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VIRTUAL REALITY, DIGITAL TECHNOLOGIES AND BRAIN REWIRING TECHNIQUES FOR INTERVENTION IN ATTENTION-DEFICIT/HYPERACTIVITY DISORDER (ADHD)

REALIDADE VIRTUAL, TECNOLOGIAS DIGITAIS E TÉCNICAS DE RELIGAÇÃO DO CÉREBRO PARA INTERVENÇÃO NO TRANSTORNO DE DÉFICIT DE ATENÇÃO/HIPERATIVIDADE (TDAH)

REALIDAD VIRTUAL, TECNOLOGÍAS DIGITALES Y TÉCNICAS DE RECABLEADO CEREBRAL PARA LA INTERVENCIÓN DEL TRASTORNO POR DÉFICIT DE ATENCIÓN/HIPERACTIVIDAD (TDAH)

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ABSTRACT

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder that affects cognitive function, behavior, and social interaction. While medication and behavioral therapy are the standard of care for ADHD, complementary and alternative interventions that leverage the brain's neuroplasticity, such as brain rewiring techniques and digital technologies, have emerged. These techniques, including cognitive-behavioral therapy, mindfulness-based interventions, neurofeedback, Neuro-Linguistic Programming, clinical hypnosis, exercise, yoga, music therapy, and working memory exercises, aim to modify the function and structure of the brain to improve cognitive function, self-regulation, and overall quality of life in individuals with ADHD. Additionally, virtual reality has shown promise as a potential tool for improving attentional control and reducing ADHD symptoms. This literature review provides an overview of the effectiveness of brain rewiring techniques, including NLP and clinical hypnosis, as well as exercise, yoga, music therapy, and working memory exercises for ADHD, and the potential utility of virtual reality for treating ADHD.

KEYWORDS: ADHD. Brain rewiring. Neuroplasticity. Cognitive-behavioral therapy. Mindfulness-based interventions. Neurofeedback. NLP. Clinical hypnosis. Exercise. Yoga. Music therapy. Working memory exercises. Virtual reality.

RESUMO

O transtorno de déficit de atenção/hiperatividade (TDAH) é um transtorno do neurodesenvolvimento que afeta a função cognitiva, o comportamento e a interação social. Embora a medicação e a terapia comportamental sejam o padrão de tratamento para o TDAH, surgiram intervenções complementares e alternativas que alavancam a neuroplasticidade do cérebro, como técnicas de religação do cérebro e tecnologias digitais. Essas técnicas, incluindo terapia cognitivo-comportamental, intervenções baseadas em mindfulness, neurofeedback, Programação Neurolinguística, hipnose clínica, exercícios, yoga, musicoterapia e exercícios de memória de trabalho, visam modificar a função e a estrutura do cérebro para melhorar a função cognitiva, autorregulação e qualidade de vida geral em indivíduos com TDAH. Além disso, a realidade virtual tem se mostrado promissora como uma ferramenta potencial para melhorar o controle da atenção e reduzir os sintomas do TDAH. Esta revisão da literatura fornece uma visão geral da eficácia das técnicas de religação do cérebro, incluindo PNL e hipnose clínica, bem como exercícios, yoga, musicoterapia e exercícios de memória de trabalho para o TDAH, e a utilidade potencial da realidade virtual para o tratamento do TDAH.

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PALAVRAS-CHAVE: TDAH. Religação cerebral. Neuroplasticidade. Terapia cognitivo-comportamental. Intervenções baseadas em mindfulness. Neurofeedback. PNL. Hipnose clínica. Exercício. Yoga. Musicoterapia. Exercícios de memória de trabalho. Realidade virtual.

RESUMEN
El trastorno por déficit de atención e hiperactividad (TDAH) es un trastorno del neurodesarrollo que afecta la función cognitiva, el comportamiento y la interacción social. Si bien la medicación y la terapia conductual son el estándar de atención para el TDAH, han surgido intervenciones complementarias y alternativas que aprovechan la neuroplasticidad del cerebro, como las técnicas de reconexión cerebral y las tecnologías digitales. Estas técnicas, que incluyen la terapia cognitivo-conductual, las intervenciones basadas en la atención plena, el neurofeedback, la programación neurolingüística, la hipnosis clínica, el ejercicio, el yoga, la musicoterapia y los ejercicios de memoria de trabajo, tienen como objetivo modificar la función y la estructura del cerebro para mejorar la función cognitiva. , autorregulación y calidad de vida en general en personas con TDAH. Además, la realidad virtual se ha mostrado prometedora como una herramienta potencial para mejorar el control de la atención y reducir los síntomas del TDAH. Esta revisión de la literatura brinda una descripción general de la efectividad de las técnicas de reconfiguración del cerebro, incluida la PNL y la hipnosis clínica, así como el ejercicio, el yoga, la musicoterapia y los ejercicios de memoria de trabajo para el TDAH, y la utilidad potencial de la realidad virtual para tratar el TDAH.

PALABRAS CLAVE: TDAH. Recableado cerebral. Neuroplasticidad. Terapia cognitivo-conductual. Intervenciones basadas en mindfulness. Neurofeedback. PNL. Hipnosis clínica. Ejercicio. Yoga. Musicoterapia. Ejercicios de memoria de trabajo. Realidad virtual.

1. INTRODUCTION

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by symptoms of inattention, hyperactivity, and impulsivity[5]. ADHD affects an estimated 5-10% of children and 2-5% of adults worldwide[50, 60] and is associated with significant impairments in academic, occupational, and social functioning. While the standard of care for ADHD typically includes medication and behavioral therapy, emerging brain rewiring techniques, digital technologies, and alternative interventions are showing promise as complementary or alternative treatments for ADHD by harnessing the brain's neuroplasticity.

Brain rewiring techniques, also known as neuroplasticity-based interventions, aim to modify the function and structure of the brain to improve cognitive, emotional, and behavioral functioning by leveraging the brain's neuroplasticity. These techniques, such as cognitive-behavioral therapy, mindfulness-based interventions, neurofeedback, Neuro-Linguistic Programming (NLP), and clinical hypnosis, rely on the brain's ability to reorganize and form new neural connections to improve cognitive function, self-regulation, and overall quality of life in individuals with ADHD. In addition, recent studies have investigated the potential of NLP and clinical hypnosis as brain-rewiring techniques for individuals with ADHD. These techniques could be used to improve communication and social skills, increase self-

awareness, and reduce anxiety in individuals with special needs[18-20]. While the efficacy of NLP and clinical hypnosis for ADHD has not been fully established, these studies suggest that they may have potential as complementary treatments for ADHD.

In addition to traditional treatments, exercise, yoga, music therapy, and working memory exercises have also been investigated as potential interventions-brian rewiring techniques for ADHD. Exercise and yoga have been shown to improve attention and executive function in children with ADHD[34, 14]. Mayer-Benarous, Benarous, Vonthron, and Cohen conducted a systematic review and found that music therapy may improve attention and social skills in children with ADHD, as well as in children with autistic spectrum disorder and/or other neurodevelopmental disorders[43]. Additionally, working memory exercises have been shown to improve working memory and attention in children with ADHD[51].

Virtual reality has been explored as a potential tool for improving attention, memory, and executive function in individuals with ADHD by harnessing the brain's neuroplasticity. For example, virtual reality environments can simulate real-world situations to provide learning and behavior modification opportunities. Recent studies have shown that VR-based interventions can potentially improve attention, behavior, and academic performance in children and adolescents with ADHD, as well as executive function in children and adults with ADHD[56, 53]. Furthermore, a study by Drigas et al. (2022) explores the use of virtual reality and metacognition training techniques for learning disabilities and suggests that virtual reality may be a promising tool for improving cognitive function and metacognitive skills in individuals with learning disabilities, including ADHD, who often struggle with executive functioning and metacognitive skills[21].

This study aims to provide a comprehensive literature review of brain rewiring techniques, exercise, yoga, music therapy, working memory exercises, and virtual reality as potential interventions for Attention-Deficit/Hyperactivity Disorder (ADHD). Specifically, this review aims to summarize the current state of research on the effectiveness of these interventions in improving cognitive function, self-regulation, and overall quality of life in individuals with ADHD. Additionally, this review seeks to contribute to the practical and research aspects of ADHD treatment by identifying literature gaps and suggesting future research directions.

2. METHODOLOGY

This review article was conducted using a systematic search of four electronic databases: PubMed, Research Gate, Google Scholar, and PsycINFO. The following search terms were used: "ADHD" AND ("brain rewiring" OR "neuroplasticity" OR "cognitive-behavioral therapy" OR "mindfulness-based interventions" OR "neurofeedback" OR "NLP" OR "clinical hypnosis" OR "exercise" OR "yoga" OR

"music therapy" OR "working memory exercises" OR "virtual reality"). The search was limited to studies published in English language peer-reviewed journals between 2010 and 2023. We also conducted a manual search of the reference lists of included studies and relevant review articles to identify any additional studies.

Inclusion criteria for this review were studies that investigated the effectiveness of brain rewiring techniques or virtual reality interventions in improving cognitive function, self-regulation, or overall quality of life in individuals with ADHD. Studies that were conducted in clinical or non-clinical populations, with both children and adults, were included. Studies that reported on other neurodevelopmental or psychiatric disorders were excluded, as were studies that did not meet the inclusion criteria or had a high risk of bias.

3. NEUROPLASTICITY AND ADHD

3.1. OVERVIEW OF NEUROPLASTICITY

Neuroplasticity refers to the brain's ability to change and adapt in response to new experiences, learning, and environmental stimuli. The brain can create new neural connections, reorganize existing ones, and even generate new neurons in response to stimulation, which allows for continued growth and development throughout life. Neuroplasticity plays a critical role in learning, memory, and recovery from injury or disease and that the dynamic nature of the brain and changing rules of neuroplasticity have important implications for these processes[65].

3.2. NEUROPLASTICITY IN ADHD

Individuals with ADHD exhibit differences in brain structure and function, including alterations in the prefrontal cortex, anterior cingulate cortex, basal ganglia, and cerebellum, which may contribute to the characteristic symptoms of inattention, hyperactivity, and impulsivity associated with the disorder[25].

Research suggests that individuals with ADHD may have impaired neuroplasticity when compared to neurotypical individuals, as noted in the systematic review by Weyandt et al. that examined the literature on neuroplasticity in children and adolescents with various psychiatric and neurological disorders, including ADHD[68]. However, various interventions, such as cognitive-behavioral therapy, mindfulness-based interventions, and neurofeedback, have been found to enhance neuroplasticity in individuals with ADHD.

Additionally, exercise, yoga, music therapy, and working memory exercises have been found to positively impact neuroplasticity in individuals with ADHD. Studies by Voss et al. and Chaddock et al. have shown evidence for exercise-induced brain plasticity[64, 12]. Furthermore, a systematic review by Weyandt et al. found that cognitive-behavioral therapy, mindfulness-based interventions, and

neurofeedback can improve neuroplasticity in individuals with ADHD[68]. Studies have also shown that exercise[34], yoga[13], music therapy[43], and working memory exercises[51] can positively impact neuroplasticity in individuals with ADHD. Moreover, working memory exercises have been found to enhance neuroplasticity in studies by Liu et al. and Ackermann et al.[41, 2].

These interventions aim to modify the function and structure of the brain to improve cognitive function, self-regulation, and overall quality of life in individuals with ADHD. Therefore, leveraging the brain's neuroplasticity through these interventions may provide a promising avenue for the treatment of ADHD.

4. BRAIN REWIRING TECHNIQUES

4.1. COGNITIVE BEHAVIORAL THERAPY (CBT)

Cognitive behavioral therapy (CBT) is an effective approach for promoting cognitive and emotional regulation in individuals with ADHD[6]. CBT focuses on identifying and modifying negative patterns of thinking and behavior that contribute to attentional control and emotional regulation and has been found to be particularly effective when used in combination with other treatments such as neurofeedback[15]. Abdollahian et al. conducted a randomized controlled trial that compared cognitive-behavioral play therapy with a control group in children aged 7-9 years with ADHD[1]. The results showed significant improvements in ADHD symptoms in the experimental group compared to the control group, indicating the effectiveness of cognitive-behavioral play therapy in reducing symptoms of ADHD.

Several recent studies have demonstrated the effectiveness of cognitive behavioral therapy (CBT) in improving ADHD symptoms and related impairments. Auclair et al. conducted a systematic review and meta-analysis of studies on the effectiveness of CBT for ADHD in adults and found that CBT was effective in reducing symptoms of ADHD and improving quality of life in adults with ADHD[7]. Young, Moghaddam, and Tickle (2020) conducted a systematic review and meta-analysis of randomized controlled trials examining the efficacy of CBT for adults with ADHD and found that CBT was significantly more effective than control conditions in reducing ADHD symptoms and improving functioning[69].

Other studies have examined the effectiveness of CBT for specific ADHD-related impairments. Evans et al. conducted a randomized controlled trial that showed significant improvements in ADHD symptoms, executive functioning, and quality of life in adults with ADHD who received CBT compared to those who received treatment as usual[23]. Sciberras et al. conducted a randomized controlled trial to investigate whether the treatment of anxiety in children with ADHD using CBT improved child and family outcomes[55]. Sprich et al. conducted a randomized controlled trial of CBT for ADHD in medication-treated adolescents and found significant improvements in ADHD symptoms, functional impairment, and

anxiety[58].

Overall, these studies provide compelling evidence for the effectiveness of CBT in treating ADHD and associated impairments.

4.2. MINDFULNESS

Mindfulness is a type of meditation that involves paying attention to the present moment with curiosity and openness, rather than judgment, preconceived ideas, or automatic reactions[16]. Mindfulness-based interventions have shown promise for improving attentional control and executive functioning in individuals with ADHD[62, 59]. One study found that an eight-week mindfulness-based intervention was associated with significant improvements in attentional control and executive functioning in adults with ADHD[45].

Meppelink and colleagues conducted a randomized controlled trial to compare the effectiveness of mindfulness training and medication in the treatment of childhood ADHD[44]. Their findings suggest that mindfulness training was equally effective as medication in reducing ADHD symptoms. Additionally, Lee and colleagues (2022) conducted a systematic review and meta-analysis and found that mindfulness parent training was effective in reducing parenting stress and ADHD-related behaviors in children[40].

The neural mechanisms underlying the effectiveness of mindfulness for ADHD are not fully understood, but it is believed that mindfulness training may promote changes in neural networks associated with attentional control and self-regulation[35]. These findings suggest that mindfulness-based interventions may be a promising approach for improving attentional control and reducing symptoms of ADHD in both adults and children.

Moreover, Tercelli and Ferreira provided a systematic review of mindfulness-based interventions for children and young people with ADHD and their parents, which may provide further insights into the effectiveness of mindfulness-based interventions for ADHD[59]. Lo and colleagues also provided a study protocol for a randomized, controlled clinical trial to examine the effect of a family-based mindfulness intervention on children with ADHD and their parents[42].

4.3. NEUROFEEDBACK

Neurofeedback has been identified as a potential treatment intervention for ADHD, as it aims to help individuals with ADHD learn to regulate their brain activity and improve their attention and impulse control. According to Enriquez-Geppert et al., neurofeedback involves measuring brain activity using EEG or other neuroimaging techniques and providing real-time feedback in the form of visual or auditory cues[22]. This feedback helps individuals to learn to modulate their own brain activity within a target range.

Therefore, neurofeedback may be a useful adjunctive treatment for ADHD alongside other interventions such as medication and behavioral therapy.

Neurofeedback has shown promise for improving attentional control and cognitive flexibility in individuals with ADHD. Gevensleben and colleagues found that neurofeedback was associated with significant improvements in attentional control and cognitive flexibility in children and adolescents with ADHD[26]. Similarly, Bink et al. found that neurofeedback was associated with improvements in attentional control, working memory, and executive functioning in adolescents with ADHD[10]. A meta-analysis by Cortese et al. reported that neurofeedback had significant effects on clinical and neuropsychological outcomes in children and adolescents with ADHD[15]. Furthermore, Lee and colleagues (2022) conducted a systematic review and meta-analysis that showed theta/beta-based neurofeedback training significantly improved attention in children with ADHD[39]. These studies suggest that neurofeedback is a promising approach for improving attentional control and cognitive functioning in individuals with ADHD. However, further research is needed to fully understand the neural mechanisms underlying the effectiveness of neurofeedback.

4.4. NEURO-LINGUISTIC PROGRAMMING (NLP)

Neuro-Linguistic Programming (NLP) is being investigated as a potential technique for improving outcomes for individuals with Attention-Deficit/Hyperactivity Disorder (ADHD)[18]. NLP techniques, such as affirmation, visualization, anchoring, reframing, role-playing, and role modeling, have been studied as a possible brain rewiring technique for individuals with ADHD[18, 32, 36]. For instance, a case study by Jeyanthi et al. showed that a 9-year-old boy with ADHD who participated in an intervention program combining NLP techniques with exercise demonstrated a positive impact on attention and motor skills[32].

Furthermore, Kudliskis investigated the use of NLP strategies in boosting learning experiences and school performance of students with mild special educational needs, such as ADHD[36]. Although no measurable impact on students' learning experience was demonstrated, teachers reported that NLP enhanced students' confidence and self-esteem, with significant improvements observed on students' behavior. Additionally, NLP techniques have been found to increase motivation, decrease anxiety, and improve language proficiency in young learners[38].

Individualized and personalized treatment plans that incorporate multiple brain rewiring techniques, including NLP, may be effective in improving outcomes for individuals with ADHD who may not respond to traditional treatments[18, 31]. Therefore, NLP holds promise as a technique for improving outcomes in ADHD. Moreover, it has been explored as an innovative technique for education and teaching[61].

4.5. CLINICAL HYPNOSIS

Clinical hypnosis is another brain rewiring technique that has shown promise for individuals with ADHD. Through guided relaxation and suggestion, clinical hypnosis can help individuals reframe negative thought patterns and develop more positive coping strategies. In a study by Hiltunen et al., clinical hypnosis was found to be a more effective treatment than CBT for adult individuals with ADHD in terms of long-term outcomes[30]. The study showed that after a six-month follow-up period, individuals who received hypnotherapy had significantly fewer ADHD symptoms compared to those who received CBT. This suggests that clinical hypnosis may be a valuable treatment option for adults with ADHD, but further research is needed to fully understand its effectiveness and the underlying mechanisms. Similarly, Virta et al. found that hypnotic suggestions improved reaction times in continuous performance tests in adults with ADHD and healthy controls[63]. The study involved a single hypnosis session, during which participants were given hypnotic suggestions aimed at improving their sustained attention and impulse control. Results showed that the ADHD group had a significant improvement in reaction time compared to the control group.

Sawni and Breuner reported that clinical hypnosis was an effective mind-body modality for adolescents with behavioral and physical complaints[54]. The study involved the use of hypnosis for a range of conditions, including ADHD, anxiety, and pain management. Results showed significant improvements in symptoms and quality of life for the majority of participants. While more research is needed to fully understand the effectiveness of clinical hypnosis for ADHD, it may be a valuable addition to personalized treatment plans that incorporate multiple brain rewiring techniques[19, 20].

4.6. EXERCISE

Exercise is a well-known intervention for individuals with ADHD. Physical activity has been found to improve cognitive function, including attention and working memory, in individuals with ADHD[9, 66, 72]. Exercise has also been shown to reduce symptoms of ADHD, including hyperactivity and impulsivity. The benefits of exercise can be attributed to the increase in blood flow and oxygen to the brain, which can improve neural connections and cognitive function. Exercise can also help individuals with ADHD regulate their emotions and improve their mood, which can be particularly beneficial for individuals who struggle with emotional dysregulation.

A meta-analysis by Vysniauske et al. found that physical exercise had positive effects on functional outcomes in the treatment of ADHD[66]. Another study by Benzing et al. found that acute bouts of physical activity enhanced executive functions in children with ADHD[9]. Ziereis and Jansen also found that physical activity had positive effects on executive function and motor performance in children with

ADHD[72]. These findings suggest that exercise can improve cognitive function and may be beneficial for individuals with ADHD.

4.7. YOGA

Yoga has emerged as a promising intervention for individuals with ADHD, with multiple studies providing evidence for its effectiveness. Cohen et al. found that a yoga intervention improved attention, impulsivity, and hyperactivity in preschool-aged children with ADHD symptoms[14]. Petsche also reported improvements in attention in students diagnosed with ADHD following a yoga program[48]. Chou and Huang found that an eight-week yoga program improved sustained attention and discrimination function in children with ADHD[13]. Beik et al., reported that yoga training improved executive functions in children with ADHD[8], while Agarwal and Sarthi provided a review of studies that support the efficacy of both yoga and mindfulness as interventions for children with ADHD[3]. The benefits of yoga may be attributed to the mindfulness component of the practice, which can help individuals with ADHD regulate their attention and focus. Yoga also involves physical postures and breathing exercises, which can improve body awareness and control. These findings suggest that yoga may be a valuable intervention for individuals with ADHD, providing a holistic approach to managing symptoms and improving overall well-being.

4.8. MUSIC THERAPY

Music therapy has emerged as a promising intervention for individuals with ADHD, with multiple studies providing evidence for its effectiveness. Zhang et al., conducted a Cochrane review and found that music therapy may have a positive effect on ADHD symptoms in children and adolescents[71]. Another study by Park et al. reported that music therapy improved depression symptoms in children and adolescents with ADHD by activating serotonin and improving stress coping ability[47]. Additionally, a systematic review by Mayer-Benarous et al. found that music therapy may improve social communication, emotional regulation, and behavior in children with autism spectrum disorder and other neurodevelopmental disorders[43]. Music therapy involves listening to and creating music, which can stimulate neural connections and improve executive function. The emotional and cognitive engagement that comes with listening to and creating music may contribute to the benefits of music therapy. These findings suggest that music therapy may be a valuable intervention for individuals with ADHD and other neurodevelopmental disorders, providing a non-invasive and enjoyable approach to improving cognitive function and emotional well-being.

4.9. WORKING MEMORY

Working memory exercises have been identified as a cognitive training intervention that targets the working memory system in the brain. Individuals with ADHD often struggle with working memory, which is responsible for temporarily holding and manipulating information in the mind. Working memory exercises involve tasks that require individuals to hold and manipulate information in their minds, such as remembering a sequence of numbers or letters. Research has demonstrated that these exercises can improve working memory capacity and attention in individuals with ADHD[4, 17, 51].

A meta-analytic review by Rapport et al. found that cognitive training programs designed to train working memory, other executive functions, and attention improved cognitive, academic, and behavioral outcomes in children with ADHD[51]. Another study by Dentz et al. reported that working memory training improved working memory capacity and attention in adults with ADHD[17]. Additionally, a review by Al-Saad et al. found that working memory training interventions showed promise in improving working memory and attention in individuals with ADHD[4].

These findings suggest that working memory exercises may be an effective intervention for individuals with ADHD, improving cognitive function and potentially mitigating some of the associated academic and behavioral challenges. Therefore, working memory training may be a valuable intervention for individuals with ADHD, providing a targeted approach to improving working memory capacity and attention.

In conclusion, the brain rewiring techniques discussed in this article, including cognitive behavioral therapy (CBT), mindfulness, neurofeedback, neuro-linguistic programming (NLP), clinical hypnosis, exercise, yoga, music therapy, and working memory exercises, have all shown promise in improving cognitive function, attention, and executive function in individuals with ADHD. While further research is needed to fully understand the long-term effectiveness of these interventions and their potential to be used in conjunction with traditional interventions such as medication and behavioral therapy, the studies presented in this article suggest that these interventions may be promising approaches for improving the lives of individuals with ADHD. Thus, these brain rewiring techniques may be valuable additions to personalized treatment plans for individuals with ADHD.

5. EFFECTIVENESS OF BRAIN REWIRING TECHNIQUES FOR ADHD

Brain rewiring techniques, such as cognitive behavioral therapy, mindfulness, neurofeedback, NLP, clinical hypnosis, exercise, yoga, music therapy, and working memory exercises, have shown promise in improving attentional control and reducing symptoms of ADHD. However, the evidence supporting their effectiveness is not always consistent[15]. Cognitive behavioral therapy has been

associated with small to moderate improvements in ADHD symptoms, and the effect is stronger when used in combination with other treatments such as medication[57]. Mindfulness-based interventions, yoga, and music therapy have also shown promise in reducing ADHD symptoms and improving cognitive function, but more research is needed to fully understand their potential[24, 43, 47, 48, 71]. Working memory exercises have been found to be effective in improving working memory and attention in individuals with ADHD[17, 51]. While the evidence supporting the effectiveness of neurofeedback for ADHD is mixed, recent studies have explored the potential of clinical hypnosis and virtual reality in special education, including for individuals with ADHD[19- 21]. However, more research is needed to fully understand the effectiveness of these interventions and identify factors that contribute to treatment success.

5.1. NEURAL MECHANISMS

The specific neural mechanisms underlying the effectiveness of brain rewiring techniques for ADHD are not fully understood, but it is believed that they may involve changes in the functioning of specific brain networks that are associated with attention and self-regulation[15, 46]. Cognitive behavioral therapy, mindfulness-based interventions, neurofeedback, clinical hypnosis, NLP techniques, exercise, yoga, music therapy, and working memory exercises have all been associated with changes in the functioning of specific brain regions and networks that are involved in attentional control, cognitive regulation, and emotional processing[69,29,33,17,43,47 48,51,66,71]. For example, cognitive behavioral therapy has been found to be associated with changes in the functioning of prefrontal and parietal brain regions that are associated with cognitive control and attentional regulation[67]. Mindfulness-based interventions have been found to be associated with changes in the functioning of the default mode network, which is involved in self-referential processing[11]. Neurofeedback has been found to be associated with changes in the functioning of the dorsolateral prefrontal cortex, which is involved in attentional control and working memory[29, 46]. Similarly, clinical hypnosis, NLP techniques, exercise, yoga, music therapy, and working memory exercises have all been found to be associated with changes in brain networks associated with language processing, sensory perception, and emotional regulation[43,47,48,51,66].Overall, while the specific neural mechanisms underlying the effectiveness of brain rewiring techniques for ADHD are not fully understood, it is believed that they may involve changes in the functioning of specific brain networks that are associated with attention and self-regulation.

5.2. PERSONALIZED AND INDIVIDUALIZED TREATMENT PLANS FOR ADHD

Personalized and individualized treatment plans that incorporate multiple brain rewiring techniques may be most effective for individuals with ADHD[15]. These treatment plans may be tailored to

the individual's specific symptoms, strengths, and challenges, and may include a combination of cognitive behavioral therapy, mindfulness, neurofeedback, NLP, clinical hypnosis, working memory exercises, yoga, and music therapy[48,43,66]. By tailoring treatment plans to the individual, clinicians can address specific aspects of the individual's attentional control and emotional regulation, and may be more likely to achieve long-term improvements in ADHD symptoms. However, developing personalized and individualized treatment plans requires a comprehensive understanding of the individual's unique needs and may involve additional resources and time.

In summary, brain rewiring techniques such as cognitive behavioral therapy, mindfulness, neurofeedback, NLP, clinical hypnosis, working memory exercises, yoga, and music therapy hold promise for improving attentional control and reducing symptoms of ADHD. While the evidence supporting their effectiveness is not always consistent, these techniques may be most effective when used in combination with other treatments and tailored to the individual's specific needs. Understanding the neural mechanisms underlying the effectiveness of these techniques may also provide important insights into the nature of ADHD and potential targets for intervention.

6. VIRTUAL REALITY AND DIGITAL TECHNOLOGIES FOR ADHD INTERVENTION

Digital technologies, including virtual reality (VR), have become increasingly popular as potential alternatives for treating ADHD. According to Gkora and Karabatzaki, these technologies can also enhance motivation in individuals with learning disabilities, which is an essential component of successful treatment[27].

Emotional and behavioral disorders can significantly impact students in the classroom, and digital technologies such as virtual reality (VR) may be used to help control such difficulties[28].

VR is an immersive technology that simulates real-world environments using computer-generated graphics and sensory feedback. Recent studies have shown promising results for the use of VR in the treatment of ADHD. A study by Shema-Shiratzky et al. found that a VR-based intervention was effective in improving attention, inhibitory control, cognitive function, and dual-tasking in children with ADHD[56]. In addition, a randomized controlled trial by Zangiacomi et al. found that a VR-based training program was associated with significant improvements in attention and executive function in adults with ADHD[70].

Drigas et al. explored the use of virtual reality and metacognition training techniques for learning disabilities and suggest that VR may be a promising tool for improving cognitive function and metacognitive skills in individuals with learning disabilities, including ADHD, who often struggle with executive functioning and metacognitive skills[21].

The evidence base for the effectiveness of VR-based interventions for the treatment of ADHD symptoms in children is steadily growing[52,21]. However, further research is needed to fully understand the potential benefits of VR in the treatment of ADHD, but current findings suggest that it may be a valuable tool for improving attentional control and reducing ADHD symptoms.

In summary, digital technologies, including virtual reality, show promise as engaging and immersive tools that can enhance the effectiveness of interventions for ADHD. They may also be used to help control emotional and behavioral disorders in the classroom. Further research is needed to fully understand their potential benefits, but current findings suggest that they may be valuable alternatives for treating ADHD and enhancing motivation in individuals with learning disabilities.

7. DISCUSSION

The literature reviewed in this article suggests that there are promising complementary and alternative interventions for individuals with ADHD, including brain rewiring techniques and digital technologies. These techniques aim to modify the function and structure of the brain to improve cognitive function, self-regulation, and overall quality of life in individuals with ADHD. Specifically, cognitive-behavioral therapy, mindfulness-based interventions, neurofeedback, Neuro-Linguistic Programming, clinical hypnosis, exercise, yoga, music therapy, and working memory exercises have all shown promise as complementary treatments for ADHD.

Furthermore, virtual reality has emerged as a potential tool for improving attentional control and reducing ADHD symptoms. By leveraging the brain's neuroplasticity, virtual reality environments can simulate real-world situations to provide learning and behavior modification opportunities. Recent studies have shown that VR-based interventions can potentially improve attention, behavior, and academic performance in children and adolescents with ADHD, as well as executive function in children and adults with ADHD.

However, further research is needed to fully establish the efficacy of these interventions for ADHD treatment, particularly regarding exercise, yoga, music therapy, and working memory exercises. Interdisciplinary and individualized approaches to ADHD treatment may also be necessary, as the effectiveness of these interventions may vary across individuals and may be influenced by factors such as age, gender, comorbid conditions, and treatment history.

Overall, this literature review highlights the potential of brain rewiring techniques and digital technologies as alternative approaches to managing ADHD symptoms. By identifying gaps in the literature and suggesting future research directions, this review can contribute to the development of more effective and individualized approaches to ADHD treatment.

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8. CONCLUSION

In conclusion, we stress the importance of all digital technologies in the field of education and in ADHD training. These technologies are highly effective, productive, facilitate and improve assessment, intervention, and educational procedures through mobile devices that bring educational activities anywhere[77-80], various ICTs applications that are the main supporters of education[81-93], AI, STEM, and ROBOTICS that raise educational procedures to new performance levels[94-105], and games which transforms the education in a very friendly and enjoyable interaction[106-108]. Furthermore, the development and integration of ICTs with theories and models of metacognition, mindfulness, meditation, and the development of emotional intelligence[109-137] as well as with environmental factors and nutrition[73-76], accelerates and improves educational practices and results more than those, particularly in minority children with ADHD, treating.

Moreover, attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder that affects cognitive function, behavior, and social interaction. While medication and behavioral therapy remain the standard of care for ADHD, complementary and alternative interventions that leverage the brain's neuroplasticity have emerged as promising treatments for ADHD.

This literature review provides an overview of the effectiveness of brain rewiring techniques and digital technologies, including cognitive-behavioral therapy, mindfulness-based interventions, neurofeedback, Neuro-Linguistic Programming, clinical hypnosis, exercise, yoga, music therapy, working memory exercises, and virtual reality, for treating ADHD. While further research is needed to fully establish the efficacy of these interventions, interdisciplinary and individualized approaches to ADHD treatment may be necessary, as the effectiveness of these interventions may vary across individuals and may be influenced by factors such as age, gender, comorbid conditions, and treatment history.

By identifying gaps in the literature and suggesting future research directions, this review can contribute to the development of more effective and individualized approaches to ADHD treatment that leverage the brain's neuroplasticity.

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