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Research article

Neurocognitive and Linguistic Deficits in Developmental Dyslexia

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Abstract

Background: It has been suggested that dyslexic individuals manifest difficulties in phonological awareness, rapid naming, morphological awareness, and short-term memory. Nevertheless, the percentage of these difficulties varied among languages. **Materials and Methods:** A group of children who have developmental dyslexia, aged from 6.5 to 10 years, were investigated to determine the percentage of neurocognitive and linguistic deficits in Arabic speaking dyslexic individuals. **Results:** Rapid automatized naming was found to be the most common deficit occurring in all participants. Other linguistic, auditory, visual and memory difficulties were noticed. The percent of deficits in their abilities was determined and discussed. **Conclusion:** The present study suggested that dyslexia is a complex neurodevelopmental disorder rather than a simple disorder related to a phoneme-grapheme correspondence disorder. Furthermore, it emphasized the importance of thorough assessment of different neurocognitive and linguistic abilities using different scales and detailed tests for better design of remediation programs for children having developmental dyslexia.

Key words: Developmental dyslexia, cognition, language, deficits.

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1. Introduction

The neurocognitive and linguistic deficits in developmental dyslexia (DD) have been investigated in some Alphabetic and non-alphabetic languages. It has been suggested that dyslexic individuals manifest difficulties in phonological awareness, rapid naming, morphological awareness, and short-term memory. Nevertheless, the percentage of these difficulties varied among languages [1, 2]. Therefore, the aim of this study was to determine the neurocognitive and linguistic difficulties in Egyptian Arabic speaking children with developmental dyslexia. This would help in better understanding of the complexity of the disorder and in proper designing of interventional plans for such individuals.

2. Materials and Methods

A cross-sectional descriptive study of 20 Arabic speaking participants with developmental dyslexia was performed.

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The participants were recruited from the learning disability and special needs education clinic, Medical Research Centre of Excellence, National Research Centre, Cairo, Egypt. Their age ranged from 6.5 to 10 years. Their IQ scores ranged from 90 to 115. They obtained a score (1) or more in the dyslexia assessment test [3, 4]. They had similar socioeconomic status. They were 14 males (70%) and 6 females (30%). They did not have a history of motoric developmental delay. Children who manifested abnormalities on neurological examination, one hour EEG abnormalities or sensory deficits were excluded from the study. They were divided into two subgroups according to their gender and comparison between both groups regarding each estimated percent was performed. The mean chronological age for males was (8.6 ±1.1) and it was (8.9±0.9) for females. The mean IQ for males and females was (97.6±7.5) and (94.5±3.4) respectively. Their academic grades ranged from first to fifth primary. Written consents from their parents were obtained.

Assessment of Neurocognitive and Linguistic Skills:

The tests and scales used for assessment of the neurocognitive and linguistic abilities were as follows:

1. Psychometric evaluation was performed using the Arabic version of Stanford Binet Intelligence Scale"4th edition" which includes verbal Reasoning, visual reasoning, quantitative reasoning and short-term memory [5, 6]. Difficulties in the performance were considered when the final score of the sub-item was below 90.
2. Dyslexia Assessment Test sub-items include: rapid naming, bead threading, one minute reading, postural stability, phonemic segmentation, two minute spelling, backward digit span, nonsense passage reading, one minute writing, verbal fluency and semantic fluency [3,4]. Deficits were considered when the child obtained one minus (-) or more in any evaluated sub-item.
3. Illinois Test of Psycholinguistic Abilities (ITPA) [7,8] which has the following subtests for assessing different abilities: auditory reception, visual reception, auditory association, visual association, verbal expression, manual expression, auditory sequential memory, grammatic closure, visual closure, and visual sequential memory. The child's ability was considered delayed when the difference between the mean of his or her standard scores and the standard score of this ability was more than 6.
4. The Standardized Arabic Language Test (SALT) [9] by which language ages were obtained for receptive and expressive syntax, semantics, pragmatics and prosody. Furthermore, the total language age was obtained. The items of the test were considered delayed when the difference between the obtained language age and the child's chronological age was more than 6 months.
5. The Test of Semantics was used for assessment of semantics at both word and sentence levels. It was used for the children who ranged from 6.5 to 8.5 years. The word level part included testing synonyms, antonyms and hyponyms. The sentence level part included testing the ability to arrange 3-step or 4-step sequencing cards [10]. The test items were considered delayed when the child's score was less than what is expected from him according to the test manual.
6. Phonological Awareness (PA) Test was performed to assess the word awareness, syllable awareness, rhyme awareness and phoneme awareness [11]. The test items

were considered delayed when the child's score was less than what is expected from him according to the test manual.

3. Results

The percent of participants showing deficits in each item of the used tests is illustrated in tables 1, 2 and 3. All participants manifested difficulties in rapid naming sub-item or subtest of the dyslexia assessment test. The most common defective abilities were verbal fluency followed by phonemic segmentation. None of the participants manifested difficulties in quantitative reasoning, verbal reasoning, manual expression, visual sequential memory, prosody development or in blending syllables into words. Comparison between males and females regarding the percent of participants showing deficits in all tested abilities revealed non-significant difference.

Table 1. Percent of participants showing deficits in the sub-items of the Stanford Binet Intelligence Scale, the dyslexia assessment test and the Illinois test of psycholinguistic abilities

Test Type	Sub-items	Percent of Participants Showing Deficits (%)
Stanford Binet Intelligence Scale	Verbal reasoning	0
	Visual reasoning	23
	Quantitative reasoning	0
	Short-term memory	23
Dyslexia Assessment Test	Rapid naming	100
	Bead threading	25
	One min reading	70
	Posture stability	30
	Phonemic segmentation	90
	Two min spelling	75
	Back ward digit span	50
	Non sense passage reading	95
	One min. writing	80
	Verbal fluency	95
	Semantic fluency	65
Illinois Test of Psycholinguistic Abilities	Auditory reception	50
	Visual reception	20
	Auditory association	10
	Visual association	15
	Verbal expression	5
	Manual expression	0
	Auditory sequential memory	5
	Grammatic closure	45
	Visual closure	35
	Visual sequential memory	0

Table 2. Percent of participants showing deficits in the items of the Arabic language test and the test of semantics

Test type	Items of the tests	Percent of Participants Showing Deficits (%)
Arabic Language Test	Receptive language age	15
	Expressive language age	5
	Semantics age	5
	Prosody age	0
	Pragmatics age	15
	Total language age	5
Test of Semantics	Synonyms	40
	Antonyms	40
	Hyponyms	50
	Sequencing	55

Table 3. Percent of participants showing deficits in the items of the phonological awareness test

Test items	Percent of Participants Showing Deficits (%)
Segmenting sentence into words	20
Blending syllables into words	0
Segmenting words into syllables	10
Isolating initial phonemes	20
Isolating final phonemes	30
Isolating middle phonemes	65
Blending onset and rimes into words	30
Segmenting words into onset and rimes	30
Blending phonemes into words	55
Segmenting words into phonemes	50
Recognizing rhyming words	45
Generating rhyming words	10
Deleting initial phonemes	55
Deleting final phonemes	65
Deleting middle phonemes	70
Substituting initial phonemes	65
Substituting final phonemes	70
Substituting middle phonemes	70
Phoneme- grapheme correspondence	75
Producing multisyllabic words	30

4. Discussion

Developmental Dyslexia (DD) is a neurogenetic disorder characterized by unexpected low reading achievement despite adequate intelligence, education and motivation [12]. The neurocognitive developmental dysfunctions in DD may involve multifocal cortical system including the linguistic system [13]. Dyslexia is related to a phonological awareness deficit which is a lower order process disorder and it has been always referred to as a specific type of learning disability [14,15]. In spite of being a higher order process deficit, rapid

naming deficit is frequently reported with DD even though in non-alphabetic languages speakers [2]. This is consistent with the present pilot study in which all participants manifested rapid naming deficit and 95% of them manifested verbal fluency deficit which is also a sign of vocabulary deficit. Other defective items that reflected a word finding difficulty or a rapid automatized naming (RAN) deficit in the present study included auditory association and semantic fluency. Moreover, other forms of higher order process disorders were observed such as semantic deficits (up to 55% in sequencing) and to lesser extent the syntactic deficits (45% in grammatic closure). This is in accordance with Schulz et al. [15] and Cantiania et al. [16] who reported semantic and syntactic deficits in dyslexic individuals. Moreover, 50% of the participants faced difficulties in auditory reception, and 10% in auditory association which mirror an auditory processing problem. Ortiza et al. [17] reported auditory and visual perceptual deficits for linguistic and non-linguistic stimuli in children who are at risk of DD which implies that the perceptual deficits are a cause rather than a result. However, the percent of deficits in receptive linguistic stimuli and in visual non-linguistic stimuli was minimal in the participants of this study. This could be attributed to older age of the participants in the present study which may have helped them to overcome such difficulties. Furthermore, the verbal working memory deficit was frequent among participants (50% in backward digit span). However, the verbal sequential rote memory was only defective in 5% of participants and none of them manifested a visual sequential memory deficit. Therefore, the verbal working memory is suggested to influence the development of reading. This is in agreement with Moura et al. [18] who reported deficits in the verbal working memory not in the visual memory and suggested a relation between the working memory performance and the prediction of reading and spelling abilities. Notwithstanding, Trecya et al. [19] reported a sequential short-term memory deficit and suggested a potentially causal involvement of the sequential short-term memory processes in reading acquisition. The different linguistic and genetic attributes of participants could explain such disagreement between different studies. On the other hand, Willcutt et al. [20] reported common association between reading disorder and mathematical disorder. This was not the case in our series based on the psychometric testing which revealed normal quantitative development.

Neuroanatomical structural and functional brain studies shed light on the possible brain regions involved in DD and its associated disorders. The left inferior frontal gyrus was related to reading deficit and to syntactic deficits [21]. In addition, the left temporoparietal region was responsible for phonological processing, phoneme-grapheme correspondence and semantics [15,22,23]. Furthermore, difficulties in auditory processing were related to the insular cortices and to the left inferior frontal gyrus [24]. The percent of males with dyslexia in this study was 70% which is consistent with Rutter et al. [25] who reported that dyslexia is more common in males. To our knowledge, the difference between dyslexic males and females concerning the percent of deficits in their abilities was not previously investigated.

It is noteworthy that verbal reasoning was normally developed in the participants. Nevertheless, linguistic assessment using other more detailed tests revealed syntactic, semantic, and pragmatic deficits in a

considerable percent of them. Thus, the detailed assessment of individuals with such disorder is mandatory for highlighting the interlacing deficits that constitute developmental dyslexia.

Conclusion

Dyslexia is a complex neurodevelopmental disorder rather than a simple disorder related to lower order process disorders or a phoneme-grapheme correspondence disorder. Furthermore, the thorough assessment of different linguistic and cognitive abilities using different scales and detailed tests is mandatory for the proper design of remediation programs for children with developmental dyslexia.

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