Reading difficulty in children: auditory and visual modalities' affection

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Background
Many research studies have explained that an auditory processing deficit might be the underlying cause for some forms of reading difficulties. However, deficits affecting other modalities, such as vision might be the other potential contributing factor.
Objectives
This research investigated both central auditory processing abilities and the visual pathway in children having scholastic underachievement due to reading difficulties.
Patients and method
The study group consisted of 15 children (eight male and seven female) between the age of 5 and 15 years. They had scholastic underachievement due reading difficulties. All children were subjected to a standardized Arabic central auditory test battery for children. It included tests for selective auditory attention, dichotic listening, memory, and temporal processing abilities. Other tests that were administered included electrophysiologic measures, auditory event-related potentials (P300), and visual-evoked potential (P100), as well as the Illinois test of psycholinguistic abilities and screening test for risk for dyslexia to verify reading complains and to assess psycholinguistic abilities.
Results
Central auditory test battery that was accompanied by abnormal auditory event-related potentials (P300) revealed abnormal pattern mainly affecting temporal processing and memory abilities. However, some children had additional dichotic listening or selective auditory attention deficit. Abnormal visual-evoked potential (P100) was detected in the majority of children. The Illinois test revealed visual pattern affection in those children.
Conclusion
Children with reading difficulties had temporal processing disorder and memory deficit pattern. Furthermore, there was an association between visual affection and reading difficulty that supports multimodality affection in those children. Hence, the remediation program for these children should include both auditory and visual modalities.

Keywords:
central auditory processing, dyslexia, reading difficulty, visual-evoked potentials

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Introduction

The term 'dyslexia' is used to describe specific and significant impairment in reading abilities, unexplainable by any kind of deficit in general intelligence, learning opportunity, general motivation, or sensory acuity [1]. In more recent years, the term 'reading disability' has become preferred over dyslexia to describe children who have difficulty acquiring a wider variety of literacy skills.

Although there is no consistent evidence of one underlying biological or neurological cause of reading disability, phonological awareness skills have been shown consistently to impact early reading achievement. Several researchers have suggested that auditory processing disorder may contribute to the development of generalized learning disabilities or more specific reading and language disorders [2].

However, other theories support that any visual pathway defects with or without corresponding auditory defects can potentially be the fundamental cause of reading problems [3]. Moreover, functional MRI studies have shown that characteristic posterior brain areas are typically involved in reading and reading-related tasks in children and adults. They include both the temporoparietal circuit that may

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reflect mapping the sounds of languages (phonemes) to its written counterparts (letters/graphemes) and the occipitotemporal circuit that may be involved in the processing of words or pseudowords 'visual word form area' [4,5]. Hence, this research aimed to investigate both central auditory processing abilities and their relationship with visual pathway in children with reading difficulties.

Patients and methods

The study group consisted of 15 children (eight male and seven female) with a mean age of 8.5±2.7 years (range: 5–15 years). They were referred to the Central Auditory Clinic at the Audiology Unit, Ain Shams University, due to scholastic underachievement, mainly due to reading difficulties.

Informed consent was obtained from parents of all participants, and approval of the Ethical Committees was obtained.

Methods

Children included in this study were selected according to the following inclusion criteria:

(1) Normal hearing sensitivity (not exceeding 15 dBHL in frequencies from 250 to 8000 Hz) and normal middle ear functions.
(2) Normal visual acuity.
(3) Average or above average intellectual ability (IQ).

Hence, all children were subjected to the following:

Preliminary evaluation

It included basic audiological evaluation (pure tone, speech audiometry, and tympanometry), as well as examination of visual acuity and psychosocial evaluation.

Standardized Arabic central auditory test battery for children [6]

It included tests for selective auditory attention (Arabic speech in noise test, dichotic listening, and Arabic competing sentences for children); auditory memory tests (Arabic memory tests for recognition, content, and sequence) [7]; and temporal processing abilities (pitch pattern test [8], auditory fusion test (AFT), and time compressed speech 40%) [9].

Scoring: Correct score% of each test was calculated and compared with the standardized normative values for the same age group and an abnormal result was considered when the scores were beyond lower 95% confidence limit.

Electrophysiologic measures

(1) Auditory event-related potential (P300) was examined using evoked response audiometer Amplaid MK12. P300 potentials were recorded from surface disc electrodes: the active electrode in forehead FPz, the reference, and the ground electrodes on the mastoid (M1 and M2). Responses to oddball paradigm were collected using 1 and 2 kHz tone bursts, binaural representation at 70 dBSPL. Stimuli were presented at a rate 0.5/s; 1 kHz represented nontargeted stimuli (80%) and 2 kHz represented targeted stimuli (20%) with a total number of 100 stimuli in each run. Responses were averaged through filter 20–100 Hz with 800 ms analysis times. Abnormal responses were considered when P300 response was absent, or if delayed latency or decreased amplitude beyond 2 SD of the mean value of the laboratory normative data was noticed.
(2) Visual-evoked potential (VEP) (P100) was examined using counterpoint 2 MK Dantic equipment. The participants were seated on a chair in a semidark environment at 100 cm from TV screen and asked to focus on a black cross in the center of the screen. The stimuli consisted of black and white checker board-patterned stimuli at a rate of 1.5 Hz monocular recordings. Visual potentials were recorded from surface disc electrodes: the active electrode 5 cm above the inion Oz, the reference in the mid frontal area Fz, and the ground on forehead FPz. One hundred responses were averaged through filter 3–100 Hz with 500 ms analysis time. Two reproducible recordings were averaged. Abnormal VEP were considered when P100 response was absent, or if delayed latency or decreased amplitude beyond 2 SD of the mean value of the laboratory normative data was noticed.

Language and reading test

(1) Screening test for risk for dyslexia was also carried out to verify the reading complain using the modified standardized Arabic dyslexia screening test [10]. It consisted of 10 subtests: rapid naming test, bead threading, one minute reading, postural stability, two minute spelling, backward digit span, nonsense passage reading, one minute writing, verbal fluency, and semantic fluency. According to the total scores, the child is either considered at risk for dyslexia or not considered.
(2) The Illinois test of psycholinguistic abilities using modified standardized Arabic version [11] that

consists of 12 subtests was carried out. Scoring determined the language age and the psycholinguistic abilities' profile.

Statistical analysis

All data were collected and analyzed using an IBM computer statistical package for the social science program (SPSS, version 13) by an expert statistician. The mean±SD were calculated. Student's *t*-test was used for two independent means with normal distribution. Pearson's correlation coefficient test (*r*-test) was used to correlate between two independent quantitative data. The ranked Spearman correlation test was used for nonparametric data. A *P* value less than 0.05 was considered significant.

Results

The study group consisted of eight male and seven (%) female patients with a mean age of 8.5±2.7 years (range: 5–15 years).

Central auditory test battery results

The mean±SD of scores of different central auditory tests and the distribution of abnormal results are presented in Tables 1 and 2 and Fig. 1. The majority of children (93.3%; 14/15) had abnormal scores in AFT, 60% (9/12) of children had abnormal scores in the pitch pattern test, and 33.3% (5/15) of children had abnormal scores in time compressed speech (40% compression), indicating temporal processing deficit. Memory deficits were found in 86.6% (13/15) of children; additional dichotic listening deficit was found in seven (46.6%) children, and selective auditory attention deficit in five (33.3%) children.

Electrophysiologic measure results

There was delayed P300 latency in 93.3% (14/15) of the children, and additional decreased amplitude was found in six children. The mean±SD are represented in. Abnormal P100 was encountered in 11/15 (73.3%) children. One patient had absent response bilaterally and seven (46.6%) of them had both delayed latency and decreased amplitude bilaterally. Normal latency with decreased amplitude bilaterally was found in three children and unilaterally in one child (Tables 3 and 4).

Psycholinguistic and reading test results

Risk for dyslexia was found in 13/15 (86.6%) children of the study group, which confirmed their primary complain. Their psycholinguistic age mean was 6.1±1.1 years (range: 4–7 years), which was significantly lower than their chronological age (*P*=0.01). The majority of children (13/15; 86.6%) had abnormal visual sequential memory, thus reflecting visual pattern affection. Auditory sequential memory and verbal expression deficit were found in 5/15 (33.3%) children, grammatical closure in 4/15 (26.6%), manual expression in 3/15 (20%), and auditory reception (AR) and visual closure in 2/15 (13.3%) (Fig. 2).

Table 1 Mean±SD of central auditory test battery scores (correct%)

	Mean±SD
SPIN	
Rt	82.8±14.7
Lt	83.27±17.0
CS	
Rt	84.9±15.2
Lt	79.1±18.16
PPS	
Rt	75.63±13.9
Lt	73.75±13.8
TC (40%)	
Rt	80±28.2
Lt	79.27±27.8
AFT	22.1±9.5
Memory C	3.47±1.187
Memory S	3.62±1.04

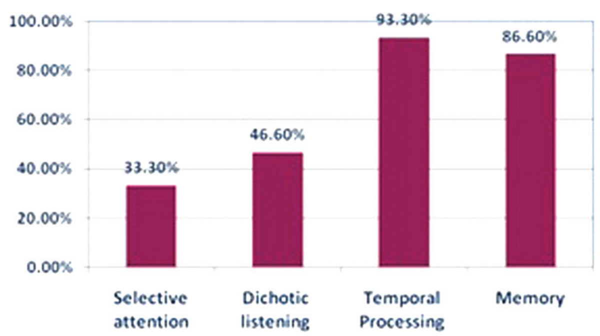
AFT, auditory fusion test; CS, competing sentence test; Lt, left; Memory C, memory for content; Memory S, memory for sequence; PPS, pitch pattern test; Rt, right; SPIN, speech in noise test; TC, time compressed test.

Table 2 Distribution of central auditory tests' abnormality

	Normal [*N* (%)]	Abnormal [*N* (%)]
SPIN	10 (66.6)	5 (33.3)
CS	8 (53.3)	7 (46.6)
Memory	2 (13.3)	13 (86.6)
Temporal subtests		
AFT	1 (6.6)	14 (93.3)
PPS	6 (40)	9 (60)
TC (40%)	10 (66.6)	5 (33.3)

AFT, auditory fusion test; CS, competing sentence test; PPS, pitch pattern test; SPIN, speech in noise test; TC, time compressed test.

Figure 1



Distribution of central auditory ability abnormality.

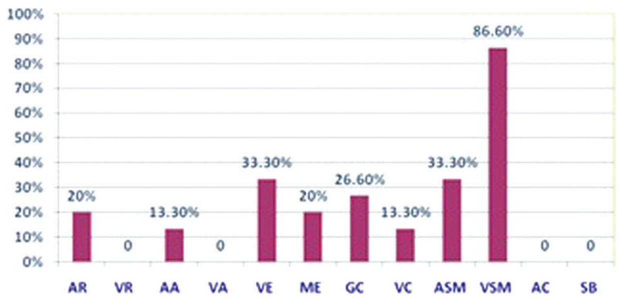
Table 3 Mean±SD of auditory P300 and visual P100 peak latencies and amplitude

	Latency (ms) (mean±SD)	Amplitude (μv) (mean±SD)
P300	420.53±51.68	7.173±1.41
P100		
Right	107.79±16.1	6.18±5.9
Left	108±16.7	5.28±5.5

Table 4 Distribution of abnormal auditory P300 and visual P100 values

	Latency [*N* (%)]	Amplitude [*N* (%)]
P300	14 (93.3)	6 (40)
P100	7 (46.6)	11 (73.3)

Figure 2



Distribution of psycholinguistic ability abnormality. AA, auditory association; AC, auditory closure; AR, auditory reception; ASM, auditory sequential memory; GC, grammatical closure; ME, Mannual expression; SB, sound blending; VA, visual association; VC, visual closure; VE, verbal expression; VR, visual reception; VSM, visual sequential memory.

Correlation studies

The relationship between central auditory test, and psycholinguistic test results versus electrophysiological measures

In the central auditory test battery, AFT (one of the temporal tests) had a significant positive correlation with P300 latency (r=0.65; P=0.03). The χ^2-test showed a positive correlation between AFT and P100 latency (P=0.02 for the right side and P=0.02 for the left side). As for psycholinguistic test battery, there was a significant correlation between visual reception test and P100 latency (r=0.68; P=0.00), as well as between AR test and P300 latency (r=0.52; P=0.04), grammatical closure and P300 (r=0.74; P=0.00).

The relationship between central auditory test results and psycholinguistic test

Furthermore, there was a significant correlation between visual sequential memory and auditory memory test (r=0.62; P=0.01). At the same time, there was a significant correlation between AFT and AR (r=0.62; P=0.04).

Discussion

Audiologically, most dyslexic children have normal hearing thresholds, but many may have an undiagnosed auditory processing disorder [12]. In the present study, auditory processing deficit in both temporal and memory abilities was encountered in the majority of children. In addition, their language age was significantly lower than their chronological one. This pattern of deficit is consistent with the previous assumption that temporal processing deficit is associated with impairments in the phonological aspects of language and reading skill development [13,14].

When analyzing scores of different auditory temporal tests used in this study, AFT had the highest percentage (93.3%) of abnormal scores. Moreover, there was a significant correlation between AFT and AR. AFT is a gap detection task and was considered as an important measurement for temporal resolution [15]. This is in agreement with the notion that temporal resolution is very critical for speech perception and consequently for developing normal speech and reading abilities [16].

Memory is vital to the acquisition of reading, as memory skills are important to remember letters, sounds represented by letters and letter blends, sight words, decoding strategies, and word meanings. In the current study, we found that there was both auditory memory deficit in 83.3% of children and visual sequential memory affection in 93%. This coincides with the previous studies that indicated lower memory skills that were found among reading disabled peers [17].

There was a significant correlation between visual and auditory memory deficits. This may suggest that visual and auditory memory deficits in dyslexics seemingly stems from the same root problem, which is temporal processing. Readers with dyslexia may be unable to correctly encode the phonological characteristics of verbal messages, yielding inefficient information to be maintained in their short memory.

Additional dichotic listening deficit was detected in seven (46.6%) children. Several studies have found links between dyslexia and dichotic skills (specifically binaural integration) listening [12,18]. A possible impaired interhemispheric transfer hypothesis was suggested based on the evidence of impaired interhemispheric sensory and motor information in dyslexics, as well as structural asymmetry found by neuroimaging [19].

Speech perception in noise is a challenging task for children with reading impairment as neural timing is degraded by background noise. However, we found selective auditory attention deficit only in five (33.3%) children.

In the current study, delayed P300 latencies were detected in the majority of the children (93.3%). This is consistent with previous P300 findings in dyslexic children [20,21]. In fact, several processes are necessary to obtain P300, including the auditory cortex, for the detection, sensation, and discrimination of acoustic stimuli, complex network for the reticular formation, as well as memory function. P300 findings world be related to the associate (abnormality) in those children. However, the significant correlation that was found between P300 latencies and AFT may suggest that auditory cognition was significantly affected by the temporal resolution deficit in those children.

On the other hand, abnormal visual-evoked P100 was detected in 73.3% of children, mainly bilateral affection. Although P100 is nonlocalizing to the site of lesion, these findings would reflect bilateral visual pathway dysfunction. Prolonged P100 latencies were significantly correlated to decreased visual reception test scores, which confirmed the relationship between visual pathway dysfunction and visual perception tasks. Moreover, there was a significant relation between AFT and P100 latencies that may suggest that temporal processing affected both auditory abilities and visual pathway. This is in agreement with the theory assuming that a general multimodal temporal processing deficit is an underlying cause of reading failure rather than a specifically auditory temporal processing deficit [22].

Conclusion

Children with reading difficulties had auditory temporal and memory deficit pattern. Visual affection was detected by both VEPs and psycholinguistic abilities. These findings support multimodality affection in those children.

Recommendations

(1) Temporal and memory abilities should be screened for children with reading difficulties.
(2) The remediation program for these children should include both auditory and visual modalities.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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