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Auditory Recognition of Words and Digits in Multitalker Babble in Learning-Disabled Children with Dichotic Listening Deficit

Mohammad Ebrahim Mahdavi,[1,2,*] Akram Pourbakht,[1] Akram Parand,[3] Shohreh Jalaie,[4] Maryam Rezaeian,[2] and Elham Moradiju[2]

[1]Department of Audiology, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran
[2]Department of Audiology, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[3]Faculty of Psychology and Education, University of Tehran, Tehran, Iran
[4]Department of Physiotherapy, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran

[*]*Corresponding author*: Mohammad Ebrahim Mahdavi, Department of Audiology, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran. E-mail: mahdavime@sbmu.ac.ir

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Abstract

Background: Previous studies have reported the weakness of recognition of speech-in-noise and dichotic listening deficit in Learning-Disabled (LD) children. This study aimed at further investigating these two deficits in LD children.
Methods: Overall, 33 LD children with dichotic listening deficit from a government rehabilitation center and 39 normal-achieving (NLA) children from three elementary schools were selected with the convenience sampling method to participate in this cross-sectional study (Tehran, Iran). Learning-disabled children were categorized in two categories of unilateral dichotic separation deficit (UDSD) and bilateral dichotic separation deficit (BDSD).
Results: Mean ($\pm$ SD) of signal-to-noise ratio (SNR) for binaural recognition of words and digits-in-noise in LD children (3.5 ± 1.7 and -11.0 ± 2.1 dB, respectively) was significantly higher than corresponding means of NLA children (1.8 ± 1.1 and -13.8 ± 1.1 dB, respectively ($P = 0.001$)). Mean SNR of the right ear in BDSD children in recognition of words-in-noise (5.0 ± 1.9 dB) was significantly higher than that of the right ear in UDSD children (3.5 ± 1.5 dB; $P = 0.018$, $d = 0.96$).
Conclusions: Monaural and binaural recognition of words and digits-in-noise are impaired in LD children with dichotic listening deficit. It seems that BDSD children show an inter-aural asymmetry in recognition of words-in-noise with poorer performance in the right ear.

Keywords: Dichotic Listening, Learning Disability, Speech Intelligibility

1. Background

A listener's capability for extracting speech presented in nonlinguistic noise is defined as recognition of speech-in-noise. This ability depends on several mechanisms of the auditory system, including frequency resolution, temporal resolution and integrity of neurophysiologic transmission along central auditory nervous system (1) and listener cognitive function (2). The common result of previous behavioral researches performed on various groups of children with language, reading and learning disorders, is the difficulty of speech perception in background noise (3, 4). Abnormal ear asymmetry in dichotic listening is a prevalent sign in children with learning disability (5). Pinheiro et al. (2010) (6) confirmed previous studies, which reported children with learning disability show inferior performance than children without learning disability in dichotic listening tests.

Since learning-disabled (LD) children represent a population of children with high possibility of deficiency in performances of dichotic listening and recognition of speech-in-noise, it is feasible to investigate how LD children's ability to recognize speech-in-noise is associated with dichotic listening deficit. A school-aged child may indicate a unilateral or bilateral dichotic deficit. It is not known, who requires more signal-to-noise ratio (SNR) to perform equivalent to normal children in the same age range when learning within a classroom. Most previous studies have investigated recognition of speech-in-noise in LD children using tests that determine the recognition performance as a percentage of correct answers, while the result of the new generation tests that express speech recognition performance in SNR (50%) is more meaningful for specialists in selecting a management strategy for LD children in educational environments. So far, digit materials, representative monosyllabic words with minimal language load, have not been used for assessment of recognition of speech-in-noise in LD children. All of the above-mentioned issues have been addressed in the cur-

rent study.

2. Objectives

The first purpose of this study was to compare recognition of words and digits in presence of multitalker babble between LD children with dichotic listening deficit and NLA children. The second purpose was to evaluate the ability of LD children for recognition of speech-in-noise considering binaural separation deficit.

3. Methods

3.1. Study design and Participants

The current study had a cross-sectional design and was conducted in Tehran, Iran from July 2015 to November 2015. For calculating the sample size, we conducted a pilot study on 10 LD children, who were randomly selected from LD children referred to a major government rehabilitation clinic, and 10 children with typical educational achievement from an elementary school. The sample size was calculated using the following formula for all variables. The optimum sample size was 25 children in the each group. We increased the sample size by 30% for compensation of potential sample dropout. We recorded the names of 79 LD children from the study of Esmaili at al. (2016) (7), who had referred to this clinic and were selected with the convenience sampling method, and 41 NLA children from three elementary schools, who agreed to participate in our study.

$$n = \frac{\left(S_1^2 + S_2^2\right) \times \left(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}\right)^2}{\left(\overline{X_1} - \overline{X_2}\right)^2} \quad (1)$$

α = 0.05 and β=0.2.

The primary inclusion criteria for all children were age of 6 to 12 years, education in an ordinary school, hearing thresholds lower than 20 dB HL (hearing level) in octave frequencies of 500 - 4000 Hz and normal tympanogram (Type A and tympanic peak pressure of + 50 to -50 dapa, using a calibrated AT-235 impedance audiometer; Interacoustics, Denmark). Inclusion criteria for dichotic LD children were: a unilateral or bilateral abnormal result in a Persian dichotic listening test of competing words (CW) and /or competing sentences (CS). Exclusion criteria for LD children were abnormal hearing thresholds and bilateral normal score in CW and CS test. Overall, 52 LD children, who accepted participation, were evaluated for dichotic listening deficit. Finally, 33 LD children indicated dichotic listening deficit and 19 LD children were excluded due to normal dichotic listening results. Inclusion criteria for NLA children were right-handedness and first semester report card showing normal school achievement (as the quality score of "good" or "very good"). Finally, 39 NLA children participated in the study as the control group. The groups of LD and NLA children were matched regarding the number of children per age group (6 - 7, 8 - 9, and 10 - 12 years).

3.2. Ethical Considerations

The Ethical Committee of Iran University of Medical Sciences approved the study (Code: IR.IUMS.rec.1394.2648, Date: 94/6/15). Ethical and moral issues were considered in this study. The study methods were explained to all children and one of the parents filled and signed a consent form. The children were paid for participation in the current study.

3.3. Instruments

Recognition of speech-in-quiet was examined by Persian monosyllabic words appropriate for children aged 4 to 7 years old. Adapted tests for use in Persian language include randomized dichotic digits (RDD), CW, CS, auditory recognition of words-in-noise (ARWIN) and auditory recognition of digits-in-noise (ARDIN) with acceptable test-retest reliability (8-12). The ARWIN and ADIN tests have three lists. The right ear of the children was tested by list 1, left ear by list 2 and binaural listening by list 3. The RDD test was performed under free recall and CW test under pre-cued directed attention condition.

The tests were administered in a double-wall audiometric booth by connecting a compact disc player to the audiometer (using a calibrated AC-40 clinical audiometer; Interacoustics, Denmark). Calibration of the output of the audiometer was done by a sound level meter (B & K model 2209). The speech materials of the RDD and CW tests were presented to the ears of the children at 50 dB SL (sensation level; ref: speech reception threshold), and of the CS test at 35 SL for the targeted ear and 50 dB SL for the non-targeted ear. The ARWIN was administered at 55 dB SL and ARDIN at 60 dB SL.

The clinical variables included ear scores obtained by testing dichotic listening in percentage correct and monaural and binaural SNR (50%) obtained by ARWIN and ARDIN in decibels (dB).

Since the CS test examines binaural separation, which is important for recognition of speech in noisy environments, we considered the mean minus two standard deviations of scores of NLA children in CS test as a cutoff point and categorized LD children performance in two categories of unilateral dichotic separation deficit (UDSD) and bilateral dichotic separation deficit (BDSD).

3.4. Statistics

The Kolmogorov-Smirnov statistical test was used for checking the normality assumption about the data and this assumption was not rejected for all variables. We utilized the exact method of bootstrap for statistical analysis through SPSS 21. Independent t-test was used for comparing the mean results between the groups. In this study, P values of less than 0.05 were considered significant.

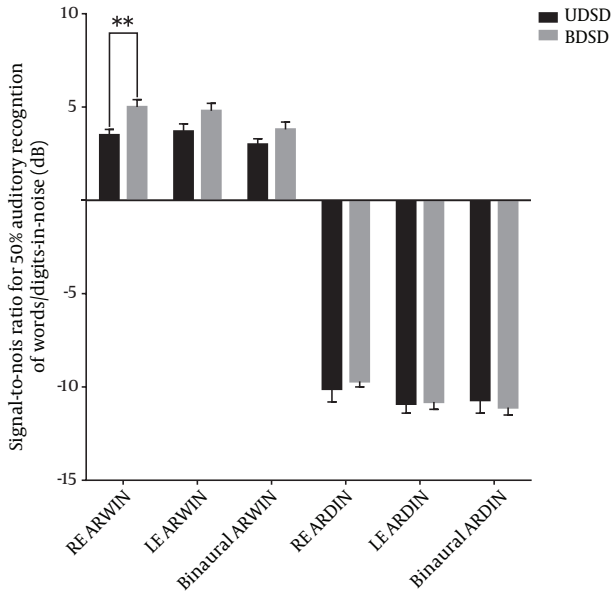
4. Results

In the current study, 52 LD children were evaluated for dichotic listening deficit. Overall, 33 LD (21 males and 12 females) children with dichotic listening deficit were entered in this study. Two NAL children did not attend the evaluation session and so 39 (25 males and 14 females) NAL children completed the study. Mean age of LD children (8.5 $\pm$ 2.0 years) did not significantly differ from mean age of NLA children (8.0 $\pm$ 1.7 years) (P = 0.188). All control NLA children were right-handed and right-handedness was seen in 27 (81.8%) and left-handedness in 6 (18.2%) of the LD children. Furthermore, UDSD was seen in 13 (39.4%) and BDSD in 20 (60.6%) children. Each group of UDSD and BDSD had three left-handed children. Mean recognition speech-in-quiet of LD children for right and left ear (RE: 99.3%, SD = 2.1%, LE: 99.4%, SD = 1.8%) did not differ significantly from corresponding means of NLA children (RE: 99.8%, SD=0.9%, LE: 99.7%, SD = 1.1%) (For the right ear, P = 0.193 and for the left ear, P = 0.402).

Comparison of mean score of the right and left ears in dichotic listening tests (RDD, CW and CS) between the two groups revealed that LD children had significantly lower performance compared to NLA children in the both ears (P = 0.001 for RDD, CW and CS tests results shown in Table 1). The tests of recognition of speech-in-noise (ARDIN and ARWIN) indicated that LD children significantly needed higher SNR compared to NLA children, (P = 0.001 for ARDIN and ARWIN test's results shown in Table 1).

Comparison of recognition of speech-in-noise between UDSD and BDSD children demonstrated that mean (SD) of the right ear ARWIN test in BDSD children (5.0 $\pm$ 1.9 dB) was significantly poorer than that of UDSD children (3.5 $\pm$ 1.1 dB, P = 0.018, d = 0.96). Statistical analysis did not detect any significant difference between UDSD and BDSD children in the left ear and the binaural listening for ARWIN and ARDIN tests and mean performance of the right ear for ARDIN test (Figure 1).

Figure 1. Comparison of Signal-to-Noise Ratio Needed for 50% Recognition of Words and Digits in Multitalker Babble in Learning-Disabled Children With Unilateral (n = 13) and Bilateral (n = 20) Dichotic Separation Deficit



On average, BDSD children needed more SNR than children with UDSD in the right ear. Error bars represent standard error of mean.

5. Discussion

The results showed that LD children with dichotic listening deficit performed poorly in recognition of speech-in-noise. On average, to perform at the same level as NLA children, LD children needed 2.8 dB higher SNRs for binaural recognition of digits and 1.7 dB higher SNRs for binaural recognition of words-in-noise (Table 1). Monaural performance of LD children in recognition of speech-in-noise was poorer than the performance of NLA children as well. This finding may have some practical significance for designing acoustical modification of classrooms and using assistive listening device for LD children with dichotic listening deficit.

Ziegler et al. (2009) and Boets et al. (2007) (13, 14) investigated perception of speech-in-noise in children with or at risk of dyslexia, which is associated with dichotic listening deficit (15). Although these two studies did not investigate the issue of dichotic listening deficit in dyslexia, their results indicate impaired perception of speech-in-noise in children with or at risk of dyslexia, which is in line with the our results. In a more relevant study, Ghannoum et al. (2014) used Arabic dichotic digits and speech intelligibility in noise tests (in percent correct) for assessment of auditory processing in LD children. Furthermore, LD children with age range of 8-10 years obtained significantly lower score in one or both ears versus the control group. Ghannoum et al. did not evaluate binaural separation (16); however, their results are in line with parts of the current study.

Table 1. Mean (SD) and 95% Confidence Interval (CI) for Dichotic Listening and Recognition of Speech-in-Noise of Normal-Achieving (n = 33) and Learning-Disabled (n = 39) Children[a]

	Right Ear					Left Ear					Binaural Listening				
	NLA Children	95% CI	LD Children	95% CI	P	NLA Children	95% CI	LD Children	95% CI	P	NLA Children	95% CI	LD Children	95% CI	P
ARWIN (dB)	2.4 (1.2)	2.0-2.8	4.4 (1.8)	3.8 - 5.0	0.001	2.4 (1.3)	2.0 - 2.8	4.3 (1.7)	3.7 - 4.9	0.001	1.8 (1.1)	1.4 - 2.1	3.5 (1.7)	2.9 - 4.1	0.001
ARDIN (dB)	-12.1 (1.6)	-12.6- (-11.6)	-9.9 (1.9)	-10.5 - (-9.2)	0.001	-12.6 (1.6)	-13.1 - (-12.1)	-10.9 (1.9)	-11.5-(-10.2)	0.001	-13.8 (1.1)	-14.1 - (-13.5)	-11.0 (2.1)	-11.7 - (-10.2)	0.001
RDD (%Correct)	92.0 (4.1)	90.7 - 93.2	68.8 (15.6)	63.3 - 73.8	0.001	73.1 (10.9)	69.7 - 76.5	56.4 (15.9)	50.5 - 61.8	0.001					
CW (%Correct)	91.2 (5.9)	90.2 - 93.9	74.2 (17.6)	68.4 - 79.7	0.001	90.0 (6.3)	88.1 - 91.9	52.6 (22.0)	44.6 - 60.1	0.001					
CS (%Correct)	96.3 (4.8)	94.8 - 97.8	69.0 (31.0)	58.0 - 80.0	0.001	87.7 (10.6)	84.3 - 91.1	28.7 (27.6)	19.4 - 38.2	0.001					

[a] LD children showed significantly poorer performance in the right and left ear than NLA children for dichotic listening and in monaural and binaural recognition of speech-in-noise tests.

Although children with learning disabilities are a heterogeneous group, the evidence from this study suggests that an LD child with BDSD in comparison to an LD child with UDSD needs more SNR for recognition of words-in-noise in the right ear, not for digits-in noise. There were no similar studies for comparison; nevertheless according to the Bellis/Ferre model of auditory processing disorder in children, the auditory decoding deficit (ADD) subprofile shows poorer performance of right ear versus left ear for low-redundancy speech and recognition of speech-in-noise tests and weakness in binaural integration and/or binaural separation for dichotic listening (17). The results of the current study may be helpful in planning aural rehabilitation of children with BDSD; for example, an ear-specific along with diotic word-in-noise training is used for children with BDSD. More studies are needed to determine whether poorer performance of the right ear in children with BDSD versus UDSD is only limited to LD children, or can be generalized to other children with BDSD. Since several studies have reported abnormality of encoding of speech-in-noise among children with learning disorders at the cortical (18) and brainstem level (19-21), it would seem useful for a study to compare encoding of speech-in-noise and speech-in-quiet between children with UDSD and BDSD, utilizing speech-evoked potentials.

5.1. Strength Points

• Comprehensive dichotic listening evaluation with attention measures (divided, selective and directed attention).

• Reporting binaural recognition of speech-in noise in LD children, not routinely assessed.

5.2. Limitations

• Limitation in generalizing the findings due to sampling of LD children only in one main center of rehabilitation with low sample size.

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