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PECULIARITIES OF THE CORRELATION BETWEEN NEUROPHYSIOLOGICAL PARAMETERS AND THE INTENSITY OF MANIFESTATIONS OF ADHD IN PRIMARY SCHOOL CHILDREN

PECULIARIDADES DA CORRELAÇÃO ENTRE OS PARÂMETROS NEUROFISIOLÓGICOS E A INTENSIDADE DAS MANIFESTAÇÕES DA ADHD EM CRIANÇAS DO PRIMÁRIO

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ABSTRACT

The article presents a comprehensive analysis of both theoretical foundations and empirical findings regarding the investigation into the correlation between neurophysiological parameters and the intensity of attention deficit hyperactivity disorder (ADHD) manifestations in primary school children. Specifically, the study examines the unique characteristics of this correlation through the utilization of neurophysiological indicators. Within each subgroup of children diagnosed with ADHD, a notable association has been observed between elevated levels of ADHD manifestations, as assessed through the Vanderbilt ADHD Diagnostic Rating Scale (VADRS), and distinctive qualitative aspects of the electroencephalogram (EEG). Additionally, the study identifies certain distinct features of brain bioelectrical activity that deviate from the norm for each respective subgroup. Notably, among children exhibiting prominent hyperactivity and impulsivity, the highest frequency of elevated indicators was consistently observed concerning the fourth type of EEG, whereas the second type of EEG was not commonly encountered within this particular subgroup. Among children with a predominant attention deficit, the second type of EEG demonstrated a prevailing occurrence of the highest mean scores, while the third type of EEG was found to be atypical within this subgroup. These findings have practical implications for the development of a psychological support program, encompassing various aspects such as conducting psychoeducational interventions within the child's environment, strategic planning and selection of corrective and developmental approaches, as well as the establishment of a comprehensive framework consisting of methods and techniques aimed at stabilizing the child's condition.

Keywords: Attention deficit hyperactivity disorder. Neuropsychology. Neurophysiology. Electroencephalogram. Behavioral disorders.

RESUMO

O artigo apresenta uma análise abrangente de fundamentos teóricos e achados empíricos sobre a investigação da correlação entre parâmetros neurofisiológicos e a intensidade das manifestações do transtorno de déficit de atenção e hiperatividade (TDAH) em crianças do ensino fundamental. Especificamente, o estudo examina as características únicas dessa correlação por meio da utilização de indicadores neurofisiológicos. Dentro de cada subgrupo de crianças diagnosticadas com TDAH, uma associação notável foi observada entre níveis elevados de manifestações de TDAH, conforme avaliado pela Vanderbilt ADHD Diagnostic Rating Scale (VADRS), e aspectos qualitativos distintos do eletroencefalograma (EEG). Além disso, o estudo identifica certas características distintas da atividade bioelétrica do cérebro que se desviam da norma para cada subgrupo respectivo. Notavelmente, entre as crianças que exibem hiperatividade e impulsividade proeminentes, a maior frequência de indicadores elevados foi consistentemente observada em relação ao quarto tipo de EEG, enquanto o segundo tipo de EEG não foi comumente encontrado neste subgrupo específico. Entre as crianças com déficit de atenção predominante, o segundo tipo de EEG demonstrou a ocorrência predominante das pontuações médias mais altas, enquanto o terceiro tipo de EEG mostrou-se atípico nesse subgrupo. Esses achados têm implicações práticas para o desenvolvimento de um programa de apoio psicológico, abrangendo vários aspectos, como a realização de intervenções psicoeducativas no ambiente da criança, planejamento estratégico e seleção de abordagens corretivas e de desenvolvimento, bem como o estabelecimento de uma estrutura abrangente composta por métodos e técnicas destinadas a estabilizar a condição da criança.

Palavras-chave: Transtorno de déficit de atenção e hiperatividade. Neuropsicologia. Neurofisiologia. Eletroencefalograma. Distúrbios comportamentais.

Introduction

Attention deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by prominent manifestations during the initial years of formal education, exerting a substantial impact on a child's scholastic learning, behavioral patterns, and emotional well-being. The cardinal pathological features associated with ADHD encompass impulsive behavior, heightened motor activity, and inadequate development of voluntary attention, as defined by the Diagnostic and Statistical Manual of mental disorders (DSM-5, 2013).

Although the manifestations of ADHD primarily manifest as behavioral traits, they are rooted in the distinctive form of the neuropsychological profile (Willcutt et al., 2012).

The application of neuroscientific research methodologies, in conjunction with the integration of psychological assessment outcomes, enables the identification of qualitative attributes of ADHD manifestations during childhood. Furthermore, this approach facilitates the differentiation of distinct subgroups of children with ADHD based on the severity of pathological manifestations, their qualitative characteristics, and patterns of brain functioning.

Electroencephalography (EEG) is a widely utilized and prominent instrumental diagnostic method employed to discern the distinctive aspects of brain bioelectrical activity. It stands as one of the most prevalent techniques in the field of neurophysiological assessment.

Literature review

Currently, there exists a paucity of research pertaining to the neurophysiological parameters of children diagnosed with ADHD, specifically focusing on the distinctive characteristics of brain bioelectrical activity within various subgroups of school-aged individuals with ADHD. However, it has been observed that a considerable number of children with ADHD exhibit notable features, such as elevated frontocentral theta and delta activity compared to age norms. This aberrant activity pattern is often associated with reduced overall alertness, increased drowsiness, and difficulties in sustaining attention when contrasted with typically developing controls (Ahmadi et al., 2020; Loo et al., 2010; Hobbs et al., 2007; Snyder & Hall, 2006).

The examination of EEG findings, alongside their correlation with symptomatology specific to various forms of ADHD, unveiled noteworthy similarities in the central cerebral cortex activity among children exhibiting predominant attention deficit and those diagnosed with combined ADHD. These shared alterations manifested as reduced activity levels and are closely associated with deficits in attentional processes. Conversely, children primarily characterized by hyperactivity did not exhibit analogous cortical changes. Notably, individuals with ADHD showcasing prominent hyperactive and impulsive behaviors displayed decreased activity in the frontal cortex, a pattern also observed in children presenting with combined symptoms. The diminished frontal activity corresponds to an insufficient level of voluntary activity regulation. Conversely, children with predominant attention deficit did not manifest such features in the frontal regions (González-Castroa et al., 2013).

Considering the distinct neurophysiological parameters in children diagnosed with comorbid disorders associated with ADHD is crucial. Among these disorders, tic disorder stands out, with a prevalence of concomitant ADHD ranging from 21% to 90% in individuals with Tourette syndrome (Robertson, 2015; Eapen & Robertson, 2015; Robertson, 2006). Analysis of EEG characteristics in tic disorders has revealed a reduction in connectivity between the frontal cortex and the parietal/temporal/occipital lobes (Duan et al., 2021; Weng et al., 2017).

Autism spectrum disorders (ASD) exhibit a notable comorbidity rate with ADHD, with approximately 50-70% of individuals with ASD displaying concurrent symptoms of ADHD (Rong et al., 2021). Extensive research has consistently indicated the presence of frontal epileptiform EEG abnormalities among children with ASD. Moreover, this group of children faces an elevated risk of developing clinical epilepsy (Kanemura et al., 2013).

Contemporary research findings regarding the distinctive aspects of ADHD, employing EEG methodology, have provided valuable insights into the utilization of power analysis within specific frequency bands. This approach enables the quantification of information on brain rhythms and aids in the identification of neural markers associated with ADHD (Kiiski et al., 2020). Furthermore, recent investigations have highlighted the significance of microstate analysis utilizing EEG, which facilitates the assessment of brain dynamics and their functional relevance in behavioral control and neurological conditions (Gui et al., 2020).

Aim

The objective of this article is to assess the correlation between the pathological manifestations of ADHD and the qualitative characteristics of bioelectrical brain activity. This investigation addresses both theoretical and practical dimensions to inform the development of a psychological support program tailored for children with neurobehavioral disorders.

Research methods

For investigating the unique characteristics of ADHD in children, a modified version of the Vanderbilt ADHD Diagnostic Rating Scale was employed, requiring parental completion. The assessment of neurophysiological indicators entailed the utilization of the EEG method, alongside the implementation of daily monitoring to capture brain bioelectrical activity patterns comprehensively. Of particular significance was the utilization of neural mapping techniques to analyze EEG indicators, as this approach holds promise in providing precise insights into the neurophysiological correlates of ADHD (Lenartowicz & Loo, 2015). The EEG-based study was conducted at multiple institutions, including the KNP "Regional Clinical Children's Hospital" in Kropyvnytskyi, the MedInvest Diagnostic and Treatment Center in Zaporizhzhia, and the Medicom Clinic in Kyiv. The completion and subsequent analysis of the Vanderbilt ADHD Diagnostic Rating Scale were carried out at the Kyivsky Dvorik Center for Psychology and Development located in Kyiv.

The results of the study were processed using correlation analysis. The Kruskal-Wallis H test was employed to assess differences in the equality of medians among multiple samples. This statistical test was chosen due to its ability to discern variations in median levels across different groups.

Results

The issue of ADHD has garnered increasing attention in the contemporary world. The growing population of children displaying attention deficit disorders, impulsivity, and hyperactivity necessitates further comprehensive investigation into this matter, encompassing its etiology as well as qualitative and quantitative manifestations. The significance of studying ADHD is further amplified by its high comorbidity rates, potential for associated secondary disorders, and the development of compensatory mechanisms as tertiary adjustments in affected children. Such compensatory mechanisms may manifest as opposition, negativism, verbal and physical aggression, withdrawal from social interactions, and difficulties in learning. In this article, we delve into the analysis of ADHD, particularly concerning its association with the distinctive features of EEG indicators.

During the completion of the questionnaire, parents were requested to respond to 50 items. Each item was scored on a scale ranging from 0 to 3, where 0 represented "never observed" and 3 indicated "observed very often." In the final block (questions 41-50), a scoring range of 1 to 5 was utilized. The questionnaire items were categorized into distinct blocks and assigned to one of seven subscales:

1. Attention deficit subscale.
2. Hyperactivity subscale.
3. Impulsivity subscale.
4. The subscale of opposition (protest) reactions.
5. The subscale of other behavioral manifestations.
6. The subscale of anxiety-depressive symptoms.
7. The subscale of social adaptation.

The responses to the questions within the first four subscales were compared against their respective mean values. The scores from the hyperactivity subscale and impulsivity subscale were combined. Subsequently, based on the findings of the data analysis, the children were classified into four distinct subgroups: those with a dominant hyperactivity profile, those with a dominant attention deficit profile, those with a mixed form of ADHD, and those with social adaptation problems. The scores from the subscales were aggregated, and the mean value for each subgroup was calculated (see Table 1).

Table 1 – The results of the Vanderbilt ADHD Diagnostic Rating Scale

Subgroup name	Number of children	Subscales (mean values)					
		1	2+3	4	5	6	7
With hyperactivity	32	8,4	13,28	4,06	0,53	4,06	24,8
With attention deficit	35	14,8	6,4	4,06	1,23	2,77	26,02
Combined form	29	14,86	15,8	5,86	2,2	2,14	26,45
With social adaptation issues	26	4,5	3,35	3,6	0,54	1,3	34,04

The study included children aged between 6 and 9 years old who were either in the early stages or already enrolled in a formal educational program. Out of the participants, 21 children received homeschooling, 14 children received homeschooling along with remedial classes, 42 children attended inclusive classes, 20 children attended both inclusive classes and remedial classes, and 45 children were enrolled in regular classes. All the children included in the study had a diagnosis of ADHD. Among the respondents, there were 27 girls and 95 boys.

The average age of children was calculated for each subgroup as follows:

1. In the subgroup of children with a dominant profile of hyperactivity and impulsivity, the average age was 6.7 years.
2. In the subgroup of children with a dominant attention deficit profile, the average age was 8.5 years.
3. In the subgroup of children with a mixed form of ADHD, the average age was 8.7 years.
4. In the subgroup of children with social adaptation problems, the average age was 9.3 years.

Based on the analysis of the EEG results, the children were classified into the following subgroups:

1. Subgroup exhibiting signs of immaturity in the frontal and central cortex.

2. Subgroup showing mild diffuse changes in cortical activity, indicating neurophysiological immaturity of the cortex.
3. Subgroup demonstrating disorganized changes in bioelectrical activity involving the anterior and posterior cortex, as well as the structures of the limbic system and subcortical structures.
4. Subgroup displaying signs of immaturity in the diencephalic brainstem structures.

Table 2 presents the mean scores for each subscale of the Vanderbilt ADHD Diagnostic Rating Scale along with their association with EEG type. In the data labeling, the highest scores on each subscale were denoted by two asterisks (**), while the second-highest scores were indicated by one asterisk (*).

According to the obtained results, the highest mean scores on the inattention scale are associated with the fourth type of EEG, characterized by signs of the immaturity of the diencephalic brainstem structures. The second most significant scores are found in the subgroup of children with the second type of EEG, which exhibits mild diffuse changes in cortical activity and signs of neurophysiological immaturity of the cortex. The lowest values are observed in children with the first type of EEG. Regarding impulsivity and hyperactivity, the highest average scores are observed in the third type of EEG, characterized by disorganized changes in bioelectrical activity in the anterior and posterior cortex, as well as the involvement of the limbic system and subcortical structures. The second most significant scores are found in the first type of EEG, which is associated with detected signs of immaturity of the frontal and central cortex. Children with the second type of EEG exhibit the lowest scores. In terms of opposition reactions, the highest mean scores are observed in children with the first and fourth types of EEG, while the lowest scores are found in children with the second type of EEG. Regarding the subscale of other behavioral manifestations, the most significant scores are observed in the group of children with the first type of EEG, followed by children with the third type of EEG. The lowest scores are observed in children with the second type of EEG.

Indicators of anxiety and depression exhibit the highest correlation with the first type of EEG. The second most significant indicators are observed in the group of children with the third type of EEG. Children with the second type of EEG display the lowest indicators in terms of anxiety and depression.

Overall, it is worth noting that the scores on scales 4.5 and 6 exhibit insignificant differences in the type of EEG, based on the obtained results. This suggests a stronger association of these indicators with other groups of factors, particularly the characteristics of the socio-psychological environment.

Regarding social adaptation indicators, the highest level of variance was observed in children with the second type of EEG, followed by children with the first type of EEG (second in terms of significance). The lowest indicators were found in children with the third type of EEG.

Table 2 – Average values of indicators by subscales of the Vanderbilt ADHD Diagnostic Rating Scale concerning the type of EEG

EEG type	Number of children (N=122)	1	2+3	4	5	6	7
EEG Type 1	29	7,83	11,03*	4,8**	1,41**	2,86**	27,83*
EEG Type 2	29	9,89*	4,96	3,83	0,89	2,2	30,45**
EEG Type 3	16	9,12	15**	4,31	1,19*	2,56	25,4
EEG Type 4	48	10,54**	10,23	4,6*	1,1	2,81*	26,27

*** – The highest indicators for each of the subscales.*

** – The second most significant indicators.*

Thus, it is possible to analyze the distribution of ADHD indicators by subscales of the Vanderbilt questionnaire for each type of EEG, relative to the total number of the highest values:

1. The first type of EEG showed the highest average values for subscales 4, 5, and 6, and the second highest values for subscales 2, 3, and 7.
2. The fourth type of EEG exhibited the highest scores on the subscale of attention deficit (1) and the second highest scores on subscales 4 and 6.
3. The second and third types of EEG demonstrated a relationship with the highest mean values for one of the subscales (7 and 2+3, respectively),

and with one of the subscales, they showed a relationship with the second most significant indicators (1 and 5).

Separately, the distribution of indicators by subscales of the Vanderbilt ADHD Diagnostic Rating Scale was analyzed for each of the selected subgroups of children with ADHD, based on their EEG type. The analysis of indicator distribution in the subgroup of children with hyperactivity and impulsivity problems (Table 3) revealed that the highest average scores were associated with the fourth type of EEG. This EEG type exhibited the highest average values for subscales 4 and 6, and the second highest values for subscales 1, 2+3, 5, and 7. Additionally, the third type of EEG showed the largest number of high values, with the highest scores observed for scales 1, 2+3, and 7, and the second highest scores for subscales 5 and 6. In contrast, the first type of EEG in this subgroup was associated with the highest mean scores on subscale 5 and the second highest scores on subscale 4. The second type of EEG was not characteristic of the subgroup of children with hyperactivity and impulsivity.

Table 3 – Mean values of the Vanderbilt ADHD Diagnostic Rating Scale subscales concerning the type of EEG for a subgroup of children with hyperactivity and impulsivity issues

EEG type	Number of children (N=32)	1	2+3	4	5	6	7
EEG Type 1	10	6,2	12,7	4,3*	0,6**	3,8	24,6
EEG Type 2	–	–	–	–	–	–	–
EEG Type 3	6	7**	13,83**	2,83	0,5*	3,83*	25,3**
EEG Type 4	16	6,56*	13,44*	4,4**	0,5*	4,31**	24,75*

In the subgroup of children with attention deficit disorder, the highest correlation of mean scores on the subscales of the Vanderbilt Questionnaire was found with the second type of EEG, as determined by the Kruskal-Wallis H Test (Table 4). This particular EEG type was associated with the highest mean scores on subscales 1 and 5. The second-highest scores were observed for subscales 2+3, 6, and 7. The first type of EEG showed the largest number of high mean values, specifically for subscales 2+3, 6, and 7. The fourth type of EEG demonstrated a correlation with the second most significant indicators for subscales 1 and 7.

Notably, no children with the third type of EEG were present in the subgroup of children with attention deficit disorder.

Table 4 – Mean values of the Vanderbilt ADHD Diagnostic Rating Scale subscales concerning the type of EEG for a subgroup of children with attention deficit disorder

EEG type	Number of children (N=35)	1	2+3	4	5	6	7
EEG Type 1	4	12,75	7,25**	3,25	1	4,25**	27,5**
EEG Type 2	14	15,36**	6,43*	4,14	1,28**	2,86*	25,93*
EEG Type 3	–	–	–	–	–	–	–
EEG Type 4	17	14,76*	6,23	4,41	1,23*	2,36	25,76

In the subgroup of children with combined ADHD, the highest number of high mean scores was observed with the first type of EEG, as indicated in Table 5. This EEG type exhibited the highest mean scores on subscales 2+3, 4, 5, 6, and 7, along with the second-highest scores on subscale 1. The fourth type of EEG in this subgroup showed the highest mean scores on subscale 1 and the second highest scores on subscales 4, 5, 6, and 7. The third type of EEG demonstrated the second-highest mean scores on subscales 2+3. Notably, no children with the second type of EEG were present in this subgroup.

Table 5 – Mean values of the Vanderbilt ADHD Diagnostic Rating Scale subscales concerning the type of EEG for a subgroup of children with combined ADHD

EEG type	Number of children (N=29)	1	2+3	4	5	6	7
EEG Type 1	9	10,6*	16,2**	6,6**	3,1**	2,4**	28**
EEG Type 2	–	–	–	–	–	–	–
EEG Type 3	10	10,4	15,7*	5,2	1,6	1,8	25,4
EEG Type 4	10	12,2**	15,5	5,8*	2*	2,2*	26,1*

In the subgroup of children with social adaptation problems, a significant association was observed with the second type of EEG, as presented in Table 6. This EEG type displayed the highest scores on subscales 6 and 7, as well as the second-highest scores on subscales 1, 4, and 5. The fourth type of EEG was linked to the highest mean scores on subscales 1 and 5, along with the second highest scores on subscale 7. Additionally, the first type of EEG exhibited the highest scores on subscale 4 and the second highest scores on subscale 6. However, the third type of EEG was not commonly observed among children in this subgroup.

Table 6 – Mean values of the Vanderbilt ADHD Diagnostic Rating Scale subscales concerning the type of EEG for a subgroup of children with social adaptation issues

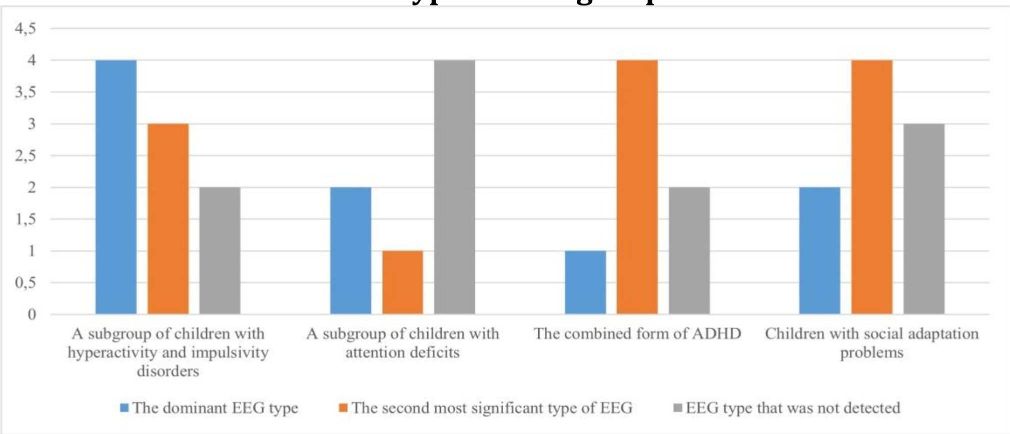
EEG type	Number of children (N=26)	1	2+3	4	5	6	7
EEG Type 1	6	3	3	3,83**	0,5	1*	33,16
EEG Type 2	15	4,8*	3,6	3,53*	0,53*	1,6**	34,6**
EEG Type 3	–	–	–	–	–	–	–
EEG Type 4	5	5,6**	3	3,6	0,6**	0,8	33,2*

Thus, within each subgroup, the dominant types of EEG were identified, along with specific features of bioelectrical brain activity that are not prevalent among children in each subgroup (refer to Histogram 1):

1. The subgroup of children with hyperactivity and impulsivity problems predominantly exhibited the fourth type of EEG, while the third type of EEG displayed the highest number of high average indicators. Children with the second type of EEG were not observed in this subgroup.
2. The subgroup of children with attention deficit disorder primarily showed the second type of EEG as dominant, whereas the first type of EEG correlated with the highest number of high average indicators. Children with the fourth type of EEG were not present in this subgroup.
3. In the subgroup of children with a combined form of ADHD, the first type of EEG was dominant, and the fourth type of EEG ranked second in terms of the number of significant indicators. Children with the second type of EEG were not included in this subgroup.

Within the subgroup of children with social adaptation problems, the second type of EEG emerged as dominant, and the fourth type of EEG exhibited the second-highest number of significant indicators. Children with the third type of EEG were not identified in this subgroup.

Histogram 1 – Distribution of EEG types in subgroups of children with ADHD



The study employed the analysis of variance method. By utilizing the Kruskal-Wallis H Test, the calculations enabled the identification of dispersion indicators within the group of children under investigation concerning their EEG type. The indicators for each subscale of the Vanderbilt ADHD Diagnostic Rating Scale were computed to examine the variations associated with the identified EEG types. The calculations yielded noteworthy distinctions in scales 2+3, which are linked to indicators of hyperactivity and impulsivity (refer to Table 7).

Table 7 – Indicators of the significance of the variance of EEG indicators among primary school children with ADHD

Number of the scale in the VADRS	Average scores for each of the scales in the group of respondents (N=122)	Asymp. Sig. (significance of differences)
1	9,56	0,130
2+3	9,79	0,00
4	4,39	0,345
5	1,13	0,534
6	2,65	0,448
7	27,5	0,160

The obtained indicators of significance amounted to 0.000, indicating that the differences observed in the groups of children with different types of EEG were statistically significant ($P \leq 0.05$). Furthermore, the level of differences reached a high significance level (P≤0.01). These findings suggest that the most substantial differences among the groups were observed in the indicators of hyperactivity and impulsivity, indicating a strong association between EEG types and these ADHD symptoms.

Discussion

The study uncovered the distinctive patterns of brain bioelectrical activity among children in different subgroups. Average indicators of ADHD symptom severity were calculated for each subgroup concerning the type of EEG. This analysis not only identified the EEG types associated with the highest ADHD manifestation scores in each subgroup but also allowed for the identification of EEG types that were atypical for children in specific subgroups. For instance, in children with dominant hyperactivity and impulsivity, the highest number of high scores was associated with the fourth type of EEG, characterized by signs of immaturity in the diencephalic brainstem structures. Dysfunction at these levels can lead to disruptions in neurodynamics, resulting in heightened excitability and secondary delays in the development of the frontal cortex responsible for inhibitory processes and self-organizational skills (Johnston et al., 2014). Conversely, the second type of EEG, characterized by mild diffuse changes in cortical activity and signs of neurophysiological immaturity of the cortex, was not typical in this subgroup. Therefore, these cortical factors can be excluded when discussing potential causes of hyperactivity and impulsivity.

The second type of EEG, characterized by mild diffuse changes in cortical activity and signs of neurophysiological immaturity of the cortex, emerged as the dominant EEG type in terms of the highest average indicators within the subgroup of children with a predominant attention deficit. Conversely, the third type of EEG, characterized by more pronounced and disorganized changes in bioelectrical activity at the anterior and posterior cortex, as well as the involvement of limbic system structures and subcortical structures, was not typical for children in this subgroup.

The subgroup of children with combined ADHD showed the highest number of high scores on the Vanderbilt subscales associated with the first type of EEG, characterized by signs of the immaturity of the frontal and central cortex. These signs may manifest as a general immaturity of volitional function, difficulties with behavioral control, and inhibition of impulsive reactions, leading to a decline in mental activity (Arnsten, 2009). However, a connection with the fourth type of EEG was also observed. In contrast, the second type of EEG, similar to children with dominant indicators of hyperactivity and impulsivity, was not characteristic of children in this subgroup.

The subgroup of children with social adaptation problems demonstrated the dominance of the second type of EEG, which is also observed in children with dominant attention deficits. However, considering the low scores on the primary manifestations of ADHD and the older age of children experiencing social adaptation difficulties, it is possible to hypothesize qualitative changes in ADHD manifestations during ontogeny. Additionally, it is important to consider the influence of past experiences on the child, which may exacerbate the most prominent issues within this subgroup. However, further research is required to investigate this aspect, and at this stage, it can only be regarded as a preliminary hypothesis. The third type of EEG was not characteristic of participants in this subgroup.

Furthermore, the application of the Kruskal-Wallis H Test yielded significant differences in the indicators of ADHD manifestations, specifically impulsivity, and hyperactivity, concerning the specific characteristics of brain bioelectrical activity. These findings hold important prognostic value, as they enable the early identification of underlying mechanisms of these disorders, such as during neuropsychological assessments of children. Moreover, these findings facilitate the prompt development of targeted intervention and developmental programs, enhancing their effectiveness. Additionally, they contribute to a more comprehensive understanding of ADHD manifestations, thus aiding in the formulation of a biologically-based model of ADHD within the child's environment during psychoeducational interventions.

Conclusions

The findings of the study demonstrate a significant relationship between EEG indicators and the intensity of ADHD manifestations. Children exhibiting prominent hyperactivity and impulsivity displayed a strong association with the fourth type of EEG, indicating a high level of connection between ADHD symptoms and this specific EEG pattern. Conversely, the second type of EEG was not commonly observed in this subgroup. In contrast, the subgroup of children with predominant attention deficit demonstrated a dominance of the second type of EEG, while the third type of EEG was atypical for this subgroup. Among children with combined ADHD, the highest scores on the Vanderbilt subscales were linked to the first type of EEG, but a connection with the fourth type of EEG was also noted. Notably, the second type of EEG was not typical for children in this group. In the subgroup of children facing challenges in social adaptation, the second type of EEG prevailed, while the third type of EEG was not commonly observed. Furthermore, the application of the Kruskal-Wallis H-test revealed significant variance indices for hyperactivity and impulsivity symptoms at a high level of significance $P \leq 0.01$ (0.000).

The data obtained in this study hold significant value as they not only establish associations between specific developmental characteristics of children with ADHD and the distinct features of bioelectrical brain activity but also identify dominant and uncharacteristic EEG indicators across different subgroups of children with ADHD.

From a practical standpoint, these findings offer a deeper comprehension of the neurophysiological underpinnings of various ADHD manifestations, thus aiding in the development of targeted correctional and developmental programs. Moreover, the acquired data can enhance the interpretation of results from neuropsychological examinations during childhood and contribute to the effectiveness of psychoeducational interventions within the child's environment. Ultimately, this research contributes to the formulation of a biologically grounded interpretive model, fostering a more comprehensive understanding of ADHD.

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