NEUROSCIENCE RESEARCH NOTES

OPEN ACCESS | RESEARCH NOTES ISSN: 2576-828X

Attention-deficit hyperactivity in elementary school children in Ulaanbaatar: spectral analysis of electroencephalogram and emotional intelligence

Amgalan Bayarsaikhan [1], Tovuudorj Avirmed [2], Bayarmaa Tsend [3], Nasantsengel Lhagvasuren [4], Battamir Enkhtuya [1] and Erdenetuya Ganbaatar [1]*

[1] Department of Pediatrics, School of Medicine, Mongolian National University of Medical Sciences, Ulaanbaatar, Mongolia.
[2] Department of Neurology, School of Medicine, Mongolian National University of Medical Sciences, Ulaanbaatar, Mongolia.
[3] Department of Psychology, Mongolian National University of Education, Ulaanbaatar, Mongolia.
[4] National Center of Mental Health, Ulaanbaatar, Mongolia.
* Correspondence: erdenetuya@mnums.edu.mn; Tel.: +976-99175770

Received: 21 December 2022; **Accepted:** 23 April 2023; **Published:** 19 May 2023
Edited by: Battuvshin Lkhagvasuren (Mongolian National University of Medical Sciences, Mongolia)
Reviewed by: Buyantungalag Battulga (Mongolian University of Life Sciences, Mongolia); Batjargal Khishigjargal (Child Medicine Academy Mongolia, Mongolia); Hui Jan Tan (Universiti Kebangsaan Malaysia, Malaysia); Angelos Papadopoulos (General Hospital of Patras "Karamandanio", Greece)
https://doi.org/10.31117/neuroscirn.v6i2.216

ABSTRACT: ADHD stands for Attention-deficit hyperactivity disorder; it is a disorder that occurs during childhood development and presents signs of reduced attention and hyperactivity/impulsivity. This study presented the direct association between emotional ability and spectral analysis of electroencephalography of Mongolian children with ADHD. Of a total of 1200 children, who were attending primary schools in Ulaanbaatar, 30 children were diagnosed with ADHD according to Teachers' and Parents' survey versions of DSM-IV ("*Diagnostic and Statistical Manual* of Mental Disorders"). The sample consisted of 60 children aged 7-12 years (20 % female and 80 males; *M age* = 9.34, *SD* = 0.96): 30 children diagnosed with ADHD and 30 healthy children as a control group and presented the same sociodemographic characteristics of the study sample. They all completed Bar-On Quotient Inventory Youth Version (EQ-i: YV), and performed electroencephalography (EEG). Results indicated that children with ADHD presented significantly lower scores in interpersonal scales, adaptability, general mood scales, and total EQ scores than the control group. Comparing forms of ADHD, the intrapersonal scale statistically differed between the hyperactive and combined forms ($p = 0.021$) and the adaptability scale between attention deficit and the combined form ($p = 0.026$). Moreover, the study found a statistically significant increase in the posterior delta and theta power, whereas there was a decrease in theta/beta and theta/alpha wave ratio in all brain parts in the ADHD group concerning the healthy group.

Keywords: Attention-Deficit/Hyperactivity Disorder; Attention; Emotional Intelligence; Electroencephalography; Power

1.0 INTRODUCTION

Attention-Deficit/Hyperactivity Disorder (ADHD) is a standard in school children, with a prevalence of 5 to 10 percent worldwide (Faraone et al., 2003). Emotional and behavioral disorders are the main barriers for children with ADHD to pursue their learning and get adapted by family and the society. In addition to these barriers, social, emotional, behavioral problems, and cognitive impairments such as executive dysfunctions are also common in ADHD (Llanes et al., 2020). According to the Bar-On model of emotional intelligence, low self-esteem, emotional instability, loneliness, and changes in mood played an important role in the development of clinical ADHD (Kristensen et al., 2014). In recent years, electroencephalography (EEG) has been widely used in diagnosing ADHD, in addition to the questionnaire method alone. Brain electroencephalography in children with ADHD showed an increase in the amplitude of the hippocampal theta wave as compared to healthy children (Loo & Makeig, 2012).

Researchers concluded that children with ADHD have less ability to express emotions, emotional changes, inner feelings and adaptation (Abo Elella et al., 2017; Panagiotidi & Overton, 2020). According to the study conducted in Italy in 2015 by using Bar-On self-assessment questionnaire 216 children aged 12 to 16 with ADHD and 154 healthy children were compared and it was found that interpersonal skills, ability to express feelings and leadership skills were statistically less in the study group. On the other hand stress management, adaptability, and general emotional ability differed between the gender (Craparo et al., 2015). One study compared EQ between 44 adolescents with ADHD and 192 healthy children by using Bar-On test. The result showed that emotional assessment ($U = 3306.50$; $p = 0.24$, $r = -0.15$) delate and stress management skills ($U = 3369.00$; $p = .036$; $r = -0.14$) were statistically lower in the group with ADHD and the emotional capabilities of the sexes did not differ (Barahona & Alegre, 2016). In a meta-analysis of 9 separate studies of 1498 electroencephalography data by Snyder and Hall (2006), the average amplitude of theta waves was increased by 32 per cent. An increase in the theta/ beta ratio was a classic symptom in ADHD.

Aims and objectives of the study

To compare the emotional capability and electroencephalography features between the children with ADHD and the control group. This study shows which subscales of emotional competence are impaired in children with ADHD and its difference in each group of ADHD. Moreover, it provides better result for ADHD-related spectral analysis for further research.

2.0 MATERIALS AND METHODS

2.1 Study Design and population

This was case-control observational study with 3 phases of data selection, EQ, and electroencephalography analysis. At the first stage, 1,200 children from the 2nd to 5th grades (age between 7-12 years old) were randomly selected by primary sampling from 5 districts of Ulaanbaatar, Mongolia. The DSM-IV (Diagnostic and Statistical Manual of Mental Disorders) classification with 18 questions was obtained from their parents and teachers. A positive score of 6 or more on the DSM-IV was considered to have ADHD. A total of 1200 children, 30 children were diagnosed with ADHD according to the DSM-IV. The diagnosis was established by the pediatric psychologist of the National Center of Mental Health, Mongolia.

In the second stage, we selected 30 children of the same age and gender from a class of children diagnosed with ADHD as the control group. The study team was in charge of explaining and providing the study information and their willingness to participate in the study for both groups. Questionnaire interview was conducted using an extended version of the Bar-On scale. For the assessment of emotional Intelligence EQ-i: YV - Emotional Quotient Inventory: Youth Version was used (Bar-On & Parker, 2000; Bar-On, 2006). Thus, "according to the Bar-On model, general intelligence was composed of both cognitive intelligence, measured by IQ, and emotional intelligence measured by EQ". The Bar-On Model of EQ comprises of five significant dimensions: intrapersonal, interpersonal, adaptability, stress management, and general mood.

Lastly, electroencephalography was performed in children with ADHD and the control group using Encephalan-EEGR-19/26 by a pediatric neurologist at the University Hospital of Mongol National University of Medical Sciences. One session of electroencephalography was based on 30 to 45 minutes for each child. The polar and relative voltages of "the four waves, delta (0.5-4Hz), theta (4-8Hz), alpha (8-13Hz) and beta (13-25Hz)" during the awake period, were selected from the part of the electroencephalography without artifact, the ratios and total voltage were calculated using spectral analysis (Gloss et al., 2016).

2.2 Ethical statements

The Research Ethics Committee approved the study protocol at "Mongolian National University of Medical Sciences" (Reg. No. 2018/Д-10). All people were informed about the study and given written informed consent before the participation. Children with ADHD and their parents were free to contribute their role either in the ADHD group or control group during the study period or withdraw from the study at any time.

2.3 Statistical evaluation

SPSS 23 software was used for descriptive and detailed analysis of survey data. Differences between groups were calculated using the One-Way ANOVA test when the dependent variables were grouped, and the independent variables continued. If the P-value is less than 0.05, it is taken into account as a statistically significant difference. Depending on the number of groups and the number of participants in the group, differences between groups were processed using Pearson's Chi-square and Fischer's criterion.

3.0 RESULTS

The group with ADHD included 7-11-year-olds (average age 9.1 ± 0.9), 24 boys, 6 girls, 12 with attention deficit disorder, 13 with hyperactivity, and 5 with comorbidities. The control group was duplicated in terms of age, gender, district, school, and class. The Cronbach's alpha score 0.802 on the Bar-On scale shows that the reliability of the test is considered sufficient, i.e. each question can be used to detect the disorder. The following table compares the emotional competency data which was determined using an extended Bar-On scale, of the ADHD and the control group. **Table 1** shows that in the group with ADHD, "interpersonal scale, intrapersonal scale, adaptability scale, general mood scale, and overall emotional competence scores were statistically lower compared to the control group, and positive impression scale did not differ between the two groups". (p = 0.163). The intrapersonal scale is high in hyperactivity, low in the combined form, adaptive criteria are high in hyperactivity, low in attention-deficit form of ADHD (**Table 2**). Interpersonal assessment, "stress management scale, general mood scale, positive impression scale, and total emotional intelligence" had no statistically significant differences between forms of ADHD. As can be seen from **Table 3**, the intrapersonal scale statistically differed between the hyperactive and combined form (p = 0.021), as well as the adaptability scale between attention deficit and the combined form (p = 0.026). Simple linear regression showed that for a 10-point increase in the ADHD score, EQ score decreases by 4 points (**Figure 1**).

Table 1. Emotional capability scale of children with ADHD and control group

Emotional capability		Median	SD	t	p
Interpersonal scale	Control group	108.1	11.8	7.2	0.024*
	ADHD	100.9	12.3		
Intrapersonal scale	CG	95.7	12.0	11.3	0.001**
	ADHD	84.4	12.8		
Stress management scale	CG	105.3	11.1	6.5	0.018*
	ADHD	98.8	9.7		
Adaptibility criteria	CG	99.3	9.4	11.0	0.002**
	ADHD	88.3	15.6		
General mood scale	CG	97.2	11.4	12.2	0.001**
	ADHD	85.0	15.7		
Positive Impression scale	CG	104.0	21.4	6.6	0.163
	ADHD	97.4	13.8		
Total EQ	CG	103.3	10.6	13.1	0.001**
	ADHD	90.2	11.9		

*p<0.05, **p<0.001, ***p<0.0001

To detect specific changes in electroencephalography waves during ADHD, 28 diagnosed and 28 healthy children were recorded and compared. The relative and total power of alpha, beta, theta, and delta waves during the awake period with eyes closed and opened were studied by comparing nine brain regions between the two groups and the type of ADHD. The average total power (224.86 μV^2) was found to be higher in the study group as compared to healthy group with power (192.75 μV^2), whereas the overall voltage was higher in the

forehead area in the control group, while predominance was observed in the posterior part of the brain in the group with ADHD (**Figure 2**), especially in the combined form.

Figure 3 shows a gradual increase in delta and theta waves in the ADHD group, as well as a statistically significant decrease in the rapid waves: alpha and beta concerning the control group. The electro-encephalography results were higher in study groups than in the healthy group, polar delta and theta waves increased "sharply compared to the control group alpha and beta waves, which are considered fast waves, were slower than in the control group confirmed by the fact that the ratio of theta/beta, theta/alpha waves were increased statistically in the group with ADHD".

Table 2. Clinical forms of ADHD and emotional capacity

Emotional scales	Group	Number	Median	Median error	P
Interpersonal scale	ADHD-In	12	98.7	3.1	0.132
	ADHD-H	13	105.7	3.4	
	ADHD-C	5	93.8	5.4	
Intrapersonal scale	ADHD-In	12	84.4	2.8	0.027*
	ADHD-H	13	89	3.7	
	ADHD-C	5	71.4	4.2	
Stress management scale	ADHD-In	12	101.6	2.2	0.125
	ADHD-H	13	95.15	2.7	
	ADHD-C	5	101.2	5.4	
Adaptability scale	ADHD-In	12	81.17	3.1	0.025*
	ADHD-H	13	96.85	4.3	
	ADHD-C	5	83.2	7.4	
General mood scale	ADHD-In	12	81.08	3.9	0.114
	ADHD-H	13	91.08	4.2	
	ADHD-C	5	78.8	8.6	
Positive Impression scale	ADHD-In	12	93.83	3.4	0.105
	ADHD-H	13	102.6	4.2	
	ADHD-C	5	92.4	4.7	
Total EQ	ADHD-In	12	88.83	2.1	0.121
	ADHD-H	13	94.23	3.6	
	ADHD-C	5	83	6.5	

*p<0.05

Table 3. Differences in emotional capacities between clinical forms of ADHD

Skills	Group	Median		P
Intrapersonal scale	ADHD-In	ADHD-H	-4.167	0.649
		ADHD-C	13.433	0.095
	ADHD-C	ADHD-In	4.167	0.649
		ADHD-C	17.600*	0.021
	ADHD-H	ADHD-In	-13.433	0.095
		ADHD-H	-17.600*	0.021*
Adaptability scale	ADHD-In	ADHD-H	-15.679*	0.026
		ADHD-C	-2.033	0.961
	ADHD-C	ADHD-In	15.679*	0.026*
		ADHD-H	13.646	0.177
	ADHD-H	ADHD-In	2.033	0.961
		ADHD-C	-13.646	0.177

*p<0.05, ADHD-In – Attention deficit, ADHD-H – Hyperactivity, ADHD-C - Combined

The posterior delta and theta waves in all parts of the brain were statistically increased correlated to the control group in the ADHD group, while the posterior alpha and beta waves in all domains were decreased. As for the relative voltage of the waves, the alpha wave has been reduced in the central part, the beta wave was reduced in all aspects, and the theta waves were increased in all regions. In the ADHD group, the ratio of theta (beta, theta) alpha waves were increased significantly in all parts of the brain.

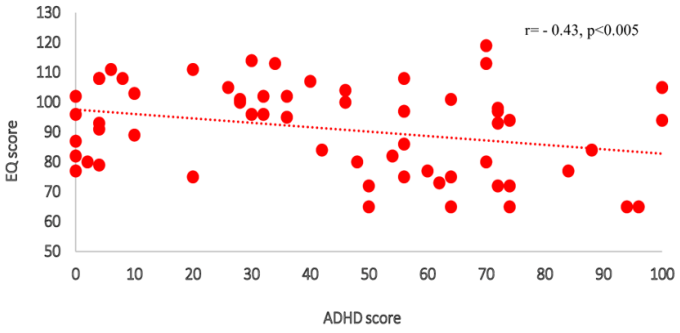

Figure 1: The relationship between ADHD DSM-4 score and emotional competence.

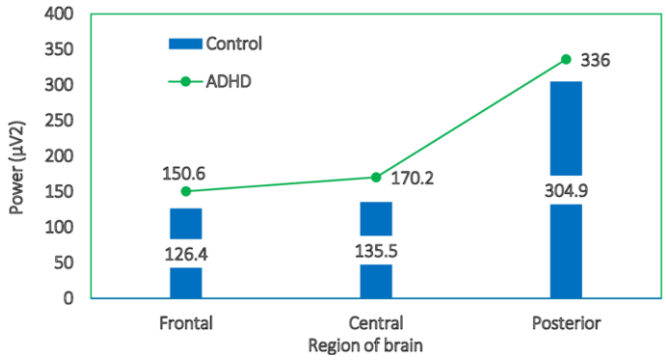

Figure 2: Voltage fluctuations of the brain in children with ADHD and the control group

The survey results taken from the parents and teachers for the diagnosis of ADHD were strongly related to the theta/ beta ratio (r = 0.72) and positively with the theta /alpha ratio (r = 0.42). The following figure shows the survey results and the percentage of theta/beta. The higher the survey score, the higher the theta/beta ratio, or the rise of survey points by 10, increased theta/beta ratio by 1.3 points (**Figure 4**).

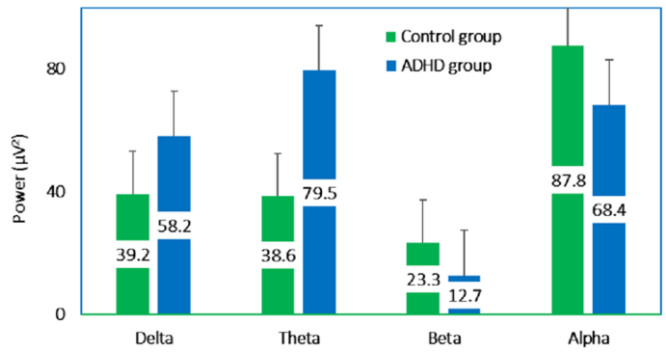

Figure 3: The average polarity of brain electrical wave of children with ADHD and the control group.

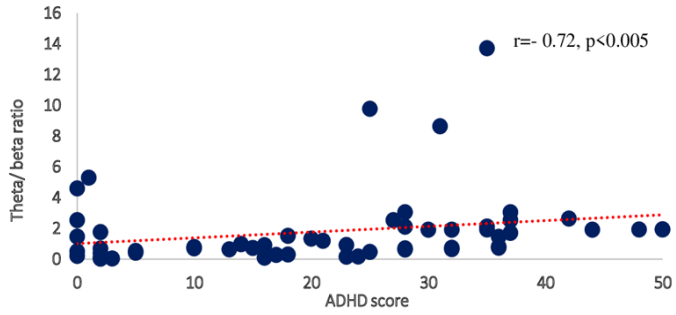

Figure 4: Questionnaire score of DSM-IV and theta/beta wave ratio.

4.0 DISCUSSION

In this study, an extended version of the Bar-On test showed that the group with ADHD had lower statistical indicators as compared to the control group in terms of "interpersonal scale, intrapersonal scale, stress management scale, adaptability scale, general mood scale, and overall emotional indicators". It is similar to a 2014 study by Kristensen H. A., with 1,388 adolescents and 3,313 young adults using the Bar-On self-assessment test, which found that stress management criteria, adaptability criteria, and interpersonal relations criteria were deficient. In this study, indicators of interpersonal relations were low in the hyperactive type of ADHD, and the stress tolerance score was low in attention-deficit type (Hansen et al., 2014; Kristensen et al., 2014). A self-assessment questionnaire-based study was conducted in Italy in 2015 which compared 216 children aged 12-16 with ADHD and 154 healthy children. The study showed statistically lower in interpersonal scale and intrapersonal scale with differing stress management. This was compatible to another study compared the EQ of 32 children with ADHD and 40 healthy children. They highlighted that the ADHD group had lower ability in interpersonal skills

(p<.01), and adaptability (p<.01) (Laporta-Herrero & Latorre-Forcén, 2020) , which supports the idea that children with ADHD need more attention on developing emotional ability.

There were limited studies on ADHD associated with EEG. Clarke et al. investigated the EEG changes in children with ADHD during childhood and again 11 years later. In children with ADHD, posterior delta and relative theta was elevated, whereas alpha activity was diminished in all areas. They demonstrated age-related changes in EEG that reductions in the delta and theta bands, and increases in the alpha and beta bands across all electrodes at their adulthood (Clarke et al., 2019). Similarly, In our study, there was a decrease in theta wave and a reduction in alpha and beta wavelength on electroencephalography in the ADHD group was compared to the control group. In Australia, electroencephalography results of 25 children with ADHD and 25 children of the same age in the awake state were compared. The IQ results using the Wechsler test was 105.6 (12.1) for the ADHD group and 124.3 (8.9) for the control group. Electroencephalography showed an increase in the polarity and relative voltage of delta waves and a slowdown in alpha waves and a negative relationship between the polar and close theta waves and mental abilities of children (Zhang et al., 2019). Reduced relative and absolute delta power in children with ADHD are consistent with some previous research on children (Shephard et al., 2018). In 2019, 43 children aged 12-15 with ADHD and 27 healthy children scored more than 80 on the Wechsler test were interviewed in China. The average IQ was 103.98 ± 11.36 in the study group and 123.92 ± 8.98 in the control group, which indicates a decrease in the IQ of children with ADHD. The conclusion that statistically significant negative relationship between the forehead beta coefficient (r = - 373, p = 0.007) and the ratio of theta/ beta waves (r = 0.411, p = 0.003) with no age correlation being observed could be in addition to the diagnostic value, maybe a criterion for the severity of the disease (Zhang et al., 2017) correlates with our findings that higher score on the parent-teacher questionnaire via "*Diagnostic and Statistical Manual* of Mental Disorders-IV", the higher the ratio of theta/beta and theta/alpha waves or was positively correlated.

Limitations

This study suffers from some limitations. First, in this study, we did not compare behavioral differences between children with ADHD and other neurodevelopmental disorders. Another rule is that the other neuropsychological tests did not support cognitive processes investigated. Moreover, the sample size of the study was relatively small, and the ratio of case to control group was 1:1.

5.0 CONCLUSION

Children with ADHD had lower interpersonal score, the intrapersonal score, the adaptability score, the general mood scale, and the overall emotional competence score than the control group. For each form of ADHD, Intrapersonal and adaptability skills were high in children with ADHD hyperactivity form, and low in combined and attention-deficit forms. In electroencephalography, the voltage of polar delta and theta waves were significantly increased in the ADHD group compared to the control group, due to the slowing of alpha and beta waves, which are considered fast waves, the ratio of theta/beta, theta/alpha waves increased statistically in the group with ADHD.

Highlights

- Children with ADHD showed deficit in interpersonal, adaptability, general mood, and with lower total EQ scores than healthy children.
- Intrapersonal scale (p= .027) and adaptability scale (p=.025) were statistically different between ADHD forms. Especially, children with ADHD combined form had lower scores than other forms.
- DSM-IV scores (Teachers' and Parents' survey version) were strongly related to theta/ beta ratio (r = 0.72) and theta /alpha ratio (r = 0.42) of EEG in ADHD group. The rise of DSM-IV score by 10 points, increased theta/ beta ratio by 1.3 points.

Author Contributions: A.B., E.G., and T.A. conceived and designed the study; B.Ts., and B.E. performed and collected the data; A.B., N.L., and E.G. analysed the data; A.B., B.Ts. wrote the paper; E.G., T.A., and A.B. reviewed and edited the paper.

Conflicts of Interest: The authors declare no conflict of interest.

References

Abo Elella, E., Hassan, G. A. M., Sabry, W., Hendawy, H., Shorub, E., Zyada, F., & Medany, O. (2017). Trait emotional intelligence in a sample of Egyptian children with attention deficit hyperactivity disorder. *Child and Adolescent Mental Health*, *22*(4), 216-223. https://doi.org/https://doi.org/10.1111/camh.12236

Bar-On, R. (2006). The Bar-On model of emotional-social intelligence (ESI). *Psicothema*, *18*, 13-25. (https://www.ncbi.nlm.nih.gov/pubmed/17295953)

Bar-On, R., & Parker, J. D. A. (2000). *The Handbook of Emotional Intelligence: Theory, Development, Assessment, and Application at Home, School, and in the Workplace*. Jossey-Bass. (Amazon. Retrieved April 27, 2023, from https://www.amazon.com/Handbook-Emotional-Intelligence-Development-Application-at/dp/0470907436)

Barahona, L. M., & Alegre, A. A. (2016). Emotional Intelligence and ADHD: A Comparative Analysis in Students of Lima Metropolitan Area. *Journal of Educational Psychology-Propósitos y Representaciones*, *4*(1), 89-114. https://doi.org/10.20511/pyr2016.v4n1.87

Clarke, A. R., Barry, R. J., Johnstone, S. J., McCarthy, R., & Selikowitz, M. (2019). EEG development in Attention Deficit Hyperactivity Disorder: From child to adult. *Clinical Neurophysiology*, *130*(8), 1256-1262. https://doi.org/https://doi.org/10.1016/j.clinph.2019.05.001

Craparo, G., Magnano, P., Gori, A., Passanisi, A., Lo Piccolo, A., & Pace, U. (2015). ADD symptoms, self-image and emotional intelligence in early adolescence. *Life Span and Disability*, *18*, 167-188.

Faraone, S., Sergeant, J., Gillberg, C., & Biederman, J. (2003). The Worldwide Prevalence of ADHD: Is it an American Condition? *World psychiatry : official journal of the World Psychiatric Association (WPA)*, *2*, 104-113.

Gloss, D., Varma, J. K., Pringsheim, T., & Nuwer, M. R. (2016). Practice advisory: The utility of EEG theta/beta power ratio in ADHD diagnosis. *Report of the Guideline Development, Dissemination, and Implementation Subcommittee of the American Academy of Neurology*, *87*(22), 2375-2379. https://doi.org/10.1212/wnl.0000000000003265

Hansen, B. H., Skirbekk, B., Oerbeck, B., Wentzel-Larsen, T., & Kristensen, H. (2014). Associations Between Sleep Problems and Attentional and Behavioral Functioning in Children With Anxiety Disorders and ADHD. *Behavioral Sleep Medicine*, *12*(1), 53-68. https://doi.org/10.1080/15402002.2013.764525

Kristensen, H. A., Parker, J. D. A., Taylor, R. N., Keefer, K. V., Kloosterman, P. H., & Summerfeldt, L. J. (2014). The relationship between trait emotional intelligence and ADHD symptoms in adolescents and young adults. *Personality and Individual Differences*, *65*, 36-41. https://doi.org/https://doi.org/10.1016/j.paid.2014.01.031

Laporta-herrero, I., & Latorre-forcén, P. (2020). Emotional intelligence in children and adolescents with attention deficit hiperactivity disorder. *Romanian Journal of Psychological Studies*, *8*, 22-30.

Llanes, E., Blacher, J., Stavropoulos, K., & Eisenhower, A. (2020). Parent and Teacher Reports of Comorbid Anxiety and ADHD Symptoms in Children with ASD. *Journal of Autism and Developmental Disorders*, *50*(5), 1520-1531. https://doi.org/10.1007/s10803-018-3701-z

Loo, S. K., & Makeig, S. (2012). Clinical Utility of EEG in Attention-Deficit/Hyperactivity Disorder: A Research Update. *Neurotherapeutics*, *9*(3), 569-587. https://doi.org/10.1007/s13311-012-0131-z

Panagiotidi, M., & Overton, P. (2022). Attention deficit hyperactivity symptoms predict problematic mobile phone use. *Current Psychology*, *41*(5), 2765-2771. https://doi.org/10.1007/s12144-020-00785-2

Shephard, E., Tye, C., Ashwood, K. L., Azadi, B., Asherson, P., Bolton, P. F., & McLoughlin, G. (2018). Resting-State Neurophysiological Activity Patterns in Young People with ASD, ADHD, and ASD + ADHD. *Journal of Autism and Developmental Disorders*, *48*(1), 110-122. https://doi.org/10.1007/s10803-017-3300-4

Snyder, S. M., & Hall, J. R. (2006). A Meta-analysis of Quantitative EEG Power Associated With Attention-Deficit Hyperactivity Disorder. *Journal of Clinical Neurophysiology*, *23*(5), 441-456. https://doi.org/10.1097/01.wnp.0000221363.12503.78

Zhang, D.-W., Johnstone, S. J., Li, H., Barry, R. J., Clarke, A. R., Zhao, Q., Song, Y., Liu, L., Qian, Q., Wang, Y., & Sun, L. (2019). Time Effects on Resting EEG in Children With/Without AD/HD. *Brain Topography*, *32*(2), 286-294. https://doi.org/10.1007/s10548-018-0690-3

Zhang, D.-W., Li, H., Wu, Z., Zhao, Q., Song, Y., Liu, L., Qian, Q., Wang, Y., Roodenrys, S., Johnstone, S. J., De Blasio, F. M., & Sun, L. (2017). Electroencephalogram Theta/Beta Ratio and Spectral Power Correlates of Executive Functions in Children and Adolescents With AD/HD. *Journal of Attention Disorders*, *23*(7), 721-732. https://doi.org/10.1177/1087054717718263