Remediation of central auditory processing disorders in children with learning disability: a comparative study

Samah M. Ahmed[a], Somaia M. Tawfik[b], Mohamed S. Bakr[a], Emad K. Abdelhaleem[a], Enass S. Mohamed[a]

[a]Department of ENT, Assiut University, Assiut, [b]Department of ENT, Ain Shams University, Cairo, Egypt

Correspondence to Samah M. Ahmed, MSc, Department of ENT, Assiut University, Egypt
Tel: +20 100 789 9137; Postal code: 71515; Fax: 088-2354130;
e-mail: samahoraky@yahoo.com

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Objective
The primary objective of this study was to compare the outcome of central auditory processing rehabilitation when using two different strategies. In the first strategy, the computer-based remediation program was used (temporal processing and phonemic awareness training). In the second strategy, the informal remediation program was used (temporal processing and phonemic awareness training).

Patients and methods
Fifty children with learning disability due to central auditory processing disorder were selected from primary schools in Assiut city. They were subjected to psychophysical test battery. It comprised dichotic digits test, pitch pattern sequence test, and electrophysiological test (cortical P1). They were divided into two equal groups, groups A and B. Each group was subdivided on the basis of age into three subgroups. Group A received the formal Auditory Training (AT) and group B received the informal AT for a minimum duration of 2 months. Re-evaluation of those children was carried out using the same test battery used in the diagnosis.

Results
The children were evaluated 1 month after training. There was a statistically significant difference in all psychophysical tests and electrophysiological P1. Subjective improvement was noticed also at the level of the questionnaire and school reports.

Conclusion
Both formal and informal remediation material used in this study proved to be effective and promising auditory training strategy for ameliorating central auditory disorder by remodeling the plasticity of the CANS.

Keywords:
auditory training, CAPD, Learning disability

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Introduction

American Speech-Language Hearing Association [1] defined central auditory processing (CAP) as the auditory mechanisms that underlie the following abilities or skills: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition, including temporal integration, temporal discrimination, temporal ordering, and temporal masking; auditory performance in competing acoustic signals (including dichotic listening); and auditory performance with degraded acoustic signals.

The behaviors and symptoms noted in individuals with central auditory processing disorder (CAPD) often overlap with those that are observed in individuals with other sensory and/or cognitive disorders. For these reasons, a multidisciplinary approach to assess individuals at-risk for CAPD is an important complement to the audiologic diagnosis of CAPD [2].

Management of CAPD is based mainly on three lines, direct skill remediation for the affected abilities, use of compensatory strategies, and acoustic modification of the listening conditions [1,3]. Direct skill remediation for the affected ability and compensatory strategies can be conducted either through formal or informal methods. Formal methods are those in which computer-based programs or special equipment is needed [4]. However, informal methods can be applied in a variety of settings by a variety of professionals with simple materials [5].

Both formal and informal auditory training programs were developed and standardized in Arabic language at Ain Shams University to suit Arabic-speaking children.

Patients and methods

Criteria for inclusion in the present study were as follows: poor school performance; normal peripheral hearing sensitivity as shown using pure-tone audiometry thresholds below 15 dB HL for frequencies 250-8000 Hz; excellent speech discrimination scores; and normal middle-ear functions. They had at least average psychointellectual abilities as measured using the Arabic Stanford Binnet test, version 4, with no associated neurological disorders. This study was done after obtaining approval from local ethical committee of Assiut University with written informed consent was obtained from parents of all children in this study.

Central auditory testing was carried out using both psychophysical test battery [pitch pattern sequence (PPS) and dichotic digits test (DDT)] and electrophysiological test using cortical P1; those with CAPD were included in the remediation programs. In addition, the phonemic awareness test was applied for children around 10 years of age.

A group of 50 school-aged children [24 male (48%) and 26 female (52%)] fulfilled the above-mentioned criteria. Their ages ranged from 6 to 12 years: half of them 'group A' received the formal training program in the form of interesting computer games for training of auditory temporal processing ability and phonemic awareness ability, and the other half 'group B' received the informal training program for training of phonemic awareness ability and auditory directives. The training lasted for 2 months, followed by re-evaluation using the same central test battery used in preremediation evaluation and phonemic awareness testing.

Statistical analysis

All values are expressed as means ± SD. Statistical analysis was carried out using the Mann–Whitney test, Wilcoxon signed-rank test, and Fisher's exact test (IBM SPSS version 16). *P* values of less than 0.05 were considered significant. Statistical analysis was conducted in IBM SPSS statistics version 16 (INC., Chicago, IL, USA).

Results

The two groups (groups A and B) were divided on the basis of age into three equal subgroups: subgroup 1 included eight children aged 6 to <8 years; subgroup 2 included eight children aged 8 to <10 years; and subgroup 3 included nine children aged 10 to <12 years. All children in this study had bilateral within-normal hearing threshold at all tested frequencies and bilateral within-normal speech reception threshold, with no statistically significant difference between the two groups and their age subgroups. They had bilateral excellent speech discrimination scores. They also had bilateral normal tympanograms (type A) and within-normal acoustic reflex thresholds.

Baseline criteria of both groups

Central auditory processing tests results

(1) PPT:
There was no statistically significant difference between the three age subgroups (A1 and B1; A2 and B2; and A3 and B3) as regards the PPT scores in both preremediation and postremediation test results ($P_1 > 0.05$). There was a statistically significant difference between the three age subgroups (A1 and B1; A2 and B2; and A3 and B3) in the PPT scores before remediation and after remediation ($P_2 < 0.05$)

(2) DDT results:
There was no statistically significant difference between the three age subgroups (A1 and B1; A2 and B2; and A3 and B3) as regards the DDT scores in both preremediation and postremediation test results in the right and left ears ($P_1 > 0.05$). There was also a statistically significant difference between the three subgroups in the DDT scores (when comparing preremediation results with postremediation results) ($P_2 < 0.05$)

(3) Cortical evoked P1 latency:
There is no statistically significant difference between the three age subgroups (A1 and B1; A2 and B2; and A3 and B3) in cortical evoked P1 average latency in preremediation test results and postremediation test results ($P_1 > 0.05$). There was a statistically significant difference between preremediation and postremediation cortical evoked P1 average latency in all subgroups (A1, B1, A2, B2, A3, and B3) ($P_2 < 0.05$).

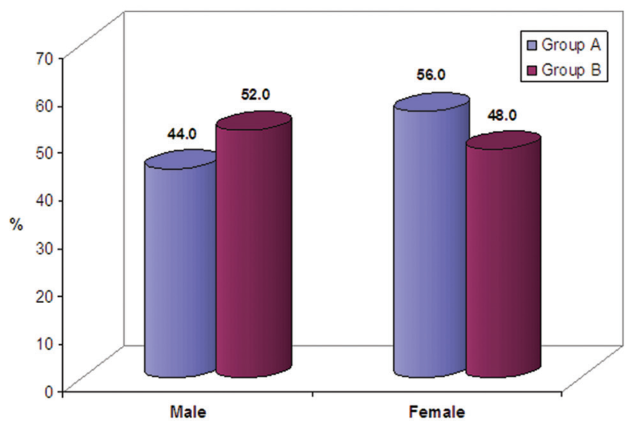
(4) Phonemic awareness test results:
There was a statistically significant difference between preremediation and postremediation phonemic awareness test results through most of its items (six out of nine) and in the test total score also.

Discussion

The children in both groups were selected to be more or less homogenous as regards age and sex; moreover, IQ was not significantly different between the two groups; this is important before starting remediation programs to avoid effects of these factors on the postremediation test results and on the amount of improvement. Thus, the children could not be selected randomly. This can be seen in Figs. 1 and 2.

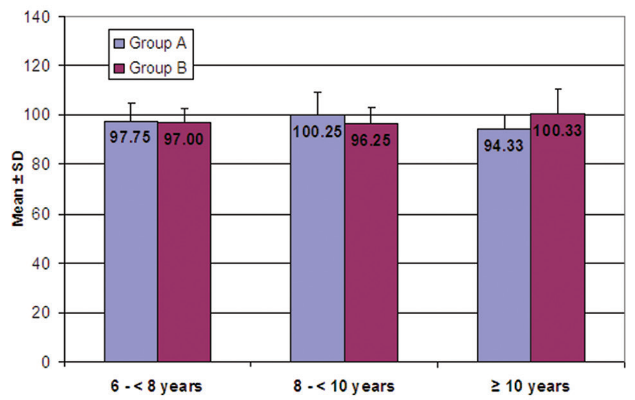
Moreover, results of the CAP tests used in this research (DDT and PPS) had no significant difference between the two groups, to avoid the effect of preremediation test results on the amount of improvement. This is presented in Tables 1–3 in preremediation test results in each group.

Figure 1



Sex distribution in both groups.

Figure 2



IQ distribution in the two study groups (group A and group B) in different age subgroups.

Table 1 Pitch pattern sequence test results in subgroups A1, A2, and A3 and subgroups B1, B2, and B3

PPT	Group A1 (mean±SD)	Group B1 (mean±SD)	P_1
Right			
Pre	0.36±0.06	0.32±0.06	0.303
Post	0.68±0.06	0.64±0.09	0.448
P_2	0.012*	0.012*	
Left			
Pre	0.28±0.06	0.27±0.06	0.560
Post	0.59±0.05	0.58±0.08	0.912
P_2	0.012*	0.012*	
PPT	Group A2 (mean±SD)	Group B2 (mean±SD)	P_1
Right			
Pre	0.44±0.08	0.45±0.07	0.710
Post	0.74±0.09	0.70±0.07	0.487
P_2	0.011*	0.012*	
Left			
Pre	0.38±0.07	0.39±0.07	0.887
Post	0.67±0.08	0.60±0.06	0.134
P_2	0.012*	0.011*	
PPT	Group A3 (mean±SD)	Group B3 (mean±SD)	P_1
Right			
Pre	0.49±0.07	0.52±0.06	0.327
Post	0.73±0.08	0.73±0.07	0.928
P_2	0.008*	0.008*	
Left			
Pre	0.43±0.08	0.47±0.06	0.219
Post	0.67±0.08	0.69±0.09	0.651
P_2	0.008*	0.007*	

**P* value < 0.05 is statistically significant. PPT, pitch pattern sequence test. P_1: Comparison between group A and group B (the Mann-Whitney test). P_2: Comparison between pre-remediation and post-remediation results in each group (Wilcoxon signed-rank test).

Psychophysical central auditory test

CAP tests used in this research were DDT and PPS. These tests are used to assess certain ability affection in children which include: Dichotic listening, (temporal ordering and sequencing) respectively.

In our study, only children with learning disability due to CAPD were included; children with normal central auditory tests were excluded from the study. This means that children with Learning Disability (LD) and auditory processing disorder comprise the study group.

Pitch pattern sequence test

Preremediation evaluation: There was no significant difference between the two groups (A and B) in different subgroups (A1 and B1; A2 and B2; and A3 and B3) ($P_1 > 0.05$).

Postremediation evaluation: There was a significant improvement in the PPT scores in both groups (A1 and B1; A2 and B2; and A3 and B3) (Table 1).

This means that both remediation programs revealed a statistically significant degree of improvement. Improvement in PPT, which indicates improvement in temporal auditory processing ability, might be attributed to the effect of both temporal processing training and phonemic awareness training.

It seems that training on discrimination and sequencing task, gap detection task, and temporal ordering task proved to enhance auditory temporal processing besides the auditory temporal processing training. This is in agreement with the findings of Tawfik *et al.* [6], who reported that PPS as a test of temporal ordering and sequencing showed marked improvement in postremediation results, although still below normative data.

However, Seats [7] did not find improvement in temporal patterning after training with FastForward program. However, his results should be taken cautiously as his study was conducted on a single subject.

Dichotic digit test

As regards the DDT scores in preremediation testing, there was no statistically significant difference between the two groups (A and B) and between different subgroups (A1 and B1; A2 and B2; and A3 and B3) (Table 2) ($P_1 > 0.05$). These was a significant improvement in both groups A and B in postremediation evaluation ($P_2 < 0.05$). This indicates the efficacy of both training programs in improving binaural integration ability.

Looking to the psychophysical central test battery scores, there was a statistically significant difference between preremediation and immediate postremediation evaluations in all tests ($P < 0.05$). This is in agreement with the findings of Tawfik *et al.* [6].

Table 2 Dichotic digit test results in subgroups A1, A2, and A3 and subgroups B1, B2, and B3

DDT	Group A1 (mean±SD)	Group B1 (mean±SD)	P_1
Right			
Pre	0.55±0.07	0.56±0.08	0.708
Post	0.80±0.06	0.79±0.10	0.913
P_2	0.011*	0.017*	
Left			
Pre	0.49±0.06	0.53±0.09	0.393
Post	0.70±0.08	0.70±0.08	0.748
P_2	0.012*	0.027*	
DDT	Group A2 (mean±SD)	Group B2 (mean±SD)	P_1
Right			
Pre	0.63±0.09	0.63±0.10	0.790
Post	0.86±0.12	0.83±0.08	0.427
P_2	0.012*	0.018*	
Left			
Pre	0.60±0.09	0.58±0.09	0.523
Post	0.85±0.12	0.78±0.07	0.097
P_2	0.012*	0.017*	
DDT	Group A3 (mean±SD)	Group B3 (mean±SD)	P_1
Right			
Pre	0.67±0.11	0.66±0.12	0.823
Post	0.83±0.11	0.84±0.06	0.531
P_2	0.035*	0.007*	
Left			
Pre	0.62±0.09	0.61±0.12	0.624
Post	0.79±0.09	0.79±0.06	0.749
P_2	0.024*	0.007*	

*P value < 0.05 is statistically significant. P_1: Comparison between group A and group B (the Mann-Whitney test). P_2: Comparison between pre-remediation and post-remediation results in each group (Wilcoxon signed-rank test). DDT, dichotic digit test.

Benefit gained from both programs was not restricted only to Auditory Temporal Processing (ATP) and phonemic awareness tasks only, but extended to involve other CAP abilities – namely, binaural integration. The generalized improvement in different CAP abilities in this study supports the suggestion that training directed to certain central auditory abilities may enhance abilities other than the targeted ones [8,9].

Therefore, improvement in group A of this study was due to computer-based auditory training. This is in agreement with findings of Tawfik *et al.* [10], who reported improvement in CAP abilities – namely, ATP tasks, selective auditory attention, auditory separation, and memory abilities following ATP computer-based training.

The improvement noticed in group B of this study following informal remediation of temporal processing and phonemic awareness is similar to that reported in the study by Tawfik *et al.* [9], in which study group children improved to match the normative data of the control group after remediation with informal remediation material. However, the preremediation test results were significantly lower than those of the control group.

Electrophysiological test

Cortical evoked P1 latency

The P1 component of the cortical auditory evoked potential shows clearly documented age-related decreases in latency and changes in morphology in normal-hearing children, providing a biomarker for the development of the auditory cortical pathways in humans [11].

Table 3 shows no statistically significant difference between the three age subgroups (A1 and B1; A2 and B2; and A3 and B3) in cortical evoked P1 average latency.

On comparing preremediation and postremediation test results, there was a statistically significant difference

Table 3 Cortical evoked P1 latency in the three age subgroups before and after remediation

Cortical Evoked P1 average latency	Group A1 (mean±SD)	Group B1 (mean±SD)	P_1
Pre	142.94±12.29	138.69±7.36	0.519
Post	134.75±12.12	135.00±6.81	0.958
P_2	0.012*	0.027*	
Cortical evoked P1 average latency	Group A2 (mean±SD)	Group B2 (mean±SD)	P_1
Pre	107.44±25.25	97.13±28.57	0.343
Post	102.56±23.83	93.56±28.73	0.343
P_2	0.011*	0.018*	
Cortical evoked P1 average latency	Group A3 (mean±SD)	Group B3 (mean±SD)	P_1
Pre	106.17±25.58	101.22±30.16	0.690
Post	104.56±25.21	93.56±26.46	0.354
P_2	0.046*	0.008*	

*P value < 0.05 is statistically significant. P_1: Comparison between group A and group B (the Mann-Whitney test). P_2: Comparison between pre-remediation and post-remediation results in each group (Wilcoxon signed-rank test).

Table 4 Comparison between phonemic awareness test results before and after remediation

Phonemic awareness test	Preremediation (mean±SD)	Postremediation (mean±SD)	*P*
Rhyme detection	3.09±0.94	6.18±0.98	0.001*
Blending of sounds to form a word	0.82±0.40	1.00±0.00	0.157
Segmentation of a word into sound	1.82±0.60	2.36±0.50	0.014*
Recognition of the first sound of the word	1.64±0.50	1.82±0.40	0.157
Recognition of the middle sound of the word	2.55±0.52	3.73±0.65	0.004*
Deletion of the first sound from the word	0.73±0.47	1.00±0.00	0.083
Deletion of the middle sound from the word	2.45±0.69	4.55±0.52	0.003*
Deletion of the last sound from the word	1.45±0.52	2.36±0.50	0.008*
Addition of a sound to the word	2.82±0.40	4.18±0.40	0.002*
Phonemic awareness test (totally)	17.36±2.98	27.18±2.36	0.003*

**P* value < 0.05 is statistically significant. P_1: Comparison between group A and group B (the Mann-Whitney test). P_2: Comparison between pre-remediation and post-remediation results in each group (Wilcoxon signed-rank test).

between subgroups in P1 average latency ($P_2 < 0.05$). This indicates a good outcome from both programs for most of the children in this study. This means that the subjective improvement in psychophysical tests could be confirmed objectively through P1 latency measurement.

Phonemic awareness test

Preremediation evaluation: The phonemic awareness test used in this study is a subitem of Arabic reading test standardized for the diagnosis of reading disability at Assiut University, Phoniatric Unit [12].

Table 4 showed a statistically significant improvement after training in most of the test items (six out of nine).

This means that both remediation programs were effective in improving phonemic awareness abilities in children with learning disability. This is attributed to the effect of phonemic awareness training included in both remediation programs. It seems that training on phoneme segmentation, omission, and building enhance phoneme awareness ability was reflected on the results of this test. This indicates that improvement in phonemic awareness ability was accompanied by improvement in reading ability. Similar results were obtained by Edwards *et al.* [13] and Scientific Learning Corporation [14], who reported enhancement of phonological awareness test scores following FastForWard (FFW) training. Tawfik *et al.* [10] also reported enhancement of phonological awareness test scores following training with ATPD. However, Angew *et al.* [15] and Strehlow *et al.* [16] reported that the improvement in phonological awareness ability following training with Auditory Temporal Processing Disorder (ATPD) did not transfer to reading ability.

This test can be considered as an objective indicator of improvement in phonemic awareness abilities after remediation programs.

Conclusion

- The outcome of both formal and informal auditory training programs used for Arabic-speaking children with learning disability due to APD showed improvement in post-training evaluation
- The temporal processing PPS and DDT were sensitive tools in monitoring the progress of training.

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Conflicts of interest

There are no conflicts of interest.

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