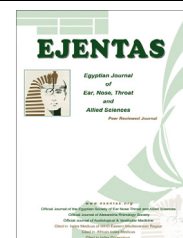




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ORIGINAL ARTICLE

Central auditory functions in primary school children with and without phonological awareness problems

Eman S. Hassan *

Phoniatric Unit, ENT Department, Assiut University, Assiut 71526, Egypt

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Central auditory functions;
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Abstract Objective: The primary objective of this study was to assess central auditory functions in a group of primary school children with dyslexia mainly phonological awareness problems and to compare their performance with children with good phonological awareness ability.

Design: A group of 52 students with phonological awareness problems (according to their performance in phonological awareness subtest of Arabic Reading Test (ART)) and 31 age- and sex matched students without phonological awareness problems participated in the study. All children were free from any neurological problems, had normal distant visual acuity, normal peripheral hearing sensitivity in both ears and IQ equal or above 90. The children from both groups were subjected to central auditory tests (CAT). Comparison between both groups in their performance in CAT was done and the correlations between CAT and items of phonological awareness subtest were examined.

Results: The students with phonological awareness problems as a group performed significantly poorer than controls on all central auditory tests. Also, there was a significant correlation between the speech perception in noise test (SPIN) and phonological awareness in the left ear mainly for (Recognition of the middle sound of the word, Deletion of the middle sound of the word and Addition of a sound to the word).

Conclusions: The group of children with phonological awareness problem showed clinically significant diminished performance compared to the group without phonological awareness problem, reflecting difficulties in the processing of auditory information.

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* Tel.: +20 88 2414165; fax: +20 88 233 3327.

E-mail address: eshh2003@yahoo.com.

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1. Introduction

Failure to acquire adequate reading skills is one of the most common neuro-behavioural problems affecting children.¹

Several theories have been developed in order to discover the etiology of dyslexia.² It has been demonstrated that one of its primary features is defective development of the phonetic

skills necessary to identify and properly use the constituent sounds of written words.

One of the hypotheses under study is based on auditory processing disorder in which, there is a sensory temporal processing deficit affects the sensory input needed for the proper phonological coding critically required for reading.^{2,3} Such a deficit could prevent the learning of precise relations between word sounds and letter sounds, leading to difficulties in associating the printed letter (grapheme) with their specific speech sound (phoneme) which is the phonological awareness ability.

Since speech and language skills are developed most efficiently through the auditory sensory modality, it is not unusual to observe speech and language problems as well as academic problems (many of them language-based), in children with central auditory processing disorder (CAPD).⁴ Sharma et al.⁵ said that up to nearly three quarters of those with language impairment and/or reading disorder are thought to also experience auditory processing deficits.

Auditory processing is a term used to describe what happens when our brain recognizes and interprets the sounds around us. Griffith⁶ defined auditory processing as the efficiency and effectiveness by which the central nervous system utilizes auditory information.

Jerger and Musiek⁷ and ASHA⁸ defined auditory processing disorder as a deficit in the processing of information that is specific to auditory modality. The auditory processing disorder is a clinical entity of difficult diagnosis, because it can be associated with numerous human communication disorders – learning disorder among them.^{7,9}

The role of central auditory processing in reading skill development and reading disorders is unclear and still subject to debate.^{10,11}

Children with CAPD do not understand or understand only portion of what is being said and they do not learn as well as other children, especially in large noisy classrooms and homes. They can appear to have difficulties paying attention or following instructions and are often misdiagnosed as having attention deficit hyperactivity disorders (ADHD).⁸ Nearly all these children lose confidence and end up feeling insecure. Rather than get real help, they are criticized or punished. Some may become isolated, withdrawn and depressed.

CAPD is assessed through the use of special tests designed to assess the various auditory functions of the brain. However, before these tests, an audiologist must rule out any peripheral hearing problems. The auditory tests fall into two major categories, Behavioral tests and Electrophysiological tests.¹²

It has been claimed that children with dyslexia show auditory processing disorders and a training of auditory perception is recommended as a therapy.¹³

Lyytinen et al.¹⁴ stated that, people who are identified as having reading disorder before grade three and who receive intensive reading education can do well. So, the prognosis is usually good if the condition diagnosed early and the person enrolled in a good remedial program.

The aim of the work is to assess central auditory functions in a group of primary school children with phonological awareness problems and compare their performance with children who have good phonological awareness ability.

2. Subjects and methods

2.1. Subjects

The study group consisted of 52 children from 4th and 5th grades of primary school with phonological awareness problems (according to their performance in phonological awareness subtest of Arabic Reading Test). The control group consisted of 31 children without phonological awareness problems. They were matched according to age, gender and education with the study group.

2.2. Methods (procedures)

Children of both groups were selected according to the following evaluation protocol:

2.2.1. I Elementary diagnostic procedures

1. Parent interview: searching for history of scholastic underachievement for the study group (failure in one or more subjects in the final exam) and good scholastic achievement for the control group, history of convulsion or any neurological disorder, subjective impression of hearing and intelligence, symptoms suggesting emotional disturbance due to repeated failure and poor self concepts.
2. Otological, vocal tract and full neurological examination: children who had neurological problems were excluded.

2.2.2. II Clinical diagnostic aids

1. Psychometric test: Children of both groups were subjected to Wechsler's Intelligence Scale for Children (WISC).¹⁵ After application of this test, all children had IQ below 90 were excluded.
2. Visual Acuity testing: Any child with diminished distant visual acuity was excluded.
3. Basic audiological assessment including pure-tone audiometry, speech audiometry and immittance audiometry. Children of both groups who had peripheral hearing loss in either ear were excluded.
4. Phonological awareness subtest of Arabic Reading Test (ART)¹⁶:

This subtest includes nine items which are: rhyme detection, blending sounds to form a word, segmentation of a word into sounds, recognition of the initial sound of the word, recognition of the middle sound of the word, deletion of the initial sound of the word, deletion of the middle sound of the word, deletion of the final sound of the word and addition of a sound to the word.

The total score of this subtest is 38. A child who scored ≤ 16 was considered dyslexic (had phonological awareness problems) and who scored > 16 was considered not dyslexic (had no phonological awareness problems).

Criteria of children in the study group:

1. School problems (failure in one or more subjects in the final exam).
2. Free from any neurological, ophthalmological or hearing problems.

3. Average or above average intelligence (≥ 90) according to WISC.
4. Scored ≤ 16 in phonological awareness subtest of ART.

Criteria of children in the control group:

1. No school problems (good academic performance).
2. Free from any neurological, ophthalmological or hearing problems.
3. Average or above average intelligence (≥ 90) according to WISC.
4. Scored > 16 in phonological awareness subtest of ART.
5. *Selected central auditory tests (CAT):*

Children of both groups were subjected to CAT which was applied by an audiologist. Test material was developed by Tawfik and Shalaby.¹⁷ The test battery consisted of:

1. Low Pass Filtered Speech (LPFS) test for children: This test measures the closure ability. Two different lists, consisted of 25 monosyllabic words, were presented monaurally one to each ear. Scoring was calculated by giving 4% point score to each correctly repeated word. The cut-off limit for LPFS test was $\leq 92\%$ according to Kamal et al.¹⁸
2. Speech Intelligibility in Noise (SPIN) test for children: This test assesses the selective auditory attention ability. It consists of 20 Arabic meaningful sentences within the vocabulary of children. The sentences were recorded with background speech noise. The test items were presented monaurally. Scoring was calculated by counting the number of correctly identified sentences. 5% point score was given to each correctly repeated sentence. The cut-off limit for SPIN test was $\leq 90\%$ according to Kamal et al.¹⁸
3. Competing Sentence (CS) test for children: It tests auditory separation ability. It consists of 15 paired, well-aligned, meaningful sentences of 4–5 words. The test items were presented simultaneously at 35 dB SL (Ref. SRT) in the target ear and at 50 dB SL (Ref. SRT) in the competing ear. The child was instructed to repeat the sentence in the target ear while ignoring that in the competing ear. Scoring was calculated by giving 6.7% point for each correct response. The cut-off limit for CS test was $\leq 86.7\%$ according to Kamal et al.¹⁸
4. Duration Pattern Test (DPT): It tests temporal ordering ability. It consists of three consecutive tones, one of which differs by being either longer or shorter than the other two. The frequency of these tones is constant but the duration is either long (500 ms) or short (250 ms). Thirty sequences were presented monaurally. The child was instructed to describe verbally each sequence heard. Scoring was calculated by giving 3.3% point for each correct response. The cut-off limit for DPT was $\leq 73\%$ according to Musiek, 1994.¹⁹

2.3. Statistical analysis

Statistical analysis was performed with SPSS. All data were expressed as mean and standard deviation. The data were evaluated by unpaired-*t* test. Pearson correlation between results of phonological awareness test and CAT was performed. The significance threshold for all tests was set at $P < 0.05$.

3. Results

The study group consisted of 52 children (30 boys and 22 girls; with mean age 10 yrs and 1 month; age range 9–11 years and 4 months). The control group consisted of 31 children (16 boys and 15 girls; with mean age 10 years and 3 months; age range 9–11 years and 2 months).

3.1. Number of children with normal and abnormal CAT in both groups

In the study group, 32 children had abnormal CAT versus 18 children in the control group (Table 1).

3.2. Comparison between study and control groups in their performance in CAT

The dyslexic group presented statistically significant inferior performance in all CAT items compared to control group (Table 2).

3.3. Correlation between results of phonological awareness test and CAT

Table 3 shows that there was no statistically significant correlation between results of phonological awareness test and CAT in dyslexic group except for the SPIN test which shows a significant correlation with phonological awareness in the left ear.

3.3.1. Correlation between items of phonological awareness and SPIN test

There was a significant correlation between SPIN test and phonological awareness test in the items involving recognition of

Table 1 Number of children with normal and abnormal CAT in the study and control groups.

CAT	Study (n: 52)		Control (n: 31)	
	No	%	No	%
Normal	20	38.5	13	41.9
Abnormal	32	61.5	18	58.1
P-Value	0.754			

Table 2 Comparison between study and control groups in their performance in CAT.

CAT		Study (n:52)	Control (n:31)	P-value
		Mean \pm SD	Mean \pm SD	
LPF test	Right	97.15 \pm 4.43	99.23 \pm 1.61	0.014*
	Left	97.00 \pm 4.47	99.23 \pm 1.61	0.009*
SPIN test	Right	93.08 \pm 7.87	96.77 \pm 5.41	0.024*
	Left	92.21 \pm 8.31	95.97 \pm 5.54	0.028*
CS test	Right	86.89 \pm 9.02	92.02 \pm 8.02	0.011*
	Left	84.99 \pm 9.03	91.27 \pm 8.47	0.002*
DP test	Right	56.98 \pm 23.61	69.55 \pm 14.51	0.009*
	Left	54.81 \pm 22.93	70.68 \pm 15.26	0.001*

* $P < 0.05$.

Table 3 Correlation between results of phonological awareness test and CAT.

CAT		Phonological awareness test	
		r-Value	p-Value
LPF test	Right	0.248	0.076
	Left	0.261	0.062
SPIN test	Right	0.221	0.115
	Left	0.291	0.036*
CS test	Right	0.077	0.590
	Left	0.050	0.724
DP test	Right	0.170	0.227
	Left	0.233	0.097

* $P < 0.05$.

the middle sound of the word, deletion of the middle sound of the word, and addition of a sound to the word (Table 4).

4. Discussion

This study was conducted to find out possible auditory causes that could contribute to dyslexia due mainly to problems in phonological awareness in primary school children. Early identification of CAPD in children is of great importance since it can lead to early remediation and thus minimizing the educational deficits often seen in those children. Children in both groups were evaluated by an Arabic Central Auditory test Battery Version for Children.¹⁷ Central auditory abilities evaluated in this study were auditory closure (measured by LPF), selective auditory attention (measured by SPIN), auditory separation (measured by CST) and temporal processing abilities (measured by DPT). These abilities are of great importance for proper listening in educational situation. Children in this study who had abnormal results in any of the central tests (LPF, SPIN, CST, and DPT) were diagnosed as having CAPD. Their number in the study group was 32 out of 52 (61.5%) and 18 out of 31 (58.1%) in the control group (Table 1). The finding that about 58% of the control group had CAPD according to CAT, may be explained by the relatively young age of the participants with age range (9–11 years). However, the performance on the majority of CAT should reach normal values by the age of 11–12 years. The second

explanation is that a high percent (41.9%) of those children in the control group had abnormal performance in the DPT which is a difficult task requiring verbal response and higher level of auditory processing. Table 2 showed that the most affected central auditory function is the temporal processing ability (mean: 56.98 for right ear and 54.81 for left ear) and to a lesser extent, auditory separation and selective auditory attention, while the closure ability was the least to be affected (mean: 97.15 for right ear and 97.00 for left ear). These findings agreed with those obtained by Kamal et al.¹⁸, Shalaby,²⁰

As regards the performance on the CAT, it was obvious that there was a statistically significant difference between study and control groups in all tests. These findings agreed with those obtained by Kamal et al.¹⁸, Shalaby²⁰, Pinheiro²¹ and Musiek et al.²² Rosen and Mnganari²³ and Amitay et al.²⁴ in two separate studies have investigated auditory processing in dyslexics, they have concluded that a subset of dyslexics do have difficulties with certain psychophysical tests. Demonet et al.²⁵ argue for abnormal patterns of cerebral activation in dyslexia more particularly at the level of the auditory cortex. Veuillet et al.²⁶ in their study, confirms the existence of deficits in auditory processes for some children with dyslexia. Pinheiro et al.⁹ pointed to the fact that the group of school-aged children with learning disorders have alterations in their attention auditory skills, acoustic information integration, sequencing and organization of the acoustic signals and the figure-back ground acoustic signal for verbal sounds which end up compromising their performance in the auditory processing tests.

The present study showed that the most affected central auditory function is the temporal processing ability. The temporal processing task involved in DP test is a difficult task requiring higher level of auditory processing and the verbal response required from those children made it more difficult. Many studies^{27–29} investigated the effect of temporal variables such as stimulus duration and task complexity in a group of dyslexic and control children. They stated that dyslexic children presented a significant drop in performance in cases of decreased stimulus duration. King et al.³⁰ investigated the extent of comorbid auditory processing disorder (APD) in a group of adults with developmental dyslexia. The results demonstrated that approximately half of the participants with developmental dyslexia had clinically significant diminished performance on the DPT that is indicative of APD. These results indicate that the percentage of persons with developmental dyslexia and comor-

Table 4 Correlation between items of phonological awareness and SPIN test.

Phonological awareness items	SPIN			
	Right		Left	
	r-Value	P-Value	r-Value	P-Value
1 Rhyme detection	0.036	0.800	0.094	0.508
2 Blending of sounds to form a word	0.181	0.199	0.134	0.435
3 Segmentation of a word into sounds	0.213	0.130	0.233	0.097
4 Recognition of the first sound of the word	0.141	0.319	0.172	0.223
5 Recognition of the middle sound of the word	0.219	0.119	0.306	0.027*
6 Deletion of the first sound of the word	0.038	0.787	0.112	0.430
7 Deletion of the middle sound of the word	0.263	0.060	0.278	0.046*
8 Deletion of the last sound of the word	0.256	0.067	0.252	0.072
9 Addition of a sound to the word	0.398	0.004*	0.401	0.003*

* $P < 0.05$.

bid APD may be substantial enough to warrant serious clinical considerations. Share et al.³¹ found that, children with reading difficulties displayed lower performance in all the temporal processing tests when compared to children without problems.

Banai and Ahissar³² obtained similar findings among dyslexic and control groups for tests involving simple stimulus discrimination and decreased performance in tasks involving identification or stimulus ordering.

In the present study there was a significant correlation between results of phonological awareness test and results of SPIN test (left ear). This correlation was mainly in items involving recognition of the middle sound of the word, deletion of the middle sound of the word, and addition of a sound to the word. These tasks of phonological awareness are the most difficult tasks and need more concentration. Many studies stated that school-aged children with learning disability have reduced response capacity facing the stimuli presented because of alterations in the development of auditory attention skills. These children have significant loss in these skills and have prolonged concentration difficulties and as a consequence, a loss in auditory information processing and perception.³³

In contrast to the present study, Pinheiro et al.⁹ stated that, in the speech-in-noise test, they did not find statistically significant differences in the performance of the two compared groups. Also, McAnally et al.³⁴ found no differences between good and poor readers in temporal discrimination ability in tasks involving the frequency variable.

Despite the large number of studies associating dyslexia with auditory temporal processing, there is still some controversy about this association. According to Tallal³⁵, one of the reasons for the existence of such doubts is related to the characteristics of the stimuli and to the tasks considered for the tests used. Also, the differences observed between studies may be related to the characteristics of the individuals in the groups examined, such as their cognitive profiles. Ben-Yehudah et al.³⁶ studied the influence of cognitive skills in auditory temporal tests and their results showed that these skills could influence the dyslexic group. Heiervang et al.²⁹ and Murphy and Schochat³⁷ are in agreement about the importance of the duration of the stimuli to be considered as a variable in studies involving dyslexia.

5. Conclusion

The group of children with phonological awareness problem demonstrated inferior performance in central auditory functions compared to the group without phonological awareness problem, reflecting difficulties on the processing of auditory information.

6. Recommendations

Central auditory testing should be highly considered for developing rehabilitative strategies and special educational programs for children with dyslexia and phonological awareness problems.

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