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Assessment of Central Auditory Processing Impairment and Cognitive Profiles in Children with Specific Learning Disabilities

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ABSTRACT

Background: Specific learning disabilities (SLDs) are a significant factor in children's academic underachievement. Around 46% of SLDs children have comorbid auditory processing disorder (APD). Cognitive functions are the ability to think and plan. Consequently, learning and academic progress are significantly affected by these disabilities.

Objective: Our study sought to evaluate whether children with SLDs have both central auditory processing (CAP) and cognitive abnormalities.

Patients and methods: A case-control study was conducted on 36 children from different schools of Zagazig city, Alsharquia government, Egypt, allocated into 2 groups, 18 with SLDs and academic underachievement (study group I) and 18 without SLDs (control group II). Medical history, otological evaluation, basic audiological examination, central screening tests (speech in noise (SPIN), dichotic digit (DDT), and pitch pattern sequence (PPS)), test for temporal resolution (Gaps in noise, (GIN)), IQ, and visuomotor ability evaluation were used to collect data.

Results: The SLDs group had lower DDT, PPS, total score and percent of GIN test versus the control groups. At the same time, the approximate threshold of GIN test in the SLDs group was significantly greater relative to the normal group. Regarding Bender-Gestalt test (BGT) test, there was highly statically significant increase scores on copy and recall phases among control group. A significant positive relationship was detected between the BGT copy and recall phases and PPS on both sides.

Conclusion: Our findings endorsed our hypothesis that most children with SLDs had subnormal scores on CAP abilities and cognitive function. The most severely affected CAP were temporal resolution and temporal ordering. Most SLDs children had visuomotor affection.

Keywords: Central auditory processing, Cognitive functions, Comorbidity, Specific learning disabilities, Visuomotor skills.

INTRODUCTION

The term "specific learning disabilities" refers to a group of conditions that have a deficit in verbal ability (both spoken and written) that cause problems with understanding or comprehending what is being said, written, reading, writing, spelling, or performing mathematical calculations. These include dyslexia, dysgraphia, dyscalculia, dyspraxia, and developmental aphasia [(1)].

To accurately diagnose SLDs, various elements, such as temporal processing abnormalities, auditory processing disorders (APD), eye movement alterations during reading, and attention deficit and hyperactivity disorder (ADHD), along with other comorbidities, make the assessment more complicated [(2)]. There are several reasons why children with "learning challenges" struggle in school, including behavioral, psychological, and emotional issues; English as a second language rather than their native tongue; inadequate education; excessive absences; or a lack of adequate curriculum. These youngsters can attain age-appropriate levels if they are supported and receive evidence-based education.

SLDs are one of the most serious neurodevelopmental disorders that interfere with students' academic progress regardless of average or above-average intellectual capacity when proper classroom and home support are provided [(3)]. They account for around 3–7% of all public-school students in Zagazig, with no gender distinction, ~ 46% of patients were presented with comorbid auditory processing disorder (APD) [(4)], making APD a possible complicating factor in SLD cases. A comprehensive psychometric test should be performed on all kids suspected of having APD [(5)].

APD testing involves observing a child's performance in several activities, such as recognizing the direction of a sound source, identifying words and phrases heard in competitive or distorted acoustic environments, or distinguishing syllable-type sounds and brief pure tones. This test identifies the child's auditory issues and the type of gnostic impairment, which is the child's particular relationship between hearing disability and language learning.

Central auditory processing (CAP) describes a set of processes and procedures that occur between the time sound is picked up by the outer ear, and the time it is processed in the auditory cortex. It includes the following abilities: localization and lateralization of sound; detection and identification of auditory stimulus variations; temporal processing (resolution, masking, and integration); and sequencing, as well as auditory context and perception in competitive contexts of the intended stimulus signals. Auditory processing involves the following mechanisms: binaural interaction, dichotic listening, monoaural low redundancy, and temporal processing [(6)].

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The Arabic central auditory processing test battery for children was created and standardized [7].

It includes the low pass filtered speech test for children (LPFS), the competing sentence test for children (CS), the speech perception in noise (SPIN) test for children, and the pitch pattern sequence (PPS) test. In addition, **Tawfik *et al.*** [8] created and standardized the memory tests and the Arabic auditory attention. Both Dichotic Rhyme tests and Arabic Dichotic Digits were standardized in 2008 [9].

Cognitive functions are the abilities to reason, think, organize, and communicate that enable us to educate, solve issues, and make sound decisions [10]. Abnormalities in these skills impair one or more processes, including language processing, visual-spatial processing, visual-motor processing, phonological processing, processing speed, and working memory, interfering with learning and academic achievement and potentially leading to emotional and behavioral problems [2].

Consequently, assessing CAP and cognitive abilities in children with SLDs is critical for detecting impairment and developing individualized remediation programs that assist children in reaching their academic potential. Accordingly, we conducted the present study.

PATIENTS AND METHODS

This is a case-control study carried out in the Audio-Vestibular Medicine Unit, E.N.T. Department, collaborating with the Psychiatry Department at Zagazig University Hospitals, Zagazig City, Alsharquia Governorate, Egypt, for a period of one year from May 2020 to May 2021.

Thirty-six children (both males and females) were allocated into two groups; including 18 children with a clinical history of SLDs with scholastic underachievement for at least 6 months as reported by teachers and relatives (SLDs group) and 18 normal children without SLDs (normal group), were involved in the studied population.

Before beginning the study, the suggested protocols were declared to all parents, who accepted to participate, and their children met the inclusion criteria mentioned below. The complete history was taken, including age, sex, and weight. Besides, a full audiological history was taken. Also, a full psychiatric history was taken to exclude other neurodevelopmental disorders depending on DSM-5 criteria. Finally, a complete otological examination was performed.

Inclusion criteria:

Subjects of both genders, of matched age (ranging from 8 to12 years), with average or above-average intelligence, normal hearing, normal middle ear function, without a history of neurological disorders or head trauma were included in the study.

Exclusion criteria:

Children with hearing loss and children with other neurodevelopmental disorders were excluded from the study.

Sample size justification:

Assuming that the mean of dichotic digits (DD) test for children with SLDs is 78.65±30.126 and the mean DD test for the control group is 99 ± 1.256 (11), and with confidence level 95%, power 80 %, so the sample size is 36 (18 in each group), using OpenEpi.

Data collection tool: Each participant in the study was subjected to the following:

a. Basic audiological evaluation.
b. Central screening tests include the Arabic speech in noise test (SPIN) test, the Arabic pitch pattern sequence (PPS) test, and the Arabic dichotic digit (DD) test for children.
c. Test for temporal resolution: Gaps in noise (GIN) test.
d. Intelligence and visuomotor skill assessment: Wechsler intelligence scale, and Bender Visual-Motor Gestalt Test.

Ethical considerations:

Before conducting the study, the researchers explained the procedures to all parents, verbal consent was taken, and those who agreed to participate signed an informed written consent document. All the study procedures of this research were performed using noninvasive testing, following the Helsinki declaration guidelines, and authorized by the Research Ethical Committee according to the obtained consent from the Institutional Review Board (IRB) at the Faculty of Medicine, Zagazig University (IRB Number: ZU-IRB#5939#05-03-2020).

Statistical analysis

The data were analyzed using SPSS for Windows (standard version 21). An initial Kolmogorov-Smirnov test was used to assess data normality. Qualitative data were expressed as frequency and percentages and were compared by Chi-square test. Continuous variables were provided as mean ± SD (standard deviation) and range. The Student t-test was used to compare two groups, while ANOVA was utilized for more than two groups. Continuous variables were correlated using Pearson's correlation coefficient (r). The p-value was set at 0.05; the results are more significant when the p-value is minimal.

RESULTS

Table (1) demonstrates a non-significant variation between the SLDs and the normal control groups regarding age, sex distribution, residence, type of school, and Wechsler intelligence scale.

Table (1): Socio demographic data, Wechsler intelligence scale among study and control groups

Socio demographic	SLDs group (n=18)	Control group (n=18)	p-value
Age (years)			
Mean ± SD	9.94 ± 1.43	9.88 ± 1.49	0.910
Min-Max	8-12	8-12	
Gender			
Male	13 (72.2%)	10 (55.6%)	0.298
Female	5 (27.8%)	8 (44.4%)	
Residence			
Urban	9 (50%)	9 (50%)	1.00
Rural	9 (50%)	9 (50%)	
Type of school			
Public	11 (61.1%)	8 (44.4%)	0.317
Private	7 (38.9%)	10 (55.6%)	
Wechsler intelligence scale (WISC)			
FSIQ	106.22±8.75	109.77±5.99	0.164
VIQ	107.55±13.12	112.38±6.65	0.172
PIQ	102.55±9.16	103.88±6.70	0.622

IQ = intelligent quotient; FSIQ = full scale IQ; VIQ = verbal IQ; PIQ = performance IQ

Our current study revealed that most of the study group ~ 94.4% had dyslexia. Moreover, in children with SLDs. The most common comorbidities among kinds of learning disabilities were dyslexia, dysgraphia, and dyscalculia; the 3 together (Table 2).

Table (2): Types of Specific Learning Disabilities (SLDs) and comorbidities among each type

Types of SLDs	Study group (n=18)
Dyslexia	
Yes	17 (94.4%)
No	1 (5.6%)
Dysgraphia	
Yes	12 (66.7%)
No	6 (33.3%)
Dyscalculia	
Yes	4 (22.2%)
No	14 (77.8%)
Co-morbidities among types of learning disabilities.	
Dyslexia, Dyscalculia, and Dysgraphia	61%
Dyslexia alone	27%
Dyscalculia alone	5.5%

There was a non-significant variation among groups I and II regarding speech in noise test (SPIN). In contrast, there was a highly statistically significant decrease in both right and left ears in the study group regarding dichotic digit and PPS test. Additionally, concerning the gaps in noise test among the SLD group (I), there was a highly significant higher approximate threshold, with a highly significant decrease in total score and percent as well as a decrease in copy and recall phases within the study group (1), relative to the normal control group (2) as presented in table 3.

Table (3): Central screening tests, Gaps in Noise test (GIN), and BGT among study and control groups

Central screening tests		Study group (n=18)	Control group (n=18)	p-value
SPIN	RT	94.44±11.99	100.00±0.00	0.058
	LT	94.58±13.09	100.00±0.00	0.063
DDT (V_1)	RT	90.55±9.37	99.16±1.91	<0.001*
	LT	85.00±10.00	98.33±2.42	<0.001*
DDT (V_2)	RT	80.94±10.58	93.91±2.78	<0.001*
	LT	72.38±8.90	91.25±1.76	<0.001*
PPS	RT	59.44±13.38	79.72±3.62	<0.001*
	LT	60.55±15.98	80.00±5.14	<0.001*
Gaps in Noise test				
RT ear	APP threshold (msc)	7.00±1.18	5.00±0.77	<0.001*
	Total score (/60)	36.54±2.25	42.60±3.30	<0.001*
	Total score (%)	60.81±3.68	70.90±5.46	<0.001*
LT ear	APP threshold (msc)	7.45±1.29	5.60±0.51	<0.001*
	Total score (/60)	35.72±3.40	41.50±3.47	<0.001*
	Total score (%)	59.09±5.64	68.90±5.68	<0.001*
BGT				
BGT	Copy phase	15.50 ± 2.20	20.94 ± 0.87	< 0.001*
	Recall phase	13.61 ± 2.06	20.38 ± 0.97	< 0.001*

SPIN = speech in noise test; DDT = Dichotic Digit; PPS = Pitch Pattern Sequence test; RT = right; LT = left; APP = approximate; V I = version I; BGT = Bender-Gestalt test

The central screening tests, GIN, and BGT Vs. other variables (gender, residence, or type of school) have been calculated for multiple correlations. Our findings demonstrated the non-significant correlation between SPIN, DD, PPS, GIN, and BGT Vs. gender, residence, or type of school (Tables 4 and 5).

Table (4): Association between central screening tests, GIN, BGT versus gender, residence, or type of school

		Gender		p value	Residence		p value	type of school		P value
		Male	Female		Urban	Rural		Public	Private	
Central screening tests										
SPIN	RT	94.61±13.91	94.00±5.47	0.926	93.33±16.58	95.55±5.27	0.707	91.81±14.70	98.57±3.77	0.256
	LT	93.84±6.50	90.00±10.00	0.346	93.33±7.07	92.22±8.33	0.764	90.90±8.31	95.71±5.34	0.195
DDT (V_1)	RT	91.92±8.30	87.00±12.04	0.333	91.66±9.68	89.44±9.50	0.630	90.00±10.95	91.42±6.90	0.763
	LT	85.38±9.67	84.00±11.93	0.801	83.33±10.89	86.66±9.35	0.496	86.36±7.77	82.85±13.18	0.485
DDT (V_2)	RT	81.15±9.60	80.40±14.10	0.897	81.94±11.50	79.94±10.17	0.701	79.54±11.28	83.14±9.80	0.499
	LT	71.57±9.89	74.50 ±5.96	0.549	71.22±8.04	73.55 ±10.03	0.594	73.13±9.44	71.21±8.55	0.669
PPS	RT	57.30±13.48	65.0 0±12.74	0.288	59.44±16.66	59.44 ±10.13	1.000	60.90±12.00	57.14±16.03	0.576
	LT	57.30±14.23	69.00±18.84	0.171	59.44±19.27	61.66±12.99	0.778	61.81±12.50	58.57±21.35	0.687
GIN										
APP threshold	RT	7.22±1.20	6.00±0.00	0.201	7.16±1.32	6.80±1.09	0.635	6.71±1.25	7.50±1.00	0.314
	LT	7.55±1.33	7.00±1.41	0.609	7.66±1.50	7.20±1.09	0.579	7.14±1.06	8.00±1.63	0.315
Total score (%)	RT	60.66±4.03	61.50±2.12	0.789	62.50±3.56	58.80±2.94	0.098	60.71±3.40	61.00±4.69	0.909
	LT	59.33±5.76	58.00±7.07	0.780	58.66±4.41	59.60±7.40	0.801	60.57±5.68	56.50±5.25	0.271
BGT	Copy phase	15.61±2.10	15.20±2.68	0.732	15.66±1.93	15.33±2.54	0.759	15.54±2.29	15.42±2.22	0.917
	Recall phase	13.61±1.93	13.60±2.60	0.989	13.77±1.48	13.44±2.60	0.743	13.36±2.20	14.00±1.91	0.540

Table (5): Association between central screening tests, GIN, BGT, and types of SLDs

		Types of SLDs			p-value
		Dyslexia	Dysgraphia	Dyscalculia	
SPIN	RT	94.11±12.27	92.50±14.22	87.50±25.00	0.722
	LT	92.35±7.52	91.66±8.34	95.00±10.00	0.777
DDT (V_1)	RT	90.88±9.55	91.25±10.47	87.50±13.22	0.811
	LT	85.29±10.22	86.25±8.01	83.75±7.50	0.891
DDT (V_2)	RT	81.58±10.54	81.45±10.79	79.37±12.31	0.932
	LT	72.23±9.15	70.79±7.64	71.87±8.00	0.903
PPS	RT	58.82±13.52	56.25±13.83	56.25±22.86	0.884
	LT	60.00±16.29	56.25±13.83	56.25±18.87	0.793
APP threshold	RT	6.90±1.19	6.71±1.25	7.00±1.73	0.936
	LT	7.60±1.26	7.42±0.97	6.66±1.15	0.486
Total score (%)	RT	61.10±3.75	61.00±3.69	58.00±3.00	0.427
	LT	58.90±5.91	59.14±6.20	62.66±7.63	0.649
BGT	Copy phase	15.52±2.26	14.50±1.50	15.25±1.70	0.389
	Recall phase	13.582.12±	12.75±1.81	13.00±1.41	0.517

SPIN = speech in noise test; DDT = Dichotic Digit; PPS = Pitch Pattern Sequence test; RT = right; LT = left; APP = approximate; V I = version.

Table (6) shows that there was a significant positive correlation between PPS at right and left sides and each of BGT copy phase and BGT recall phase.

Table (6): Correlation between BGT and other variables

		Copy phase		Recall phase	
		r	p	r	P
SPIN	RT	0.022	0.930	0.026	0.917
	LT	0.231	0.357	0.226	0.368
DDT (V_1)	RT	-0.100	0.694	-0.262	0.294
	LT	-0.254	0.310	-0.157	0.534
DDT (V_2)	RT	0.001	0.999	-0.107	0.671
	LT	0.378	0.122	0.089	0.725
PPS	RT	0.499	0.035*	0.621	0.006*
	LT	0.635	0.005*	0.649	0.004*
APP threshold	RT	0.151	0.658	-0.084	0.807
	LT	-0.167	0.623	0.028	0.935
Total score (%)	RT	0.169	0.619	-0.068	0.841
	LT	0.467	0.148	-0.188	0.579

SPIN = speech in noise test; DDT = Dichotic Digit; PPS = Pitch Pattern Sequence; test
RT = right; LT = left; APP = approximate; V I = version.

DISCUSSION

SLDs refers to a difficulty in learning and using academic skills (American Psychiatry Association) [12]. A diagnosis requires at least one of the following symptoms: reading, writing, and academic skills impairments. SLDs affect 3% to 7% of students in public schools, with a comorbid auditory processing impairment affecting around 46% of those students (APD).

There have been numerous debates among researchers over the last decades regarding the interference of cognitive performance in hearing tests [6, 13, 14], and an increasing number of studies are attempting to understand the relationship between these functions, with memory and attention functions being the most studied [15, 16]. Cognitive functions include analyzing information, planning, and communicating to learn, solve issues, and make smart decisions. Disabilities such as language processing, visual-spatial processing, visual-motor processing, phonological processing, processing speed, and working memory can lead to emotional and behavioral difficulties resulting from these impairments, which can interfere with academic progress and learning [17].

In our study, we found no significant differences in sociodemographic data (age, sex distribution, residence, and school type) between the study and control groups, which agrees with the findings of **Cunha *et al.*** [2] **and Bandla *et al.*** [11]. Increased socioeconomic level accounted for the lack of variation in residency. The high quality of instruction in public schools and the decreasing enrollment age in private schools explained why there was no difference in school type [11].

Additionally, our findings regarding the WISC revealed no statistically significant differences in performance IQ, verbal IQ, or full scale between the SLDs and control groups. Children with IQs below the average were excluded. This was in line with the early reported results of **Cunha *et al.*** [2].

Our study indicated that among the different types of SLDs, most of our study group (94.4%) had dyslexia because it is the most common type of SLD. According to comorbidities between various learning disorders, 61% had dyslexia, dysgraphia, and dyscalculia, with 27% had isolated dyslexia, and 5% had isolated dyscalculia. The combination of learning disabilities is widespread, as parents often bring their children to school with difficulties with reading, spelling, and writing. This was similar to the **Bandla *et al.*** study [11], where reading issues were 90.3 %, and combined learning impairment was 58.06 %.

However, in **Ashraf and Najam's study** [18], ~33% of SLDs participants had dyslexia, 48 % dysgraphia, and 45 % dyscalculia. Comorbidities were 30% for dyslexia and dysgraphia, 26% for dyslexia and dyscalculia, and 36% for dysgraphia and dyscalculia. SLDs were prevalent in public schools, including dyslexia, dysgraphia, and dyscalculia.

Regarding central screening tests, a non-significant variation was detected between the SLDs and the normal group in terms of SPIN. However, a highly significant decrease in both right and left ears was detected regarding DDT and PPS among the two groups. Our findings regarding the SPIN test were in line with early documented findings of **Kamal *et al.*** [19] **and Pinheiro *et al.*** [20].

In their research, **Apeksha *et al.*** [21] assessed the word identification scores about speech perception in calm and in the presence of several kinds of noise at a 0 dB signal-to-noise ratio. They showed that kids with SLDs performed worse in all listening (silent, noise, and babble) and syllables (monosyllables, bisyllables, and trisyllables) situations than children with usual development. Children with SLDs performed better in calm environments and deteriorated in noisy environments.

Even more interestingly, the version I of the mean dichotic digits test outperformed version II in terms of scores. According to **Mukari *et al.*** [22] **and Tawfik *et al.*** [23], who stated that version II is more clinically useful, many children with CAPD were missed by the version I. **Tawfik *et al.*** [23] advised using version 1 as a training technique before moving on to version II for evaluation. As a result, our current study considered the results of version II.

The fact that DDT's lower scores were greater in the left ear was due to the phenomenon of right ear advantage (REA). It is described as a higher percentage of correct answers in the RT ear than in the LT one. This phenomenon was attributed to left hemisphere dominance in language processing [24]. Our results are consistent with early studies, which confirmed a lower performance in DDT among children with SLDs [2, 25]. Children with SLDs were 2.0 times more likely than typical children to fail one or more DDT assessments (34.5 versus 16.6 %, respectively), according to **Choi *et al.*** [26].

The PPS test showed a significant variation among the two groups (I and II). This shows that such children have a problem with temporal ordering. As a result, the PPS test is a difficult exercise that demands kids to pay attention to three tones that vary in frequency and are presented in a specific order. The kids must identify the patterns and label them correctly. The task's intricacy may be a factor in poor performance. The PPS exam predicts children's word reading skills [27]. This finding was consistent with **Gokula *et al.*** [28] finding that children with word reading difficulties performed significantly worse on the frequency pattern test (FPT) than children with typical reading abilities.

In the current work, the SLDs group had a higher approximate threshold than the control group for the gaps in noise test (GIN). Total score and percent were substantially lower in the study group than in the control group. These findings support **Gokula *et al.*** [28] findings.

In our current study, the control group had a statistically significant increase in copy and recall phases compared to the SLDs group (I). In the **Mufti *et al.* study** [29], children with SLDs performed poorly on visuospatial, memory, motor, and perceptual tasks compared to controls. These tasks and skills are related to distinct aspects of learning, such as reading, writing, and math, which impact the child's academic progress. Visual-motor perception is essential for cognitive development. These cognitive deficits are a major contributor to SLDs. Visual-perceptual activities are also affected in SLD kids.

There was no statistically significant correlation between demographic data, SPIN, DD, PPS, GIN, and BGT in our current investigation. Additionally, no statistically significant relationship existed between the kind of learning disability, SPIN, DD, PPS, GIN, and BGT. BGT copy and recall phases on the right and left sides were positively correlated with PPS on both sides.

Our research has some limitations. First, the study's findings may not generalize to the larger community of SLDs children due to a lack of true sampling frame, permission, and consent from school officials. Second, the children's attention and linguistic skills were not tested. Finally, the parents' educational degree may impact the quality and amount of stimuli their children receive.

CONCLUSION

The majority of children with SLDs have subnormal CAP ability and cognitive function. The most affected auditory processing abilities were temporal resolution and temporal ordering. There was a favorable relationship between temporal ordering issues and cognitive impairment. Dyslexia was the most prevalent kind of particular learning disability. Most children with SLDs had visuomotor affection.

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