Research Article

Development of the Persian Version of Dichotic Offset Measure and Evaluation of Its Psychometric Properties in Normal-hearing Children: A Pilot Study

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Citation: Irani R, Fatahi F, Farahani S, Shomeil Shushtari S, Jalaie S, Katz J. Development of the Persian Version of Dichotic Offset Measure and Evaluation of Its Psychometric Properties in Normal-hearing Children: A Pilot Study. Aud Vestib Res. 2023;32(2):98-106.

https://doi.org/10.18502/avr.v32i2.12168

Highlights

- The dichotic offset measure (DOM) is more sensitive to the organization than SSW
- The DOM examine the dimensions of dichotic hearing at five different offset
- The DOM is one of the best markers of the integration subcategory

Article info:
Received: 04 Jul 2022
Revised: 04 Sep 2022
Accepted: 21 Sep 2022

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ABSTRACT

Background and Aim: Buffalo model consists of four Central Auditory Processing Disorder (CAPD) categories: decoding, tolerance-fading memory, organization, and integration. Integration is considered as the most complex category. The Dichotic Offset Measure (DOM) provides valuable information about the organization and integration problems. The present study aimed to develop the Persian version of the DOM (P-DOM) and evaluate its psychometric properties in normal-hearing children.

Methods: In this study, 25 normal-hearing children (13 girls) aged 7–12 years participated and were divided into six age groups. The face validity was determined based on the opinions of 15 experts, five children with CAPD, and five normal-hearing children. All children were tested with the Persian staggered spondaic word test, Persian phonemic synthesis test, and the Persian randomized dichotic digit test.

Results: The results showed the high face validity of the P-DOM. No significant differences were observed between the scores of girls and boys (p=0.394 for the right non-competing, p=0.623 for the right competing, p=0.155 for the left competing, p=0.066 for the left non-competing, p=0.174 for the total score, and p=0.701 for the reversals). Significant differences were observed in the main scores of P-DOM test among the age groups. The Spearman test showed a high test-retest reliability (r>0.69).

Conclusion: As a preliminary study it seems that the P-DOM has good validity and reliability to be used in normal-hearing children, but it needs further research with larger sample size.

Keywords: Auditory processing; dichotic offset measure; dichotic listening; integration deficit

Introduction

Auditory processing can be defined as the ability of the central auditory system to successfully utilize auditory information received from the environment [1]. Katz defined the auditory processing as a set of central auditory processes that makes the sounds understandable. Therefore, impairment at any stage of hearing processing can lead to Central Auditory Processing Disorder (CAPD) [1]. One of the most important and valid models of auditory processing is the Buffalo model, which is based on the anatomy of the central auditory nervous system [1]. There are four categories of CAPD in this model. Decoding is the most common category. The ability to process speech accurately and quickly falls into this category. Speech comprehension skills in the presence of noise, short-term auditory memory, and auditory attention fall into the tolerance-fading-memory category. The ability to follow the order and sequence of received auditory information is related to the organization category, and the optimal transfer of information between two brain hemispheres is involved in the integration category [2]. The impairment in the integration ability is directly related to the angular gyrus, corpus callosum, and other interhemispheric pathways [3].

One of the most important CAPD tests is the dichotic listening test [4]. Dichotic listening is the auditory process that involves listening with both ears. In this procedure, different stimuli are presented to the left and right ears, simultaneously [5]. Based on the mechanism of dichotic hearing, when different words are presented to both ears, the processing of the words presented to the left ear is declined in terms of quality due to the superiority of the left hemisphere in language processing and domination of crossed pathways over uncrossed pathways. This processing loss leads to a physiological phenomenon called the Right-ear Advantage (REA) [6] which refers to a condition in which the right-ear response in a dichotic test is better than the left-ear response [7]. Children with integration deficits have severe learning impairments (especially in reading and writing) and are often labeled as dyslexic [2]. The detection of integration deficit is possible only through dichotic tests. The two dichotic tests of the Buffalo model including the Staggered Spondaic Word (SSW) test and Dichotic Offset Measure (DOM), provide strong information about the functional status of the anatomical regions affecting the interhemispheric transfer. The DOM can examine the dimensions of dichotic listening [1]. This test was introduced in 1984 by Katz et al. [8]. The DOM pattern is similar to that of the SSW test, but has two major differences. First, the DOM uses the alphabet letters instead of the spondee words, reducing linguistic connection and increasing memory load and sequencing. This causes the DOM to be more sensitive to the organization category than the SSW. The second major difference in the DOM is the use of different offset times between the competing signals going into each ears. In the SSW test, competing monosyllables in all 40 test items are presented with a zero millisecond (ms) offset called "perceptual centering" in which the two competing sounds are overlapped but do not necessarily start or end at the same time. In the DOM, five offset times are used. These offset times lead to a time difference between the Right Competing (RC) and Left Competing (LC) signals are 0, 50, 100, 200, and 400 ms.

The DOM is one of the best tests of the integration category. The English version of the DOM uses all the letters of the English alphabet (except W because it is a two-syllable letter). Based on the offsets in DOM, dichotic listening is classified as hard, easy, and moderate.

Zero offset (perceptual centering) is the most difficult offset time of the DOM test and creates the hard dichotic listening along with the 50 ms offset. The 200- and 400-ms offset times create easy dichotic listening, and 100 ms is related to the moderate dichotic listening. By comparing the child's performance in hard and easy dichotic listening, the Dichotic Offset Index (DOI) can be obtained [1]. The DOM consists of 40 test items and two training items (without overlap). Dichotic offsets are presented in a specific order (to reduce the learning effect) and with varying difficulty levels and first ear condition. The sequencing of offset times is as 400, 50, 100, 0, and 200 ms. Similar to the SSW test, the half of items (odd-numbered) are first presented to the right ear and the other half (even-numbered items) are first presented to the left ear [1].

Even though the DOM has some advantages over the SSW, the Persian version of this test has not yet been developed. Thus, the present study aimed to develop the Persian version of the DOM (P-DOM) test and evaluate its psychometric properties in normal-hearing children aged 7–12 years.

Methods

Participants

In this pilot study, the psychometric properties of the P-DOM were evaluated through its administration to 25 normal-hearing children (13 girls) aged 7–12 years, di-

vided into six age groups (Table 1) who were randomly selected from schools of the district 12 of Tehran. Their peripheral auditory system health was evaluated based on the behavioral thresholds, and children with air-conduction hearing thresholds <25 dB HL at the octave frequencies between 250 and 8000 Hz [9] with a type-A tympanogram were participated in the study. Moreover, to make sure there was no CAPD in them, they were examined using the Persian version of SSW (P-SSW) test, the Persian version of the Phonemic Synthesis Test (P-PST) [10], and the Persian version of the Randomized Dichotic Digit Test (P-RDDT) [11]; only those with normal results were included in the study. Right-handed children with the normal peripheral and central hearing, no history of middle ear infection or neurological diseases, no history of professional music activity, and effective activities which improve interhemispheric function were considered. Written informed consent was obtained from the children's parents or caregivers. They were free to participate and complete the questionnaire.

Developing the Persian version of the dichotic offset measure

Recording the materials and examining their face validity

To record the materials of the P-DOM, the voice of a male talker was used. The talker had a clear speech approved by the speech therapists. Due to the one-syllable nature of the DOM materials, all Persian alphabet letters (excluding the first letter, because it is the only two-syllable letter) were recorded. A Neumann TLM microphone with a pop filter was used to record the letters. The microphone's output was delivered into Adobe Audition software installed on an Apple iMac computer. During the recording, the talker was asked to repeat that item in case of peak clipping. The final output was subjected to loudness normalization and saved in WAV audio file format. All essential instructions were provided to the talker at the beginning of the test.

After recording alphabet letters, the initial face validity was determined. For this purpose, all the recorded materials were given to 15 experts in audiology (n=5), speech therapy (n=5), and linguistics (n=5) to report if there was a problem in terms of speech expression, recording quality, and understandability of the recorded items using a form that was given to them. After applying modifications, the recorded file was given to five normal-hearing children and five children with CAPD. They were also asked to report any problems with the quality of recorded letters using a form given to them.

Perceptual synchronization and determining the central perceptual point in zero offset

At this stage, the highest quality recorded letters (with accepted face validity) were randomly placed next to each other. To apply offset times, the zero-offset point was first determined by the perceptual synchronization method. For this purpose, the two competing letters were first set at a point where they were maximally overlapped (perceptual centering). This maximum competition refers to the zero offset time. One zero offset point was set for each item. To determine the zero point of the overlapping, the starting point of the RC and LC signals were matched with each other in terms of time in Adobe Audition software.

A total of 120 items were made with the zero offset. To identify the zero perceptual offset, while the starting point of RC and LC signals was changing, the experts and normal-hearing children were first asked to state the point at which they perceived the most overlapping. This point was considered the synchronicity point of perception. Then, 120 items were given to 15 experts and they were asked to score the synchronization of RC and LC signals on a scale from 1 (poor) to 5 (excellent) using a form provided to them.

Applying offset times

After determining the zero offset or perceptual centering point, the offsets of 400, 50, 100, and 200 ms were determined based on the zero offset. Each offset refers to the distance between RC and LC letters from the perceptual centering point. For instance, to develop an item with a 100 ms offset, the first competing letter preceded the second competing letter by 100 ms from the zero point. The first two items were not overlapped and were placed only for training at the beginning of the audio file. Finally, the audio file containing two training items and 40 test items was saved in WAV format.

Determining the face validity of the final draft

The recorded file was given to 15 audiology, linguistics, and speech therapy experts to confirm the validity of the final version of the P-DOM test. Simultaneously, the recorded file was given to five normal-hearing children and five children with CAPD to comment on the comprehensibility of the letters. The final file was also sent to the developer of the main version, Katz. According to his comments (e.g. the high difficulty of the 3rd item, peak clipping of the LC in the 12th item, the high similarity between RC and LC in the 17th item, short duration of the LNC in the 26th item, etc.), final modi-

fications were applied. The test finally became ready for psychometric evaluation.

Psychometric evaluation

For psychometric evaluation of the final version of the P-DOM test, a two-channel audiometer was first used to present the items via an earphone to the normal-hearing children at the level of 60 dB HL.

Concurrent validity

To determine the concurrent validity, the results of the P-DOM were compared with the results of P-SSW. Spearman's correlation test was used to check the correlation between their scores.

Discriminant validity

Discriminant validity was determined by comparing the results of girls and boys and the results of age groups. The non-parametric Mann-Whitney U-test was used to compare the results based on gender, and the Kruskal-Wallis test was used to assess the results based on age.

Test-retest reliability

The P-DOM test was administered twice to all participants at a four-week interval (26±3 days) to determine the test-retest reliability. In the meantime, participants did not take any medicine, and it was assumed that the health of their auditory system had not changed. Moreover, the internal consistency of the P-DOM was examined by comparing the total score between the first and second half of the test.

Normative data

The P-PDOM was administered to 25 normal-hearing children to find the normative data. The normative data were obtained for the main test scores, including Right Non Competing (RNC), RC, LC, Left Non Competing (LNC), and total, as well as the DOI and reversals (sequencing error). The degree of involvement of the organization category based on the Buffalo model can only be determined through considering the reversals.

Data analysis

Data were analyzed in SPSS version 17 software (SPSS, Inc., Chicago, IL, USA). The main scores (RNC, RC, LC, LNC, and total), reversals, and DOI were reported using mean, Standard Deviation (SD), median, minimum, and maximum. The Kolmogorov-Smirnov test was used to check the normality of the data whose results showed that the data were not normally distributed ($p<0.05$). The non-parametric Mann-Whitney U test was used to compare the main scores and reversals based on gender and the Kruskal-Wallis test was used to compare the scores between the different age groups. Spearman's correlation test was used for investigation of the test-retest reliability and comparing the scores of the P-DOM and P-SSW. Cronbach's alpha coefficient was used to examine the internal consistency of the P-DOM test.

Results

Content and face validity

The materials of the P-DOM and the comprehensibility of recorded letters were finally confirmed by the experts and children.

Concurrent validity

Spearman's correlation test showed: $r=0.71$ and $p\leq0.001$ for the correlation between RNC of P-DOM and RNC of P-SSW, $r=0.56$ and $p=0.004$ for the correlation between RC of P-DOM and RC of P-SSW, $r=0.52$ and $p=0.006$ for the correlation between LC of P-DOM and LC of P-SSW, $r=0.46$ and $p=0.009$ for the correlation between LNC of P-DOM and LNC of P-SSW, and $r=0.69$ and $p\leq0.001$ for the correlation between total score of P-DOM and total score of P-SSW. Based on the findings, there was a positive correlation between the main scores of the P-DOM and P-SSW ($p<0.05$).

Discriminant validity

Mann-Whitney test results showed a $p=0.394$ for the difference in RNC, $p=0.623$ for the difference in RC, $p=0.155$ for the difference in LC, $p=0.066$ for the difference in LNC, $p=0.174$ for the difference in total score, and $p=0.701$ for the difference in reversals between girls and boys. Therefore, there was no significant difference between the performance of girls and boys in the main scores of the P-DOM test and the reversals ($p>0.05$).

Test-retest reliability

The relationship between the test and retest scores was investigated using Spearman's correlation test. An excellent and significant correlation ($r>0.69$, $p<0.05$) was obtained for the main scores ($r=0.69$ and $p\leq0.001$ for the RNC, $r=0.70$ and $p\leq0.001$ for the RC, $r=0.76$ and $p\leq0.001$ for the LC, $r=0.84$ and $p\leq0.001$ for the LNC, and $r=0.88$ and $p\leq0.001$for the total score).

Table 1. The normative data of the main scores for the Persian dichotic offset measure in different age groups

Age	N	Statistic	RNC	RC	LC	LNC	Total
7	4	Mean(SD)	9.50(1.29)	14(4.32)	19.75(4.27)	10.75(2.62)	54(6.58)
		Median	9.50	13.00	19.50	11.50	54.00
		Minimum	8	10	15	7	47
		Maximum	11	20	25	13	61
8	5	Mean(SD)	4.60(1.94)	11.20(4.32)	12.60(2.07)	6.80(4.14)	35.20(7.19)
		Median	4	11	12	6	38
		Minimum	2	7	11	2	27
		Maximum	7	18	16	12	42
9	5	Mean(SD)	4.80(1.09)	10.80(5.89)	10.20(2.58)	4.80(1.64)	30.60(6.22)
		Median	5	9	10	4	31
		Minimum	3	6	7	3	24
		Maximum	6	20	14	7	40
10	5	Mean(SD)	4.60(3.13)	9(4)	10.40(4.77)	5.60(4.15)	29.60(8.96)
		Median	4	8	9	4	32
		Minimum	2	4	5	1	16
		Maximum	10	14	18	10	39
11	3	Mean(SD)	3(2.64)	7(2)	6.66(4.72)	4.66(2.08)	21.33(9.29)
		Median	4	7	5	4	24
		Minimum	0	5	3	3	11
		Maximum	5	9	12	7	29
12	3	Mean(SD)	2.33(1.52)	4.66(3.78)	4.66(0.57)	1.66(1.15)	13.33(3.78)
		Median	2	3	5	1	15
		Minimum	1	2	4	1	9
		Maximum	4	9	5	3	16

RNC; right none-competing, RC; right competing, LC; left competing, LNC; left none competing

Internal consistency

Cronbach's alpha for the total score was reported 0.97, which indicates excellent internal consistency of the P-DOM test. Therefore, it can be said that the items in the first and second half of the P-DOM test produce similar scores.

Normative data

The mean, SD, median, minimum, and maximum of the scores of the P-DOM test are presented in Table 1. It can be seen that the performance on the P-DOM test improved with increase of age. Improvement of scores (reduced errors) with increase of age was more evident in the LC score. The Kruskal-Wallis test was used to investigate the differences between each age group regarding the total score. Figure 1 shows the total score of the P-DOM test for each age groups. There was a significant difference between age groups ($p<0.05$). Table 2 presents the results of pairwise comparison for age groups based on the total score of the P-DOM test. The results revealed a significant difference in the total score be-

Table 2. The pairwise comparison of age in terms of the total score of the Persian dichotic offset measure

Sample 1-Sample 2	Test statistic	Standard. error	p
7-8	7.70	4.93	0.11
7-9	11.20	4.93	0.02
7-10	11.20	4.93	0.02
7-11	16.66	5.61	0.00
7-12	20.66	5.61	0.00
8-9	3.50	4.65	0.45
8-10	3.50	4.65	0.45
8-11	8.96	5.37	0.09
8-12	12.96	5.37	0.01
9-10	0.00	4.65	1.00
9-11	5.46	5.37	0.30
9-12	9.46	5.37	0.07
10-11	5.46	5.37	0.30
10-12	9.46	5.37	0.07
11-12	4.00	6.00	0.50

tween the the age groups 7, 9, 10, 11, and 12 years and also between the age groups 8 and 12 years ($p<0.05$).

Reversals

The mean, SD, median, minimum, and maximum of reversals are shown in Table 3. As can be seen, the lowest and highest reversal was in 10- and 11-year-old children, respectively.

Dichotic offset index

To measure the DOI, the total error for 50 and 0 ms offsets was subtracted from those of the 400 and 200ms offsets. The mean, SD, median, minimum, and maximum of DOI are shown in Table 4. As can be seen, in all age groups, the DOI was in the negative range, indicating the poorer auditoery performance in the dichotically more challenging conditions.

Table 3. The normative data of reversal on Persian dichotic offset measure in different age groups

Age	N	Reversal	Mean(SD)	Median	Minimum	Maximum
7	4	R	4.25(2.21)	5	1	6
8	5	R	3.20(3.56)	2	0	9
9	5	R	5.20(4.96)	2	1	12
10	5	R	1.80(2.48)	0	0	5
11	3	R	5.33(2.08)	6	3	7
12	3	R	3.33(1.15)	4	2	4

R; Reversal

Table 4. The normative data of dichotic offset index in different age groups

Age	N	Mean(SD)	Median	Minimum	Maximum
7	4	–3.75(5.73)	–5	–9	4
8	5	–2.80(4.96)	–3	–8	5
9	5	–4.40(6.69)	–4	–15	3
10	5	–1.20(4.20)	0	–6	4
11	3	–4.66(1.52)	–5	–6	–3
12	3	–2.33(3.21)	–1	–6	0

Discussion

The purpose of the present study was to develop the Persian version of the DOM and evaluate its psychometric properties, and find its normative data in normal-hearing children. The DOM test is a dichotic listening assessment based on the Buffalo model of auditory processing. This test is used for assessing the organization and integration categories involving the dichotic presentation of alphabet letters at five different offset times. The DOM can also be used as a direct measure of the progress in dichotic offset training (DOT) [1].

The Persion version of the DOM showed a good face validity and internal consistency. The fluency, comprehensibility, and quality of recorded letters for the P-DOM were confirmed. Cronbach's alpha coefficient was high (0.97) for the overall P-DOM test, which indicates that the test items have good reliability and the scores of the first and second half of the test are almost equal. Moreover, a high correlation was observed between the scores of P-SSW and P-DOM. The P-DOM showed a high test-retest reliability (r>0.69).

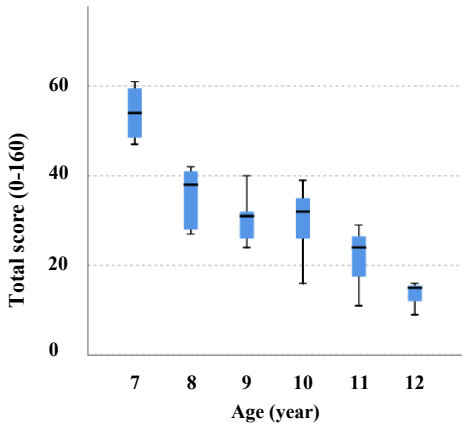

Figure 1. The mean of the total score of the Persian dichotic offset measure in different age groups

Our study also found the normative data for the P-DOM which were very similar to the data reported in the original version [1]. In Katz' study [1], most of the errors in the English version of the DOM were seen in the competitive conditions and zero and 50 ms offsets, which is consistent with the results of the present study. The slight differences in the mean number of errors between the original and Persian version, may be due to the difference in the nature and structure of the alphabet letters and sample sizes.

In comparing the children's P-DOM scores based on age, our results showed significant differences between the different age groups. The children's performance improved with the increase of age. In comparing the scores based on gender, the results showed no significant differences between girls and boys. This finding holds considerable clinical importance, as it indicates that gender is not considered as an active factor when evaluating children by the P-DOM, while age is an important factor in determining the degree of involvement for the central auditory system. In the present study, in all age groups, the mean error in competitive conditions (RC and LC) was higher than in non-competitive conditions (RNC and LNC), and the highest error rate was related to the LC condition. Jacobson [1] also reported that the LC condition of the DOM test showed the highest error. These results support the study conducted by Martins et al. [12], who reported the highest error rate in competitive conditions (especially LC) in the SSW test.

The high reversal in the DOM test indicates a deficit in the organization category. In the present study, the reversals were low, because all children had normal central auditory systems.

In the P-DOM test, the hard dichotic (0 and 50ms offsets) listening performance was poorer than easy dichotic listening (400 and 200 ms offsets) for all age groups. Thus, the DOI was in the negative range. This was expected, because at the 0 and 50 ms, competitive letters are presented with the most concurrency and simulate a really challenging dichotic condition. Similar results have been reported in Jacobson's study [1]. They compared the performance of 55 subjects with CAPD and 20 normalhearing subjects. The highest number of errors were observed at the 0 and 50 ms offsets for both groups.

Conclusion

The Persian version of the dichotic offset measure (P-DOM) test has acceptable validity and reliability for assessing the dichotic listening abilities of normal-hearing children in Iran. Further research is needed using the P-DOM as an early indicator for integration deficits and dichotic listening problems in school-aged children with learning problems. Moreover, it is necessary to conduct further studies and use more samples to add the P-DOM to the auditory processing assessment tests for Persian-speaking children in the future.

Ethical Considerations

Compliance with ethical guidelines

In the present study, all ethical considerations recommended by the Tehran University of Medical Sciences (TUMS) were taken into account, and TUMS approved the study with the ethical code of IR.TUMS.FNM.REC 1400.052. Also, Participation in the study was based on obtaining informed consent from all parents.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

RI: Study design, acquisition of data, interpretation of the results, statistical analysis, and drafting the manuscript; FF: Study design, interpretation of the results, drafting the manuscript, and revision the manuscript; SF: Study design, interpretation of the results, and drafting the manuscript; SSS: Interpretation of the results, and drafting the manuscript; SJ: Statistical analysis; JK: Study design, interpretation of the results, and drafting the manuscript.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Acknowledgements

We also sincerely thank all the participants for their cooperation in this study. special thanks to the school officials who made it possible for us to have this research during the COVID-19 epidemic, as well as all the audiology clinics that made it easy for us to access central auditory processing disorder children. The present study has been supported by Tehran University of Medical Sciences with grant number 1401-1-103-55554.

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