Chapter

ADHD as a Specific Cause for Learning Disability

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Abstract

In the spectrum of possible causes for discrepancy between the capacity to learn and the level of school achievement, Attention Deficit Hyperactivity Disorder (ADHD) has an important place. The aim of this chapter is to present obtained own results for a group of 200 pupils, mean age 10.5 ± 2.35 years, and both genders, diagnosed as ADHD following DSM-5 criteria. As psychometric tests, Kohs Block Design Test, Achenbach CBCL, ACTeRS, Stroop Color Word Task (SCWT), and Wisconsin Card Sorting Test (WCST) are used. Additionally, Q-EEG recording using Mitsar 19-channel Q-EEG 201 system was performed. Obtained results confirmed the diagnosis of ADHD as well as the presence of serious difficulties in executive system functioning through ERP's component extracted from Q-EEG analysis. In the chapter, results for Q-EEG will be discussed more extensively including subtypes. As a used nonpharmacological therapeutic approach, very positive outcome of neurofeedback treatment of these children is accentuated.

Keywords: learning problems, ADHD, psychometric tests, Q-EEG, neurofeedback

1. Introduction

Being nonattentive, nonpatient, and enable to follow the teacher instructions during classes, children with Attention Deficit Hyperactivity Disorder (ADHD) represent a huge problem in the educational process. They have additionally variety of learning difficulties.

ADHD is a clinically heterogeneous neurobehavioral disorder associated with tremendous financial costs, stress to families, adverse academic, and occupational outcomes. In adult period, this condition is not totally overcome and stay as a huge risk for addiction, dangerous behavior, unsuccessful occupation, high rate of divorces, etc.

The diagnostics of this condition change in different periods of time. As "a minimal brain damage" or as "minimal brain dysfunction," the condition was named till the 1994, where for the first time, it was renamed as Hyperkinetic Disorder. Three main symptoms, inattention, impulsivity, and hyperactivity, are listed in both manuals, the International Classification of Diseases (ICD-10) where the disorder is named as "Hyperkinetic Disorder" (HKD) and the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) where it is named as Attention Deficit Hyperactivity Disorder (ADHD). In DSM-IV, the diagnostic includes three different groups of children: the predominantly Hyperactive-Impulsive Type, the predominantly Inattentive Type, and the Combined Type of ADHD. It was approved that this disorder is more frequently found in boys [1] with the ratio of boys to girls being approximately 4:1 for all three subgroups [2].

In May 2012, American Psychological Association was revising the Fourth Edition of the Diagnostic and Statistical Manual of Mental Disorders, which included some changes in the section on specific learning disabilities. Consequently, DSM-5 considers Specific Learning Disability (SLD) as a type of Neurodevelopmental Disorder that delays the ability to learn or use specific academic skills (e.g., reading, writing, or arithmetic). In this context, SLD is a clinical diagnosis that is not necessarily synonymous with "learning disabilities" used mainly within the education system. SLD characterizes the specific manifestations of learning difficulties at the time of assessment in three major academic domains, namely reading, writing, and mathematics. The group of entities named as "Other Neurodevelopmental Disorders" includes Intellectual Disability, Autism Spectrum Disorder, Attention-Deficit/Hyperactivity Disorder, and Communication Disorders and Motor Disorders. Consequently, whatever criteria for diagnostics are followed, ADHD stays as a huge cause for learning problems.

The differences in diagnostic criteria following different manuals have influenced to the different prevalence rates. As a result, HKD is estimated to be present in approximately 0.5% of children, whereas ADHD has been reported in between 5 and 11.4% of the population [3]. The differences in diagnostics have important implications for both, diagnosis and treatment, because depending on which criteria are used, a child may or may not be considered to have a clinical disorder, which subsequently will influence on the decision about his/her involvement in the school process as well as the need of some treatment.

Many researchers mentioned that ADHD in reality represents a continuum from normal to abnormal behavior. Especially, behavioral studies of children with a predominance of inattentive type have found these children to have some specific problems. For example, inattentive children are less impulsive and less manifest conduct problems than hyperactive children. By contrast, they are more anxious, socially withdrawn, and shy and have more internalizing symptoms. Additionally, they present more frequently academic underachievement and learning problems. Inattentive children are easily confused, stare frequently, often daydream, and they are lethargic, hypoactive, and passive, which are not common in hyperactive children. More specifically, in inattentive children, it was approved deficits in speed of information processing and in focused or selective attention, whereas in the combined type of ADHD, the problem of sustained attention (persistence) and distractibility is more characteristic. These findings suggested that maybe inattentive children should be treated as special group of disorder and not be considered only as a form of ADHD [4].

Although genetic markers in the identification of children with ADHD were not jet found, it was proven that dopamine-related genes are involved in the pathogenesis (such as D1, D2, and D4) [5, 6]. Some form of heredity is additionally confirmed with the fact that this condition could be present in the same family members, especially in twins [7]. In a few recent findings, it was showed that attention deficit hyperactivity disorder (ADHD) shares similar genetic roots and brain structure with autism and obsessive-compulsive disorder (OCD). The impulsivity is characteristic behavior in all three conditions. Additionally, the brain architecture in these conditions presents abnormal findings especially in the structure of the corpus callosum, together with widespread disruptions in white matter. However, children with OCD present fewer structural alterations in comparison with those with autism or ADHD. It is the possible reason that children with autism as well as ADHD manifest earlier specific symptoms in comparison with OCD, which could have a start even in adolescence. Some rare genetic variants associated with autism and schizophrenia also increase a person's chance of having attention deficit hyperactivity disorder (ADHD) [8, 9].

Performing genetic analysis, eight copy number variants (CNVs) are identified, which are more common in people with ADHD than in those without this problem. These same CNVs are also implicated in autism and schizophrenia. In this context, the new hypothesis arises that autism, schizophrenia, and ADHD could have similar biological underpinnings [10]. However, findings do not approve susceptibility genes of larger effect for ADHD, but they can identify genes of smaller effect. Whole genome linkage studies have provided some interesting results for chromosomal regions that need to be further investigated.

The complexity of the ADHD phenotype combined with some genetic findings suggests that identifying endophenotype may be a useful strategy for exact diagnosis. An endophenotype, i.e., intermediate phenotype, is defined as a quantitative biological trait, which is heritable, is reliable in reflecting the function of a discrete biological system, and is presumed to be more closely related to the genetic cause of the disease than the clinical phenotype. The integration of these two approaches (endophenotype and genetic variants) will possibly yield to more definitive results. In this context, increased theta power in EEG record is supposed to be a candidate biological marker of genetic risk for ADHD [11].

In order to find possible neurologic basis for ADHD, many imaging techniques are used. Positron Emission Tomography confirmed that brain metabolism in children with ADHD is lower in the areas responsible for the attention, social judgment, and movement. It is confirmed also with fMRI, SPECT, or BOLD techniques. However, Q-EEG recording appeared to be more available, inexpensive, and useful indicator of brain metabolic activity. It is confirmed that low metabolic activity in the area that generates the corresponding EEG signals is characterized by increasing the slow activities (delta and theta waves) and decreasing the fast beta activities. Strong evidence for the usefulness of the Q-EEG in the diagnostic assessment of ADHD comes from a study performed by Monastra and his team [12, 13].

Many studies confirmed that the main brain system, which is impaired in ADHD, is the executive system. Two parameters are specific for the executive system: (1) arousal, as a generalized activation of the system and (2) attention/focused activation of the system, associated with working memory, action selection, action inhibition, and action monitoring.

As was mentioned before, endophenotype is becoming an important concept in the study of ADHD. The endophenotype in psychiatry can be categorized as anatomical, developmental, electrophysiological, metabolic, sensory, or psychological/cognitive. In this way, endophenotype represents simpler indicator for genetic mechanism than the visible behavioral symptoms. It helps to define subtypes of a particular disorder and can be used as a quantitative trait in genetic analysis of proband and families. In this way, Q-EEG spectrum classification of ADHD population has been developed, defining four main endophenotypes: I subtype where abnormal increase of delta-theta frequency range centrally or centrally frontally is dominant; II subtype where abnormal increase of frontal midline theta rhythm is present; III subtype with an abnormal increase of beta activity frontally; and IV subtype characterized with an excess of alpha activities at posterior, central, or frontal lobes [14].

Still, the complexity of ADHD influences on the underdiagnoses or misdiagnosis of this condition in many school children. Contrary, some hyper diagnostics are also possible. For example, in my research, many gifted children obtained the diagnosis as ADHD because the usual school program for them has been boring, and they manifested hyperactive behavior. The misdiagnose could be also the result of many comorbid disorders, which accompanied ADHD such as conduct problems, high general anxiety, depression, speech problems, autism spectrum disorder, or epilepsy. In this situation, the true ADHD could be overlapped by other similar conditions. From a neuropsychological perspective, comorbidity is considered to be the result of the same brain and cognitive mechanisms involved in attentional and behavioral regulations.

2. Sample and methods

The aim of this chapter is to present own results for a group of 200 pupils, mean age 10.5 ± 2.35 years, and both genders, diagnosed as ADHD. The majority of examinees are boys (85%) manifesting deficit of attention and concentration together with hyperactivity. In girls, the inattention was the main problem. In all of them, school achievement was less than it was been expected by parents and teachers.

Beside interview and clinical examination, the diagnosis is made by multidisciplinary team (pediatrician, neurologist, and psychologist), according criteria noted in DSM-5 manual. All children were tested with Kohs Block Design Test, the Stroop Color Word Task (SCWT), and Wisconsin Card Sorting Test (WCST) and recorded with Q-EEG. Mothers fulfilled Child Behavior Checklist (CBCL) and ADD-H: Comprehensive Parent Rating Scale (ACTeRS). Obtained results are compared with the results for control group, which is consisted of 50 healthy children matched by age and gender.

The Child Behavior Checklist (CBCL) [15], fulfilled by mothers, contains 113 questions related to depression, social communication or withdrawal, somatic complaints, some schizoid traits, hyperactivity, problems in the psychosexual development, problems in the conduct, problems with the judgment, and level of anxiety. Several forms of this instrument are available depending on the age and gender of the examinees. Symptoms are grouped as internalized and externalized. They reflect a distinction between fearful, inhibited, over controlled behavior and aggressive, antisocial, under controlled behavior. The profile can contribute to a formal diagnosis by showing the degree of child's deviance in behaviors that parents could observe better than clinicians, as well as to help to organize effective therapeutic approach.

ACTeRS [16] is composed of 24 items that measure four separate entities: attention, hyperactivity, social skills, and oppositional behavior. This instrument was developed by researchers at the University of Illinois Institute for Child Behavior and Development. In our research, ACTeRS is fulfilled also by mothers. The instrument shows the level of attention, hyperactivity, social skills, and oppositional behavior presented on percentile scale.

The Kohs Block Design Test [17] is performance test standardized to measure intelligence level for mental ages 3–19. The test is easy and understandable without the need of many verbal explanations. In this context, it is especially valuable for testing those with language and hearing difficulties. The test consists of 16 colored cubes and 17 cards with colored designs, which the subject is invited to replicate. Kohs cubes are used to assess the analytic, synthetic, and logic thinking. Block design test possesses a high degree of correlation and reliability with Binet-Simon IQ test and WISC.

The Stroop Color and Word Test (SCWT) [18] was designed to discover possible organic cause of disorder. It assesses cognitive function and provides diagnostic information on possible brain dysfunction due to organic lesions. The test is quick and easy for administration, and it is based on the facts that reading words are faster than the identification of the presented color. The validity and reliability make it a highly useful instrument.

The Wisconsin Card Sorting Test (WCST) [19] is a neuropsychological test for evaluating the mental flexibility ("set shifting") when the stimulus is changed, e.g., the attention, the working memory, and visual processing.

WCST and SCWT were performed using software named Computer Assisted Neuropsychological Diagnostics and Therapy (CANDIT) developed by the Institute of Neuropsychology, Zurich, Switzerland. Each evaluation of the child takes about 2-h duration.

The electrophysiological assessment was performed with system Mitsar 19-channel QEEG 201 (Mitsar Ltd). Quantitative EEG (Q-EEG) is a collection of quantitative methods designed to process EEG signals. The Q-EEG includes spectral and wavelet analyses of the EEG signals. The recording is made up of two conditions, eyes closed and eyes open, lasting 5 min each. In the following, data were recorded, while subjects were performing a visual continuous performance task (VCPT) from Psytask program designed by the Human Brain Institute in Saint Petersburg, Russia. This program comprises the Go/No Go task, which performance is associated with a group of psychological operations named as executive, such as detection and recognition of the stimulus, refreshing the working memory, initiation, and/or inhibition of the behavior and monitoring of the action results. The duration of the tasks was approximately 22 min. Separate channels for recording a signal from the button were used for monitoring the accuracy of the test performance and measuring the response trial.

Electrodes were placed according to the International 10–20 system using an electrode cap with tin electrodes (Electrocap International Inc.). The input signals referenced to the linked ears were filtered between 0.5 and 50 Hz and digitized at a sampling rate of 250 Hz. The impedance was kept below 5 kΩ for all electrodes. The quantitative data were obtained using WinEEG software.

The results obtained from the psychometric measuring are presented in a form of scores and compared with test norms, adopted by the age and gender of the examinees, and presented in figures and tables. The results are considered to be statistically significant at a significance level of 0.05. The data from the electrophysiological assessment were transformed with Fourier analysis and compared with a normative database, grouped by their age. For calculations in this research, the statistical program STATISTICA 10.0 was used.

3. Results and discussion

(At the beginning of this part, I must confirm that presented results are a compilation of different groups of examinees evaluated at different times, and some of them are published in Macedonian journals).

As a start in the evaluation of children with learning problems, testing the intelligence level is of primary importance. Obtained results are very useful for further evaluation especially for exclusion of the intelligence as a factor for presented problems. Evaluation with Kohs Block Design Test showed that ADHD children have intellectual capacities in the norm (IQ = 96 ± 13.15). Mean school notes were as follows: mathematics 3; language 4.5; and nature and society 3 (range 1–5).

Profile obtained for ACTeRS, fulfilled by mothers, confirmed abnormal scores in the scales for attention, social adaptation, and oppositional behavior (between 10 and 23 percentiles), which corresponds with the core symptoms of the disorder. Boys and girls presented similar results, although boys are more hyperactive than girls (**Figure 1**).

CBCL fulfilled also by mothers showed for boy's accentuated anxiety, depression, social withdrawals, and aggressive behavior. Girls are also with social withdrawals, hyperactive, and manifest delinquent behavior (**Figure 2**).

The Q-EEG assessment generally showed dominant theta activity (4–8 Hz) and deficit of beta activity (16–20 Hz) (**Figure 3**).

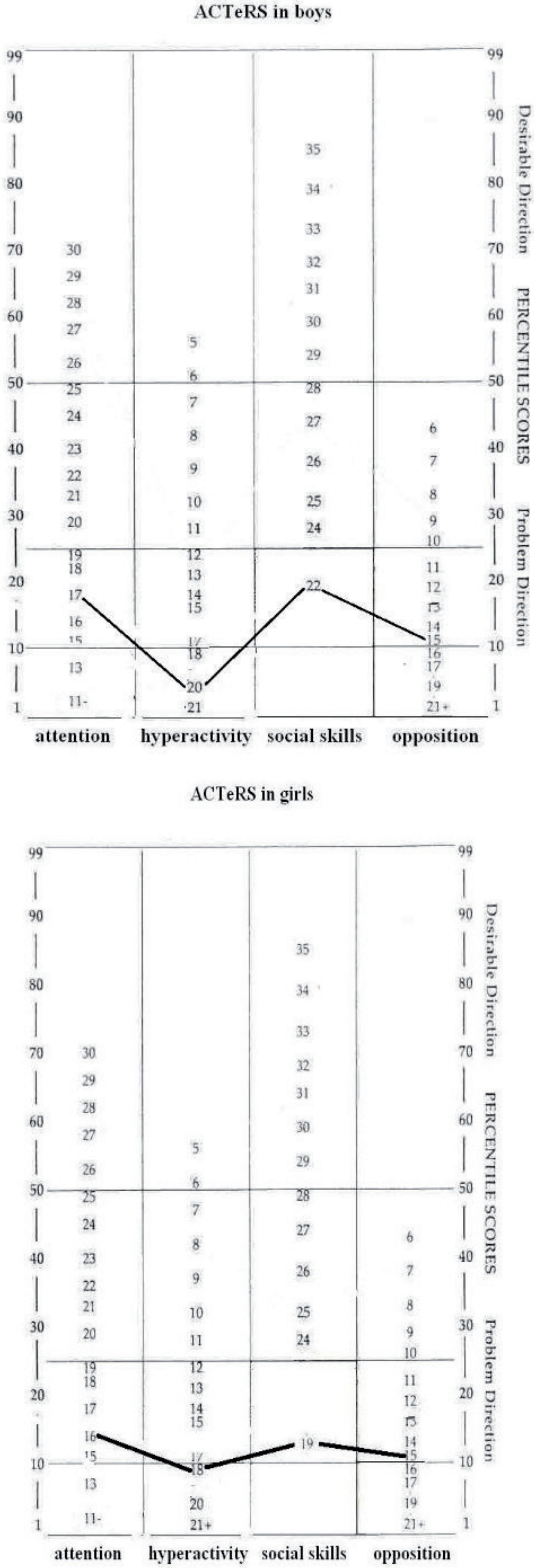

Figure 1.
Profiles obtained for ACTeRS.

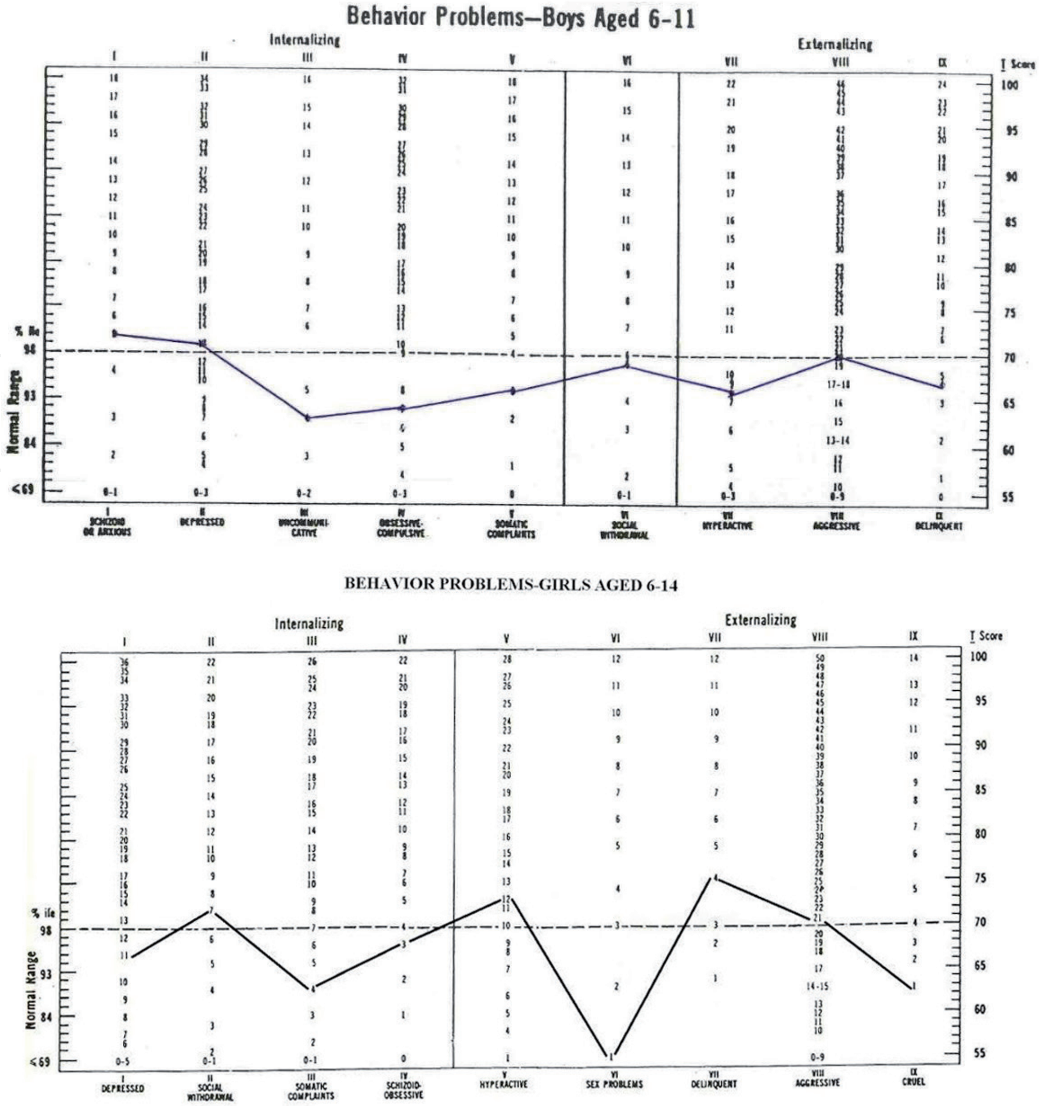

Figure 2.
CBCL profiles for boys and girls.

Theta/beta ratio is presented in **Figure 4**.

The endophenotype presented in Q-EEG records is evaluated according to Kropotov's typology [20]. In Macedonian ADHD children (N = 200), majority (48%) belongs to the combined 1 and 2 subtypes. The other 25% of children showed very slow alpha excess (subtype 4), which corresponds to inattentive form of ADHD mainly found in girls. In another 25%, we found high theta/beta ratio in frontal-central cortex (subtype 1). The subtype 3 with overactive cortex is rarely found in our sample (under 2%).

VCPT, as a part of Q-EEG analysis, showed that hyperactive children performed significantly much omission and commission errors, longer reaction time (RT), and high variation of the reaction time (var RT) compared with test norms (**Table 1**).

The analysis of P3Go component (activation processes) did not showed significant differences concerning the latency and amplitude, while for P3NoGo component (inhibition processes), the latency is not disturbed, but the amplitude is statistically lower (**Table 2**).

Generally, psychometric and psychophysiological evaluation of the examinees confirmed the hyperactivity, average intellectual capacities, and significant number of perseverative and nonperseverative mistakes. Results for VCPT showed significantly higher number of omission and commission errors related to the inattention, shorter reaction time (RT), and higher variation in reaction time (var RT) than test

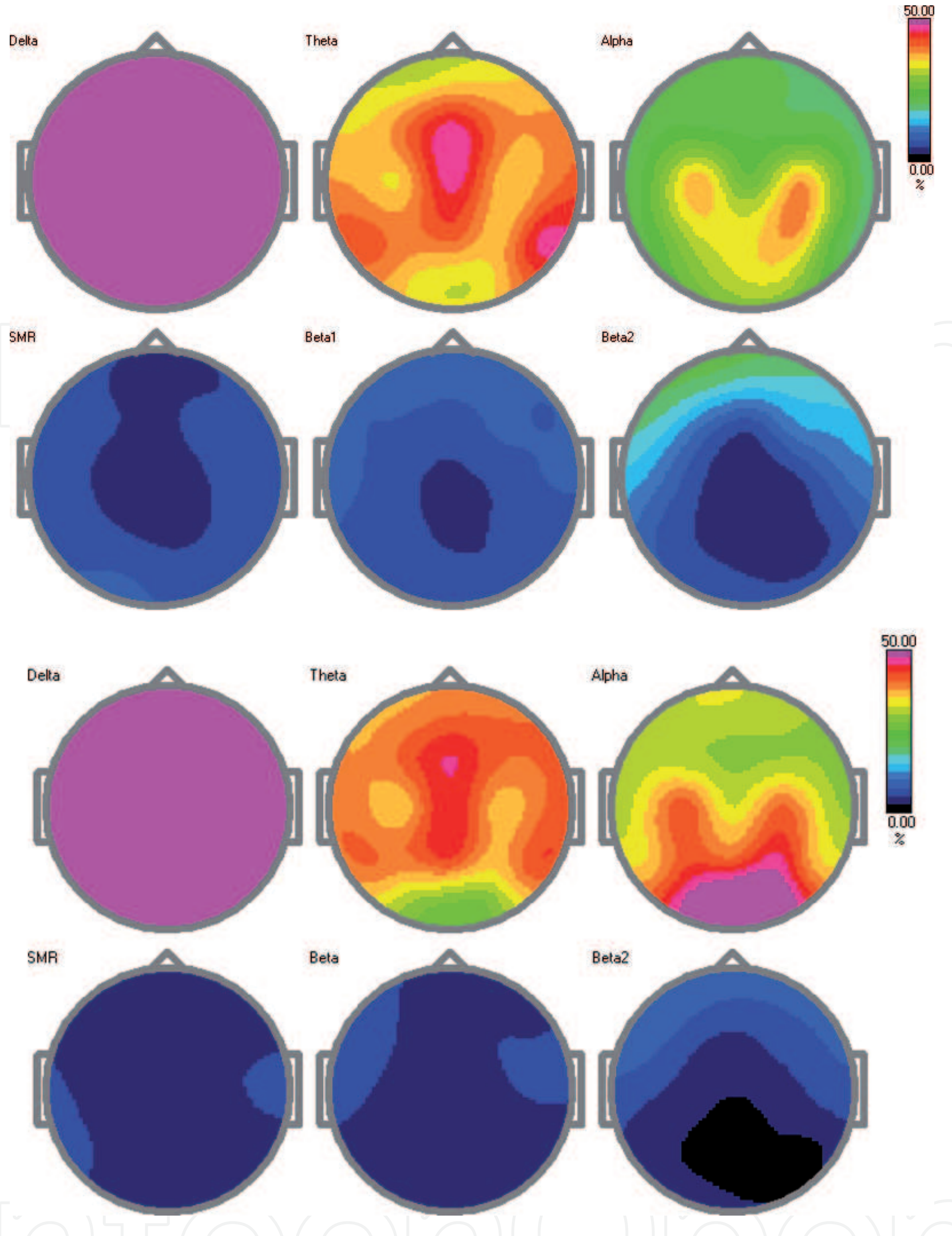

Figure 3.
Average maps of relation of EEG power spectra in ADHD children (EO upper, EC below).

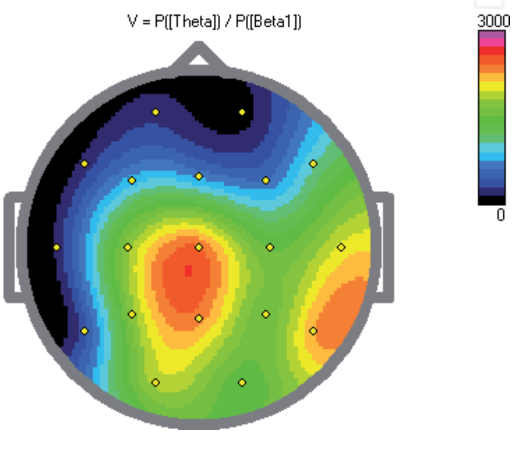

Figure 4.
Theta/beta ratio.

VCPT	ADHD	Norm	*t* test	*p* value
Omission errors (Go)	32.25	4	15.65	0.00001*
Commission errors (NoGo)	4.75	1	7.58	0.00000*
RT(ms) Go	456.89	486	−9.17	0.0001*
var RT	18.97	11.7	8.78	0.0000*
$^*p < 0.01$.				

Table 1.
Results for VCPT in ADHD children.

ERP	ADHD	Norm	*t* test	*p* value
P3Go (ms)	327.15	327.89	−0.12	0.9
P3Go (mV)	9.73	8.55	0.77	0.44
P3NoGo (ms)	402.05	415.78	−0.69	0.49
P3NoGo (mV)	4.67	6.23	−2.89	0.006*
$^*p < 0.01$.				

Table 2.
Components P3Go and P3NoGo in ADHD group.

norms. Values of P3Go component in latency and amplitude are different from the norm, while P3NoGo component showed significant difference in the amplitude.

For better understanding obtained results of analysis, a schematic presentation of components included in executive functions of the brain is shown in **Figure 5**. The components are associated with distinct psychological operations, such as engagement operations (P3bP component), comparison (vcomTL and vcomTR), motor inhibition (P3supF), and monitoring (P4monCC) operations. The ERP results in our evaluated children showed significantly lower amplitude and longer latency for the engagement (P3bP), motor inhibition (P3supF), and monitoring (P4monCC) components, which confirm the executive dysfunction.

In the treatment of our clients, we applied behavior therapy, and especially some biofeedback modalities. Any stimulant medication is not allowed in our country.

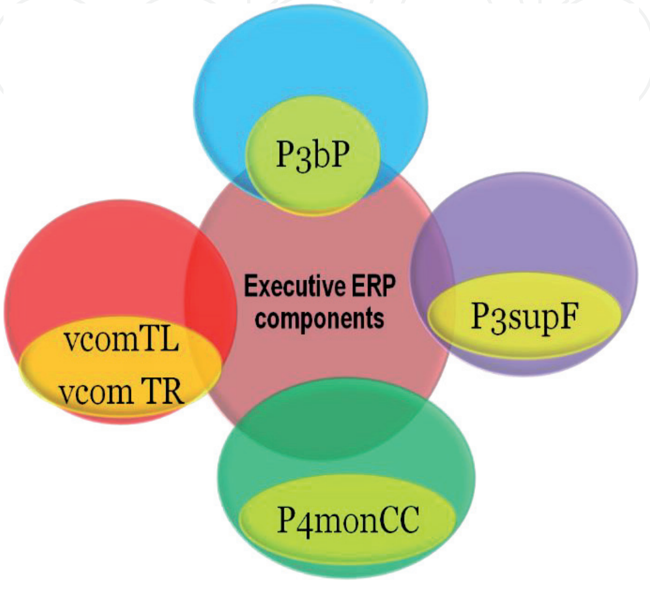

Figure 5.
Executive ERP components.

We introduced biofeedback methodology in 1996 as the first team in our region. Biofeedback is a technique, which helps to learn the control of unaware body's functions (heart rate, dermal activity, muscle tension, peripheral temperature, breathing frequency, brain waves, etc.). Biofeedback could be peripheral or central – neurofeedback. Neurofeedback is a specific behavioral therapy technique used to teach or improve self-regulation of brain activity. The goal of frequency band neurofeedback is to activate a specific brain network.

Common protocol for neurofeedback in many studies comprised diminishing theta activity and optimizing beta brain activity in specific skull points depending on the Q-EEG subtype [21–24]. For our group with ADHD, we used personalized biofeedback protocols depending on the Q-EEG subtype. Generally, we started with 3–5 sessions of electro dermal biofeedback for diminishing anxiety and stress level, and in the following, we used the neurofeedback, two times per week, in the duration of 50 min for each session. **Table 3** shows obtained results before and after biofeedback application in our patients. It is clear that with this kind of therapy, we achieved diminishing of theta, higher power of beta brain waves, changes of theta/beta ratio, and change of brain rate parameter.

In the assessment of ADHD, patient's theta/beta ratio is a parameter used in many studies [24, 25]. The brain rate parameter is indicator introduced by Pop-Jordanova N. and Pop-Jordanov J. for the evaluation of general mental arousal [26, 27]. The values of this parameter are approved in other studies performed in our country [28–30].

The most commonly reported finding in electrophysiological studies of children with ADHD is increased low frequency activity (predominantly theta) compared with age-matched normal controls. Our results are similar and correspond to the previous research examining electrophysiological measures in children and adolescents with ADHD compared with normal controls, which generally reported an increase in theta activity [31, 32] and a decrease in beta activity [33].

Having in mind that ADHD is a complex syndrome, the diagnosis must include large neuropsychological assessment to evaluate mainly the executive system because the symptoms could be different from child to child. In this context, the analysis of ERP's component extracted from Q-EEG records is a modern approach in the diagnosis of ADHD showing the difference in amplitude or latencies. Van der Meere [34] supposed that the smaller amplitude of P3 component is the result of smaller ability for the engagement of the child in the task performance. Additionally, Keage et al. [35] obtained shorter latencies of P3 component in ADHD patients. It must be mentioned that the executive system is changeable through the developmental process, which suggests that ADHD could be the result of slower developmental of some neurological parts of the brain. It is the reason why some children overcome hyperactivity and impulsivity with maturation.

In a multicenter study [24], the theta/beta ratio was found to discriminate ADHD patients and normal controls with high sensitivity and specificity. In this context, Snyder and Hall [36] based on meta-analysis concluded that

Parameter	Before NF (μV)	After NF (μV)	*t* test	Significance
Beta brain waves	4.86 ± 1.6	8.0 ± 1.38	5.23	$p < 0.01$
Theta brain waves	20.95 ± 1.38	15.29 ± 1.38	8.47	$p < 0.01$
Theta/beta	4.7 ± 1.38	2.0 ± 1.6	4.5	$p < 0.01$
Brain rate	7.86 ± 0.56	8.22 ± 0.63	6.6	$p < 0.01$

Table 3.
Main parameters before and after neurofeedback training.

the theta/beta ratio has much higher predictive power than rating scales do, for separating ADHD for healthy children. However, the absolute and relative power of theta is higher in young children than in adolescents and adults [20, 37]. High theta/beta ratios and high theta values in ADHD can be interpreted as a result of a developmental delay.

The electrophysiological characteristics of ADHD obtained with Q-EEG recording and recent machine-learning methods promise easy-to-use approaches that can be complementary to the existing diagnostic tools, especially when sufficiently large samples are used. To separate ADHD group from healthy people, neuroalgorithms are used as model for multidimensional brain networks. For this reason, subtypes of ADHD can be used as biomarkers of disorder.

For our own experience, we can conclude that quantitative EEG is a promising approach in diagnostics of this complex disorder. In other words, for diagnostics, it is not enough to listen parents and teachers, but it is imperative to apply a large psychophysiological evaluation of suspected pupils. Q-EEG results can also be helpful in predicting response to stimulant medication and in selecting protocols for neurofeedback. So, we are facing today a renaissance of EEG. On the one hand, the renaissance is associated with obtaining new knowledge regarding neuronal mechanisms of generation of electric neuronal oscillations in spontaneous EEG as well as regarding functional meaning of different waves in event-related potentials [38, 39].

Based on extensive research during the last decade, we now recognize the existence of Q-EEG subtypes in ADHD patients and understand the need of different neurofeedback protocols to correct these abnormalities. However, some of the protocols at the first year of neurofeedback era were obtained empirically without Q-EEG analysis. Most of the protocols use the conventional EEG in the frequency range higher than 0.1 Hz, while EEG at lower frequencies was used in studies of a German group at the University of Tubingen [39].

We can conclude that a Q-EEG allows to the psychologist looking for the brain functioning in easy and cheap way.

In the therapeutic approach, neurofeedback is confirmed as an excellent tool for training certain brain networks and thus improving the behavior, but the therapist is still an indispensable component in the treatment. The support, the instructions, and the presence of the professional in vicinity to the child are a guaranty for success. In some countries (i.e., Israel), different modalities of biofeedback are used in school settings for stress management as well as for training abilities for better achievement. In this context, our team have good experience with peak performance training in school children and in sport [40, 41].

4. Conclusions

- In the vide spectrum of learning disabilities, ADHD takes a large part.
- The diagnosis must be done with the collaboration of teachers, parents, pediatrician, clinical psychologist, and child neuropsychiatrist.
- Different psychometric tests can be used, but they are not sufficient for diagnostics.
- Evaluation of brain dynamics, especially executive functions are inevitable.
- Endophenotype represents simpler indicator to genetic mechanism than the behavioral symptoms and is very important for treatment plan.

- Neurofeedback confirmed its usefulness and cost-benefit as a nonpharmacological treatment. A brain-rate parameter, introduced by our team, appeared to be more realistic in the assessment and the follow up of the obtained results. In the future, we propose to include brain-rate-based neurofeedback training.

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Conflict of interest

The author declares no conflict of interest.

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