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RESEARCH ARTICLE

Comparison of Persian staggered spondaic word test's scores before and after rehabilitation in children with amblyaudia

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Abstract

Background and Aim: Amblyaudia is a diagnostic issue in central auditory processing disorder (CAPD), which is characterized by asymmetry in dichotic listening performance. This disorder negatively affects the academic performance of children by influencing their information processing, reading, attention, etc. The present study aimed to investigate the effect of the dichotic interaural intensity difference (DIID) training on all auditory processing categories of the Buffalo Model using the Persian staggered spondaic word (P-SSW) test.

Methods: The study was conducted on 17 children (11 girls and 6 boys) aged 8−12 years old diagnosed with amblyaudia. All children were first evaluated by the P-SSW test, and then participated in 10−12 sessions of the DIID training. The P-SSW test was taken again after completing the training program in order to evaluate the training effect.

Results: The paired t-test results showed a significant reduction in the mean scores of decoding ($p < 0.001$) and tolerance fading memory ($p < 0.004$) categories as well as the total mean score of P-SSW test after training. The Wilcoxon test also showed the effect of this training on the integration category ($p < 0.025$). The McNemar test, however, showed no statistically significant effect of the DIID training on the organization category.

Conclusion: The DIID training causes significant improvement in some central auditory processing categories of the Buffalo Model, including decoding, tolerance fading memory and integration.

Keywords: Dichotic interaural intensity difference; central auditory processing disorder; amblyaudia

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Introduction

Amblyaudia is an abnormal interaural asymmetry in dichotic listening tasks, which affects about half of children with central auditory processing disorder (CAPD) [1]. Amblyaudia is

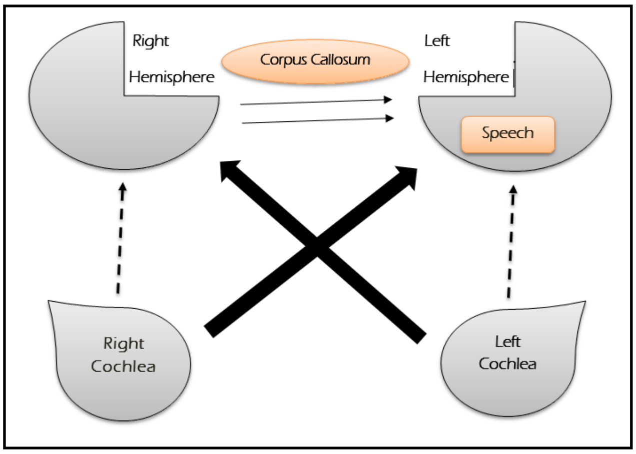

Fig. 1. Communication of the ears with the hemispheres and between the two hemispheres according to the processing model originally proposed by Kimura (1961).

characterized by deficits in the binaural integration of verbal information [2]. The main mechanism of amblyaudia is unknown, and it may similar to the mechanism of "amblyopia" in the visual system. The activity of dominant pathways in amblyopia suppresses visual information in non-dominant pathways, and ultimately leads to wrong encoding at the cerebral cortex [3]. In amblyaudia, a similar suppression by dominant ascending pathways potentially disrupts the correct encoding of auditory signals during the usual binaural processing [4]. According to the dichotic auditory processing model proposed by Kimura in 1961, individuals often have less difficulty in identifying speech signals reaching the verbal dominant hemisphere through a "contralateral" pathway (Fig. 1) [5]. Since the right ear is connected to the left hemisphere (as the language-dominant hemisphere in most individuals) via contralateral pathways, it performs better under dichotic listening evaluations. This superior performance is observed in the left ear of those whose right hemisphere is dominant for language [6]. Information is transmitted from the non-dominant hemisphere to the language-dominant hemisphere through the corpus callosum, whose dysfunction causes abnormal advantage of the dominant ear or a significant weakness in dichotic listening performance in the non-dominant ear. Incomplete myelination in children with CAPD, especially those with learning loss, causes disorders similar to neurological disorders in split-brain patients. In both cases, the inability to transmit neural signals from the right to the left hemisphere can cause dysfunction in the left ear [7]. In these conditions, the dominant and non-dominant ears are switched in individuals with right-hemisphere language dominance.

The potential characteristics of amblyaudia include difficulties in attention, speech comprehension and reading, information processing deficit, poor short-term verbal memory and poor adaptive skills [8,9]. Dichotic tests can evaluate this disorder and reveal any asymmetry between the auditory pathways by evaluating the binaural hearing system [10]. Routine methods for dichotic listening assessment are the competing word test (CWT), staggered spondaic word (SSW) test and randomized dichotic digits test (RDDT) [11].

Dichotic interaural intensity difference (DIID) training and auditory rehabilitation for interaural asymmetry (ARIA) [12] are commonly used for the rehabilitation of children with amblyaudia. DIID is a type of auditory training that affects the binaural processing disorders [13,14], whose main goal is to enhance the normal hearing ability of the non-dominant ear while maintaining the functionality of the dominant ear [7]. This type of training can help overcome the poor performance of the non-dominant ear by providing unequal levels of dichotic stimuli in a way that the non-dominant ear is stimulated at a common intensity of 50 dB HL and the dominant ear at a decreased intensity to improve the responses of the non-dominant ear. Reducing the performance level of the dominant ear seems to release the ipsilateral pathways of the non-dominant ear, which facilitates the transmission of the non-dominant ear signals to the language-dominant hemisphere [15].

Different studies have addressed the effectiveness of the DIID training in children with amblyaudia. Some studies evaluated these children in two groups of intervention and control, and reported improvements in the dichotic tests scores following the DIID training [7,12]. The present study was conducted with the aim of

Table 1. Mean (standard deviation) scores of random dichotic digit and competing word tests in children with learning disability

	n	Mean (SD) RDDT score			Mean (SD) CWT		
		Right ear	Left ear	Total	Right ear	Left ear	Total
LD children with amblyaudia							
Included in the research	17	72.41 (11.57)	40.59 (18.86)	35.94 (7.19)	79.71 (16.92)	50.94 (22.47)	32.65 (13.06)
Excluded from the research	5	67.60 (23.81)	46.60 (20.13)	43.00 (7.96)	73.60 (19.26)	62.20 (25.67)	30.20 (20.34)
LD children without amblyaudia	25	80.16 (11.57)	68.48 (10.83)	11.84 (5.14)	81.60 (15.63)	71.28 (17.82)	8.32 (4.75)

LD; learning disorder, RDDT; randomized dichotic digit test, CWT; competing word test

assessing the effect of the DIID training on the Persian version of the SSW (P-SSW) test [Hajiabolhassan et al [16] and the revised version (P-SSW; Negin et al., 2017)] by making changes using the perceptual simultaneity method [17]. We used the revised version of this test (P-SSW). The SSW test (Katz, 1962, 1968) is the main test of the Buffalo model. Smith, Katz, and Kurpita (1992) used four categories of the test results and introduced behavioral characteristics of auditory processing, including Organization (ORG), Integration (INT), Decoding (DEC) and tolerance-fading memory (TFM) [17]. The present study evaluated the effectiveness of DIID training in children diagnosed with amblyaudia based on the pre- and post-test scores of the P-SSW test.

Methods

Study population and procedures

This is an interventional study with a pretest/post-test design. The study population consisted of 47 children with amblyaudia. According to the Edinburgh handedness inventory [18] score, 15 (88.2%) were right-handed and 2 (11.8%) left-handed. All children were selected from one rehabilitation center, and were accompanied by one of their parents when participating in rehabilitation sessions in this center. Their learning disabilities had been diagnosed by the psychologists in this center. Of 47, 30 were excluded from the study (25 for having inter-hemispheric asymmetry < 25% and 5 due to having disorders such as uncontrolled attention-deficit/hyperactivity disorder and autism or because their parents did not cooperate during attendance of their children in the rehabilitation sessions). Having normal air-conduction hearing thresholds at 500, 1000, 2000 and 4000 Hz (≤ 15 dB) [19], asymmetry ratio of less than 5 dB between the two ears measured in a quiet room using a screening audiometer (ASA84, Pejvak Ava Co., Iran), and identifying interhemispheric asymmetry over 25% (Table 1) between the two ears in the CWT and RDDT were considered the criteria for including the children in the study [20,21]. Their parents/caregivers signed a written informed consent on behalf of them. Then, the first author completed the Buffalo Model questionnaire [22] for the children through interviewing their parents. The children with low scores were then evaluated with the Persian version of CWT [20] and RDDT [21]. These tests were carried out in a quiet room using a DELL laptop at the most comfortable level (35−55 dB HL). The output of the laptop and the earphone (Beevo BV-HM 780) were measured using a sound level meter. The integrity of the tympanic membrane and external ear of all 17 children was examined with an otoscope. After a rest period, at the end of the first session, children were evaluated by the P-SSW test [17], and the results were recorded in files assigned to each child.

P-SSW test

The P-SSW consisted of 4 practice items and

40 test items. Odd numbered items were first presented to the right ear and then to the left ear, and the even numbered items were first presented to the left ear. Each item contains two spondaic words whose monosyllable one is presented to the right ear and then simultaneously to both ears. The monosyllable four is provided to left ear with no competition. Each monosyllabic word is shown with a mark. The subject must repeat the monosyllabic words presented to each ear correctly to earn a score. So, during the test, each word was scored individually. If the participant failed to repeat the word or repeated with an error, the word was crossed out in the marking scheme column and calculated as a mistake in the final mark recording. There were four conditions examined in P-SSW test: 1) right noncompeting (RNC): a monosyllabic word presented to the right ear, which is noncompeting; 2) right competing (RC): a monosyllabic word presented to the right ear and is overlapped with the next monosyllabic word; 3) left competing (LC): a monosyllabic word presented to the left ear in competition with the previous monosyllable; and 4) left noncompeting (LNC): a monosyllabic word presented to the left ear which is noncompeting. To calculate the P-SSW score, all the errors that calculated under different conditions (RNC, RC, LC, LNC) were added and the total number of errors in each condition was written down in the last column provided in the answer sheet [23].

Dichotic interaural intensity difference training

The DIID training began from the second session by exposing the ears to different intensities of dichotic stimuli in a way that the impaired ear receives the initial level and the stronger ear receives decreased levels of intensity, which improves the impaired ear's response [15]. This method is based on facilitating the transmission of the left ear signals to the left hemisphere language locus by releasing the ipsilateral pathways of the impaired ear through reducing the intensity of the stimuli provided to the stronger ear [13]. In this study, different intensities of dichotic stimuli were presented to the ears of subjects using Sound-Forge™ software and according to a clinically-proposed protocol. The training began after determining the crossover rate (the level where the performance of the weaker ear crosses over that of the stronger ear) and continued at the previous intensity level in the dominant ear or at a new increased intensity depending on the subject's needs [7]. After 10−12 sessions, when the number of sessions was reduced in some of the children due to their better progress, the P-SSW test was repeated to examine the training effect. These children participated in 10−12 sessions of the DIID training (2−3 sessions per week, each for 25−30 minutes) [15] generated using Sound-Forge™ software with digits as materials. The P-SSW test was also repeated after the end of training program.

Data analysis

Data were statistically analyzed in SPSS 24 software (IBM Corp., Armonk, NY, USA). The normality of data distribution was examined using the one-sample Kolmogorov-Smirnov (K-S) test. Parametric tests are used if the distribution is normal, and non-parametric tests are used for abnormal data distribution. The K-S test results revealed that, except for INT and ORG whose distributions were abnormal before and after the intervention, the distribution of variables was normal. Hence, the paired t-test, Wilcoxon test and McNemar test were used to compare the scores of P-SSW test before and after training.

Results

Participants were 17 children with amblyaudia (11 girls and 6 boys) aged 8−12 years (mean age = 9.4 ± 1.5 years). They were assigned into the test group to evaluate the effect of DIID training as our audiologic marker. The results of these tests showed that 15 (88.2%) children were right-ear dominant and 2 (11.8%) left-ear dominant.

The paired t-test results showed a significant reduction in the mean scores of DEC ($p < 0.001$) and TFM ($p < 0.004$) after training compared to the pretest scores (Table 2). The Wilcoxon test results also showed a significant decrease in INT

Table 2. Statistical measures of decoding, tolerance-fading memory, integration, and total scores of Persian staggered spondaic word test before and after the dichotic interaural intensity difference in children with learning disability and amblyaudia

	Before		After		
Measure	**Mean(SD)**	**Min – Max**	**Mean(SD)**	**Min – Max**	**p**
DEC	4.35 (1.32)	2 - 6	2.05 (1.29)	0 - 4	< 0.001
TFM	3.00 (1.17)	1 - 4	2.05 (1.19)	0 - 4	0.004
INT	0.82 (0.52)	0 - 2	0.52 (0.51)	0 - 1	0.025
Total	41.41 (19.44)	16 - 91	21.29 (15.06)	6 - 58	< 0.001

DEC; decoding, TFM; tolerance fading memory, INT; integration

score after training ($p < 0.025$) (Table 2). The paired t-test also reported a significant reduction in the total mean score of P-SSW test after the intervention ($p < 0.001$) (Table 2). However, the McNemar test results showed no statistically significant effect of DIID training on ORG ($p = 0.453$).

Discussion

The present study examined the effects of dichotic interaural intensity difference (DIID) training on the auditory processing categories of the Buffalo Model in children with amblyaudia using the P-SSW test. The effect of the DIID training on the P-SSW test score was measured statistically by analyzing all the categories (DEC, ORG, INT and TFM) and comparing their scores before and after the intervention. The results revealed that the DIID training was successful to significantly reduce the DEC, TFM and INT errors, while it exerted no significant effect on ORG. Furthermore, a significant decrease in the total score of P-SSW test was observed, suggesting the effectiveness of this method in reducing the general errors of this test.

Given that the majority of fibers are contralateral in the central auditory nervous system [24], and the contralateral pathways are dominant in dichotic skills [25], the right ear signals are directly transmitted to the left hemisphere as the language-dominant hemisphere in most people, whereas the left ear signals are first transmitted to the right hemisphere and then to the left hemisphere through the corpus callosum. In case of any disorder in the corpus callosum, transmission of signals from the right to the left hemisphere is disrupted. As a result, individuals with this disorder, exhibit deficits in repeating the signals presented to the left ear, which is referred to as amblyaudia [26]. In 1984, Musiek et al. reported many similarities between children with learning disabilities and those with neurological disorders caused by damage to the corpus callosum; however, they found that this reduced ability was associated with delayed myelin maturation in these children [27]. Salamy reported the age of myelin maturation in children to be 10−12 years. Defective and delayed myelination in children with learning disabilities causes different disorders, including speech processing deficits in the presence of background noise and deficits in locating sound [28]. As mentioned before, in this study we used children with amblyaudia selected from among 47 children with learning disabilities.

We used the P-SSW test as the main criterion for assessing the effectiveness of the DIID training. It was performed on the subjects before and after the intervention. Some studies have used this test to investigate the effectiveness of different rehabilitation methods in children with amblyaudia [29]. The DIID Training facilitates the transmission of the left ear signals to the left hemisphere language locus by releasing the ipsilateral

pathways of the impaired ear through reducing the intensity of the stimuli presented to the stronger ear [13]. DEC disorder was more prevalent in subjects compared to other auditory processing categories in the Buffalo Model. This disorder occurs at the phoneme level, and ultimately causes difficulty in identifying, recognizing, manipulating and memorizing phonemes. Deficits in writing, reading and spelling, and delayed responses with the increased speed of speech can be observed in children with this disorder. The incidence of this disorder can profoundly affect the children's academic and communication performance [17]. Due to the importance of this category in the Buffalo Model, different studies have been conducted on it. Given the sensitivity of the phonemic synthesis test in detecting the problems associated with this disorder [30], and although the phonemic rehabilitation highly improve DEC in children with CAPD [31,32], the present study suggests that the DIID training can also facilitate the improvement of the DEC disorder.
The TFM disorder is the second most prevalent auditory processing disorder after the DEC disorder in patients. The incidence of this disorder causes a poor speech comprehension in difficult environmental conditions and deficits in the short-term memory. Educational problems such as weakness in reading comprehension, poor expressive language as well as poor writing skills are observed in children with this disorder [17].
As the most severe type of auditory processing disorder, the INT disorder can cause inability in the integration of auditory information with other functions, including vision and other nonverbal speech dimensions, and its most important characteristic is learning disability, mainly in reading and writing [17]. According to our findings, the DIID training can help patients with these three auditory processing disorders in the Buffalo Model. Each element of the SSW test indicates to one of the categories of the Buffalo Model. DEC and TFM play a key role under the RNC overlapping condition. Under the RC and LNC conditions, the DEC plays the main role, while under the LC condition, the INT has the most important role and the TFM has a less important role [33].
According to the results of the DIID training, it seems that the improvement of the P-SSW test score that indicated the DEC and TFM is due to the improvement of performance in the inter-hemispheric pathways. In other words, by facilitating the patient's main problem in the INT and with a better communication between the two hemispheres, the correct stimulation of the left hemisphere (which is the main place for DEC and TFM) can lead to the improvement of P-SSW test scores in terms of DEC and TFM.
ORG is another auditory processing category of the Buffalo Model. Sequencing and reversing errors are the main features of this category. Disorder only in this category cannot increase educational problems, but disorders in this and other categories together can exacerbate the existing complications and problems [17]. The results of our study suggested that the DIID training alone cannot cause significant improvement in the ORG category.

Conclusion

Given the negative effects of amblyaudia on the educational performance of children with this disease, as a central auditory processing disorder, its diagnosis and treatment is crucial. The DIID training can significantly improve some auditory processing categories of the Buffalo Model including DEC, TFM and INT, but had no significant effect on the ORG disorder.

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Conflict of interest

The authors declared no conflicts of interest.

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