Performance of children with mild or moderate sensory hearing loss on central auditory tests

Mona Mourad[a], Mohammed Talaat[a], Rania Abdou[b], Ghada Abdelkader[a]

[a]Department of ENT, Audiology Unit, [b]Department of ENT, Phoniatrics Unit, Faculty of Medicine, Alexandria University, Alexandria, Egypt

Correspondence to Rania Abdou, MD, Otolaryngology Departement - Faculty of Medicine - Chompollion Street - Azareeta Alexandria Egypt, Tel: 01005688879; fax: 5230502;
e-mail: abdou@hotmail.com

Received 10 January 2016
Accepted 3 May 2016

The Egyptian Journal of Otolaryngology
2016, 32:298–305

Hearing is fundamental to the development of successful language skills. Deficits in hearing acuity and auditory processing (AP) can profoundly obstruct effective communication. Our study aimed to evaluate the performance of children with mild and moderate sensory hearing loss (HL) on central AP tests. The study included 50 children: 10 children with normal hearing who were used as controls; 20 children with mild sensory HL; and 20 children with moderate sensory HL. Both male and female children were equally represented. All children underwent otoscopic examination, pure tone audiometry, tympanometry, and acoustic reflex measurements. Questionnaires on central AP disorders, dyslexia, and attention deficit hyperactivity disorder were answered by the parents. Screening tests for AP abilities [pitch pattern sequence test, speech perception in noise (SPIN) right SPIN, left SPIN, dichotic digit test] were conducted. All children were then examined with the full versions of the previous tests in addition to auditory fusion test – revised, masking level difference test, binaural fusion test, competing sentence test, and low pass-filtered test. Arabic-version dyslexia assessment was carried out for those who failed the tests. The study revealed that children with mild and moderate HL who failed the screening tests also failed the full version tests, and when tested by the Arabic-version dyslexia assessment test, dyslexia was found as a comorbid condition.

Keywords:
auditory processing, auditory processing disorders, children, peripheral hearing loss, screening

Egypt J Otolaryngol 32:298–305

1012-5574

Introduction

Hearing is fundamental to the development of successful language skills. Deficits in hearing acuity and auditory processing (AP) can profoundly obstruct effective communication. Sensory hearing loss (HL) is a major cause of childhood disability worldwide, with an estimated prevalence of one in 2000 neonates and six in 1000 children by 18 years of age [1].

Experimentally induced peripheral HL in animals and the resulting auditory deprivation has frequently been reported to produce specific alterations in anatomy and physiology as well as in the electrophysiology of the brainstem auditory nuclei [2].

There is increasing evidence in the literature that deprivation of sound stimulation can negatively influence the central structures of the auditory system, which correlates with the degree and time of detection of HL [3].

The ASHA Consensus Committee (2005) defined auditory processing disorder (APD) as an observed deficiency in one or more of the following behaviors: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition, including temporal resolution, temporal masking, temporal integration, and temporal ordering; auditory performance decrements with competing acoustic signals; and auditory performance decrements with degraded acoustic signals [4].

The prevalence of APD in school-aged children can be estimated at 5–7%, with a 2 : 1 ratio between boys and girls [5].

In patients with sensory HL, the evaluation of central auditory functions may define whether peripheral hearing impairment influences timing and spectral signal processing in the brain auditory pathway.

Patients and methods

The present study included:

(1) The study group included 20 children with mild sensory HL and 20 children with moderate HL.
(2) The control group included 10 children with normal peripheral hearing matched for age and sex.

Inclusion criteria

(1) Age 6–12 years.
(2) Affliction with mild HL with bilateral flat symmetrical audiogram configuration and pure tone average ranging from 25 to 40 dB.
(3) Affliction with moderate HL with bilateral flat symmetrical audiogram configuration and pure tone average ranging from 40 to 55 dB.
(4) Normal middle ear function and intact acoustic reflex (AR).
(5) Good speech discrimination scores.

Methods

(1) Tympanometry and AR threshold measurement using an AT235 tympanometer were carried out.
(2) Pure tone audiometry was performed using a double-channel clinical audiometer (model Madsen Astera by Otometrics, Taastrup, Denmark).
(3) Speech audiometery was performed using a double-channel clinical audiometer (model Madsen Astera), including determination of Speech Reception Threshold using Arabic spondee words and Word Discrimination Scoring using Arabic phonetically balanced words.
(4) Questionnaires for attention deficit hyperactivity disorder, dyslexia, and central AP disorders were administered to and answered by the parents to exclude the presence of these comorbidities.

AP screening tests

General arrangement

All AP test stimuli were presented using a laptop CD player through headphones. Three tests were selected for different auditory skills: the Pitch Pattern Sequence Test (PPST) [6], Speech perception in noise (SPIN) Test [7], and the Dichotic Digit Test (DDT) (S. Tawfik, A. Abdel-Maksoud, H. Weiheba unpublished data). They were shortened from the original tests for screening as follows:

PPST: Twelve items were chosen to represent the six combinations, and each combination was represented twice.

DDT: Five series were chosen.

SPIN: Five sentences were selected for each ear, complying with the sentence length in the original test.

Administration was conducted with participants seated in a quiet room. The test materials were presented at the most comfortable level (MCL).

Participants received instructions and were allowed practice sessions before testing. The duration of screening was 10–15 min. Responses were recorded in the respective scoring sheets. Correct scores were calculated as a percentage of the respective maximum scores. Scores were compared with the data collected in the previous study conducted at Alexandria University [8].

Children's PPST: The test consists of 12 frequency patterns. The tones in each frequency pattern were a combination of two frequencies, 880 and 1122 Hz. Each participant was instructed to verbally indicate the order of the tone pattern they heard. The correct score was calculated as a percentage of maximum scores [6].

Reversal patterns were also calculated. The test duration was ~3–4 min.

Speech in noise test: Ten meaningful Arabic sentences within the vocabulary level of the children were chosen from the original standard Arabic test. These sentences were recorded with background broadband noise. The signal-to-noise ratio was set at 0 dB. Five different sentences were presented monaurally to each ear at MCL. A score of 1 was given to each correct word in the sentence [7].

Dichotic digit test: The test consisted of five items. Four different digits were presented per item. Two pairs of digits were presented: one pair to each ear simultaneously. Participants were instructed to repeat all digits heard, irrespective of order of presentation. A correct response for each ear was determined, as well as a total score for both ears (S. Tawfik, A. Abdel-Maksoud, H. Weiheba unpublished data).

Behavioral tests for AP

General arrangement

Full versions were used; test stimuli were presented from a double-channel clinical audiometer (Madsen Astera) through supra-aural TDH-49 headphones, and all tests were performed in a sound-treated room. Participants received instructions regarding test performance and practice sessions before the administration of each test. The test materials were presented at MCL for each child. Responses were recorded on uniform score sheets.

Pitch pattern sequence test: The full version was composed of 60 frequency patterns. The participants were instructed to verbally repeat the tone patterns they heard [6].

SPIN test for children: The test consisted of 20 meaningful Arabic sentences within the vocabulary level of the children. Ten different sentences were presented monaurally. Scoring was calculated by counting the number of correctly identified words within the sentence. The percentage scores were calculated for each ear [7].

Dichotic digits test: The test had 20 items, with four different digits in each item; two pairs of digits were presented, one to each ear simultaneously. The participant was instructed to repeat all that he or she had heard in both ears, irrespective of the order of presentation (S. Tawfik, A. Abdel-Maksoud, H. Weiheba unpublished data).

The correct responses for each ear were determined. A correct response was allocated to each digit that was repeated correctly, irrespective of order. The right ear score was defined as the percentage of correctly repeated digits in the right ear. A similar system was used for the left ear scores, and the combined score was the percentage of correct digits in both ears.

Auditory fusion test-revised (AFT-R): The test is administered in a diotic mode. The auditory fusion threshold is the average of the milliseconds at which the two tones, for the ascending and descending interpulse interval series, are perceptually fused and heard as one [9].

Binaural masking level difference (MLD) test: Pulsed tones of 500, 1000, and 2000 Hz were introduced to both ears simultaneously: inphase SøNø, then out of phase in the SπNø, followed by SøNπ. The level of noise was adjusted until the participant reported the tone to be equally loud in the two situations [10]. The threshold was then calculated.

Competing sentence test (CST): This consists of sentences presented dichotically, target sentence presented at 35 dB SPL, and competing sentence presented at 50 dB SPL. The listener is instructed to repeat the target sentence only and ignore the message in the other ear [11].

Low pass-filtered test (LPF): The word materials were filtered using a low pass filter with a cutoff frequency of 500 Hz and a high pass filter with a cutoff frequency of 3000 Hz presented monaurally. The percentage of correctly reported phonemes determined the score in each ear [11].

Binaural fusion test (BFT): The test consists of 25 spondees. The stimuli are band pass, so that the low-pass segment of each word is presented to one ear and the high-pass segment is presented to the other. The listener is instructed to repeat the words heard and the test is scored by calculating the percentage of correct responses (S. Tawfik, A. Abdel-Maksoud, H. Weiheba unpublished data).

Statistical analysis

Data were analyzed using the statistical program for social sciences software package, version 20.0 [12]. Qualitative data were described using number and percentage. Qualitative data were described using range (minimum and maximum), mean, SD, and median. Comparison between different groups regarding categorical variables was made using the χ^2-test.

Results

Pure tone audiometry

There were no significant statistical differences between pure tone average thresholds between the right and left ears in both HL groups as their audiograms were of flat configurations.

Tympanometery

All participants had type A tympanograms and intact AR at frequencies of 500, 1000, 2000, and 4000 Hz, but the thresholds of both groups of children with HL were higher than the thresholds of normal control children.

Screening for AP

For interpreting the screening results of the tested children, we considered the data collected from the screening project for central AP performance in primary-school children, conducted in Alexandria, Egypt [8].

To select students who performed poorly on the tests, the 10th percentile was arbitrarily chosen. A composite score that describes categorically the performance of each child on the four tests – that is, PPST, SPIN right ear, SPIN left ear, and DDT – was assigned for each child. The composite score varies between 0 and 4. A composite score of 0 reflects no failure on any of the four tests. A score from 1 to 4 designates the number of tests for which the performance score was in the vicinity of the 10th percentile. The 10th percentile value for PPST, SPIN right ear, SPIN left ear, and DDT was 16.7, 4.2, 14.3, and 50%, respectively [8].

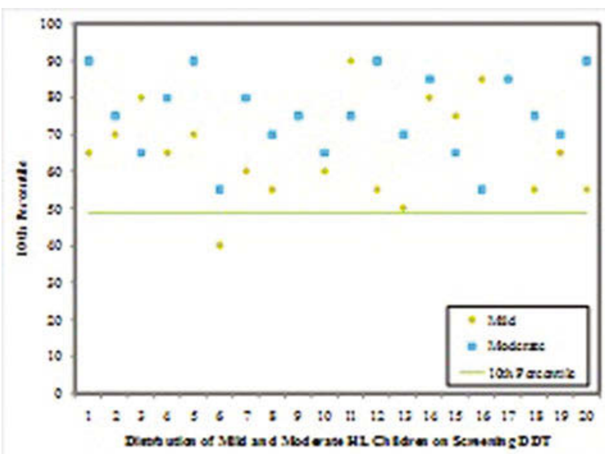
DDT

On screening, the combined scores of the right and left ears of all children exceeded the 10th percentile except for one child with mild HL (Fig. 1). In the full version there were significant statistical differences between the scores of the normal children and those of the mild and moderate HL children, but the mean values exceeded the 10th percentile.

PPST

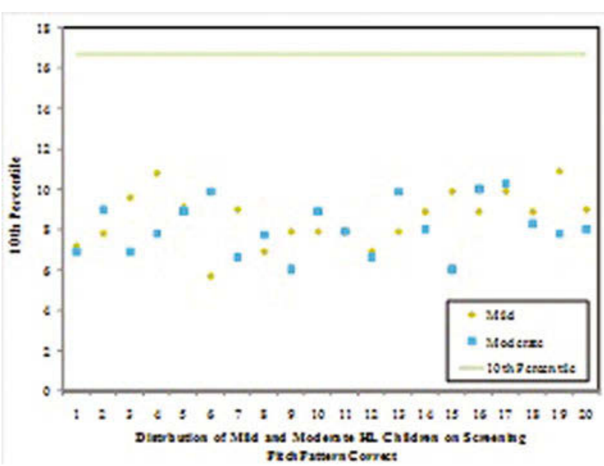
Screening mild and moderate HL childen with the PPST revealed scores lower than the 10th percentile for both groups (Fig. 2), whereas the majority of children had correct scores exceeding the 10th percentile on the full version PPST.

Figure 1



Distribution of scores of mild and moderate HL children on screening DDT in relation to the 10^{th} percentile.

Figure 2



Distribution of the results of mild and moderate sensory HL children on screening PPST in relation to the 10^{th} percentile.

SPIN

The mean SPIN right ear score in mild HL children exceeded the 10th percentile except for two children with scores less than the 10th percentile, whereas the scores of moderate HL children exceeded the 10th percentile except in the case of four children (Fig. 3).

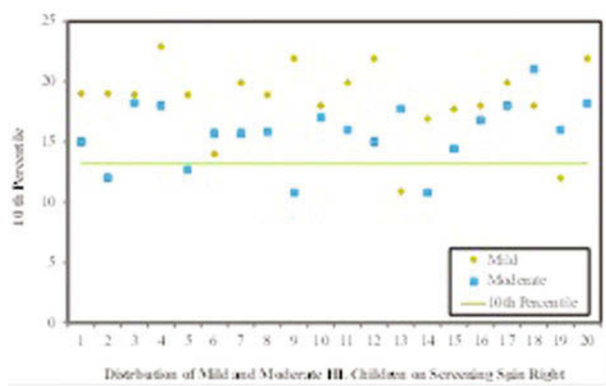
The mean SPIN left ear in mild HL children exceeded the 10th percentile except in the case of four children, whereas the scores of moderate HL children exceeded the 10th percentile except in the case of seven children (Fig. 4).

On full version SPIN, the mean values of both right and left ears of mild and moderate HL children were within normal ranges.

MLD

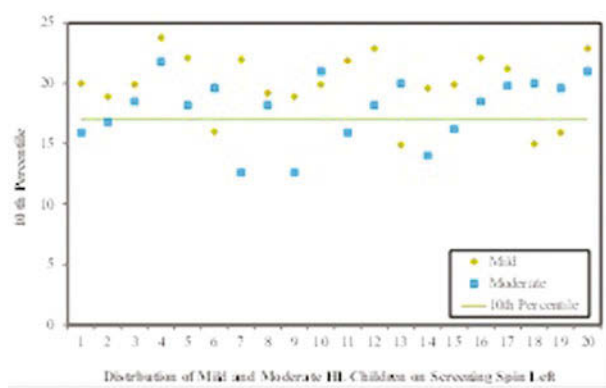
The results of mild and moderate HL children and their controls on the MLD test at 500, 1000, and 2000 Hz in both S0N0-S0Nπ and S0N0-SπN0 exceeded the 10th percentile.

Figure 3



Distribution of mild and moderate Sensory HL children on screening SPIN RT.

Figure 4



Distribution of mild and moderate sensory HL children on SPIN LT.

AFT-R

There were significant statistical differences between the mild and moderate HL children and their controls at 250, 500, and 2000 Hz as the HL children showed prolonged thresholds at these frequencies, whereas there were no significant differences at 2000 and 4000 Hz.

BFT

There were significant statistical differences between mild and moderate HL children and their controls as their scores were less than those of normal hearing children.

LPF speech test

There were significant statistical differences between the normal group and mild and moderate groups and also between mild and moderate groups for both right and left ears. There was also a significant statistical difference between the right and left ear scores in the moderate HL group.

CST

There were significant statistical differences between the normal group and the two HL groups and also a significant difference between the two HL groups as regards both ears on the CST.

By further analysis of the results of the mild and moderate HL children who had composite score 3 on screening tests, we followed their individual performances on AFT-R, and found that they had prolonged thresholds compared with normal children (Figs 5 and 6). The performance of these children was low on the SPIN, CST, LPF, and BFT tests as well.

Discussion

All children with mild and moderate sensory HL included in this study fulfilled the inclusion criteria of bilateral flat symmetrical audiograms, so that their HL could be compensated for by increasing the presentation level equally across all the frequencies during central AP tests, type A tympanogram and intact AR.

The children of the two groups were classified on the basis of the composite scores attained by them on the screening test for their AP abilities.

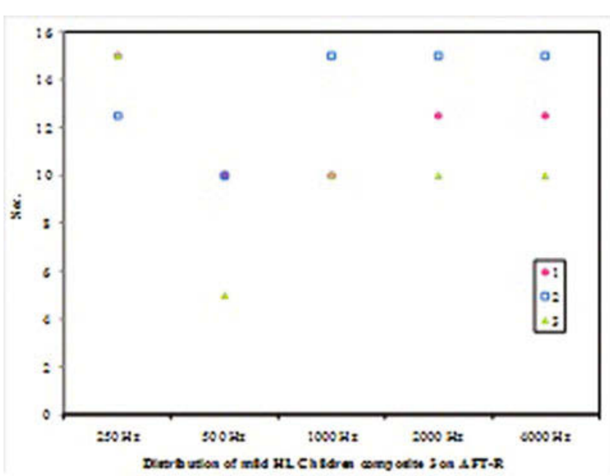
DDT

The combined scores of both the right and left ears of all the children with mild and moderate sensory HL exceeded the 10th percentile on the screening version of the DDT except for one child with mild HL. In the full version of the test, the right and left ear scores were much better in the mild group than in the moderate group, although both were lower than that of the normal group. Also the right ear advantage was clearly evident in both groups. But the results of both groups exceeded the 10th percentile and hence there was no effect of the HL on DDT.

PPST

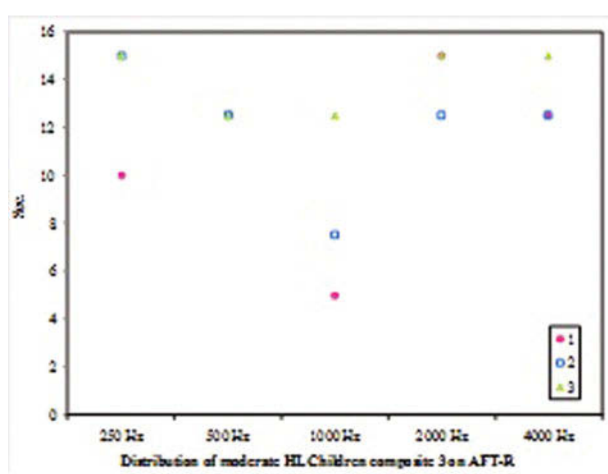
There was a drop in correct scores in both groups in the screening version, as both groups scored less than the 10th percentile. However, on applying the full version of the test, the majority of the scores of both mild and moderate sensory HL children exceeded the 10th percentile in the PPST, although there were significant statistical differences between both groups and the normal group. Thus, under optimum listening

Figure 5



Distribution of the three children with mild HL who have composite score 3 on AFT-R.

Figure 6



Distribution of the three children with moderate HL who have composite score 3 on AFT-R.

conditions the performance of HL children on the PPST improved.

SPIN

On screening the mild and moderate groups, statistically significant differences were found between the scores of the right and left ears in the mild and moderate HL group, with the scores of the mild group being better than the scores of the moderate group for both right and left ears. In the full version, the mild group scored significantly lower than the control group in both right and left ears. Their scores were still better than those with moderate HL for both right and left ears, although both groups' scores were significantly lower than those of the normal control group. However, their scores still exceeded the 10th percentile. Hence, we can state that the normalcy of the speech processing depends on the degree of HL.

MLD

The scores of both groups exceeded the 10th percentile on 500, 1000, and 2000 Hz frequencies for both SπNø and SøNπ.

AFT-R

The scores of the AFT-R showed that there were no significant statistical differences between mild HL children and the normal control group except at 250 Hz where the average threshold is higher than that of the normal control group. The scores of the moderate HL group showed that there were significant statistical differences at all frequencies except at 4000 Hz where the average threshold equals that of the normal hearing group.

However, both groups' scores were within the normal range.

BFT

The results of both the mild and moderate HL children were lower than those of the control group, although the children with mild HL have higher scores compared with those of the moderate group. Mild and moderate sensory HL children showed impaired binaural fusion scores in comparison with the control group.

LPF

The scores of the mild and moderate sensory HL children were lower than the scores of the normal control group, although the scores of the mild group were better than those of the moderate group.

CST

The scores of the mild and moderate sensory HL groups were lower than those of the normal group. The scores of the mild HL group were better than the scores of the moderate group.

(1) We followed the performance of the children who had composite score 3 on the screening test, and hence we followed their individual performance on the comprehensive tests to evaluate the effects of their HL on the tests for temporal processing.
(2) The AFT-R test:

    Both mild and moderate HL groups with composite score 3 showed prolonged thresholds in some frequencies. The influence of HL caused by a sensorineural problem was broadly investigated in psychoacoustic paradigms of temporal resolution assessment. The results of the investigations showed that it does impact temporal resolution, in such a way that individuals with HL have longer duration thresholds when compared with individuals without HL. This finding is consistent with our results.
(3) Competing sentences test and speech in noise test:

    Children belonging to the mild and moderate HL groups with composite score 3 exhibited lower performances compared with the normal group in both tests. Speech recognition in noise is a complex process that is dependent on the detection of spectrotemporal cues in the target signal. Several researchers suggest that redundancy of the speech signal, along with contextual and indexical information, facilitates the understanding of speech in adverse listening conditions [12,13]. Numerous studies indicate that glimpsing is one strategy by which speech in noise is understood [14,15]. In the case of children and individuals with hearing impairment, researchers still have a limited understanding of which cues are most beneficial to perceive speech in noise [16].
(4) Low pass-filtered speech test

    The scores of both groups of children were lower than those of the normal group in the low pass-filtered speech test. This can be attributed to the fact that children with HL may require greater audibility of high-frequency acoustic information than children with normal hearing as they have less linguistic experience. It has been suggested that reduced linguistic experience limits the extent to which children with HL are able to compensate for the reduced quality and quantity of speech cues inherent in limited-bandwidth conditions [17–19].

(5) For further analysis of the results of these six children, we tried to retrospectively conduct a dyslexia test on them and compare its results with the questionnaire on dyslexia that we used at the start of the study. However, we recruited only two of them and conducted an Arabic-version dyslexia test [20].

The test is composed of 11 items: rapid naming, bead threading, 1 min reading, postural stability phonemic segmentation, 2 min spelling, backward digit span, 1 min writing, nonsense passage reading, verbal fluency, semantic fluency. The test eventually yields an 'at risk quotient ARQ' that would discriminate dyslexic children from nondyslexic children.

We compared our dyslexia checklist with the parameters of the dyslexia test and found that most of these items were included in our questionnaire:

(1) Rapid naming corresponds to the question: does the child suffer from any difficulties in determining the right from the left or in naming the days of the week?
(2) Bead threading corresponds to the question: does the child suffer from any difficulty in tying his shoes?
(3) One-minute reading corresponds to the question: does the child suffer from slow reading and bad handwriting?
(4) Two-minute spelling corresponds to the question: does the child suffer from any difficulties in spelling and in writing paragraphs?
(5) Backward digit span corresponds to the question: does the child have any difficulties in recalling something from memory, such as telephone numbers, days of the week, or months of the year?
(6) One-minute writing corresponds to the question: does the child suffer from difficulties in dictation?
(7) Verbal fluency corresponds to the question: does the child struggle to find suitable words during conversation?

From the previous comparison, we found that our questionnaire covered the majority of the items included in the dyslexia test. However, the parents of our studied children gave negative responses to these questions, implying that these children had no dyslexia. This was not true, as the results of the dyslexia test on these children showed that both children were dyslexic. Thus, from this we can conclude that any child with peripheral HL should be tested with central tests, and if the central auditory tests fail, a dyslexia test should be conducted.

Conclusion

In children with HL, perceptual processing of the auditory properties of speech reveals some problems in processing temporal sequences. The normality/abnormality of results varies as a function of degree of loss.

Screening for and comprehensive evaluations of AP performance are reliable when using the criteria of percentile selection and composite score. Children with peripheral sensory HL who fail the central auditory tests should be subjected to a dyslexia test.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1 American Academy of Pediatrics. Joint Committee on infant hearing position statement principles and guidelines for early hearing detection and intervention programs. Pediatrics 2012; 120:898–921.
2 Bennett KE, Haggard MP. Behaviour and cognitive outcomes from middle ear disease. Arch Dis Child 1999; 80(1):28–35.
3 Downs MP, Yoshinaga-Itano C. The efficacy of early identification and intervention for children with hearing impairment. Pediatr Clin North Am 1999; 46(1):79–87.
4 ASHA. (Central) Auditory processing disorders. The role of the audiologist 2005. Available at: http://www.asha.org/policy/PS2005-00114/. [Accessed 30 June 2010]
5 Santucci G. Lecture presented at Washington University. St Louis, MO: Santucci G. Washington University; 2003.
6 Pinheiro ML. Tests of central auditory functions in children with L.D. In: Keith Red, ed. Central auditory dysfunction. New York, NY: Grune and Stretton; 1977. 1–15.
7 Tawfik S, Shalaby A. Development and standardization of Arabic central test battery for children. in: Proceedings of XXIII world congress of international association of logobedics and phoniatrics; 1995:416–419.
8 Mourad M, Hassan M, ELbanna M, Asal S, Talaat M, Elmoazen D, *et al*. Central auditory processing performance of primary school children in Alexandria, Egypt phase I.
9 McCroskey RL, Keith RW. Auditory fusion test revised: Instruction and User's Manual. St. Louis: Auditec; 1996. 31–40.
10 Aithal V, Yonovitz A, Aithal S. Tonal masking level differences in Aboriginal school children: implications for binaural interaction, auditory processing disorders and education. Aust N Z J Audiol 2006; 26:31–40.
11 Willeford JA. Assessing central auditory behavior in children. A test battery approach. In: Keith R, ed. Central auditory dysfunction. New York, NY: Grune & Stratton; 1977. 43–72.
12 Kirkpatrick L, Feeney B. A simple guide to IBM SPSS statistics for version 20.0. Belmont, CA: Wadsworth, Cengage Learning; 2013.
13 Assmann P, Summerfield A. The perception of speech under adverse listening conditions. In Greenberg S, Anisworth WA, Popper AN, Fay RR, eds. Speech processing in the auditory system. Berlin, Germany: Springer-Verlang; 2004. 18.
14 Assmann PF, Summerfield Q. The contribution of waveform interactions to the perception of concurrent vowels. J Acoust Soc Am 1994; 95 (1):471–484.
15 Culling JF, Darwin CJ. Perceptual separation of simultaneous vowels: within and across-formant grouping by F0. J Acoust Soc Am 1993; 93 (6):3454–3467.
16 Eisenberg LS, Shannon RV, Martinez AS, Wygonski J, Boothroyd A. Speech recognition with reduced spectral cues as a function of age. J Acoust Soc Am 2000; 107(Pt 1):2704–2710.

17 Nittrouer S, Boothroyd A. Context effects in phoneme and word recognition by young children and older adults. J Acoust Soc Am 1990; 87 (6):2705–2715.

18 Glista D, Scollie S. Development and evaluation of an English language measure of detection of word-final plurality markers: the University of Western Ontario Plurals Test. Am J Audiol 2012; 21(1):76–81.

19 Wolfe J, John A, Schafer E, Nyffeler M, Boretzki M, Caraway T, Hudson M. Long-term effects of non-linear frequency compression for children with moderate hearing loss. Int J Audiol 2011; 50(6):396–404.

20 Aboras Y, Abdou R, Kozou H. Development of an Arabic test for assessment of dyslexia in Egyptian children. Bul Alex Fac Med 2008; 44:653–662.