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RESEARCH ARTICLE

Development and psychometric evaluation of Persian version of fused dichotic rhymed word test for 6-11 year-old Persian speaking normal children

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Abstract

Background and Aim: Dichotic listening tests have been used to study right ear advantage (REA). Fused dichotic rhymed word test (FDRWT), using rhymed words, is advantageous because of reducing the effect of attention on the test results. Development of Persian version of the FDRWT, and evaluation of its psychometric properties in normal children were the aims of the present study.

Methods: This study was conducted in two parts: selecting Persian monosyllabic word pairs according to the intended criteria and assessing content validity through Lawshe method. The test was set in a dichotic condition using four lists. Each list contains 30 pairs of words which were administered on 204 normal right-handed children from six different age groups (6-11 years old) of both genders. In order to evaluate the reliability of the test, retest was carried out within one to three weeks after the initial test.

Results: Content validity index (CVI) of FDRWT was 0.89. The results indicated greater right ear average scores for all the age groups ($p<0.001$). The average ear advantage for the age groups $\leq$ 10 years old was significantly higher than that of 11 year-old age group. The test has excellent internal consistency and high reliability ($p<0.001$).

Conclusion: The findings showed desirable validity and reliability of Persian version of the FDRWT so it can be used in evaluation of hemispheric language specialization in Persian-speaking children. More studies are needed to examine the test results in children suspected of having central auditory processing deficits.

Keywords: Dichotic listening; fused dichotic rhymed word test; children; Persian language

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Introduction

Binaural hearing leads to the increase of loudness, improvement of sound quality, better word recognition, and an increase in ease of listening, compared to monaural hearing [1]. Binaural hearing also plays an important role in perception of speech in noisy condition and sound localization [2,3]. Bilateral representation of hearing information starts from brainstem and continues into brain cortex [4]. The mechanism of binaural integration can be evaluated using behavioral methods, such as dichotic listening

tests. The term "dichotic" refers to the condition where two different acoustic stimuli are simultaneously presented to the right and left ears. The common finding in studies of dichotic listening of verbal stimuli has shown the right ear advantage (REA) over the left ear that means more correct responses from the right ear indicating the left hemisphere advantage for verbal processing [5]. Kimura reported that, in average, REA is seen in right-handed children from the age of 4 to 9 confirming the left hemisphere advantage for verbal processing in this age range [6]. Dichotic listening test is a non-invasive method for examination of the role of hemispheric asymmetry and interhemispheric transfer of information (via corpus callosum) in speech processing [5,7]. Developmental myelination of corpus callosum occurring in the first two decades of life has an essential role in the interhemispheric transfer of hearing information and during its maturation an improvement is seen in the ability to process dichotic information [8]. The left ear scores improve faster than the right ear scores during development, and this leads to a reduction in the REA. The minimum difference between the right and left ear scores has been reported for the age group of around 11 to 12 years old, which is similar to that reported in adults [9], however, due to the left hemispheric advantage (verbal hemisphere), some right ear advantage still remains [5]. Lack of normal development of binaural processing and binaural integration in the central auditory system in children may lead to such problems as impairments in lateralization and sound localization, difficulty of hearing in noise and competing sounds, and problems in learning complex concepts, following conversations, and remembering heard information [10,11].

Numerous dichotic tests with different linguistic contents have been designed to assess binaural processing. Linguistic content of dichotic tests has some impact on the value of REA [12]. Most studies have used digits as test material. Although digits have less contextual cues as compared to sentences and disyllabic words, they form a closed-set test, too familiar and have limited frame of response that may result in easier recognition and thus, overestimation of dichotic ability [13]. Previous studies have pointed out the overestimation in the single and double dichotic digit tests for children [9,14]. Monosyllabic words with minimum contextual cues and when presented in open-sets are in the mid-spectrum of difficulty [13].

Given the limitations of other dichotic tests, such as low test-retest correlations, and prevalence of left ear advantage (LEA) in righthanded people, the fused dichotic rhymed words test (FDRWT) has been taken into consideration [15]. Previous studies have shown the validity of this test in assessing hemispheric asymmetry [15-18] and corpus callosum performance in normal and abnormal cases [19]. In this test, due to simultaneous presentation of words with the same waveform, a single concept is received by subjects (they just comprehend one word each time) [15], therefore, the error due to the order of recalling the stimuli is reduced [17]. In addition, the FDRWT is less affected by changes in attention compared to other dichotic tests [20,21].

Available Persian dichotic tests in children include dichotic competing words [22] and single [23] and double digit tests [24]. Due to lack of dichotic word tests for children in Persian, in present study we have focused on development and evaluation of psychometric properties of the Persian version of the FDRWT in normal children aged 6-11 years old.

Methods

The present study had two parts: development of the test, and administration and evaluation of its psychometric properties.

Development of the test

A list of Persian monosyllabic word pairs with a consonant-vowel-consonant (CVC) structure were selected from Moein Persian Dictionary [25], differing only in their initial (Persian) stop consonants (/G/, /g/, /k/, /t/, /d/, /b/, /p/, /ʔ/) as in the original version of the FDRWT [15]. Since previous studies have shown the role of temporal information in the results of dichotic

listening laterality, i.e. syllables with a longer voice onset time (VOT) lead to errors in the scores of the ear they were presented to, and even dominance over REA [26,27], we have paired consonants according to similarity of their VOTs (each word pair consisted of consonants with similar VOTs of the Persian stop consonants [28]). First, the initial list consisting of 34 word pairs was developed and then 22 word pairs appropriate for the age of children (29) were selected.

The content validity ratio (CVR) of the selected words was calculated by asking the opinions of 10 experts (audiologists and speech and language pathologists). Using the Lawshe's three-option questionnaire, they were asked to provide their opinions about the congruence of the words with the goal and necessary properties of the test. The minimum acceptable CVR for this number of experts was 0.62; therefore, those words which received two negative opinions were removed from the list. After items were identified, the content validity index (CVI) was computed for the whole test. The CVI is the mean of the CVR values of the items [30] and finally a list consisting of 15 word pairs was developed.

Words were recorded in a studio by a male talker with a clear voice and the standard Persian accent. The word pairs were made equivalent in terms of pitch contour and the start and end time of utterance using the Adobe Audition software version 6 (Adobe Inc, California, USA).

A pilot administration of the test was carried out on 15 children aged 6-11 years old. According to their responses, word pairs with a high error rate were restated by the talker or replaced with more proper words.

The final material consisted of four lists each includes 15 randomly selected word pairs and each pair is repeated twice in each list (total is 30 word pairs in each list) but in the second time the order of presenting words in each pair changes. The 15 word pairs were randomly repeated twice in each list and in the second repetition, the word was presented to the opposite ear [15]. The silence interval between stimuli was 4 seconds, and the total duration of the test administration was about 10 minutes.

Administration and evaluation of psychometric properties of the test

The present cross-sectional study was conducted on a total of 204 children aged 6-11 years old, from both genders in primary schools of Tehran. The inclusion criteria were: interest in participation in the study; being right-handed and monolingual; normal otoscopic examination and hearing; no history of brain injury or neurological, psychological, or language disorders; and no poor academic performance. Handedness was determined by the Edinburgh Handedness Inventory [31]. Participants' hearing was examined using a clinical two-channel audiometer (Midimate 622, GN Otometrics, Denmark) at the frequencies from 250 to 8000Hz, with the hearing threshold criterion of better than 20 dB HL. The consents for participation in the study were obtained from all parents.

Testing was carried out in a silent room in each school, using a laptop (Dell, Inspiron N5010) and headphones with frequency response 18-20000 Hz (Philips, SHL3100) attached to the laptop. Headphones' output level was measured at 70-100% of the output level of the computer using a Bruel & Kjaer's sound level meter (analog model, 1/3 octave band), and was found to be 72-78 dB SPL (~52-58 dB HL) that was at the most comfortable loudness level (MCL). The following instruction was given to the child before starting the test: "you will hear a list of words. Each time, two words are simultaneously presented to your ears, each to one of them, but, only one of them is heard; repeat that word loudly please. When you are able to hear both words, repeat the one you heard more clearly." The results were recorded by the examiner. In each list, the score of each ear, the total score, and also the ear advantage were calculated with the following formula R-L/R+L, R and L standing for the scores of the right and left, respectively [15]. 20 students from all age groups of both genders were randomly retested by the same examiner within one to three weeks after the initial administration of the test

Table 1. Content validity ratio of dichotic rhymed word test items (n=15)

Items	CVR
/bɒːd/,/dɒːd/	0.8
/duːʃ/,/guːʃ/	0.8
/bɒːz/,/gɒːz/	1
/del/,/gel/	0.8
/bɒːɢ/,/dɒːɢ/	1
/dom/,/gom/	0.8
/buːɢ/,/duːɢ/	1
/puːtʃ/,/kuːtʃ/	0.8
/piːr/,/tiːr/	1
/pær/,/tær/	1
/tær/,/kær/	0.8
/tɒːr/,/kɒːr/	0.8
/tuːr/,/kuːr/	0.8
/tɒːdʒ/,/kɒːdʒ/	1
/buːd/,/duːd/	1
Mean	0.89

to examine the reliability of the test in one time repeat.

In the present study, the CVR, CVI and the Cronbach's alpha coefficient were used to examine content validity and internal consistency, respectively. The Cronbach's alpha value≥0.9 is excellent, 0.9> α ≥0.8 is good, and 0.8> α ≥0.7 is acceptable [32]. Test-retest reliability was assessed by the intraclass correlation coefficient ($ICC_{(1,2)}$), Pearson's correlation coefficient and paired t-test. A paired samples t-test was used to compare scores between the left and right ears, and an independent samples t-test was used to examine the effect of age and gender. All analyses were performed using the SPSS 16. The statistical significance level was set at $p<0.05$.

Results

The content validity ratio (CVR) for the test materials was found to be 0.8 to 1. Table 1 shows the CVR for each word pair and the resulting CVI was 0.89. The Cronbach's alpha coefficient was found to be 0.95 and 0.94 for the right and left ears, respectively. The results indicate excellent internal consistency of the test. Table 2 summarizes the results and p values of $ICC_{(1,2)}$, Pearson correlation and difference of mean values using a paired t-test for right ear, left ear and ear advantage. The difference between mean measures was not significant ($p>0.05$) and the test showed a high reliability ($p<0.001$).

The results indicated a significant difference between the scores of the left and right ears in all age groups ($p<0.001$). Among the 204 participants, 96.5% showed REA, 1% showed LEA, and 2.5% no ear advantage. Table 3 shows the mean and standard deviation of both ears and ear advantage scores for different age groups. Comparison of ear advantage showed a significant difference between the age group ≤ 10 years old and the age group older than 10 years old (the 11-year-olds) ($p=0.03$).

According to the results, there was a significant correlation between age and the total average score ($r=0.23$, $p=0.001$), and the total average score increased with the increase of age. No significant gender difference was found for the ear advantage ($p=0.06$).

Discussion

In the present study, the most appropriate word pairs were selected based on the following criteria: having the same rhymes, starting with stop consonants with the same VOT, and having the highest CVRs. Finally, four lists each including 15 pairs of selected words with twice repetition in each list (60 words in each list) were developed.

Pearson and intraclass correlation coefficients (ICC) indicated high test-retest reliability. In some studies, reliability of the test has been controlled by comparison of the results of the functional magnetic resonance imaging (fMRI) and the Wada test which revealed test results in

Table 2. Test-retest reliability of dichotic rhymed word test items within one to three weeks interval (n=20)

	Number of examiner	Rate of test		Right ear	Left ear	Ear advantage
Intraclass correlation coefficient	1	2	**Single measures (Confidence interval)**	0.87 (0.69-0.94) (p<0.001)	0.88 (0.73-0.95) (p<0.001)	0.88 (0.72-0.95) (p<0.001)
			Average measures (Confidence interval)	0.93 (0.82-0.97) (p<0.001)	0.94 (0.84-0.97) (p<0.001)	0.94 (0.83-0.97) (p<0.001)
Pearson correlation	1	2		0.87 (p<0.001)	0.89 (p<0.001)	0.88 (p<0.001)
The mean measures comparison*	1	2		0.04 (p=0.84)	0.21 (p=0.29)	0.0094 (p=0.46)

*Paired t-test

children are valid [17,18].

In this study, there was a significant difference between the average scores of right and left ears. The higher score for the right ear in all age groups is consistent with the opinion of Kimura regarding the ERA, meaning left hemispheric advantage for language processing in children [6]. In our study, 96.5% of the participating children showed REA. In the original version with the test subjects being between the ages of 15 and 67 years old, 85% of the participants showed REA and according to the authors, if those who did not show significant laterality advantage were discounted, the estimate would be 98% [15]. In a study of single digit dichotic test in the Malay language in children aged 6-11 years old [9], significant REA was only observed at the age of 6 and 7; these results attributed by authors to an easy and uncha-llenging test for the auditory system. Their results are different from the present study which shows the difference up to age 10 which may be due to relative difficulty of words compared to digits. Moncrieff, using dichotic competing words and random digits tests, examined the performance of 5-12 year-old children, and found different results in terms of the prevalence of ear advantage. In the digits test, 80-85% of participants showed REA, but in the competing words test, higher prevalence of LEA was observed, especially among right-handed participants (about 25%). It was not clear whether the LEA in children was due to right hemispheric advantage or less stability of

Table 3. Mean (standard deviation) of both ears scores and ear advantage for different age groups

	Mean (SD) score			
Age (yr. mo)	**Right ear**	**Left ear**	**Ear advantage***	**p****
6-6.11	16.86 (1.44)	12.44 (1.38)	0.15 (0.09)	< 0.001
7-7.11	16.97 (1.12)	12.29 (1.06)	0.16 (0.06)	< 0.001
8-8.11	17.91 (1.49)	11.83 (1.40)	0.20 (0.09)	< 0.001
9-9.11	17.65 (1.32)	11.95 (1.46)	0.19 (0.09)	< 0.001
10-10.11	18.02 (1.61)	11.74 (1.66)	0.21 (0.10)	< 0.001
11-11.11	16.97 (1.43)	12.67 (1.38)	0.14 (0.09)	< 0.001

*According to the (R-L/R+L) formula

**Paired t-test for comparison of scores between right and left ear

the direction of ear advantage in a younger age [33].

In the present study, the average REA in children less than 10 years old was significantly higher than those being more than 10 years old. In the Malay version of the dichotic double digits test in children aged 6-11 years old the average score of the left ear increased faster than right, and led to the reduction of REA [9].

The results of our study showed a significant correlation between age and the total average score of FDRWT (r=0.23), and also indicated an increase in the total average score with increasing age. The lack of maturation of the central auditory system or cognitive performance may be the cause of a poorer performance in younger age.

The REA was unexpectedly found to be lesser in the 6 and 7 year-old groups than 8 year-old group in our research which is maybe due to children's tendency to repeat one word in a word pair without paying too much attention to the heard stimuli. Fernandes and Smith used the log-linear analysis to control this error but controlling the stimulus dominance did not change the results of dominant hemisphere categorization in the FDRWT [17].

Conclusion

The findings of the present study showed that the Persian version of the fused dichotic rhymed words test (FDRWT) is valid and reliable, and can be used in evaluation of the central auditory system performance in Persian-speaking children. More studies are needed to compare the test results with those using objective methods, such as imaging techniques.

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