Research Article

Exploring the Correlation between Binaural Processing Abilities and Auditory Processing Domains Questionnaire Scores in Children with Specific Learning Disabilities

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Short running title: Exploring the Correlation between Binaural…

Highlights:

- Children with SLD exhibited abnormalities in binaural processing assessments
- There was some correlation between dichotic tests and APDQ-P in children with SLD

ABSTRACT

Background and Aim: A Specific Learning Disability (SLD) is a neurological disorder thought to arise from dysfunctions within the central nervous system. Children with SLD often exhibit cognitive, linguistic, and auditory processing challenges, including deficits in binaural processing. Considering the overlapping elements of binaural processing and the areas evaluated by the Auditory Processing Domains Questionnaire (APDQ) —such as auditory, linguistic, and attentional skills —this study sought to examine the correlation between binaural listening, as measured by auditory tests, and the subscales of the APDQ in children with SLD.

Methods: A sample of 20 children aged 8–12 years with diagnosed SLD was selected. The Persian version of the APDQ (APDQ-P) was used to assess some auditory processing, attention, and language skills. Binaural processing abilities were evaluated through Binaural Masking Level Difference (BMLD), Persian Auditory Recognition of Words in Noise (PARWIN) and three dichotic tests. Statistical analysis was conducted to investigate the correlation between APDQ-P scores and binaural processing test results.

Results: A positive correlation was identified between the results of dichotic listening tests and APDQ-P scores. Specifically, the results of the left-ear competing sentence test showed a significant correlation with all the APDQ-P subscales.
Conclusion: The study's results likely demonstrate the validity of the APDQ-P in representing dichotic listening skills. The findings of this study also highlight the significance of integrating both behavioral auditory tests and questionnaire-based evaluations to achieve a deeper understanding of how auditory behaviors, relate to the outcomes of binaural processing assessments in children with SLD.
Keywords: Binaural processing; questionnaire; learning disabilities

Introduction

Specific Learning Disabilities (SLDs) is a neurodevelopmental disorder significantly impede students' academic progress, irrespective of their intellectual capacity [1]. Auditory Processing Disorders (APD) frequently occur in children with SLDs, which can involve binaural processing deficits [2-4].
Binaural processing begins with binaural interaction at the brainstem level and continues in higher regions of the auditory system. Neural pathways associated with dichotic listening, another form of binaural processing, are also activated when different auditory inputs simultaneously reach the ears. Both binaural interaction and dichotic listening play a critical role in an individual's ability to understand speech in noisy environments [5].
Deficits in binaural interaction and dichotic listening abilities, including difficulties with binaural integration and separation, are commonly seen in children with learning disabilities. These challenges contribute to communication difficulties, particularly in noisy environments. These issues are evident in the atypical results of tests such as dichotic listening and Binaural Masking Level Difference (BMLD) tests. [6-8].
Language and cognitive skill deficits, including attention, have also been reported in children with SLD [3, 4]. Many binaural processing tasks require adequate language and attentional abilities. For instance, dichotic listening reveal insights on language, selective and divided attention abilities alongside auditory processing [9].
Documenting and quantifying difficult behaviors related to auditory processing is essential and can be effectively accomplished using specific questionnaires [10]. By examining the correlation between the results of central auditory processing questionnaires and related behavioral assessments, researchers can develop more targeted interventions to manage challenging behaviors [11].
Some studies have shown that APD questionnaires can effectively capture patient symptoms that align with APD tests [10, 12]. In a study, Zamiri Abdollahi et al. investigated the link between the spatial word-in-noise test and the Spatial Hearing Questionnaire (SHQ). They evaluated sixty-six adults aged 18–40, divided into three groups: those with normal hearing, those with mild hearing loss, and those with moderate hearing loss. Both the spatial word-in-noise test and the Persian version of the SHQ were administered to all participants. The findings revealed a significant positive correlation between the results of the spatial word-in-noise test and the Persian SHQ across all groups [12].
Auditory Processing Domains Questionnaire (APDQ) is a reliable tool among APD screening questionnaires. APDQ is used to assess various aspects of auditory processing, language skills, and some aspects of attention in individuals aged 7–17 years [13].
In studies on the screening of APD in children with learning disabilities and typically developing children, the APDQ demonstrated high sensitivity in identifying children with auditory processing issues [3, 14]. In another study, the number of children suspected of auditory processing disorder who exhibited difficulties in the APDQ, dichotic digit test, as well as monaural speech-in-noise perception, was approximately similar [15].
No studies were found in the reviewing literatures investigating the direct relationship between binaural processing abilities and APDQ scores in children with SLD. Shared aspects of binaural processing and the items evaluated in the APDQ, which include auditory, linguistic, and attentional skills, make it reasonable to explore how the questionnaire scores correlate with binaural processing test results. Therefore, this study aimed to examine how binaural processing abilities may correlate with the Persian version of the Auditory Processing Domains Questionnaire (APDQ-P) scores in children diagnosed with SLD.

Methods

Forty-two children aged 8 to 12 diagnosed with SLD were selected through convenience sampling from three local educational centers for learning disabilities. Out of these, twenty children met the inclusion criteria and

were included in the population for this correlational study. The inclusion criteria required participants to have a normal hearing threshold (≤20 dB HL) across frequencies from 250 Hz to 8 kHz, symmetrical hearing thresholds between both ears (difference ≤10 dB), normal tympanograms, a word recognition score of ≥90% in silence, right-handedness, no neurological or psychological disorders, and no relevant medications and normal auditory memory based on the digit span task. Additionally, participants needed BMLD test score of ≤7 dB [16], and abnormal results on the Persian Auditory Recognition of Words in Noise (PARWIN) and Persian Randomized Dichotic Digits Test (PRDDT) according to the published norms (normative data) of Mahdavi et al. study [7] to confirm the presence of auditory processing disorder. Exclusion criteria include children’s lack of cooperation during the research and the child contracting diseases that interfere with the study's objectives during the study period.
Written informed consent was obtained from all parents after explaining the study's objectives and procedures.

Procedures
Binaural behavioral tests, including the BMLD, PARWIN, PRDDT, Persian Pediatric Competing Words Test (PPCWT), and Persian Pediatric Competing Sentences Test (PPCST), were administered to children. The tests were conducted using a calibrated X455LD laptop (ASUS, China) connected to HS-50 headphones (A$_4$TECH, China). All assessments took place in a room treated for optimal acoustics. Each test session included a minimum of two practice items to ensure participants understood the tasks before proceeding.
The APDQ-P was also used to investigate behavioral manifestations of auditory processing, language and attention problems.
The validity and test-retest reliability of the APDQ-P and all behavioral tests have been documented in other studies [7, 13, 17, 18].

Persian auditory processing domains questionnaire
The APDQ-P is a reliable and valid questionnaire used to screen children aged 7–17 for APD [3, 13]. It also assesses language and attention skills. It has 52 items and parents or teachers fill out the questionnaire based on the child's behavior [3, 14]. The questionnaire consists of 3 main subscales: auditory processing (31 items), attention control (10 items), and language (11 items). Another subscale, called Targeted Auditory Processing (TAP), also exists, but due to the overlap of its questions with the AP subscale, we did not include it in current study. The formula for calculating the questionnaire score is derived by dividing the sum of scores for each subscale by four times the total number of items in that subscale, and then multiplying by 100 [3].

Binaural masking level difference
The BMLD measures the auditory system's ability to detect target signals in noise by evaluating the phase differences of signals presented to the ears [5]. We used an application to perform the BMLD test. The application was run on the laptop and assessed the BMLD with very precise sound intensity level steps (1 dB) [19]. The student was instructed to raise a hand or verbally indicate when he/she heard a tone amidst the noise. It was emphasized that the child should concentrate solely on detecting the tone. Both ears received a narrow-band in-phase noise centered at 500 Hz with an intensity of 60 dB SPL. The noise was listened to for 4–5 seconds. Following this, a 500 Hz in-phase tonal signal at 60 dB SPL was presented simultaneously to both ears (S0N0 condition). If the child signaled, the signal intensity decreased initially in 10 dB increments. In the absence of a response, the intensity increased in 5 dB steps. As the threshold approached, the steps adjusted to 2 dB decreases and 1 dB increases. This process was repeated at least three times near the threshold to ensure accuracy. The procedure was then repeated under SπN0 conditions, where the signals differed by 180° in phase, but the noises were in-phase (0° difference). Thus, the threshold for a 500 Hz pure tone amid narrow-band noise was determined under both S0N0 and SπN0 conditions. BMLD was subsequently calculated by subtracting SπN0 thresholds from S0N0 thresholds [6, 19].

Persian auditory recognition of words in noise
The PARWIN test evaluates speech recognition using 35 monosyllabic words amidst multi-talker babble noise. This test assesses the signal-to-noise ratio needed to achieve 50%-word recognition. The Signal-to-Noise Ratio (SNR) decreased from +24 dB to 0 dB in 5 dB steps, with five words presented at each SNR level. The test

items were presented binaurally at a 55 dB sensation level in reference to the speech reception threshold [7]. The Spearman-Kärber equation was used to calculate the SNR 50%. The formula is: "SNR 50%=i+1/2(d)–(d)(#correct)/(w)", where *i* represents the initial presentation level (+24), *d* is the decrement step size (4), *w* is the number of words per step (5), and "correct" refers to the number of words correctly repeated [20].

Persian randomized dichotic digit test

This widely used test evaluates binaural integration skills. The test has two parallel lists, each comprising 54 items. The lists contain three sets: one-pair, two-pair, and three-pair digits. In each list of this test, a raw score of 108 is assigned for each ear. Ultimately, the raw scores are converted into the corresponding percentage. The test was conducted in a free recall condition and at a 50 dB sensation level in reference to the speech reception threshold [7, 18].

Persian pediatric competing words test

The Persian pediatric competing words test assesses children's ability to hear monosyllabic words dichotically, focusing on divided and directed attention. This test evaluates binaural integration and includes four practice items along with 30 trial items. The speech test materials were presented at 50 dB SL (above the speech reception threshold) and the test was conducted under pre-cued directed attention conditions. The participant needed to first repeat the word presented to either the left or right ear, followed by repeating the word presented to the opposite ear. PPCWT had a raw score of 30 for each ear, totaling 60, with each word assigned one score. The final score was reported as the percentage of correctly repeated words [7, 17].

Persian pediatric competing sentences test

This test specifically evaluates binaural separation skills in dichotic listening. The test consists of 20 pairs of sentences: the first 10 for the right ear and the next 10 for the left ear. Test materials were delivered to children's ears at 35 SL for the target ear and 50 dB SL for the non-target ear. Participants were instructed to repeat only the sentences heard in the specified ear. Scores were based on the correctly repeated keywords in each sentence, and accuracy percentages were reported separately for each ear [5, 7].

Statistical analyses

The Kolmogorov-Smirnov test indicated that all variable values in this study followed a normal distribution. Descriptive statistics, including mean, Standard Deviation (SD), minimum, maximum, and range, were utilized. The Pearson's correlation test was used to examine the relationship between APDQ-P scores and binaural processing test outcomes. Data analysis was conducted using SPSS version 17.

Results

The study sample included 20 children with learning disabilities (7 females and 13 males) with an average age of 8.83±1.0 years. Table 1 displays the descriptive values for the subjects' performance on auditory processing measures and the main domains of APDQ-P. The study, as detailed in Table 2, analyzed the relationships between BMLD, PARWIN, three dichotic tests, and the main domains of APDQ-P.

Relationship between Persian randomized dichotic digit test and Persian auditory processing domains questionnaire

Pearson's correlation analysis revealed significant positive correlations between left PRDDT and the AP and language domains of the APDQ-P questionnaire ($p \leq 0.05$).

Relationship between Persian pediatric competing words test and Persian auditory processing domains questionnaire

The analysis of the correlation between PPCWT and the APDQ-P domains revealed a positive correlation, with right PPCWT being positively correlated with the AP domain of APDQ-P ($p \leq 0.05$).

Relationship between Persian pediatric competing sentences test and Persian auditory processing domains questionnaire

The correlation analysis between left PPCST and the AP, attention and language domains of the questionnaire indicated a significant relationship ($p \leq 0.05$). Figure 1 illustrates the correlation between the left PPCST scores and all three domains of the APDQ-P through scatter plots.

Relationship between Persian auditory recognition of words in noise and Persian auditory processing domains questionnaire

The correlation analysis between PARWIN and the APDQ-P domains was conducted, and the results indicated no significant correlation between this word in the noise test and any domains of the APDQ-P ($p \geq 0.05$).

Relationship between Binaural masking level difference and Persian auditory processing domains questionnaire

A Pearson's correlation was conducted to investigate the relationship between the BMLD test and APDQ-P domains. The results showed no correlation between these evaluation methods ($p \geq 0.05$).

Relationship among the other binaural tests

Pearson's correlation analysis revealed significant correlations between left PPCWT with left PRDDT and left PPCST ($p \leq 0.05$). Additionally, significant correlations were observed between right PPCST and right PPCWT and between left PPCST and left PRDDT ($p \leq 0.05$).

Discussion

This study aimed to examine the relationship between the results of binaural processing tests including some dichotic tests (random dichotic digits, competing words, and competing sentences), the BMLD, PARWIN, and the APDQ-P in children with SLDs. While the results of some tests used in this study did not show significant correlations with other tests, meaningful relationships were observed among certain scores taken using other assessment tools. Understanding the relationship between various auditory processing disorders in children with SLD and their observable behavioral manifestations, as tracked through specific questionnaires, can guide the management of behavior issues associated with such deficits. For instance, one common maladaptive behavior linked to auditory processing difficulties in SLD children is the inability to follow verbal instructions in noisy environments. Developing tailored rehabilitation programs aimed at addressing auditory processing deficits that impair speech perception in noisy environments may help in managing challenging behaviors such as becoming easily distracted in noisy settings and potentially improve learning outcomes in this population [2, 11].

In the present study, based on the criteria reported in the study by Leite Filho et al, an BMLD threshold of less than or equal to 7 dB was used, which can be considered an indicator of binaural interaction weakness in children aged 7–12 years [16]. The mean BMLD in the present study was 5.6±1.09 dB. Various studies have reported different results regarding the performance of children with learning disabilities on the BMLD test [7, 21, 22]. The different types of auditory processing disorders in children with learning disabilities are likely the main reason for this variability. Overall, it appears that poor performance on the BMLD test in children with learning disabilities is associated with reduced speech perception in the presence of competing signals [7].

Previous studies investigating speech perception in noise among children with learning disabilities indicate that this ability is impaired in most of these children [2, 7]. The results of words in noise test in the present study (3.12±0.83 dB) were consistent with those of Mahdavi et al. (3.5±1.7 dB) whose research was the most similar to the current work. The mean test results in the study conducted by Mahdavi et al. on typically developing children were 1.8±1.1 [7].

The average results of the participants in the present study on the competing sentences, competing words, and dichotic digit tests (Table 1) differed by minus 2 standard deviations at least in one ear from the normative values reported in the studies by Mahdavi et al (right PRDDT: 92.0 (4.1), left PRDDT: 73.1(10.9), right PPCWT: 91.2(5.9), left PPCWT: 90.0(6.3), right PPCST: 96.3(4.8), left PPCST: 87.7(10.6) [7]. These findings are somewhat similar to the results obtained in two studies by Mahdavi et al. on children with learning disabilities [7, 23]. The larger sample size in Mahdavi et al.'s studies and the different types of dichotic disorder in the children studied may explain this slight difference.

In terms of the diversity of dichotic disorders, including amblyaudia and dichotic dysaudia, 55% of participants had amblyaudia based on the PPCWT and 20% based on the PRDDT. Amblyaudia refers to a condition where

the score of the dominant ear is normal, but the score of the non-dominant ear is below the normal range or a typical score in the non-dominant ear combined with an above-average score in the dominant ear. This conditions, results in greater-than-normal interaural asymmetry [24]. Additionally, 75% of participants had dichotic dysaudia according to the PRDDT, and 30% according to the PPCWT, while the remaining participants did not fit into either of these two categories. In cases of dichotic dysaudia, there is either a symmetric weakness affecting both ears in dichotic listening tests, or the dominant ear shows abnormal results while the non-dominant ear performs within the normal range [24]. Our criterion for identifying dichotic disorders was based on the PPCWT and PRDDT tests separately. We did not use a third test to determine the type of dichotic disorder. Out of 40 tests evaluating binaural integration, 22 tests showed dysaudia, while 15 tests in total showed amblyaudia. Therefore, dichotic dysaudia was more prevalent than Amblyaudia. Based on the PPCST test, 50% of individuals showed unilateral weakness, and 30% showed bilateral weakness. The other participants displayed results within the normal range.
In this study, the mean scores for the Auditory Processing (AP), Attention (ATT), and Language (Lang) scales in children with learning disabilities were found to be below the cutoff values established by Ahmadi et al. According to their findings, the normative scores were 89.81±11.56 for the auditory processing subscale, 72.20±15.94 for the attention subscale, and 91.42±12.89 for the language subscale [3]. Study by O'Hara and Mealings also demonstrates lower-than-normal questionnaire scores in children with learning disabilities [25].

Correlation analysis

Relationship among binaural masking level difference and Persian auditory processing domains questionnaire

In the present study, BMLD and APDQ-P domain scores did not show a significant correlation. Given the role of attention in the BMLD test, it was expected that the results of this test would correlate with the attention subtest of the APDQ-P questionnaire. However, this hypothesis was not confirmed in the present study. To date, no study has investigated the relationship between the results of this test and the items of the APDQ-P questionnaire. However, some studies have reported no relationship between BMLD and cognitive abilities, including attention [26, 27]. Although selective attention plays a role in the BMLD, this test alone may not have the capacity to monitor changes in this skill [28]. Additionally, in this study, we used the tonal BMLD test; perhaps if the speech BMLD test had been used, correlations with the attentional or linguistic domains of the questionnaire would have been observed, as during the speech BMLD test, broader areas of the central auditory system, which are also involved in attention and language skills, are activated [19].

Relationship between Persian auditory recognition of words in noise, and Persian auditory processing domains questionnaire

Correlation analysis showed no relationship between the PARWIN test and any of the APDQ-P domain scores. A study directly examining the relationship between the results of the PARWIN and APDQ-P tests in children with SLD, similar to the present paper, was not found for comparison. However, to explain the obtained results, we refer to findings from related studies. Moore, in a study, found a weak correlation between the speech-in-noise test and communication and auditory skills as measured by the Children's Communication Checklist-2 (CCC-2) and Children's Auditory Performance Scale (CHAPS) questionnaires, as well as intrinsic attention, despite using a very large sample size [29]. In another study, no correlation was observed between the CCC questionnaire results, which assess language skills, and the speech perception subtest of the SCAN test. Additionally, this subtest did not show any correlation with attention assessment tests [30]. It appears that sentence recognition in noise requires more cognitive processing and skills, such as attention, compared to word recognition in noise which we utilized in present study [31].

Relationship between dichotic tests and Persian auditory processing domains questionnaire

Unlike the BMLD and PARWIN tests, the dichotic listening tests showed correlations with the domains of the APDQ-P questionnaire. The hypothesis of this study was confirmed by the significant correlation between some dichotic test results and the domains of the questionnaire. The PPCST results demonstrated the highest correlation with the APDQ-P scores. Competitive sentence test scores for the left ear showed a significant relationship with all three sections of the questionnaire. This might be due to the use of sentence material, which is closer to real-life situations and selective attention tasks assessed in the questionnaire [26]. The right ear scores in this test did not show a significant correlation with the questionnaire domains. The number of individuals with unilateral deficits in this test was higher in our study compared to bilateral cases; otherwise, right-side results might have also correlated with the questionnaire. A study has shown that better language performance corresponds to enhanced dichotic auditory separation abilities, as observed during the CST test [32]. Therefore, it is not unexpected that lower-than-normal language domain results are associated with weaker left ear performance, which generally underperforms the right ear in dichotic language processing tasks such as CST.

The PRDDT test for the left ear also showed a significant correlation with the auditory processing and language scores of the APDQ questionnaire. The relationship between language performance and auditory processing has been demonstrated in several studies [33, 34]. Considering that the right ear typically performs better than the left ear in language skills, it is likely that language impairments manifest more prominently in the left ear. This aligns with the greater left ear deficits observed in the dichotic digit test in children with learning disabilities [32].

The results of the right-ear competitive words test also showed a significant correlation with the auditory processing subscale of the questionnaire. However, due to the small sample size and the fact that in this study, the results of the right-ear competitive words test were correlated with the right-ear competitive sentence test, no definitive interpretation can be made. This is because it was the left-ear competitive sentence results, not the right ear that demonstrated a correlation with the questionnaire items.

Most previous studies have shown correlations between the results of the DDT and behavioral assessments or attention-related reports obtained through questionnaires [30, 35]. In a study without correlation analysis, however, the results from the APDQ-P questionnaire were consistent with the outcomes of the dichotic digit test [27]. The lack of correlation between the dichotic digit and competitive words tests with the attention domain of the questionnaire may be attributed to the different types of attention assessed in these tests (divided attention) compared to the attentional skills evaluated in the questionnaire items. Additionally, the conditions under which these tests are administered may differ from the real-life situations that children typically encounter and have been evaluated using APDQ-P [26].

Relationship among Binaural masking level difference, dichotic tests and Persian auditory recognition of words in noise

In correlation analyses, significant relationships were observed between the results of certain tests. All three dichotic tests showed significant correlations in the left ear. Although different attentional and dichotic tasks are evaluated in these three tests, especially between the competing sentences test and the other two tests, namely the competing words and dichotic digit tests, their results in the left ear were significantly correlated. Additionally, the results of the competing sentences and competing words tests also showed a significant correlation in the right ear. Besides the shared neural structures and pathways activated during dichotic tasks, it can be said that sustained attention also plays a role in carrying out all three dichotic tests [30].

However, BMLD and PARWIN showed no correlation with each other or with the dichotic tests. It is possible that if we had used speech-based BMLD instead of tonal BMLD, a correlation might have been observed due to the similarity of the materials with other tests used in this study. This is because speech-based BMLD involves regions beyond the lower brainstem [19] and probably, neural pathways more similar to those involved in speech perception in noise and dichotic listening tests were implicated.

It is recommended that future similar studies not only increase the sample size but also have the questionnaire completed by the child's teacher. Despite sufficient explanations provided to the parents, it seems that due to varying levels of parental education, the assistance of the teacher in completing the questionnaire is necessary. Furthermore, the use of a control group is suggested to examine the correlation between the results of binaural auditory evaluations and APDQ-P questionnaire scores for a more accurate analysis of this correlation in children with learning disabilities.

Conclusion

The observed correlation between the results of dichotic listening tests and questionnaire items in present study likely supports the validity of the questionnaire in assessing auditory skills related to dichotic processing. The dichotic competitive sentence test, which assesses selective attention, showed the highest similarity to the conditions of the Persian version of the Auditory Processing Domains Questionnaire (APDQ-P) items. Using the APDQ-P in conjunction with binaural auditory assessments is suggested to obtain a clearer understanding of issues related to binaural processing and their behavioral manifestations in real-world auditory conditions. This improved understanding will assist in designing appropriate binaural auditory rehabilitation programs for children with specific learning disability.

Ethical Considerations

Compliance with ethical guidelines

The study was approved by the Ethics Committee of Iran University of Medical Sciences under the code No. IR.IUMS.REC.1399.300.

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Authors' contributions

MM: Study design, acquisition of data, statistical analysis and drafting the manuscript; NR: Study design and supervision, interpretation of the results and revision of the manuscript; MA: Interpretation of the results and revision of the manuscript; MM: Statistical guidance and revision of the manuscript.

Conflict of interest

There is no conflict of interest.

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Table 1. Descriptive statistics for binaural processing measures and the three domains of the Persian auditory processing domains questionnaie

Tests	Mean(SD)	Max	Min	Range
BMLD	5.60(1.09)	7.00	4.00	3.00
PARWIN	3.12(0.83)	4.40	1.40	3.00
RPPCWT	81.82(12.63)	96.66	60.00	36.66
LPPCWT	69.66(16.78)	96.66	40.00	56.66
RPPCST	86.25(15.73)	100.00	45.00	55.00
LPPCST	48.50(24.55)	95.00	7.50	87.50
RPRDDT	69.53(12.20)	90.74	47.22	43.52
LPRDDT	47.31(14.58)	67.59	18.51	49.08
AP	62.59(10.56)	80.64	45.16	35.48
ATT	38.56(14.74)	67.50	15.00	52.50
LANG	63.84(13.78)	84.37	34.09	50.28

BMLD; binaural masking level difference (dB), PARWIN; Persian auditory recognition of words in noise (signal-to-noise ratio 50%), RPPCWT; right Persian pediatric competing words test (percentage of correct answer words), LPPCWT; left Persian pediatric competing words test (percentage of correct answer words), RPPCST; right Persian pediatric competing sentences test (percentage of accurately answered sentences), LPPCST; left Persian pediatric competing sentences test (percentage of accurately answered sentences). RPRDDT; right Persian randomized dichotic digits test (the percentage of digits repeated), LPRDDT; left Persian randomized dichotic digits test (percentage of digits repeated, AP; auditory processing domain of the Persian version of the auditory processing domains questionnaire (scores in percentage), ATT; attention domain of the Persian version of the auditory processing domains questionnaire (scores in percentage), LANG; language domain of the Persian version of the auditory processing domains questionnaire (scores in percentage)

Table 2. Correlation between the binaural test results and the scores in the Persian auditory processing domains questionnaie

		PARWIN	BMLD	RCWT	LCWT	RCST	LCST	RDDT	LDDT
BMLD	**r**	–0.156							
	p	0.511							
RCWT	**r**	–0.045	–0.084						
	p	0.849	0.726						
LCWT	**r**	–0.026	0.250	0.290					
	p	0.913	0.288	0.215					
RCST	**r**	0.148	0.084	**0.555***	0.098				
	p	0.533	0.725	**0.011**	0.681				
LCST	**r**	–0.130	0.118	0.193	**0.679****	–0.046			
	p	0.585	0.619	0.415	**0.001**	0.847			
RDDT	**r**	0.272	0.017	0.295	0.187	0.209	0.243		
	p	0.246	0.942	0.207	0.429	0.376	0.302		
LDDT	**r**	0.135	0.222	0.074	**0.664****	–0.234	**0.611****	0.412	
	p	0.570	0.347	0.757	**0.001**	0.322	**0.004**	0.071	
AP	**r**	0.033	–0.041	**0.487***	0.405	0.205	**0.453***	0.347	**0.642****
	p	0.890	0.865	**0.029**	0.077	0.385	**0.045**	0.134	**0.002**
ATT	**r**	–0.229	0.035	0.101	0.321	–0.358	**0.613****	0.018	0.360
	p	0.332	0.883	0.671	0.167	0.121	**0.004**	0.940	0.119
Lang	**r**	0.126	–0.210	0.366	0.378	0.205	**0.577****	0.423	**0.517***
	p	0.598	0.930	0.112	0.101	0.385	**0.008**	0.063	**0.020**

* Significant at 0.05 level, ** Significant at 0.01 level

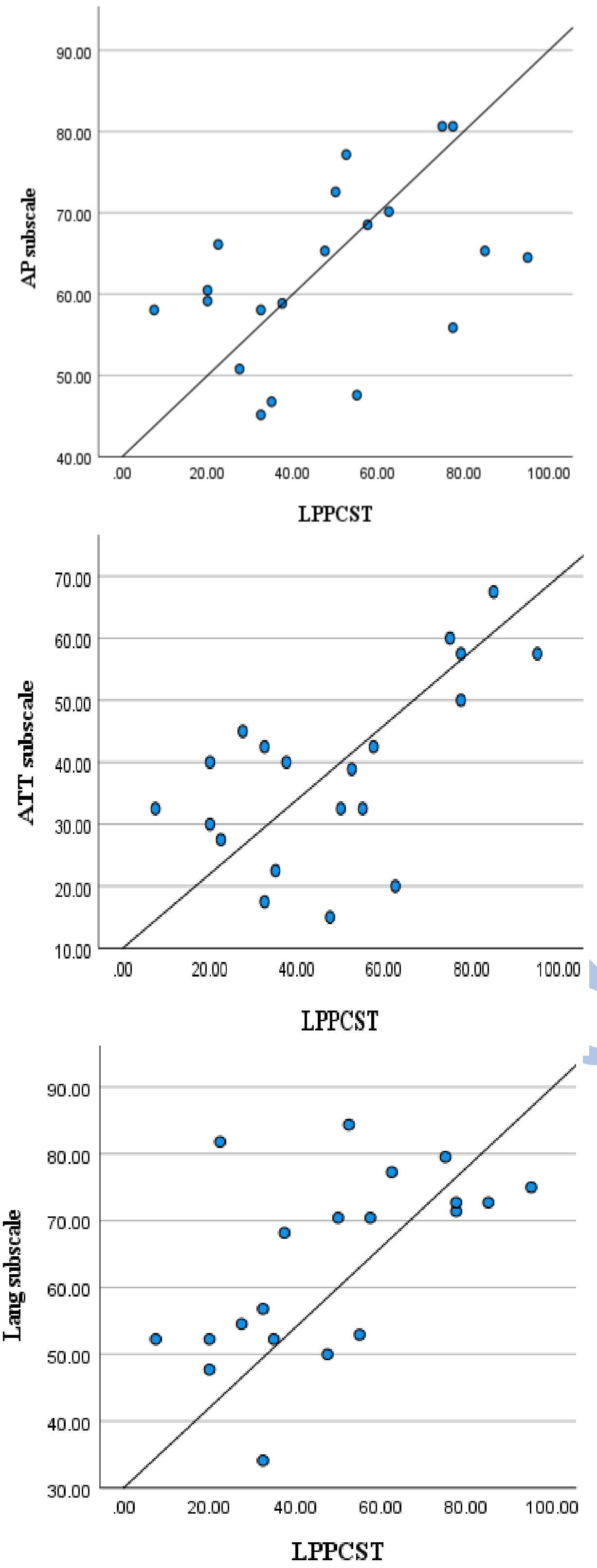

Figure 1. Scatter plots illustrating the relationship between left Persian pediatric competing sentences test and three main subscales of the Persian version of the auditory processing domains questionnaire. AP subscale; auditory processing domain of the Persian version of the auditory processing domains questionnaire, LPPCST; left Persian pediatric competing sentences test, ATT subscale; attention domain of the Persian version of the auditory processing domains questionnaire, Lang subscale; language domain of the Persian version of the auditory processing domains questionnaire