong executive functioning due to the nature of the functions of the anterior cingulate cortex and hippocampus (Fu et al., 2023).

The corpus callosum is also affected as there are abnormalities in the structure that cause issues in the communication between the hemispheres which are critical to executive functioning (Yu et al., 2023). Abnormalities in interhemispheric communication may be related to genetic factors that adjust the dopamine receptor activity (Mariggiò et al., 2021). Individuals with ADHD experience an adjustment in their basal ganglia where there are changes in the caudate nucleus and putamen guiding discrepancies in motor control and cognitive functions including executive function elements (Yu et al., 2023). Dopaminergic dysregulation in these regions is connected to impaired cognitive functions, which accentuates the role of dopamine in the basal ganglia (Mariggiò et al., 2021). To treat an individual's dysfunctional executive functioning it is imperative to understand the neuroanatomy and neurophysiological components that define the differences between an individual with ADHD and an individual without ADHD. Research can continue to support the treatment of individuals through pharmacological and behavioral means effectively treating a patient's abnormal brain structure and functionality.

ADHD has several effective options for treatment such as Cognitive Behavioral Therapy, diet-based therapy, and pharmacological therapy. The most commonly used treatment for ADHD is pharmacological therapy. Some of the various drugs used to treat the symptoms are stimulants like Amphetamines, Bupropion, Atomoxetine, and Modafinil. The typical drugs chosen to treat executive functioning symptoms are stimulants like Methylphenidate and

Amphetamines (Mechler et al., 2022). Amphetamine-based medications can assist in the treatment of ADHD symptoms by providing the patient with an increase in dopamine and norepinephrine in the prefrontal cortex (Mechler et al., 2022). Alternatively to pharmacological treatments, Cognitive Behavioral Therapy (CBT) is commonly used to assist in the treatment of the symptoms of ADHD. The cognitive treatment part of CBT is used to help patients engage and recognize their poorly adapted behaviors. The behavioral aspect of CBT supplies the patient with the skills needed to effectively alter their behavioral patterns to improve the aspects of their executive functioning skills (Qiu et al., 2023).

Pharmacological Treatment

Amphetamine medications function by inhibiting the dopamine and norepinephrine transporter, vesicular monoamine transporter 2, and monoamine oxidase activity. With this inhibition, the amount of dopamine and norepinephrine in the synaptic cleft increases. This positively impacts the efficiency of dopamine and norepinephrine activity in the prefrontal cortex, leading to improved executive and attention in patients (Mechler et al., 2022). Amphetamines are able to function in this way because their structure is similar to that of the neurotransmitters. The amphetamine isomers including D-amphetamine and L-amphetamine contain an aromatic ring and a nitrogen on the aryl sidechain. Due to this, they are able to function as monoamine reuptake transporters, which have low specificity for different monoamines. This leads to the amphetamines releasing different monoamines in the central nervous system (Heal et al., 2011). The amphetamines then are able to inhibit the reuptake of dopamine and epinephrine by and slight inhibition of monoamine oxidase, which is the enzyme responsible for breaking down monoamines. This dual action increases the concentration of neurotransmitters in the synaptic cleft, leading to enhanced stimulation of noradrenergic and

dopaminergic receptors. This mechanism is fundamental to the therapeutic effects of amphetamines in treating ADHD and other conditions, as the augmented release of catecholamines and subsequent rise in neurotransmitter levels are key to their action in the CNS (Heal et al., 2011).

The use of amphetamines needs careful control as the medication has addictive qualities if not properly controlled and dosed. It is important to consider what a patient is seeking in treatment such as acute usage in a day or if they are looking for symptomatic relief throughout the majority of the day. Many forms of amphetamines offer a slower-release formulation that can be taken at the beginning of the day and is constantly distributed throughout the patient's body during the day as well as a short-acting dose that is aimed to solve acute needs. Instances that a short-acting formulation could be beneficial to a patient is if they plan on using the medication to complete homework or a task that is only a few hours as depending on the person the short-acting formulation will last 4-6 hours (Siefried et al., 2020). However, if a patient aims for the medication to work throughout a school or workday a slower-release formulation might be ideal as they release between 8-12 hours (Siefried et al., 2020). Another crucial factor to consider is the patient's age as their dosage will change with their age. Patients will typically make frequent visits to their healthcare provider when initially starting the medication and will start on the smallest dosage. At each visit, the provider will analyze whether or not the patient should stop, change, or adjust the dosage of the medication (Nazarova et al., 2022). This way the patient can effectively treat their symptoms with minor to no negative drawbacks, such as addiction, too strong of a dose, or side effects.

An important advantage to consider with the usage of amphetamines is the vast clinical data there is on the usage and effectiveness of amphetamine-based medications. The

understanding of amphetamine actions in the brain has been able to be studied and optimized for patient use (Cortese et al., 2021). Patients can look up the effects amphetamines will have on their brains as well as consider what potential negative effects it could have on them. With all the clinical data on the usage and effectiveness of amphetamines, providers can properly dose their patients to satisfy the resolution of their symptoms. Patients are also able to easily take the medications to mitigate their executive functioning symptoms without having to engage with more time-consuming or extensive work to reduce the severity of their symptoms.

Amphetamines also come with several drawbacks as they are known to have the potential for abuse. Amphetamines were shown to create dependence behaviors in some patients of the medications (Siefried et al., 2020). Patients may feel reliant on the drug for proper daily function in order to not feel problematic executive functioning. Missing a dose of medication can make the patient unable to complete tasks that are part of their normal day. Another considerable drawback of amphetamine medication is although it is convenient a patient may feel strong adverse side effects from the usage of the medication. These side effects can negatively impact a patient's life making it difficult for them to enjoy themselves or get through a regular day. Considering that these medications do not work for everyone as well it is important to consider how effective the medication is compared to the strength of its side effects on the patient. Due to the nature of the treatment, a patient will likely take it daily for their whole life, which can pose significant financial issues as the patient will have to be able to afford it to continue to feel reduced issues in executive functioning.

Cognitive Behavioral Therapy

Cognitive Behavioral Therapy is commonly used for those who seek a holistic intervention that will be effective for a lifetime. CBT seeks to enable a client to control the

negative executive function outcomes related to ADHD by using cognitive therapy as well as behavioral therapy. CBT aims to help the patient be able to identify the negative executive function behaviors that lead to these outcomes and then replace them with positive behaviors that significantly reduce struggles related to their executive functioning. Research has shown that CBT can adjust the connectivity in the prefrontal-striatal-cerebellar circuits (Qui et al., 2023). These structures are involved in cognitive functions such as memory, decision-making, and problem-solving which are important to adjusting executive function behaviors. Children with ADHD often show a decrease in functional connectivity in various regions of the brain with significant issues with the prefrontal and posterior cortices. These areas are important for executive function, which leads to symptoms that negatively affect a patient's executive function ability.

Event-related potential (ERP) studies have displayed irregularities by attenuated amplitudes and increased latencies in ERP components, which are expressed by deficits in executive functioning (Qui et al., 2023). Literature has emphasized the importance of interhemispheric connectivity and its role in cognitive functions. Research suggests that CBT can improve functional connectivity in the brain, especially in regions like the frontoparietal network and the cerebellum, which are key to cognitive processes such as memory and decision-making (Liang et al., 2022). The use of CBT does not alter the dopamine and norepinephrine responses in the brain, but it can help the brain change to be able to function with new behaviors acting with various levels of neurotransmitters.

CBT can provide a patient with the skills to properly adjust their executive functioning skills for the entirety of their life. This can be beneficial as once a patient has properly changed their behaviors they can discontinue their sessions. Unlike medication treatment, the patient will

be able to stop treatment but still be in control of their executive functioning (Qui et al., 2023). Making a patient take control of their behaviors, has the potential to make them feel more in control of their life rather than feeling reliant on an outside source for control over their ability for daily executive functioning tasks. CBT addresses the behavioral causes ADHD can have, leading CBT to be a treatment that can provide a solution to an array of symptoms (Fullen et al., 2020).

The strongest downfall of CBT is the pricing of therapy sessions can lead it to be a less cost-effective choice of treatment (Dijk et al., 2021). If a patient does not have healthcare they will experience a higher financial burden of engaging with CBT than those with it. Results of the financial burden that CBT can have is a patient may not engage in sessions frequently enough to see positive results, which could lead to a patient investing in a treatment that gave them no benefit. The typical CBT treatment of ADHD patients involves 90-minute sessions where the patient engages with the therapist until the patient feels they have had significant improvement and do not need to continue with further sessions (Young et al., 2020). Due to the nature of therapy, the treatment can be substantially time-consuming as it is an investment into a patient's future, which could potentially be a poor choice of treatment if a quick short-term fix is desired.

Discussion

The usage of medications and CBT both provide immense benefits with great opportunities to improve executive functioning symptoms of ADHD. The multifaceted nature of ADHD creates a need for there to be a holistic approach to treatment, where patients can treat their symptoms immediately as well as develop long-term skills to cope with executive functioning symptoms. A study conducted by Li & Zhang (2024), uncovered that the use of pharmacotherapy and CBT leads to improved efficacy than pharmacotherapy alone. The usage of

CBT tends to take larger amounts of time to improve symptoms while using medications like amphetamines tends to show more rapid results, however, the results are not continued if medication usage is discontinued. This research emphasizes the necessity of using CBT for sustained improvement as patients can improve their symptoms. Amphetmine-based medications can have many side effects that may prove not to be ideal for patients to have continuous use throughout their lives. Patients may desire to use amphetamines to treat their symptoms immediately but it may be desirable for them to combine the usage with CBT, so they can find reduced symptoms even if they discontinue the use of the medication (Li & Zhang, 2024).

CBT is the stronger candidate for treatment as it is able to provide long-term results post-treatment. According to Qui and colleagues (2023), CBT can change the connection in the prefrontal-striatal-cerebellar circuits, which are areas involved with essential executive function operations. This would likely provide a much more permanent change in executive function behavior as it adjusts the connections related to these behaviors. The use of amphetamines does not provide a permanent reduction in symptoms because it only reduces these symptoms while there is an effective dose in the body (Mechler et al., 2022). Using CBT is similar to the use of medications as there are many different therapists available similar to how many different medications are on the market. Patients can find a therapist who is a right fit for them and helps them reduce their executive functioning symptoms. Although CBT is an excellent choice for treatment, similar to amphetamines it does come with significant cons to consider such as time commitment and affordability. Highlighting that there is no universal treatment, and each individual's unique case must be examined to determine the most effective treatment.

There is a need for further research on the ways that CBT affects the behaviors of brain circuits. The improved symptoms of ADHD from CBT leave permanent changes in behavior

which results in adjusted connections in the brain (Qui et al., 2023). Understanding these adjustments is critical to improving how CBT is conducted and researching which forms of CBT result in more reduced symptoms. There is expansive data on the effects of man-made medicines on ADHD for example Mechler et al. (2022), reviewed the various pharmacological medications available for ADHD and their effects on patients. However, there is not a lot of clinical data on natural forms of medicine's effects on ADHD symptoms. Research has shown there are strong potential benefits from using herbal medicine. According to Bell and Colleagues (2019), many herbal medicines were shown to have positive effects on ADHD with the strongest herbal medicine being mushrooms.

Recently published by Haijen et al. (2022), is a study that followed ADHD patients who used conventional pharmacological medicines and patients who self-administered small doses of psychedelics, including psilocybin mushrooms, to see how symptoms would result in both groups. In a retrospective survey study, the study showed positive effects on emotion regulation (ER) and reductions in ADHD symptoms compared to conventional treatments for ADHD. Haijen et al. (2022) wanted to explore the lengths of the previous study. They found that there were mixed results in improvement of well-being and decreases in ADHD symptoms. One of the studies they performed found that there were significantly reduced ADHD symptoms in the microdose group compared to the conventional pharmacological treatment group. This further emphasizes that there is potential for the use of natural medicine like mushrooms as a treatment for ADHD, however, there needs to be a larger more controlled study on the subject. Haijen and Colleagues (2022), reported that there needs to be a placebo-controlled experimental study to further investigate if microdoses present a positive effect on ADHD, as there were limitations of

the study like the reliance on self-report measures and lack of control over the drug type used and dosage for the microdose group.

ADHD is a neurodevelopmental disease that is frequently diagnosed in children in the USA, with a significant prevalence rate (CDC, 2024). Factors believed to be involved in the cause of ADHD are genetic and environmental factors. ADHD is known to have impairments in executive functioning in diagnosed individuals. These deficits can be attributed to problematic functionality of the dopaminergic and GABAergic systems of the brain (Fu et al., 2023; Mariggiò et al., 2021). The two most common treatments are pharmacological treatments, like amphetamines, and cognitive behavioral therapy (CBT). Pharmacological treatments tend to have the most rapid results but are not sustained when the effective dose is removed from the body. CBT takes longer to take effect in a patient but nonetheless provides a long-term solution that is not reliant on habitual consumption of medicine every day to see a reduction in executive functioning symptoms of ADHD. Given the lasting benefits, CBT is the superior treatment option since patients do not have to deal with side effects and become in control of their once-poor executive functioning behaviors. For the future of treating ADHD, it is important to investigate the ways CBT can improve symptoms and what forms of CBT are most effective, also it would be beneficial to study how natural forms of medicine like mushrooms and diets can improve symptoms.

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