Comparing outcome of formal and informal remediation programs in children with central auditory processing disorder

Samah M. Oraky[a], Somaia Tawfik[b], Mohamed Salama[a], Enass S. Mohamed[a]

[a]Audiology Unit, Department of ENT, Faculty of Medicine, Assiut University, Assiut, [b]Audiology Unit, Department of ENT, Ain Shams University, Cairo, Egypt

Correspondence to Samah M. Oraky, MSc, Audiology Unit, Department of Otolaryngology, Assiut College of Medicine, Assiut 71515, Egypt; Tel: +20 100 789 9137; fax: +20 882 333 327; e-mail: samahoraky@yahoo.com

Received 5 January 2017
Accepted 15 January 2017

The Egyptian Journal of Otolaryngology
2017, 33:502–507

Aim
The aim of this study was to compare the outcome of central auditory processing rehabilitation when using two different strategies:

In the first strategy, computer-based remediation program (temporal processing and phonemic awareness training) was used.

In the second strategy, informal remediation program (temporal processing and phonemic awareness training) was used.

Patients and methods
Fifty children with learning disability due to Central Auditory Processing Disorder (CAPD) were selected from primary schools in Assiut city. They were subjected to psychophysical test battery. It comprised dichotic digits, pitch pattern sequence, auditory fusion test and electrophysiological test (cortical P1). They were divided into two equal groups (A and B): 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 performed using the same test battery used in the diagnosis.

Results
There was a statistically significant difference in all psychophysical tests and electrophysiological P1. Subjective improvement was noticed also at the level of the questionnaire.

Conclusion
Both formal and informal remediation programs used in this study proved to be effective and promising AT strategies for ameliorating central auditory disorder.

Keywords:
CAPD, formal, informal, learning disability, remediation

Egypt J Otolaryngol 33:502–507

1012-5574

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 CAPD often overlap with those that are observed in individuals with other sensory and/or cognitive disorders. For these reasons, a multidisciplinary approach to assessment of the individual 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], whereas 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 (AT) programs were developed and standardized in Arabic language at Ain Shams University to suit Arabic-speaking children.

Patients and methods

This study was conducted after obtaining approval from the local ethics committee of Assiut University with

written informed consent obtained from parents of all children in this study. Criteria for inclusion in the present study were poor school performance, normal peripheral hearing sensitivity as shown by pure tone audiometry thresholds less than 15 dBHL for frequencies 250–8000 Hz, excellent speech discrimination scores, and normal middle-ear functions. They had at least average intelligence quotient (IQ) as measured by the Arabic Stanford Binnet test, version 4, with no associated neurological or ophthalmological disorders. Those with peripheral hearing loss, below-average IQ, any degree of mental retardation, and visual or neurological disorders were excluded from this study.

Central auditory testing was performed using psychophysical tests [dichotic digits (DDT), pitch pattern sequence (PPS), and auditory fusion test (AFT)] and electrophysiological test using cortical P1; those with CAPD were included in the remediation programs.

A group of 50 school-aged children [24 (48%) male and 26 (52%) female] fulfilled the above-mentioned criteria. Their age 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 temporal processing ability (Table 1). Training lasted for 2 months, and then re-evaluation using the same central test battery used in preremediation evaluation was performed 1 month after the end of the remediation programs.

Statistical analysis

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

Table 1 Age and sex distribution of both groups A and B

	Group A (*n*=25) [*N* (%)]	Group B (*n*=25) [*N* (%)]	*P* value
Sex			
Male	11 (44.0)	13 (52.0)	0.571
Female	14 (56.0)	12 (48.0)	
Age			
Mean±SD	8.90±1.73	8.99±1.67	0.841
Range	6.08–11.33	6.08–11.42	

Results

Basic audiologic evaluation

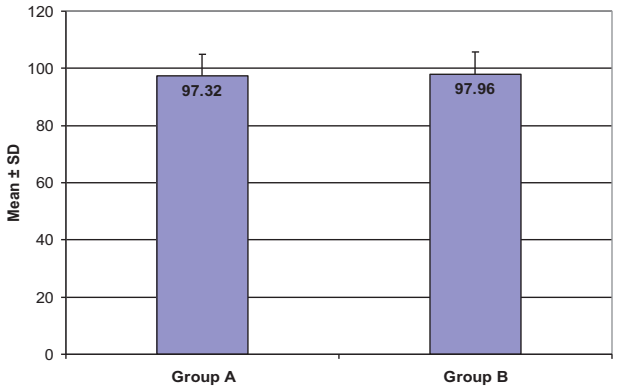
All children in this study had bilateral normal hearing threshold at all tested frequencies and bilateral normal speech reception threshold, with no statistically significant difference between the two groups (Figs. 1 and 2 and Table 2). They had bilateral excellent speech discrimination scores. They had also bilateral normal tympanograms (type A) and normal acoustic reflex thresholds.

Central auditory processing tests results

Results of CAPD questionnaire showed a statistically significant difference between the preremediation and postremediation test, as shown in Table 3.

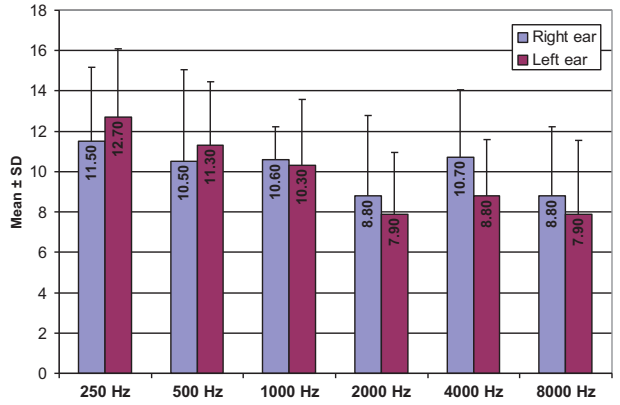
Results of psychophysical tests (DDT, PPT, and AFT) used in this study showed a statistically significant difference between the preremediation and postremediation test results, with no statistically significant difference between the two groups

Figure 1



Intelligence quotient distribution of both study groups A and B.

Figure 2



Pure tone audiometric (PTA) threshold in dBHL at different frequencies for right and left ears in both groups A and B.

in the preremediation and postremediation test results, except in AFT at 250 Hz in postremediation evaluation. This is demonstrated in Table 4.

Results of cortical evoked P1 showed a statistically significant difference between the preremediation and postremediation test results in cortical P1 latency in the two groups, with no statistically significant difference between the two groups, as can be shown in Fig. 3.

Comparison of the amount of improvement between the two groups

Psychophysical tests

As regards the change in PPT and DDT, there is no statistically significant difference between both groups (A and B), but the mean of change is more in group A than in group B, as shown in Fig. 4.

Looking to the improvement in AFT, there is no statistically significant difference between both groups (A and B) as regards the change in AFT at all frequencies, except at 250 Hz where the mean of improvement is more in group A than in group B (Fig. 5).

Electrophysiological test

Looking to the change in cortical evoked P1 latency, there is no statistically significant difference between both groups (A and B), as demonstrated in Table 5.

Discussion

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

In addition, results of the CAP tests used in this research (DDT, PPS, and AFT) and cortical P1 had no significant difference between both groups to avoid the effect of preremediation test results on the amount of improvement, as can be viewed in Table 4 and Fig. 3.

Table 2 Speech reception threshold in dBHL for right and left ears in both groups A and B

SRT	Group A(*n*=25) (mean±SD)	Group B (*n*=25) (mean±SD)	*P* value
Right ear	10.40±3.51	9.00±3.82	0.174
Left ear	10.60±3.23	8.80±3.89	0.079

SRT, speech reception threshold.

Table 3 Results of central auditory processing questionnaire before and after application of the remediation programs in both groups

Questionnaire	Group (A) (*n*=25) (mean±SD)	Group (B) (*n*=25) (mean±SD)	P_1 value
Preremediation	52.37±12.55	49.17±11.80	0.372
Postremediation	63.92±13.47	60.86±10.51	0.389
P_2 value	0.005*	0.001*	

*Statistically significant difference.

Table 4 Results of behavioral central auditory tests before and after application of the remediation programs in both groups

	Group A (*n*=25) (mean±SD)	Group B (*n*=25) (mean±SD)	P_1 value
DDT			
Right ear			
Preremediation	61.50±10.05	61.80±10.89	0.969
Postremediation	83.00±10.08	82.00±7.97	0.537
P_2 value	0.000*	0.000*	
Left ear			
Preremediation	57.30±9.52	57.60±10.22	0.991
Postremediation	77.90±11.10	75.70±7.99	0.363
P_2 value	0.000*	0.000*	
PPT			
Right ear			
Preremediation	43.18±8.67	43.58±10.57	0.821
Postremediation	71.92±7.74	69.18±8.23	0.416
P_2 value	0.000*	0.000*	
Left ear			
Preremediation	36.90±9.09	37.96±10.77	0.667
Postremediation	64.24±7.73	62.38±8.58	0.514
P_2 value	0.000*	0.000*	
Auditory fusion test			
250 Hz			
Preremediation	25.80±5.98	27.20±7.51	0.745
Postremediation	15.60±3.48	20.40±5.04	0.000*
P_2 value	0.000*	0.001*	
500 Hz			
Preremediation	24.40±6.90	24.20±8.50	0.867
Postremediation	16.20±3.96	17.20±4.35	0.649
P_2 value	0.000*	0.001*	
1000 Hz			
Preremediation	22.70±7.60	19.70±7.34	0.208
Postremediation	15.50±4.02	14.50±4.79	0.336
P_2 value	0.000*	0.002*	
2000 Hz			
Preremediation	22.10±8.28	21.50±8.23	0.813
Postremediation	16.10±5.00	14.80±5.99	0.217
P_2 value	0.003*	0.001*	
4000 Hz			
Preremediation	29.00±7.71	27.60±7.99	0.544
Postremediation	21.70±3.80	20.70±7.05	0.222
P_2 value	0.001*	0.000*	

DDT, dichotic digits. P_1, comparison between groups A and B (Mann–Whitney test). P_2, comparison between preremediation and postremediation in each group (Wilcoxon's signed-rank test).
*Statistically significant difference.

Psychophysical central auditory test

CAP tests used in this research were DDT, PPS, and AFT. These tests are used to assess certain ability affection in children, which include dichotic listening, temporal processing, and temporal resolution, respectively.

Pitch pattern sequence test

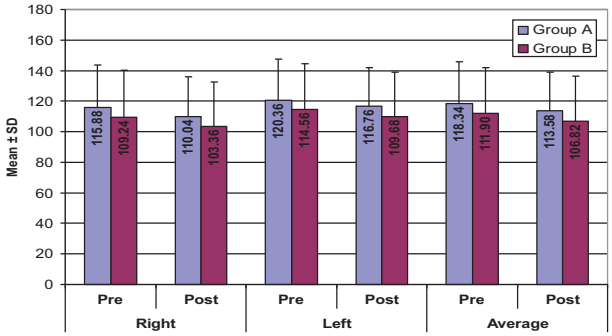
Preremediation evaluation: There is a statistically significant difference between the preremediation and postremediation evaluation, with no statistically significant difference between the two groups (A and B) in the preremediation or the postremediation evaluation. This means that there is significant improvement in the PPT scores in both groups (Table 4).

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 besides the auditory temporal processing training proved to enhance auditory temporal processing. This is in agreement with the study 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.

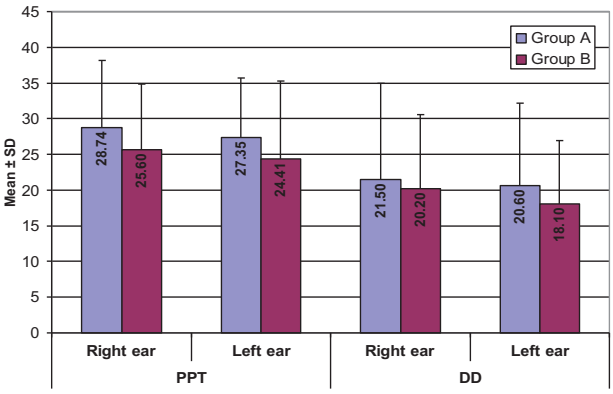
On the other hand, Seats [7] did not find improvement in temporal patterning after training with FastForward

Figure 3



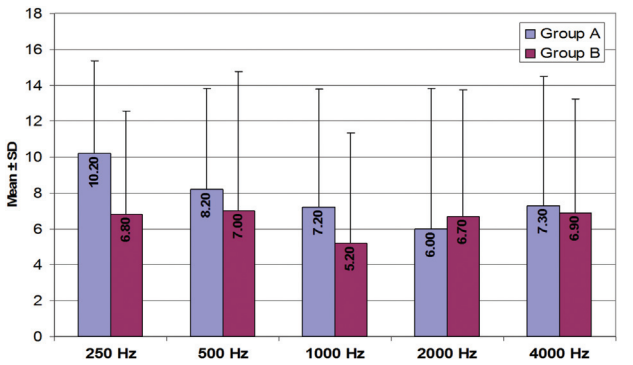
Results of cortical P1 latency before and after application of the remediation programs in both groups.

Figure 4



Comparison of mean of change in PPT and dichotic digits (DDT) between both groups A and B.

Figure 5



Comparison of mean of change in auditory fusion test between both groups (A and B).

Table 5 Comparison between preremediation and postremediation phonemic awareness test results in both groups

Phonemic awareness test	Preremediation (mean±SD)	Postremediation (mean±SD)	*P* value
Rhyme detection (R1)	3.09±0.94	6.18±0.98	0.001*
Blending of sounds to form a word (R2)	0.82±0.40	1.00±0.00	0.157
Segmentation of a word into sound (R3)	1.82±0.60	2.36±0.50	0.014*
Recognition of the first sound of the word (R4)	1.64±0.50	1.82±0.40	0.157
Recognition of the middle sound of the word (R5)	2.55±0.52	3.73±0.65	0.004*
Deletion of the first sound from the word (R6)	0.73±0.47	1.00±0.00	0.083
Deletion of the middle sound from the word (R7)	2.45±0.69	4.55±0.52	0.003*
Deletion of the last sound from the word (R8)	1.45±0.52	2.36±0.50	0.008*
Addition of a sound to the word (R9)	2.82±0.40	4.18±0.40	0.002*
Phonemic awareness test (totally)	17.36±2.98	27.18±2.36	0.003*

*Statistically significant difference.

program. However, his results should be taken cautiously, as his study was conducted on a single patient.

Dichotic digit test

As regards the DDT scores in preremediation testing, there was no statistically significant difference between the two groups (A and B), as shown in Table 4 (P_1>0.05). This table showed also a statistically significant difference between preremediation and postremediation evaluations. Significant improvement in both groups A and B postremediation evaluation indicates efficacy of both training programs in improving dichotic listening ability.

Auditory fusion test

AFT results showed a statistically significant difference between preremediation and postremediation evaluation at all frequencies with no significant difference between the two groups (A and B), except at 250 Hz in postremediation evaluation, as shown in Table 4.

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

Benefit gained from both programs was not only restricted to ATP and phonemic awareness tasks but also extended to involve other CAP abilities namely dichotic listening and temporal resolution abilities. 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 because of computer-based AT. This is in agreement with the findings of Tawfik *et al*. [10], who reported an 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 the study reported by Tawfik *et al.* [9], in which the study group children improved to match the normative data of the control group after remediation by 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 development of the auditory cortical pathways in humans [11].

Table 6 showed no statistically significant difference between the two groups in cortical evoked P1 average latency.

When comparing preremediation and postremediation test results, there was a statistically significant difference in both groups in P1 latency in both ears, P_2 value less than 0.05. This refers to 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

The phonemic awareness test used in this study is a subtest of Arabic reading test standardized for diagnosis of reading disability at Assiut University-Phoniatric Unit [12].

Table 5 showed a statistically significant improvement in postremediation evaluation 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. We can conclude that training on phoneme segmentation, omission, 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 Cooperation [14] reported enhancement of phonological awareness test scores

Table 6 Comparison of mean of change in cortical evoked P1 latency between both groups (A and B)

Cortical evoked P1 latency (ms)	Group A (n=25) (mean±SD)	Group B (n=25) (mean±SD)	P value
Right ear	5.84±4.01	5.88±4.56	0.799
Left ear	3.60±4.39	4.88±4.48	0.171

Mann–Whitney test.

following FastForWard (FFW) training. In addition, Tawfik *et al.* [10] reported enhancement of phonological awareness test scores following training of Auditory Temporal Processing Disorder (ATPD). However, Angew *et al.* [15] and Strehlow *et al.* [16] reported that improvement of phonological awareness ability following training of ATPD did not transfer to reading ability.This test can be considered as an objective indicator of improvement of phonemic awareness abilities after remediation programs.

Conclusion

(1) Formal and informal remediation programs used in this study proved to be effective and promising AT strategies for ameliorating CAP disorder. The improvement was reported in different CAP abilities.
(2) Cortical P1 latency can be used as a biomarker of CAPD improvement after remediation therapy, as a statistically significant shorter latency was observed in postremediation P1 testing.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1 American Speech-Language-Hearing Association. (Central) Auditory Processing Disorders, Working Group on Auditory Processing Disorders; 2005 (Technical Report). Retrieved from: http://www.asha.org/docs/html/TR2005-00043.html. Technical Report. p. 1–20.
2 Chermak GD. Central resources training: cognitive, metacognitive, and metalinguistic skills and strategies. In: Chermak GD, Musiek FE, editors Handbook of (central) auditory processing disorder. Volume II: comprehensive intervention. San Diego, CA: Plural; 2007. pp. 107–166.
3 Bellis T. Interpretation of central auditory assessment results. In: Bellis T, editor. Educational setting. Chapter 7. London: Singular Publishing Group Inc.; 1996. pp. 167–193.
4 Musiek FE, Baran JA, Schochat E. Selected management approaches to central auditory processing disorders. Scand Audiol 1999; 28(Suppl 51):63–76.
5 Tye-Murray N. Foundations for aural rehabilitation. San Diego: Singular Publishing Group; 1998.
6 Tawfik S, Hassan DM, Mesallamy R. Evaluation of long term outcome of auditory training programs in children with auditory processing disorders. Int J Pediatr Otolaryngol 2015; 79:2404–2410.
7 Seats T. Treatment efficacy of temporal exercises in the habitation of central auditory processing disorder. Quoted from Medwetsky L. Central auditory processing [Chapter 26]. In: Katz J, editor. Handbook of clinical audiology. 5th ed. Baltimore, MD, USAL: Williams and Wilkins; 1998. pp. 510–524.
8 Chermak GD, Musiek FE. Auditory training: principles and approaches for remediating and managing auditory processing disorders. Semin Hear 2002; 23:297–308.
9 Tawfik S, El-Danasoury I, Shalaby A, Ramadan M. Development of an Arabic remediation program for central auditory processing disorder in children. In: International association of logopedics and phoniatrics: proceedings CAPD composium. 2009 (Available from: http://ialp.info/Proceedings-CAPD-Composium-Cairo-2009-pg16343.html).
10 Tawfik S, Sadek I, El-Kholy W, Thabet M. Remediation of temporal processing disorder in Egyptian children using computer-based program [Doctorate Degree Thesis]. Cairo: Ain Shams University; 2006.
11 Campbell JD, Cardon G, Sharma A. Clinical application of the P1 cortical auditory evoked potential biomarker in children with sensorineural hearing loss and auditory neuropathy spectrum disorder. Semin Hear 2011; 32:147–155.
12 Abou El-Ella MY, Sayed EM, Farghaly WM, Abdel Haleem EK, Hassan ES. Construction of an Arabic reading test for assessment of dyslexic children. Neurosciences (Riyadh) 2004; 40:487–500.
13 Edwards V, Giaschi D, Dougherty R, Edgell D, Bjornson B, Lyons C, Douglas R. Psychophysical indexes of temporal processing abnormalities in children with developmental dyslexia. Dev Neuropsychol 2004; 25: 321–354.
14 Scientific Learning Corporation. Improved language and early reading skills by students who used fast for word middle & high school, MAPS for learning. Product Rep 2004; 8:1–4.
15 Angew J, Dorn C, Eden G. Effect of intensive training an auditory processing on reading skills. Brain Lang 2004; 88:21–25.
16 Strehlow U, Haffner J, Bischof J, Gratzka V, Parzer P, Resch F. Does successful training of temporal processing of sound and phoneme stimuli improve reading and spelling? Eur Child Adolesc Psychatry 2006; 16:21–29.