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The relationship between speech difficulties and brain laterality in Attention Deficit Hyperactivity Disorder and Specific Learning Disorder

Dikkat eksikliği ve Hiperaktivite Bozukluğu ve Özgül Öğrenme Bozukluğunda Beyin Lateralitesinin Konuşma Problemleri ile İlişkisi

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ABSTRACT

Aim: We aimed to examine the behavioral determinants of brain laterality and their associations with speech difficulties in children with Attention Deficit Hyperactivity Disorder (ADHD) and Specific Learning Disorder (SLD).
Methods: This cross-sectional study was conducted with a clinical sample of 7-18 years old patients with ADHD and/or SLD diagnosis. Patients' sociodemographical, developmental and medical information were taken during their clinical interviews. Behavioral determinants of brain laterality were assessed by several motor tasks. These tasks were "handwriting" for handedness, "looking through the telescope" for eyedness, and "hitting the ball or standing on one foot" for footedness.
Results: A total of 130 patients participated in the study. Left side preference and crossed laterality were common in patients with SLD (with or without comorbid ADHD) but not in patients with pure ADHD. Left eyedness/footedness were associated with speech disorders (p<0,05).
Conclusions: This study has shown that even after controlling for other factors affecting the development of brain laterality SLD, but not ADHD, is associated with left-sided preference and cross laterality. The relationship between speech disorders and left-eyedness/footedness in ADHD and SLD patients suggests that development of brain laterality is actually mediated by speech development.

Keywords: ADHD, SLD, brain laterality, speech disorders

ÖZ

Amaç: Bu çalışmada Dikkat Eksikliği Hiperaktivite Bozukluğu (DEHB) ve Özgül Öğrenme Bozukluğu (ÖÖB) tanıları olan çocuklarda beyin lateralitesinin davranışsal belirteçleri ve bunların konuşma problemleri ile ilişkisinin incelenmesi amaçlanmıştır.
Yöntemler: Bu kesitsel çalışma DEHB ve/veya ÖÖB tanılarına sahip 7-18 yaşındaki hastalardan oluşan klinik bir örneklem ile yürütülmüştür. Hastaların sosyodemografik, gelişimsel ve medikal bilgileri klinik görüşme sırasında alınmıştır. Beyin lateralitesinin davranışsal belirteçleri çeşitli motor görevler ile değerlendirilmiştir. Bu görevler el tercihi için "kalem ile yazma", göz tercihi için "teleskoptan bakma", ayak tercihi için "topa vurma" veya "tek ayak üzerinde durma" idi.
Bulgular: Çalışma DEHB ve/veya ÖÖB tanısı olan toplam 130 hasta ile tamamlanmıştır. Sol el-göz ve ayak tercihi ve çapraz lateralite ÖÖB (komorbid DEHB olsun veya olmasın) tanısı olan hastalarda sık iken sadece DEHB tanısı olanlarda değildi. Sol göz/ayak tercihi konuşma bozuklukları ile ilişkili idi (p<0,05).
Sonuçlar: Bu çalışma beyin lateralitesini etkileyen diğer faktörlerin kontrol edilmesinden sonra bile DEHB'nin değil ama ÖÖB'nin sol-yan tercihi ve çapraz lateralite ile ilişkili olduğunu saptamıştır. DEHB ve ÖÖB olan hastalarda konuşma bozuklukları ve sol göz/ayak tercihi arasındaki ilişkiyi gösteren diğer bulgumuz ise bu bozukluklardaki beyin lateralitesinin gelişimine aslen konuşma gelişiminin aracılık ettiğine işaret etmektedir.

Anahtar Kelimeler: DEHB, ÖÖB, beyin lateralitesi, konuşma bozuklukları

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INTRODUCTION

Attention Deficit Hyperactivity Disorder (ADHD) and Specific Learning Disorder (SLD) are among the common psychiatric disorders of childhood [1]. Recently, the Turkey Epidemiology Study has shown that the prevalence of ADHD and SLD in children is 12,4% and 0,5%, respectively [2]. The two disorders frequently coexist with each other, and genetic and environmental factors play leading role in their etiology. Although their pathophysiologies have not been fully understood yet, right hemisphere dysfunction and atypical cerebral asymmetry have been demonstrated in both ADHD and SLD patients [3,4].

Hemispheric asymmetries are required for the functional organization of the human brain. In the vast majority of people, the motor areas, the posterior (sensory) speech center (Wernicke's field) and the anterior (motor) speech center (Broca's field), are generally better developed in one of two hemispheres. This better developed hemisphere, so called the dominant hemisphere, is the left one in 90% of people [5]. Atypical asymmetry, moving away from the typical laterality pattern, indicates pathological changes in the left and right hemispheres and/or in between hemispheres [3]. Besides the ADHD and SLD, atypical brain lateralization has been shown in several other psychiatric disorders including speech disorders (SD) which are frequently coexist with especially SLD [6].

Hand, eye, ear and foot preferences are the behavioral measurements of brain laterality. Since it is inexpensive and easy, handedness is often used as an indicator of cerebral lateralization in clinical settings [7]. Handedness is correlated with cerebral asymetries, and right handedness refers to left brain dominance [8]. Although most of the people in society have right-handedness, some are left-handed. Moving away from right-handedness has been associated with schizophrenia [9], autism [10] as well as SD, such as stuttering [11]. Handedness is also influenced by gender (higher incidence of left-handedness in males), genetics and intrauterine posture [5]. Moreover, laterality and associated handedness influenced by conditions including birth complications [12], neurodevelopmental disorders, obsessive-compulsive disorder [13] and medical conditions such as epilepsy and autoimmune disorders [14]. Increased rates of left handedness have been shown in some autoimmune and inflammatory diseases and also in hearing loss [5]. In general, a right-handed person is expected to have right eye/ear/foot preferences. However, in some people at least one of the hand, eye, ear and foot preferences is different from the others, which is defined as crossed laterality.

Studies on ADHD and SLD present inconsistent findings related to handedness in the affected children. This may be related to differences in sample selection among studies. To the best of our knowledge, studies have been mainly conducted on a single disorder, and there is no information about whether coexisting developmental disorders (including speech problems) or medical conditions related to atypical brain laterality, are excluded. In this study, we aimed to examine brain laterality and its relationship with speech difficulties in patients with pure ADHD, pure SLD and Comorbid ADHD + SLD, in the absence of any chronic medical disease, birth complications, neurodevelopmental disorder or major psychiatric/neurological disorder. We hypothesized that left side preferences and crossed laterality were common in all groups. We also hypothesized that speech difficulties (SD and speech delay) were more common in SLD patients and they were related to left side preference and crossed laterality in other words atypical brain laterality.

METHODS

Children aged 7 to 13 who were followed up with ADHD and/or SLD diagnoses from the child psychiatric outpatient clinic were included in the study. Children with other comorbid psychiatric disorder (other than SD) including Autism Spectrum Disorder, Anxiety Disorder, Mood Disorder, Psychotic disorder, Tic Disorder, medical disorders including congenital/acquired neurological disease, chronic physical illness, birth complications and vision or hearing impairments, were all excluded from the study. Each patient was assessed with standardized intelligence tests and those with a total score of at least 80 were included in the study.

All participants were evaluated by clinical psychiatric examination based on DSM-5. Individual and parental sociodemographic information of the patients were questioned during clinical interview and recorded in the data form created by the researchers. During the same interview, each child was asked to participate in a series of motor tasks to determine their handedness, eyedness and footedness. For handedness "the hand preferred in handwriting", for eyedness "the eye used when looking through telescope", and for footedness "the foot used when hitting the ball or standing on one foot" were used. When crossed laterality was detected, it was recorded on the data form. The study was approved by the local ethics committee of a training and research hospital protocol number 2019/190 and was performed in accordance with the ethical standards established in the Helsinki Declaration, 1989. All participants and their parents were informed about the study and their written and verbal consents were received.

Data form: It was formed to get information related to child's gender, age, history of speech delay (starting to use sentences after 3 years of age), time of delivery (term, pre-term, post-term) and exposure to tobacco smoke during intrauterine or postnatal period, current SD (stuttering or articulation disorder) and parental educational status, family history of SLD and speech delay in the first or second degree relatives.

Statistical Analysis: For evaluating the study data, in addition to descriptive statistical methods (mean, standard deviation, median, frequency, ratio), the Shapiro-Wilk test and boxplot graphics were used for variables with normal distribution. The Student T test was used for intergroup comparisons of normally distributed variables. The Pearson Chi-Square test and Fisher-Freeman Halton test were used for comparison of qualitative data. Significance was evaluated at the $p < 0.05$ level. NCSS (Number Cruncher Statistical System) 2007 & PASS (Power Analysis and Sample Size) 2008 Statistical Software (Utah, USA) program was used for statistical analysis.

RESULTS

A total of 130 children with a mean age of 8.88 ± 1.34 years (age range 7 to 13 years) participated in this study. Of them 45 had pure SLD (SLD Group), 30 had pure ADHD (ADHD Group) and 55 had comorbid ADHD + SLD (Comorbid Group).

Patient groups were similar in terms of age, gender and monthly family income. Groups differed in terms of the parental education levels, family history of SLD and speech delay, and this difference was due to the ADHD group. Compared to the other two groups, the ADHD group had higher parental educational levels, and lower rates of family history of speech delay and SLD ($p < 0.05$) (Table 1).

The groups differed significantly in terms of speech delay history and SD rates. In the SLD group and Comorbid group, speech delay (44,4% and 47,3% respectively) and SD (42,2 % and 34,5% respectively) were very common. In the ADHD group the ratios of delayed speech (10%) and SD (none) were significantly lower than the other two groups ($p < 0.05$) (Table 2).

In the SLD group left handedness was present in 26,7 % (n=12), left eyedness was present in 42,2 % (n=19), left footedness was present in 22,2 % (n=10) and crossed laterality was present in 33,3 % (n=15) of patients. These ratios were 20% (n=11), 43,6 % (n=24), 20 % (n=11) and 40% (n=22) in the Comorbid group. Compared to the other two groups, the ADHD group had higher ratios for right handedness, eyedness and footedness and lower ratio of crossed laterality ($p < 0.05$) (Table 3). Handedness, eyedness, footedness and crossed laterality were not related to speech delay ($p > 0.05$). Left handedness-eyedness-footedness and crossed laterality were higher in patients with SD, but the rate of left eyedness and left footedness were statistically significantly higher among patients with SD ($p < 0.05$) (Figure 1).

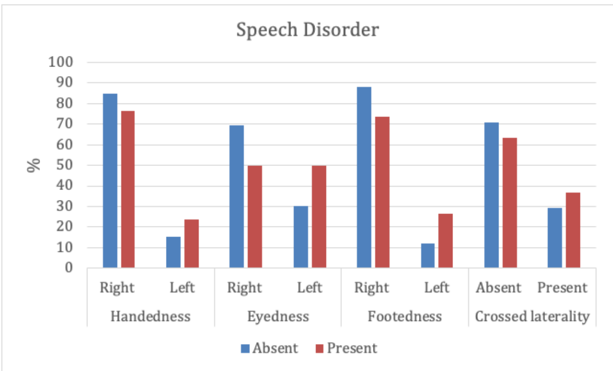

Figure 1: Examination of relationship between the behavioral indicators of laterality and speech disorder in participants

Table 1: Comparison of groups according to demographic characteristics of participants

		Total	SLD- Group	ADHD Group	Comorbid Group	P
Age	Mean ±SD	8,88 ±1,34	8,73 ±1,29	9,07 ±1,31	8,91 ±1,41	[a]0,520
	Min-Max (Median)	7-13 (9)	7-12 (9)	7-12 (9)	7-13 (8)	
		N(%)	N(%)	N(%)	N(%)	
Gender n(%)	Girls	38 (29,2)	11 (24,4)	9 (30)	18 (32,7)	[b]0,660
	Boys	92 (70,8)	34 (75,6)	21 (70)	37 (67,3)	
Family income n (%)	<MMW	20 (15,4)	8 (17,8)	4 (13,3)	8 (14,5)	[b]0,904
	MMW	73 (56,2)	24 (53,3)	19 (63,3)	30 (54,5)	
	>MMW	37 (28,5)	13 (28,9)	7 (23,3)	17 (30,9)	
Mothers' educational level n (%)	No school	12 (9,2)	6 (13,3)	0 (0)	6 (10,9)	[c]0,001**
	Primary school	87 (66,9)	32 (71,1)	14 (46,7)	41 (74,5)	
	Middle school	26 (20,0)	7 (15,6)	12 (40,0)	7 (12,7)	
	University	5 (3,8)	0 (0)	4 (13,3)	1 (1,8)	
Fathers' educational level n(%)	No school	5 (3,8)	2 (4,4)	1 (3,3)	2 (3,6)	[c]0,019*
	Primary school	84 (64,6)	29 (64,4)	18 (60,0)	37 (67,3)	
	Middle school	32 (24,6)	13 (28,9)	4 (13,3)	15 (27,3)	
	University	9 (6,9)	1 (2,2)	7 (23,3)	1 (1,8)	
Family history of SLD n (%)	Absent	76 (58,5)	21 (46,7)	30 (100)	25 (45,5)	[b]0,001**
	Present	54 (41,5)	24 (53,3)	0 (0)	30 (54,5)	
Family history of speech delay n (%)	Absent	83 (63,8)	24 (53,3)	25 (83,3)	34 (61,8)	[b]0,027*
	Present	47 (36,2)	21 (46,7)	5 (16,7)	21 (38,2)	

[a]Student T Test, [b]Pearson Ki Square Test, [c]Fisher Freeman Halton Test, *p<0,05, **p<0,01, MMW=Monthly Minimum Wage

Table 2: Comparison of the groups in terms of speech delay, speech disorder, birth time, intrauterine tobacco smoke exposure

		Total N(%)	SLD Group N(%)	DEHB Group N(%)	Comorbid Group N(%)	p
Speech Delay	Absent	81 (62,3)	25 (55,6)	27 (90)	29 (52,7)	[b]0,002*
	Present	49 (37,7)	20 (44,4)	3 (10.0)	26 (47,3)	
Speech Disorder	Absent	92 (70,8)	26 (57,8)	30 (100)	36 (65,5)	[b]0,001*
	Present	38 (29,2)	19 (42,2)	0 (0)	19 (34,5)	
Birth time	Term	105 (80,8)	35 (77,8)	25 (83,3)	45 (81,8)	[c]0,790
	Pre-term	16 (12,3)	7 (15,6)	4 (13,3)	5 (9,1)	
	Post-term	9 (6,9)	3 (6,7)	1 (3,3)	5 (9,1)	
Intrauterine tobacco smoke exposure	Absent	68 (52,3)	25 (55,6)	14 (46,7)	29 (52,7)	[b]0,749
		62 (47,7)	20 (44,4)	16 (53,3)	26 (47,3)	

[b]Pearson Ki Square Test, [c]Fisher Freeman Halton test, *p<0,01

Table 3: Comparison of the groups in terms of behavioral indicators of brain laterality

		Total N(%)	SLD Group N(%)	DEHB Group N(%)	Comorbid Group N(%)	p
Handedness	Right	107 (82,3)	33 (73,3)	30 (100)	44 (80)	[b]0,010*
	Left	23 (17,7)	12 (26,7)	0 (0)	11 (20)	
Eyedness	Right	83 (63,8)	26 (57,8)	26 (86,7)	31 (56,4)	[b]0,012*
	Left	47 (36,2)	19 (42,2)	4 (13,3)	24 (43,6)	
Footedness	Right	109 (83,8)	35 (77,8)	30 (100)	44 (80)	[b]0,022*
	Left	21 (16,2)	10 (22,2)	0 (0)	11 (20)	
Crossed laterality	Absent	89 (68,5)	30 (66,7)	26 (86,7)	33 (60)	[b]0,039*
	Present	41 (31,5)	15 (33,3)	4 (13,3)	22 (40)	

bPearson Ki Square Test, *p<0,05

DISCUSSION

We demonstrated that left-footedness and left eyedness were associated with Speech Disorders in patients with SLD and/or ADHD. Besides, left side preferences and crossed laterality were common among SLD (with/without ADHD) but not in pure ADHD patients. Our hypotheses related to brain laterality in ADHD were rejected. Since it is the first study to evaluate behavioral markers of brain laterality in ADHD and SLD by controlling other environmental factors that may affect brain laterality, and considering its relationship with speech difficulties, we think that its results will contribute to the literature.

Learning is a complex and dynamic process based on both perceptive and motor acts. Researchers state that laterality is paramount to the development of academic achievement. Learning difficulties can be a consequence of laterality disruption and disturbances on spatial organization [15]. In their study Scerri et al., (2011) have found that in SLD patients, greater relative right-hand skill is associated with minor allele of single nucleotide polymorphism, which is an intron of PCSK6, a gene that encodes a protein involved in left-right axis determination [8]. Increased rates of left handedness in dyslexia have been demonstrated [16]. In their study, Siviero et al (2002) have shown that increased left handedness (15,4 % vs 0%), but not left eyedness (30,8% vs 26,7%), is more common in dyslexia than normal controls [13]. Another finding of laterality in SLD patients is the increased crossed-laterality rates (as high as 46,4%) [13] which has been shown to be associated with academic achievement or intelligence [15]. These finding indicates that cerebral asymmetry and dyslexia are linked with each other.

This study demonstrated the presence of abnormal brain laterality in SLD patients (with or without comorbid ADHD) compared to healthy controls and ADHD patients. Because we excluded any environmental risk factors affecting the development of laterality, our findings support the studies that has demonstrated the association of left-handedness and crossed laterality with SLD itself.

Human language is a complex communication system processed by specialized brain systems localized in the left cerebral hemisphere in the majority of people. It has been proposed that handedness emerged as a consequence of the evolution of language [8]. In patients with specific language impairment, significant lack of left lateralization in all core language regions (inferior frontal gyrus-opercularis, inferior frontal gyrus-triangularis, supramarginal gyrus and superior temporal gyrus), across single or combined task analysis [17] and hypoactivation at rest affecting the right parietal region and a right hyperactivation with lower left asymmetry involving the temporal lobes [18], have been reported in fMRI studies. In this study, we found that speech problems were common among SLD patients, and in these SLD patients, whether they had comorbid ADHD or not, left eyedness and left footedness were associated with SD but not with speech delay. Dyslexia and specific language impairment are common childhood disorders that show considerable co-morbidity and diagnostic overlaps and have been suggested to share some genetic etiology [19]. In this context, our finding related to speech problems and laterality suggests that the main determinant of brain laterality is the speech development in patients with SLD.

In ADHD samples right hemisphere dysfunction is demonstrated in many studies. Simoes et al. (2017) state that atypical brain laterality together with right hemisphere dysfunction are among the main components of ADHD [7]. Decreased brain laterality has been shown to be associated with inattention [20] and total ADHD symptom [21] scores. Consistently, compared to right handed students, left handed ones have a higher probability of suffering from ADHD [7]. Studies demonstrate that in ADHD patients, non-right handedness [7,22] and crossed laterality (79-41% in ADHD and control groups, respectively) are more common and cross laterality is associated with behavioral problems [23]. On the contrary, there are studies showing that in ADHD handedness is not different [24] and not associated with symptom scores or comorbidity [25]. Besides, Tran and Voracek (2018) found that footedness, not the handedness, correlated with symptomatology in ADHD [24].

Our findings demonstrated that left side preferences and cross laterality were not high among pure ADHD cases and even statistically significantly lower in these patients, compared to SLD patients. Besides the strong genetic influences, early life environmental stressors (pre-peri and postnatal) and learning processes play role in handedness [12]. Many other psychiatric disorders (including SLD, autism, schizophrenia, anxiety disorder), medical diseases (such as epilepsy, autoimmune diseases, hearing and vision impairments) and birth complications have been reported to affect lateralization of the brain function [5,12,13,14]. Based on this knowledge in order to assess the relationship between a specific neurodevelopmental disorder and brain laterality, other factors should be controlled and excluded. However, it is not clear whether the environmental factors affecting brain laterality were controlled in the previous studies. Because all these factors were controlled and excluded in this study sample, we think that our study shows the laterality ratios in ADHD more accurately than previous studies.

Potential limitations of our study include the relatively small sample size, the lack of a healthy controls and the absence of assessment of ambiguous laterality in the patients. Moreover, assessment of ear preference by audiometric measurements will be helpful in determining brain laterality.

CONCLUSIONS

Results of this study showed that left side preference was associated with speech disorders in ADHD and SLD patients, and many SLD patients, but not ADHD patients, had left side preference and crossed laterality, as well as speech difficulties. These findings suggest that speech may a mediating role in development of behavioral indicators of laterality. Studies with larger sample size and with healthy controls will be useful to further examination of the relationship between speech problems, SLD and brain laterality.

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