EFFECTIVENESS OF COMPUTER BASED AUDITORY TRAINING IN CHILDREN WITH CENTRAL AUDITORY PROCESSING DISORDERS-EVIDENCE FROM ELECTROPHYSIOLOGICAL STUDY

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LIST OF ABBREVIATION

(C)AP-Central auditory processing

(C)APD- Central auditory processing disorder

CBAT – Computer based auditory training

CG-Control group

DPOAE- Distortion Product Otoacoustic Emission

EG-Experimental group

ERS- Early reading skills

F0-Fundamental frequency

FFR- Frequency following responses

GDT – Gap detection test

H2-Second harmonics

H3-Third harmonics

H4- fourth harmonics

LD- Learning Disability

LE: Left ear

MATLAB-Matrix Laboratory

MLR-Mid-latency response

MMSE-Mini-mental state examination

ms- Millisecond

PDT – Pitch discrimination test

PTA- Pure tone audiometry

RE: Right Ear

SCAP- Screening checklist for auditory processing

SD: Standard Deviation

Sp-ABR- Speech evoked auditory brainstem responses

SPIN- Speech in noise

Sp-LLR- Speech evoked long latency response

SRT- Speech reception threshold

STAP- Screening test for auditory processing

TMTF – Temporal modulation transfer function

WRS- Word recognition score

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ABSTRACT

The children withcentral auditory processing disorders (CAPD) finds difficulty in following oral instruction and understanding of speech in presence of background noise; ask for repetition, even exhibit poor academic performance on listening tasks. The present study was aimed to evaluate the effectiveness of computer based auditory training (CBAT) in children withCAPD. The objectives included were (1) Comparison between pre-training, post-training, after one week and one month cessation of training, based on outcomes of psychophysical tests which mainly assesses central auditory function (SPIN, PDT, GDT, & TMTF) in children withCAPD. (2) Comparison between pre and post-training outcomes of electrophysiological tests (speech evoked ABR and LLR) in children withCAPD. To accomplish the above objective the children across the school in Mysuru city were screened using SCAN and STAP for children with CAPD. Twenty eight children with CAPD were selected based on detail diagnostic CAPD tests randomly for the CBAT using inclusion criteria. These 28 children with CAPD were further sub-grouped into 4 groups randomly based on different stimuli used for the CBAT. Group-I included 7 children, provided CBAT using speech based stimuli without Earobics. Group-II included 7 children; they were provided speech based stimuli with Earobics. Group-III included 7children were provided non-speech stimuli. Group-IV included 7children were provided non-speech stimuli with Earobics. The psychophysical tests (Speech in noise, Gap detection test, Pitch discrimination test, and temporal modulation transfer function) were performed before CBAT, immediately after CBAT, 1 week after CBAT, and 1 month after CBAT. The electrophysiological tests (Speech evoked ABR and LLR) were carried out before and immediately after the CBAT. The computer based auditory training provided for 12 sessions, each session for 25-30 minutes for a total duration of 5 weeks. The result showed that there was *a significant improvement in all psychophysical tests immediately after the CBAT as well as retention was noticed even after 1 week and 1 month cessation of computer based training. There are studies supports that the psychophysical tests that the sensitivity of these tests is good in predicting even small changes in the auditory processing skills and also that any type of auditory training can bring a changes in the psychophysical tests. Electrophysiological tests such as Sp-ABR showed no significant difference, this could be due to the conviction that plasticity at the level of auditory brainstem is poor. However, electrophysiological test like long latency response shows neuron changes at cortical levels and this could be observed that Sp-LLR latency parameters showed some amount of significant changes (improvement) after CBAT. To conclude the CBAT is one of the effective approaches for providing auditory training for children with CAPD.*

Key Words: (Central) Auditory processing disorder, Auditory evoked brainstem response, Auditory evoked late latency response, Computer based auditory training, Reading disorders, Learning disability

INTRODUCTION

Central auditory processing refers to perception of auditory information in the central nervous system (CNS) as well as neurobiological activity that underlies and gives rise to electrophysiological auditory potentials. Central auditory processing includes the auditory mechanisms that underlie the following abilities or skills such as 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 and auditory performance with degraded acoustic signals (ASHA, 1996; Bellis, 2003; Chermak&Musiek, 1997). The central auditory processing disorder (CAPD) is a condition, where the deficiency observed in one or more above mentioned behaviours (Yalcinkaya& Keith, 2008). However, these children will have normal hearing and normal intelligence (ASHA, 1996).

Auditory processing deficit has been estimated to be present in 2 to 5% of school going children in western countries (Chermak&Musiek, 1997). In another study, Rupp and Stockdell (1978) were noticed language deficit in 15 to 20% of school going children. Out of these, 70% had some kind of auditory based problems. In India, Ramaa (1985) found the incidence of learning disability in 3% school going children. Study done by Muthuselvi and Yathiraj in 2009 were found 6.9% of children to be at risk for CAPD, out of the 3120 children that were considered for the study based on screening checklist of auditory processing questionnaires. Children with CAPD exhibit poor auditory skills like difficult to follow the oral instruction, difficult to understand the speech in background noise. It usually co-exists with learning difficulty, language problem, reading, writing and spelling errors (Mcarthur& Bishop, 2004a; 2004b; ASHA 2005). Hence, there is a need of CAPD intervention for these children in Indian Population.

There are several studies which tried to explore the different ways of improving the skills of children with central auditory processing disorders alone and/related populations like learning disability, language learning impairments, specific language impairment, dyslexia, and specific reading difficulty. The above mentioned group of children showed benefit with different mode of training such as deficit based training or direct remediation training. Present study focused on computer based auditory training and hence studies related to computer based training are discussed in literature.

Computer based auditory training (CBAT) to stimulate auditory processing

The computer based training is one of the methods of effective auditory training which provides an active participation of trainee (Fu & Galvin, 2007). Hence, there is a need to study on efficacy of computer based training in children with central auditory processing disorders. The computer based auditory training (CBAT) are also used for children with co-morbid disorders like language impairment and/or reading disorders (Loo, Bamiou, Campbell &Luxon, 2010).

Marler, Champlin, and Gillam (2001) provided Fast ForWord (FFW) training for 4 children with language learning impairment (LLI) to improve the auditory temporal processing abilities, where 2 children with LLI received FFW training and another 2 children received a bundle of computer assisted instruction (CAI). They had considered 3 typically developing children as a control group. They used simultaneous and backward masking for evaluation to check the effect of training. Pre-training evaluation showed 3 children having elevated backward masking thresholds in comparison with typically developing children. The training was given for 4 weeks and both the groups showed progressively better simultaneous and backward masking thresholds. The authors concluded that the improvement shown was may be due to practice or maturation effect, as improved masking thresholds was also noted in typically developing children. But the population which they have considered was too small to comment about the statistical significance.

Hayes, Warrier, Nicol, Zecker, and Kraus (2003) studied the benefit with Earobics training on children with learning problems related to language, learning and reading. They reported a positive training effect on the phonological awareness skills (sound blending task) among children with learning problems compared with an untrained group. However, no significant changes reported in other reading and spelling measures after training. Similar study done by Troia and Whitney (2003) were reported significant improvement in expressive language and greater gain in phonological awareness skills (limited to blending task) in the training group. However, neither group showed improvement in reading skills in above mentioned study.

Agnew, Dorn, and Eden (2004) performed auditory duration judgment (accuracy) task to assess the effectiveness of FFW intervention on the auditory processing abilities of poor academic performers. They had considered 7 children with poor academic performance for the FFW training. The training intervention program used was Fast ForWord, and score of 90% achievement in five out of seven tasks was required. The training was provided for 100 minutes a day, for five days a week and this was given for approximately 4-6 weeks. Children showed significant improvement in accuracy on the auditory judgment task after FFW, as reported by authors.

Rouse and Krueger (2004) recruited 512 children with specific reading disorder (SRD) where 272 children were considered for FFW training and 240 children as untrained group. The study concluded that there was no significant difference in improvement between trained and untrained groups. As a contradictory Stevens, Fanning, Coch, and Sanders (2008), considered 20 children for computerized training, in that 8 children were diagnosed with specific language impairment (SLI) and 12 typically developing children served as control group. They conducted study for comparison between improvement with training and without training. The result showed there was an improvement with FFW training for both typically developing and children with specific language impairment (SLI).

Strehlow, Haffner, Bischof, Gratzka, Parzer, and Resch (2006) studied children with specific reading disorders (SRD) and grouped them based on two different mode of training i.e. sound processing training group and phoneme processing training group. The former group were required to identify the pattern of frequency modulated tonal pairs, either upwards or downwards gliding and later group had to identify the consonant vowel syllables (e.g. /ba/, /pa/, / ta /, & /da/) and their order. In addition to the above two groups, there were oneuntrainedgroup to compare the benefit derived from different mode of training.The results revealed improvement in reading skills after sound and phoneme processing training but this was not a genuine result of the training as similar gains were observed in the untrained group too.In addition, although they had observed specific training effects in both sound and phoneme processing training groups in post-training evaluations. But the effect of sound processing training weakened over a 12 month period, whereas the effect of phoneme processing training remained relatively stable after 12 months. They also reported that improvement was not a result of test–retest or maturation effects as the untrained comparison groups showed no significant change.

Study done by Valentinue et al. (2006) used FFW training for the children with specific reading difficulties (SRD) in the age range of 7 to 10 years. However, study did not have control group for the comparison. They reported there was an improvement in phonological awareness and language skills due to FFW training. They had also showed that the backward masking thresholds improved after FFW training and improvement was retained even after 6 months post training evaluation. In a similar line, Veuillet, Magnan, Ecalle, Thai-Van, and Collet (2007), considered 18 children with SRD in the age range of 8-14 years. They were divided into two groups, one group was given with the audio-visual computer game and another group was not given any training. They demonstrated positive training effect on reading skills of children, and no significant change were observed in the untrained group. Study done by Gillam et al. (2008) reported positive effect of training on 216 children with SLI in four training conditions (FFW, computer-assisted language intervention, individualized language intervention, and academic enrichment). Children demonstrated better backward masking thresholds immediately after training and at 3 and 6 months' follow-up. All the children showed significant improvement in both language tests as well as backward masking thresholds.

Loo et al (2010) reviewed 16 articles on CBAT in which children with reading, language and related learning difficulties, were participated. Further, the extent of benefit of CBAT for children with auditory processing disorderalong with other co-morbid conditions was also documented. Out of 16 studies, FFW was used in 13 studies and Earobics was used in remaining 3 studies as CBAT program. The CBAT training included both speech and non-speech based tasks. They noticed that phonological awareness skills had greater effect using FFW and Earobics with speech based training. But there was a little effect with audio-visual method using non-speech training. They concluded that there is an evidence of improvement in children with CAPD but needs a further research for supporting the above preliminary findings. Similarly, Fey et al (2011) had reviewed 25 studies for finding out the efficacy of the auditory intervention in children with APD. The age group considered for inclusion of studies was 6 to 12 years children who were diagnosed as APD and/or primary spoken language disorder. This reviewed articles showed that the intervention used in APD are evidence based intervention. They had concluded that the experimenter should be aware of the limitations of the available evidences and should monitor the written and spoken language level of the children during intervention.

Audiological assessments in measuring the outcome of the auditory training

The underlying mechanism of the auditory processing may be assessed using electrophysiological and behavioural measures. Auditory evoked potentials (AEPs) have long been recognized as a reliable tool for providing objective information about the structural and functional integrity of the central auditory system (Hall, 1992; Kraus & McGee, 1992). Brainstem electrophysiological response elicited by speech stimuli may provide additional insight into the auditory processing abilities of children with CAPD. Electrophysiological studies have been shown abnormal sub-cortical processing in children with central auditory processing deficit (Kumar & Singh, 2015) and learning problem (Cunninghum, Nicol, Zecker, & Kraus, 2001; King, Warrier, Hayes, & Kraus, 2002; Russo et al., 2004; Wible et al., 2004). Studies have also reported abnormal cortical processing in children with learning problem (Warrier et al., 2004; Schochat et al., 2010; Kumar & Gupta, 2014) and children with central auditory processing deficit (Alonso &Schochat, 2009).

Electrophysiological assessments in measuring the outcome of the auditory training

Alonso and Schochat (2009) used electrophysiological measure (p300) for the measurement of the efficacy of the auditory training program in children with CAPD. They considered 29 children with CAPD in the age range of 8-16 years. The auditory training was given for 8 days for 50 minutes as weekly session. P300 evoked potential were measured before and after training and results showed better morphology of the P300 and it was further complimented with behavioural measures.

Warrier et al. (2004) studied speech evoked cortical potential in children with learning problems to monitor the effect of training. The result showed that children with learning problems, especially those with atypical speech-evoked cortical responses (increased N2 latency) in noise, improved to within the typical range after training. In addition, the improvement noticed due to training in the trained group was also associated with better performance on the speech discrimination ⁄da-ga⁄ task. However, there were no changes in the same measures observed for the untrained group. Hence, they reported that training resulted in significant gains on a sound blending task.

Russo, Nicol, Zecker, Hayes, and Nina-Kraus (2005) had studied the effect of training on 19 children with learning disability (LD)in the range of 8-12 years of age. Out of 19 children, control group had 10 children whereas experimental group comprises 9 children with LD. They performed both the tests i.e. speech-evoked auditory brainstem responses in noise and speech perception-in-noise (SPIN) as outcome measures before and after training. They demonstrated that the overall morphology of auditory brainstem responses waveform recorded in noise was poorer than in quiet condition, but due to training it improved and resembled more closely to the response in quiet. Further, trained group also demonstrated significant gains in SPIN test as reported. Hence, overall from the above studies it is concluded that electrophysiological test do help in monitoring the changes due to CBAT in these children.

Behavioural assessments in measuring the outcome of the auditory training

Schaffler et al. (2004) identified 140 children with dyslexia and deficit in auditory processing skills. They practiced auditory skills, where the children scored low level to improve the auditory listening skills. These children were provided the listening training with five different auditory tasks such as intensity and frequency discrimination, gap detection, time-order judgment& side-order judgment using two alternative forced choice procedures. After training in these auditory tasks, 70–80% of children with dyslexia showed improvement in intensity discrimination, frequency discrimination, and gap detection, but only 36% and 6% showed improvement in time-order judgment and side-order judgmentrespectively. In addition, they also reported that the auditory-trained group showed improvement in phonological skills and made fewer spelling errors than the visually trained and untrained group. These improvements in spelling skills were further retained uptoat 6 months follow-up. It was concluded that low-level auditory deficits can be improved by practice in order to give the dyslexics more phonological help when trying to transfer what they hear.

McArthur in 2007 studied specific auditory processing tasks such as frequency discrimination, masked frequency, vowel discrimination, and consonant–vowel discrimination to train a group of children with SRD or SLI. They had considered children with SLI or SRD with specific auditory processing deficits and showed improvement in the targeted processing skills after training, indicating a specific training effect. They were reported that improvements noticed in this study was not a result of test–retest or maturation effects as the untrained comparison groups showed no significant change.

Need for the study

The intervention for children with CAPD is important and the strong evidence based literature on management approach is lacking (Chermak&Musiek, 1997; Ferre, 1998). Neuroplastic changes in the auditory system can occur due to the results of auditory experience, passive listening, or active auditory training (Bosnyak et al., 2007; Sheehan et al., 2005; Trembley et al., 1998). Literature on neuroplasticity suggests that the changes in neural cells at cortical level and neuromaturation are dependent at least partly on stimulation (Bellis, 2003). Therefore, comprehensive management of CAPD should include auditory stimulation designed to bring functional changes within the central auditory nervous system (Bellis, 2003;Musiek&Chermak, 1994).

In literature, there are several training programme has been carried out in children who have temporal based deficit (Alexander & Frost, 1982; Bellis &Anzalone, 2008; Ferre, 1997; Merzenich et al., 1996; Tallal et al., 1996; Temple et al., 2003; Turner & Pearson, 1999; Vanaja& Sandeep, 2004; Yathiraj&Mascarenhas, 2003). Some programs are speech based training (Ferre, 1997; Tallal et al., 1996; Temple et al., 2003; Turner &Pearson, 1999) where as others included both non-speech and speech based training (Maggu&Yathiraj, 2011; Merzenich et al., 1996; Yathiraj&Mascarenhas, 2003). Studies reported improvement using both non-speech and speech based stimuli among children with CAPD. Hence, present study considered providing computer based training using both non-speech and speech based task.

In recent years, computer-based training has been recommended for children with language, learning, and reading difficulties. This recommendation is based on the assumption that some children with these difficulties may have co-existing auditory temporal processing deficits. Secondly, it is based on the premise that auditory training enables a reorganization (remapping) of the brain’s neurons by capitalizing on the brain’s plasticity. Hence, present study was focusing on changes if any that occur due to training in children withCAPD. Since, cortical reorganization of the auditory brain can be induced by auditory stimulation or exposure, and may involve the activation of inactive neuronal connections and ⁄ or the new formation of more efficient synaptic connections. Further, changes in neural substrates are often associated with behavioural changes, as reflected by measures of listening performance, auditory processing tests, language assessments, as well as objective estimation using neuroimaging and neurophysiological tests. Hence, both behavioural and electrophysiological measures were considered in the present study before and after the computer based training.

Several researchers have noticed the improvement in children with CAPD in modality specific training (English, Martonic& Moir, 2003; Priya&Yathiraj, 2007; Maggu&Yathiraj, 2011). Further, studies have confirmed the improvement in children with auditory processing deficits alone or associated with other co-morbid disorders based on electrophysiological studies (Alonso &Schochat, 2009; Hayes et al., 2003; Jirsa, 1992; McAurther et al., 2010; Russo et al., 2005; Schochat et al., 2010; Warrier et al., 2004; Yencer, 1998) and psychophysical or behavioural studies (Johnston et al., 2009; Maggu&Yathiraj, 2011; Merzenich et al., 1996; Musiek&Schochat, 1998; Priya&Yathiraj, 2006; Putter-Katz et al., 2002; Yathiraj&Mascarenhas, 2003). The intervention for such children is important since there is a need of evidence based literature on management approach (Chermak&Musiek, 2007). The CBAT has cited as an important role for effective auditory training (Fu & Galvin, 2007). However, still there is a dearth of evidence based practice to document the effectiveness of computer based auditory training in children with central auditory processing disorders. Hence, present study were focused on computer based training targeted to children with CAPD using non-speech and speech based task and estimate the benefit driven if any using behavioural and electrophysiological measures.

Aim of the study

The present study aimed to evaluate the effectiveness of computer based auditory training in children with central auditory processing disorders.

Objective of the study

- Comparison between pre-training, post-training, after one week and one month cessation of training, based on outcomes of psychophysical tests which mainly assesses central auditory function (SPIN, PDT, GDT, & TMTF) in children with central auditory processing disorders.
- Comparison between pre and post-training outcomes of electrophysiological tests (speech evoked ABR and LLR) in children with central auditory processing disorders.

METHOD

The study was aimed to find out the effect of computer based auditory training in children with central auditory processing disorders by means of psychophysical and electrophysiological tests. To achieve the above aim, the below mentioned method was adapted. The procedure included in the method is, the selection of the participants, and providing the Computer based auditory training. For the measurement of the effect of training in psychophysical tests (speech-in-noise test, gap detection test, pitch discrimination test, and temporal modulation transfer function test) and electrophysiological tests (speech evoked auditory brainstem response, &speech evoked late latency response) tests were administered.

Participants

There were 935 children with normal hearing in the age range of 8-12 years were screened from different Schools of the Mysuru city, Karnataka. The questionnaire based CAPD screening was performed using screening checklist for auditory processing (SCAP). Out of 935 children, 143 children failed in SCAP and were referred further for audiological screening test for auditory processing (STAP). Among 143 children tested for STAP, 75 children were failed in one or, more than one sub-test of STAP. These 75 children were screened for their age adequate cognition skill, language skill, and reading skill. Further detailed basic audiological evaluation and auditory processing evaluations (speech-in-noise test, Gap detection test& Dichotic CV test) were carried out and finally 44 children were diagnosed as having CAPD based on criteria defined by ASHA (2005)and they were not having any cognition, language and reading deficit. Out of 44 children, randomly 28 children with CAPD were considered for the CBAT.

These 28 children withCAPDwere further randomly divided into4 groups (Group-I, Group-II, group-III & group IV) based on the stimulus (speech & non-speech) based tasks used for

CBAT.The Group-Ichildren were providedCBAT using computer assisted listening training (CALT) with only speech stimulus without Earobics;Group-IIchildren with speech based stimuli and Earobics, Group-III Non-speech stimuli without Earobics whereas Group-IV Non-speech stimuli with Earobics. There were 7 children with CAPD in each group was selected randomly. The consent form obtained from all the participantsin written/oral form and they were explained the detail proceduresbefore recruiting them for the study. The method and research design were approved by the AIISH ethical committee.

Table 1: *Details of diagnostic APD tests*

Sl. No.	**SPIN***		**GDT**	**Dichotic CV**			**Remarks**
	RE	**LE**	**BE**	**RE**	**LE**	**BE**	**Fail/Pass**
1	13	12	4.7	17	15	10	Fail in SPIN & GDT
2	11	11	14.4	18	14	11	Fail in SPIN & GDT
3	9	10	2.77	12	9	3	Fail in SPIN & DCV
4	12	11	2.33	11	10	4	Fail in SPIN& DCV
5	11	11	324.85	13	11	7	Fail in SPIN & GDT
6	10	10	29.68	18	12	9	Fail in SPIN & GDT
7	14	14	8.1	17	14	8	Fail in SPIN& GDT
8	12	12	29.33	20	13	10	Fail in SPIN & GDT
9	13	11	3.4	18	12	9	Fail in SPIN & GDT
10	12	10	24.07	14	11	5	Fail in SPIN & GDT
11	13	15	9.5	17	14	8	Fail in SPIN & GDT
12	11	12	7.59	15	12	6	Fail in SPIN & GDT
13	12	12	1.72	12	8	4	Fail in SPIN & DCV

14	12	11	70.48	18	15	7	Fail in SPIN & GDT
15	12	12	3.73	19	16	8	Fail in SPIN & GDT
16	12	12	3.16	14	11	6	Fail in SPIN & GDT
17	13	12	10.44	12	9	3	Fail in SPIN, GDT& DCV
18	12	11	6.95	18	14	8	Fail in SPIN & GDT
19	13	12	4.99	17	13	7	Fail in SPIN & GDT
20	12	12	31.07	14	11	5	Fail in SPIN & GDT
21	11	13	3.74	19	13	8	Fail in SPIN & GDT
22	4	5	9.54	14	11	7	Fail in SPIN & GDT
23	4	13	6.22	15	12	8	Fail in SPIN & GDT
24	6	13	1.95	12	10	3	Fail in SPIN &DCV
25	11	13	2.16	11	8	5	Fail in SPIN & DCV
26	9	9	2.38	13	10	4	Fail in SPIN & DCV
27	7	11	2.39	12	7	3	Fail in SPIN & DCV
28	1	3	9.26	11	9	3	Fail in SPIN, GDT& DCV

*****_Maximum Scores: 25; RE: Right Ear; LE: Left Ear; BE: Both Ears; SPIN: Speech in Noise test; GDT: Gap detection test; DCV: Dichotic CV test_

Inclusion criteria

The children were examined to rule out other co-morbid conditions and presence of peripheral hearing impairment. Seventyfivechildrenwere screened for cognition using Modified Mini-Mental Scale for CognitionFunction for children (MMSC), and all the participants passed in this screening.The language evaluation was done for 75 children using Bankson Language Screening test (BLST), whereout of 75, only 71 children were passed in BLST. Further, early reading skills (ERS)test were performed on these 71 children, in which 65 children with CAPD were having age appropriate grade. Additionally, hearing sensitivity (thresholds of ≤ 15 dB HL) in the frequency range of 250 to 8000 Hz, click evoked ABR,speech identification scores (SIS) and middle ear function were examined, out of 65 children, 60children were having normal peripheral hearing sensitivity and normal middle ear function in both ears.

Exclusion criteria

Children were excluded for having language deficiency, reading deficiency and presence of other peripheral hearing problem. There were 4 children with CAPD excluded based on BLST and 3 children with CAPD based on ERS test. One child was observed to be having middle ear problem at the time of testing and hence excluded from the study.

Instrumentation

- A calibrated diagnostic audiometer, GSI-61 with TDH-50 headphones, was used for estimating the air conduction thresholds at octave frequencies between 250 Hz and 8000 Hz. same audiometer with Radio ear B-71 bone vibrator was used for bone conduction testing at octaves frequencies between 250 Hz and 4000 Hz.
- A calibrated speech audiometry, GSI-61 with TDH-50 headphones, was used for estimation of speech recognition as well as speech identification scores.
- A calibrated middle ear analyzer (GSI-tympstar)was used to obtain tympanogram with a probe tone frequency of 226 Hz and the acoustic reflex thresholds was measured for octave frequency between 500 Hz and 4000 Hz for both ipsilateral and contralateral reflexes.
- A personal laptopwas used for psychoacoustic tests such as GDT, PDT, and TMTF.
- Auditory brainstem responses to click stimuli and speech stimuli as well asauditory long latency responses were recorded using Biologic Navigator Pro EP (version 7.0) system.

Test material

To evaluate the effect of CBAT, the below mentioned central auditory processing behavioural tests were used.

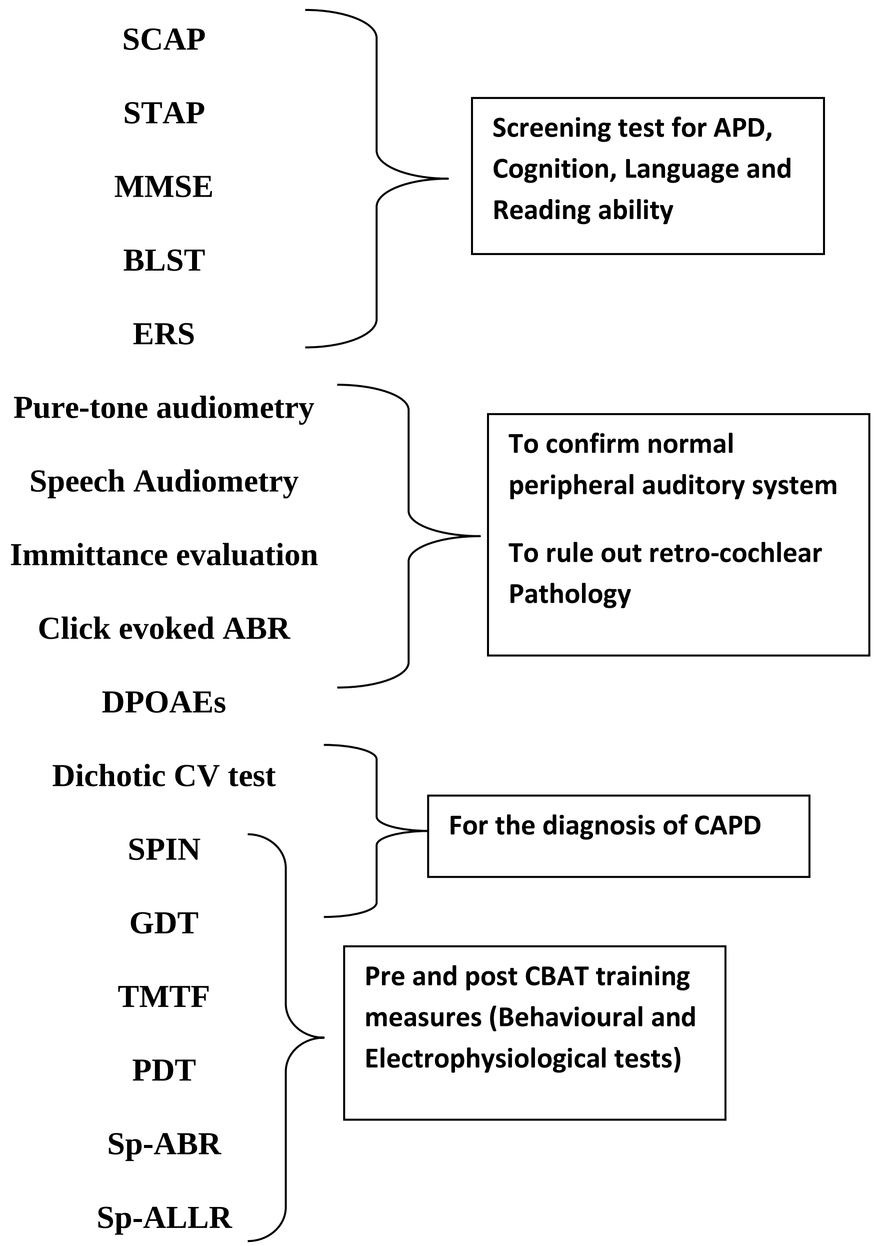
- Speech-in-noise test
- Gap detection test
- Pitch discrimination test
- Temporal modulation transfer function test

Among the above mentioned test, SPIN was performed using calibrated double channel clinical audiometry. The remaining GDT, PDT and TMTF tests were carried out using personal laptop.

Test Environment

Audiometric testing and administration of psychophysical as well as electrophysiological tests were carried out in sound treated room with the ambient noise levels within permissible limits (ANSI 1991). Audiometric testing was done in double room situation. However,psychophysicalCAPD tests and electrophysiological testing was done in single room situation. The CBAT was provided in the quite room with less distracted surrounding.

Schematic representation of the comprehensive assessment protocol used in the present study



Note: *SCAP: Screening checklist for auditory processing; STAP: Screening test for auditory processing; MMSE: Mini-mental state examination; BLST: BanksonLanguage screening test; ERS: Early reading skill test; DPOAE: Distortion product otoacoustic emission; Dichotic CV test: Dichotic consonant vowel test; SPIN: Speech-in-noise test; GDT: Gap detection test; TMTF: Temporal modulation transfer function test; PDT: Pitch discrimination test; Sp-ABR: Speech evoked Auditory Brainstem Response; Sp-ALLR: Speech evoked auditory late latency response*

Procedure

The study was performed as preliminary screening, a detailed psychophysical and electrophysiological assessment for central auditory processing before CBAT was done for all the participants. The speech and non-speech based stimuli using CBAT was provided for each group and outcomes were measured. The outcomes are also measuredafter one week and one month cessation of CBAT using only psychophysicaltests.

Preliminary screening

The preliminary screening which includes SCAP and STAP were performed. Pure-tone audiometry and Immittance evaluation were carried out using calibrated instruments on the participants to estimate their hearing threshold and to check middle ear function. Click evoked ABR testing was also performed on all the participants to verify normal transmission of auditory stimuli through the brainstem auditory pathway.

The Screening Checklist for Auditory Processing (SCAP):

The screening checklist for auditory processing was developed by Yathiraj and Mascarenhas (2003).This is a checklist consisted of 12 Yes/No questions. The pass/fail criteria recommended by developers were as a score of more than 6 out of 12 questions to be considered at risk for CAPD. A total of 724 children were screened using this questionnaire from different schools in Mysuru city, Karnataka. Each question was explained to children/class teachers and then they were asked to mark yes or no, as response. Out of 724 children, 122 children scored above 6out of 12 questions i.e. considered as at risk for CAPD and were further recruited for STAP test.

The Screening test for auditory processing (STAP):

Screening test for auditory processing was developed by Yathiraj and Maggu (2012) in Indian population, which includes 4subsections (speech-in-noise test, dichotic consonant vowel test, gap detection test & auditory memory test). STAP were administered using personal laptop with headphone at most comfortable loudness level on 122 children at risk for CAPD. Out of these 122 children,43 childrenwerefailed in one or more than one sub-tests of STAP and considered as at risk for CAPD. They were further referred for other evaluations such as cognition, language, reading skill test and routine audiologicalevaluation.

Modified Mini-Mental Scale for Cognitive Function in Children (MMSC):

Modified mini-mental scale for cognitive function in children developed in 2005, covers areas of cognitive functions i.e., orientation, attention-concentration,registration, recall and language in asingle set of questions for use in children agedbetween 3-14 years. The testing was done for those children who had not passed in SCAP and STAP tests of central auditory processing. There were 43 children at risk for CAPD evaluated and all were passed in MMSC test.

Bankson Language Screening Test (BLST)

Bankson language screening testconsisted of five subtestsi.e. semantic knowledge, morphological rules, syntactic rules,visual perception and auditory perception. BLST was performed on 43 children, out of which 39 children at risk for CAPD were passed in language screening test.

Early Reading Skill (ERS)

The early reading skilltest was used to evaluate the reading ability of the school going children from grade 1 to grade VIII. This test was performed to exclude those children having reading and writing difficulty. The test was carried out on 39 children at risk for CAPD, 36 children were identified as age appropriate grade scale based on ERS test.

Detailed Audiological evaluation

The participants possessed bilateral air-conduction and bone conduction pure-tone thresholds withinnormal limits (≤ 15dB HL). They had at least a fair agreement between speech recognition threshold (SRT) and the pure-tone average. The word recognition score (WRS) was above 90% in quiet. All the participants had 'A / As' type tympanogram with reflexes present in both ears. They had normal transmission of auditory stimuli as verified with click evoked ABR; Distortion product otoacoustic emission (DPOAE) was carried out on 35 children at risk for CAPD and showed normal outer hair cell (OHC) function in both ears.

Pure-tone thresholds were obtained using modified Hughson and Westlake procedure (Carhart&Jerger, 1959) at octave frequencies from 250 Hz to 8000 Hz for air conduction and between 250 Hz to 4000 Hz for boneconduction stimulation. Speech recognition score were estimated using the standardized pairedword list in the participants' native language. Speech identification score were obtained at 40 dB above SRT using the standardized phonemically balanced (PB) word lists in the participants' native language. Using a 226 Hz probe-tone at 85 dB SPL, the tympanogram were obtained by varying the air pressure in the ear canal from +200 to -400 daPa. Ipsilateral and contralateral acoustic reflex thresholds were obtained at octave frequencies from 500 to 4000 Hz using the same probe-tone frequency as mentioned above. Distortion product otoacoustic emissions (DPOAEs) were measured using DP Echoport ILO (Version 6). A standard DPOAE probe tip was positioned in the individual's ear canal. Throughout the measurement the ratio (f2/f1) was kept constant i.e., 1.22. The stimulus intensity levels were also held constant at L1 = 65 and L2 = 55 dB SPL. The level of the 2f1-f2 DPOAE were depicted as a function of frequency as a DPgram in between 1000 Hz to 6000 Hz. DPOAE were considered to be present when they were at least 3 dB above the corresponding noise level (Moulin et al., 1993).

Speech in Noise (SPIN) test was performed at 0 dB signal-to-noise ratio (SNR) for both ears (Ref SRT). The cut-off criteria used for the SPIN was less than 40% scores in either ear with reference to the speech identification scores (SIS) in Quiet. The detail of the SPIN test is mentioned in Table 1. Gap detection test was done using MATLAB with maximum likelihood procedure. The cut-off criterion used for the GDT was less than 3 millisecond. Dichotic CV test developed by Gowri (2001) was used for assessing binaural integration ability of the children at risk for CAPD. The cut-off criteria defined by the developer were used for the final diagnosis.

Out of 44 children with CAPD, 43 children were having normal peripheral sensitivity in both ears.Only one child had ear discharge and excluded from the study. Hence finally out of 43 children with CAPD, 28 children with confirmed CAPD were recruited randomly for CBAT.

Psychophysical and electrophysiological assessment

Once the normal click-evoked ABR and normal hearing sensitivity was confirmed, psychophysical and electrophysiological assessment was carried out before CBAT. Psychophysical tests includes were SPIN, GDT, PDT and TMTF test.Electrophysiological tests includes were speech evoked ABR (sp-ABR) and speech evoked LLR (Sp-LLR).

Sp-ABR and Sp-LLR was acquired monaurally using speech stimuli /da/ in single-channel electrode placement.The site of electrode placement was prepared with skin preparation gel. Silver chloride electrodes were used to record ABR and LLR with a conducting paste. Responses were differentially recorded from Ag-AgCl electrodes. Each electrode had impedance less than 5 kΩ. Two repeatable recordings were obtained in order to verify reliability of the responses. While conducting click-evoked ABR, speech-evoked ABR and speech-evoked LLR tests, children were asked to be comfortably seated in a reclining chair. They were instructed to avoid any extraneous movements of head, neck and limbs during testing. The click-evoked ABR, Sp-ABR and Sp-ALLR were acquired using single-channel electrode placement to ensure the precise transmission of signal through auditory nerve to cortex. A speech-evoked ABR test parameter included were wave V, wave A, and V/A slope as well as F0, H1 and H2. Speech evoked LLR test parameter included were latency of wave P1, N1, P2 and N2 as well as peak-to-peak amplitude (P1-N1, N1-P2& P2-N2). Peaks was marked on the resultant waveform which was obtained after '*weighted-add*' of two replicable waveform. The below mentioned test protocol was used for the recording of click evoked ABR, speech evoked ABR and speech evoked LLR (Table 2).

Table 2: *Recording parameters of click-evoked ABR, speech-evoked ABR and speech evoked LLR*

Sl.No.	**Parameters**	**Click-evoked ABR**	**Speech-evoked ABR**	**Speech evoked ALLR**
1	Stimulus	Click (100 µs duration)	40-ms /da/ stimulus	40 ms /da/ stimulus
2	Electrode Placement	Inverting- M1 Non Inverting- Cz Ground- M2	Inverting- M1 Non Inverting- Cz Ground- M2	Inverting- M1 Non Inverting- Cz Ground- M2
3	Intensity	90 dB nHL	80 dB nHL	80 dB nHL
4	Polarity	Rarefaction	Alternating	Alternating
5	Filter setting	100 – 3000 Hz.	100 – 2000 Hz.	1-30Hz
6	Repetition rate	11.1/sec	10.9/sec	1.1/sec
7	Total no. of sweeps	2000	2000	200
8	Impedance	< 5k Ω	< 5k Ω	< 5k Ω
9	No. of Channels	One	One	One
10	Analysis Time	10ms	60ms	500ms

A battery of psychophysical tests which assesses central auditory processing was administered for all groups i.e. SPIN, PDT, GDT and TMTF test. These measures were carried out using "*Maximum likelihood procedure*" tool box which implements a maximum likelihood procedure in psychoacoustic tool box from the Matrix Laboratory (MATLAB) software version 7.8.0 (R2009a) except SPIN test. The maximum likelihood procedure employs a large number of candidate psychometric functions and after each trial it calculates the probability (or likelihood) of obtaining the listener's response to all of the stimuli that have been presented given each psychometric function. The psychometric function yielding the highest probability is used to determine the stimulus to be presented in the next trial. This procedure was used for all temporal processing tests (PDT, GDT & TMTF). In all of the psychophysical tests, stimuli were presented binaurally via a laptop using headphone presented at most comfortable level. Participants were given 3-4 practice trials before the commencement of each test. All psychophysical tests were carried out in a quiet room. The duration of the test session was last for approximately 120 to 150 minutesincluding electrophysiological and psychophysical tests.

Auditory Training settings

Computer based auditory training (CBAT) training was providedbased on four groups. Group-I includes 7 children, provided CBAT with computer assisted listening training (CALT). Group-II included 7 children; they were provided CALT with Earobics. Group-III included 7 children, was provided non-speech stimuli.Group-IV included 7 children, were provided non-speech stimuli with Earobics.

Group 1: The children (N = 7), were given training using a computer assisted listening training developed by Kumar (2013). All the stimuli in CALT are speech based tasks. CALT includes detection, discrimination, and identification and comprehension tasks at different levels of difficulty. The difficulty levels increases in hierarchy from simple to complex tasks. There are several lists of items in each section. The discrimination tasks were varied based on the duration i.e. sentences versus words or phrases and it was closed-set task. The participant was asked to respond by selecting same/different options. Identification section had both open and closed-settask. In addition, the comprehension section had open set task which includes answering the questions after listening to the stories.

Group 2: The children (N = 7), were provided with CALT along with Earobics training. The games available in Earobics training were karloon’s balloons, rhyme time, basket full of eggs, CC coal car train, caterpillar connection and rap-a-tap-tap tasks. The above tasks are focused on auditory attention, word discrimination, auditory and sequential memory, phoneme identification, recognition of sound in word, rhyming, and language comprehension.

Group 3: The children (N = 7), were provided with non-speech stimuli. Non-speech based stimuli was developed by Maggu (2010), this was used as frequency discrimination tasks. Here the task was to discriminate frequency in terms of duration of pure tone. The stimulus consisted of 2 stimuli, 3 stimuli, and 4 stimuli i.e. the difficulty levels vary from one choice to 3 choice. The children were asked to say which one was having longer duration or shorter duration based on the instruction given. The frequencies used were 250 Hz and 1000 Hz pure tone.

Group 4: The children (N = 7), were provided with non-speech and Earobics. The details about non-speech based stimuli are described in group 3 and description about Earobics is mentioned in group 2.

The CBAT was given for 12 sessions for each participant in 5 weeks period. The duration of training for each session was in the range of 25-30 minutes. The training was conducted in less distraction environment. Participants were monitored by the experimenter during the session for documentation and assistance if required. The appropriate positive reinforcements like stickers (tangible) were provided when the child completed each level. The computer based training material also contained the reinforcement and they even act as feedback for the children. It contains verbal reinforcement, which motivates the children for active participation. The children were considered for next level only, if they complete the present level with 90% accuracy. After the cessation of computer based auditory training, as mentioned above similar procedures was carried out for psychoacoustic and electrophysiological measures for each participant.

The outcome measures immediately after CBAT

For all 28participants,post training evaluation was carried out. The post-training evaluation included was electrophysiological test and psychoacoustic test done immediately after CBAT. As mentioned in pre-training evaluation heading, same procedure was adopted to evaluate after CBAT for post-training evaluation. The tests included were Sp-ABR, Sp-LLR, SPIN, GDT, PDT and TMTF test.

The outcome measures after 1 week cessation of CBAT

The number of participants included was 26 for 1 week after CBAT evaluation. Two participants could not attend the 1 week after cessation of CBAT evaluation as they had changed the school.Those2 participants were from the Group II (Speech with Earobics).

The outcome measures after 1 month cessation of CBAT

Theeffect of CBAT was assessed after 1 month cessation of training for 20 participants only. The 8 participants did not turn up for follow up evaluation after 1 month. From Group I, 1 participant; from Group II, 2 participants; from Group III, 2 participants; from Group IV, 3 participants were not participated in after 1 month cessation of CBAT evaluation.

Only psychophysical (SPIN, GDT, PDT and TMTF) tests were performed after 1 week and 1 month cessation of CBAT. The procedure adopted for assessment was as mentioned earlier in pre-training evaluation. The procedure was kept constant for the comparison of pre and post-training effects as well as to check the retention of the effect of CBAT after 1 week and 1 month cessation of training.

STATISTICAL ANALYSIS

The collected data were entered into the statistical tool box i.e. Statistical Package for Social Sciences (SPSS, version 18.0) and statistical analysis were performed. Descriptive statistics and non-parametric tests were carried out in the study.

The raw scores of SPIN, GDT, PDT, TMTF 8Hz and TMTF 200Hz were measured for all the groups for pre-evaluation, post-evaluation, after one week and one month cessation of training. The mean, standard deviation (SD) and median were obtained using descriptive statistics. The Friedman's test was performed to see the significant difference between the evaluations followed by Wilcoxon signed ranks test, if the difference was observed. For between group comparisons,Kruskal Wallis test was performed followed by Mann Whitney U test, if the difference was observed.

Latency of Sp-ABR (Wave V, and A) , VA slope, F0, H1 and H2 parameters were considered for Sp-ABR. Latency (Wave P1, N1, P2& N2) and peak-to-peak amplitude (P1-N1, N1-P2, & P2-N2) of Sp-LLRwere measured for all the groups for pre-evaluation and post-evaluation of CBAT. The mean, SD and median were obtained using descriptive statistics. The Wilcoxon signed ranks test was performed to see the effect of training.

RESULT

The outcomes of all the psychophysical and electrophysiological tests were analysed using descriptive and non-parametric statistics for all the groups.Also the effect of withdrawal of training was checked after 1 week and after 1month of cessation of the training. The pre-training, post-training, 1 week after cessation and 1 month after cessation evaluations were compared using Friedman's test followed by Wilcoxon signed ranks test to examine the effect of CBAT for all the participants. The results are discussed under the headings of each training type in the subsequent sub-sections.

Effect of training using speech based stimuli (without Earobics) on psychophysical responses

CBAT was used for training using speech based stimuli. A total of 7 children underwent this training. The psychophysical responses were obtained before training and compared against the performance soon after training, 1 week after cessation of training and 1 month after cessation of training (Figure 1 to 4).

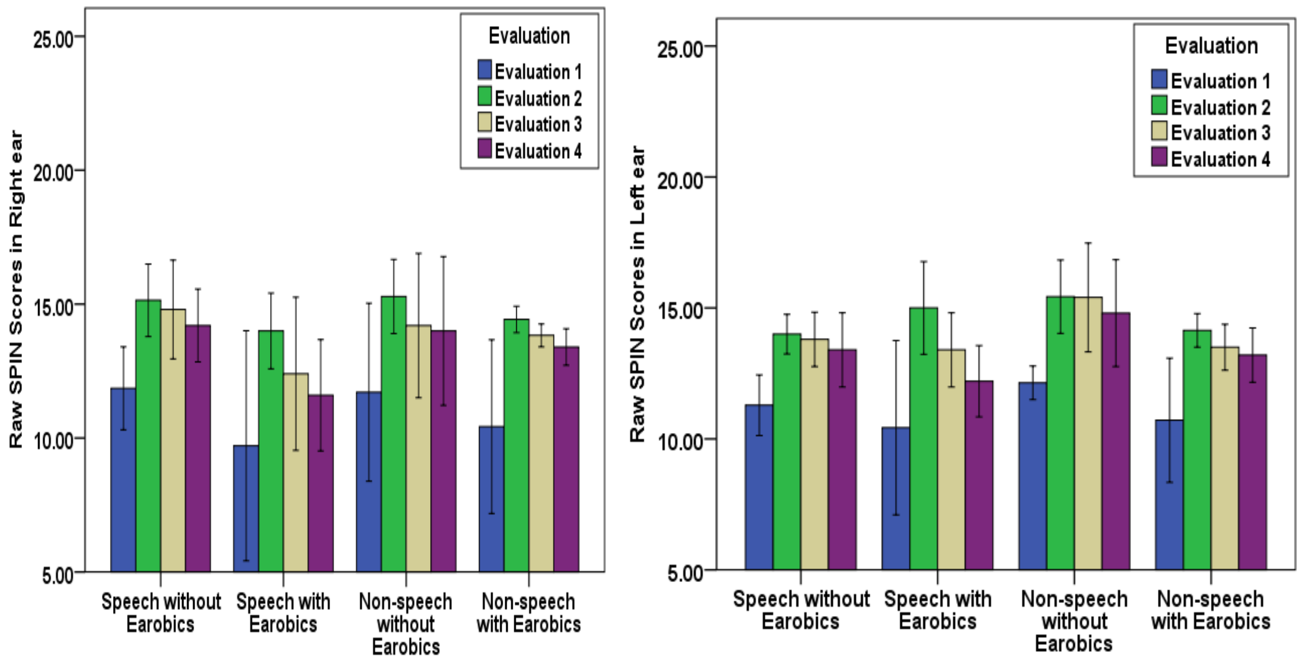


Figure 1: SPIN scores in right ear and left ear across different evaluations

(Evaluation 1: Before training: Evaluation 2: After training: Evaluation 3: After 1 week of post-training; Evaluation 4: After 1 month of post training)

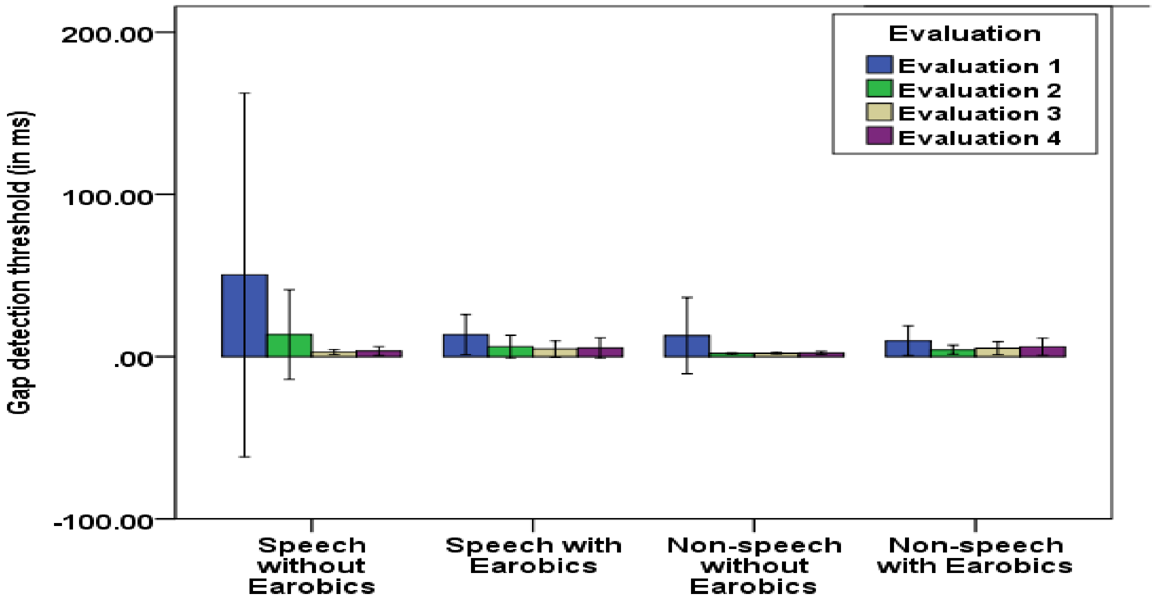


Figure 2: Gap detection thresholds across different evaluations

(Evaluation 1: Before training: Evaluation 2: After training: Evaluation 3: After 1 week of post-training; Evaluation 4: After 1 month of post training)

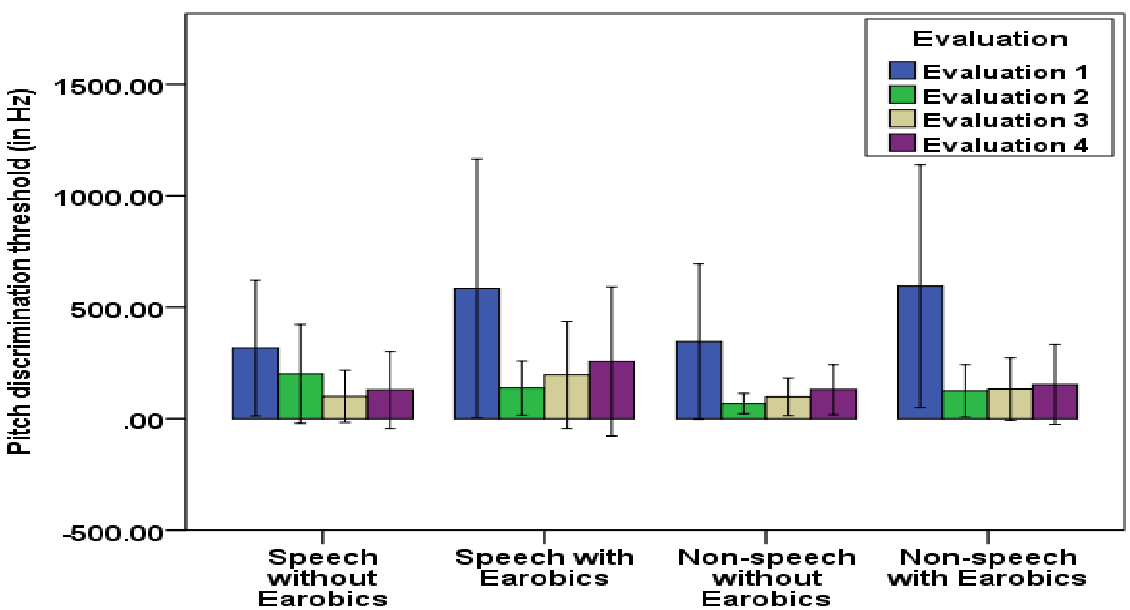
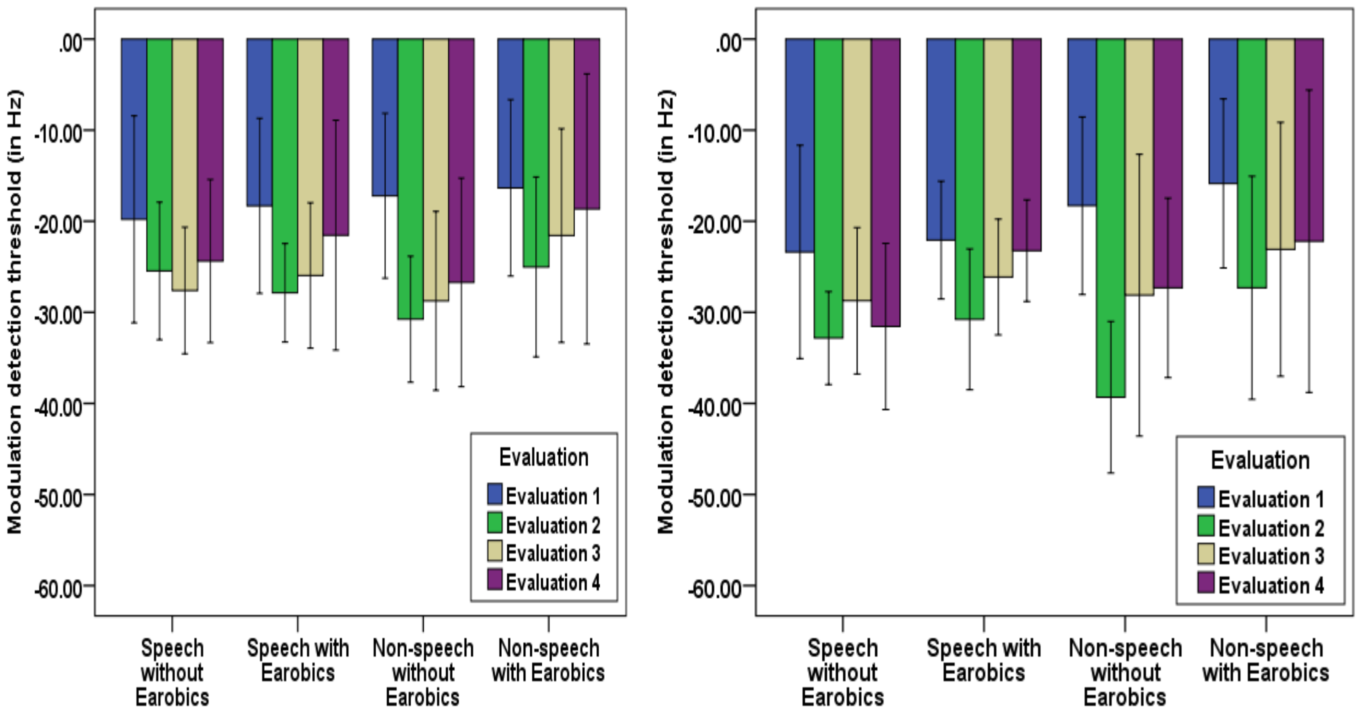


Figure 3: Pitch discrimination thresholds across different evaluations

(Evaluation 1: Before training: Evaluation 2: After training: Evaluation 3: After 1 week of post-training; Evaluation 4: After 1 month of post training)



a) TMTF-200Hz b) TMTF-8 Hz

Figure 4: Modulation detection thresholds across different evaluations

(Evaluation 1: Before training: Evaluation 2: After training: Evaluation 3: After 1 week of post-training; Evaluation 4: After 1 month of post training)

All the participants showed better psychophysical performance (scores or thresholds) for post-training, 1 week after training and 1 month after training compared to pre-training performance on all the tests. Friedman test followed by Wilcoxon signed rank test was done for remaining participants across evaluations. Table 3shows the mean, standard deviation and median performance scores / thresholds for various tests across the evaluation points.

Table 3.

Mean, standard deviation and median of SPIN scores (in right and left ears), GDT, PDT and TMTF-200 Hz, and TMTF-8 Hz for group of participants who received training using speech based stimuli without Earobics

	Pre-training		Post-training		1-week Post training		1-Month Post-training	
	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median
SPIN RE	11.85 ± 1.67	12.0	15.14 ± 1.46	15.0	14.80 ±1.48	15.00	14.20 ± 1.09	14.00
SPIN LE	11.28 ± 1.25	11.0	14.0 ± 0.81	14.0	13.80±0.83	14.00	13.40 ± 1.14	13.00
GDT	50.35 ± 121.12	2.77	13.61 ± 29.81	2.33	2.71±1.27	2.25	3.41 ± 2.20	2.63
PDT	316.98 ± 328.63	172.00	200.95 ± 239.41	61.00	100.60±93.91	76.80	129.26 ± 139.14	80.00
TMTF 8 Hz	-23.37 ± 12.65	-28.35	-32.82 ± 5.52	-33.20	-28.72±6.46	-26.00	-31.55 ± 7.35	-29.11
TMTF 200 Hz	-19.78 ± 12.28	-20.60	-25.45 ± 8.15	-26.80	-27.60±5.95	-25.20	-24.37 ± 7.21	-21.80

Note: 'RE'- Right ear; 'LE': Left ear.

Friedman test was done to compare within groups for different psychophysical tests. There were significant differences observed only for SPIN-RE ($\chi^2(3)=12.70$, p=0.005) and SPIN-

LE performance ($\chi^2(3)=13.21$, $p=0.004$). However, there were no statistically significant difference noticed for GDT, PDT, TMTF-8 Hz and TMTF-200 Hz (Appendix 1). Wilcoxon signed rank test was used to compare between different evaluations for SPIN scores in right ear as well as in left ear (Table 4). The results revealed there is a significant change due to training as post-training scores and further the impact of training retains as reflected in post-training evaluations after 1 week and after 1 month in both SPIN right ear and left ear scores.

Table 4

Wilcoxon signed rank test outcome for SPIN in right ear and left ear across different evaluations

Tests	Evaluations	Post-training	1 week after training	1-month after training
SPIN-RE	Pre-training	-2.34*	-2.03*	-2.04*
	Post-training		-1.32	-1.85
	1 week after training			-1.73
SPIN-LE	Pre-training	-2.45*	-2.12*	-2.06*
	Post-training		-1.00	-1.32
	1 week after training			-1.41

*p<0.05

Effect of training using speech-based and Earobics-based stimuli on psychophysical responses

For training using speech-basedand Earobics-based stimuli both, CBAT was used. A total of 7 children underwent training using this combination. The psychophysicalperformance was evaluatedbeforeinitiation of the training,post-training (soon after training), 1 week after training, and 1 month after training (Figure 1, 2, 3 & 4).

All the participants showed better performance (scores or thresholds) on the psychophysicalmeasuresduring evaluations conducted after the training on all the tests thanthepre-training performance. The mean and median of SPIN, GDT, PDT, TMTF-8 Hz, and TMTF-200 Hzscorestended to suggest towards better scores after the training using speech-based and Earobics-based stimuli than before training in children with CAPD. The mean, standard deviation and median of scores/thresholds of various psychophysical tests in children with CAPD who received training using both speech-based stimuli and Earobics-based stimuli are represented in Table 5.

Table 5.

Mean, standard deviation and median values for various psychophysical tests in children with CAPD who received training using both speech-based stimuli and Earobics-based stimuli

	Pre-training		Post-training		1-week Post training		1-Month Post-training	
	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median
SPIN-RE	9.71 ±4.64	12.00	14.00 ±1.52	14.00	12.40 ±2.30	14.00	11.60 ±1.67	12.00
SPIN-LE	10.42 ±3.59	11.00	15.00 ±1.91	15.00	13.40 ±1.14	13.00	12.20 ±1.09	12.00
GDT	13.54 ±13.38	4.10	6.14 ±7.54	2.17	4.74 ±4.05	2.50	5.42 ±4.99	3.01
PDT	583.93 ±627.48	199.00	137.76 ±130.92	69.00	196.68 ±193.61	89.00	256.77 ±269.37	94.00
TMTF 8 Hz	-22.07 ±10.38	6.97	-30.77 ±8.36	-28.00	-26.13 ±5.11	-24.40	-23.23 ±10.16	-21.95
TMTF 200 Hz	-18.31 ±6.97	-17.00	-27.85 ±5.84	-28.67	-25.96 ±6.43	-26.60	-21.53 ±4.49	-21.64

Note: ‘RE’- Right ear; ’LE’- Left ear.

Friedman test was done to compare within groups for different psychophysical tests. There were significant differences observed for SPIN-RE ($\chi^2(3)=13.53$, $p=0.004$), SPIN-LE ($\chi^2(3)=14.75$, $p=0.002$), GDT ($\chi^2(3)=9.85$, $p=0.02$), PDT ($\chi^2(3)=10.20$, $p=0.017$), TMTF-8 Hz ($\chi^2(3)=9.24$, $p=0.026$), and TMTF-200 Hz ($\chi^2(3)=8.87$, $p=0.03$) performance. Wilcoxon signed rank test was used to compare between different evaluations for different psychophysical tests (Table 6). The results revealed that there is a significant change due to training as post-training scores and further the impact of training retains as reflected in post-training evaluations after 1 week and after 1 month in both SPIN right ear and left ear scores.

Table 6

Wilcoxon signed rank test outcome for different test across different evaluations among children with CAPD trained using speech based stimuli with Earobics

Tests	Evaluations	Post-training	1 week after training	1-month after training
SPIN-RE	Pre-training	-2.38*	-2.02*	-1.82
	Post-training		-1.63	-2.04
	1 week after training	-		-1.63
SPIN-LE	Pre-training	-2.38*	-2.04*	-2.06*
	Post-training		-1.84	-2.06*
	1 week after training			-2.12*
GDT	Pre-training	-2.20*	-1.75	-1.75
	Post-training		-2.02*	-2.02*
	1 week after training			-1.48
	Pre-training	-2.36*	-1.75	-2.02*

PDT	Post-training		-2.02*	-1.75
	1 week after training			-1.21
TMTF-8 Hz	Pre-training	-2.19*	-1.48	-0.67
	Post-training		-2.02*	-2.02*
	1 week after training			-2.02*
TMTF-200 Hz	Pre-training	-1.99*	-1.75	-0.94
	Post-training		-1.82	-2.02*
	1 week after training			-2.02*

Effect of training using non-speech-based stimuli (without Earobics) on psychophysical responses

For the non-speech based training, 7 children received training using CBAT. The responses for various psychophysicaltestswerecomparedfor pre-training, post-training, 1 week after training, and 1 month after training (Figure 1, 2, 3 & 4).

All the participants showed better psychophysical performance (scores or thresholds) for post-training compared to pre-training performance on all the tests. Evaluation at one week and one month after training showed improvement compared to pre-training scores. The descriptive statistics was used to obtain mean, standard deviation and median SPIN scoreswhich are represented in Table 7.

Table7:

Mean, standard deviation and median values for various psychophysical tests in children with CAPD who received training using non-speech-based stimuli

	Pre-training		Post-training		1-week Post training		1-Month Post-training	
	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median
SPIN RE	11.71 ±3.59	12.00	15.28 ±1.49	15.00	14.20 ±2.16	14.00	14.00 ±2.23	14.00
SPIN LE	12.14 ±0.69	12.00	15.42 ±1.51	15.00	15.40 ±1.67	15.00	14.80 ±1.64	14.00
GDT	12.91 ±25.42	3.50	1.90 ±0.47	1.93	2.07 ±0.44	2.17	2.21 ±0.83	1.80
PDT	345.95 ±376.62	123.00	68.00 ±48.80	45.00	98.23 ±67.54	79.91	130.42 ±90.42	96.00
TMTF 8 Hz	-18.29 ±9.78	-20.00	-39.32 ±9.00	-42.40	-28.12 ±12.45	-27.75	-27.31 ±7.93	-27.07
TMTF 200 Hz	-17.21 ±10.54	-19.40	-30.75 ±7.48	-34.25	-28.74 ±7.90	-34.25	-26.71 ±9.21	-28.17

Note: RE: Right ear, & LE: Left ear

Friedman test was done to compare within groups for different psychophysical tests. There were significant differences observed for SPIN-RE ($\chi^2(3)$ =14.73, p=0.002), SPIN-LE ($\chi^2(3)$ =13.50, p=0.002), GDT ($\chi^2(3)$ =10.20, p=0.01), PDT ($\chi^2(3)$=11.16, p=0.011), TMTF-8 Hz

($\chi^2(3)$ =10.20, p=0.017), and TMTF-200 Hz ($\chi^2(3)$=11.12, p=0.011) performance. Wilcoxon signed rank test was used to compare between different evaluations for different psychophysical tests (Table 8). The results revealed that there is a significant change due to training as post-training scores and further the impact of training retains as reflected in post-training evaluations after 1 week and after 1 month.

Table 8

Wilcoxon signed rank test outcome for different test across different evaluations among children with CAPD trained using Non-speech based stimuli without Earobics

Tests	Evaluations	Post-training	1 week after training	1-month after training
SPIN-RE	Pre-training	-2.41*	-2.06*	-2.04*
	Post-training		-2.12*	-2.07*
	1 week after training			-1.00
SPIN-LE	Pre-training	-2.41*	-2.06*	-2.06*
	Post-training		-1.00	-2.00*
	1 week after training			-1.73
GDT	Pre-training	-2.36*	-2.02*	-1.75
	Post-training		-2.02*	-0.94
	1 week after training			-0.13
PDT	Pre-training	-2.36*	-2.02*	-2.02*
	Post-training		-1.75	-1.75
	1 week after training			-1.75
TMTF-8 Hz	Pre-training	-2.36*	-1.75	-2.02*

	Post-training		-2.02*	-1.75
	1 week after training			-0.67
TMTF-200 Hz	Pre-training	-2.36*	-2.02*	-2.02*
	Post-training		-1.06	-1.21
	1 week after training			-1.21

Effect of training using non-speech-basedand Earobics-based stimuli on psychophysical responses

For non-speech-based and Earobics-based stimuli, a total of 7childrenreceived training using CBAT. The psychophysical output was checked for pre-test and later the same was compared with post-training, 1 week after training, and 1 month after training (Figure 1, 2, 3 & 4).

All the participants showed better psychophysical performance (scores or thresholds) for post-training, and 1 week after training compared to pre-training performance on all the tests. Friedman test followed by Wilcoxon signed rank test was done for different psychophysical tests across evaluations. The mean, standard deviation and median of scores/thresholds of various psychophysical tests in children with CAPD who received training using both non-speech-based stimuli and Earobics-based stimuli are represented in Table 9.

Table9.

Mean, standard deviation and median of scores/thresholds of various psychophysical tests in children with CAPD who received training using both non-speech-based stimuli and Earobics-based stimuli

	Pre-training		Post-training		1-week Post training		1-Month Post-training	
	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median
SPIN RE	10.42±3.50	12.00	14.42±0.53	14.00	13.83±0.40	14.00	13.40±0.54	13.00
SPIN LE	10.71±2.56	12.00	14.14±0.69	14.00	13.50±0.83	13.00	13.20±0.83	13.00
GDT	9.79±9.85	6.95	4.23±3.06	2.67	5.19±3.84	4.10	6.09±4.26	6.23
PDT	594.88±588.50	427.00	125.11±127.47	53.00	132.83±133.41	63.00	153.75±144.05	89.00
TMTF 8 Hz	-15.85±10.47	-19.80	-27.30±13.23	13.23	-23.08±13.27	-23.32	-22.20±13.37	-21.22
TMTF 200 Hz	-16.34±10.04	-15.40	-25.01±10.66	-27.40	-21.57±11.17	-25.40	-18.65±11.93	-21.40

Note, RE: Right ear, & LE: Left ear

Friedman test was done to compare within groups for different psychophysical tests. There were significant differences observed for SPIN-RE ($\chi^2(3)=13.29$, $p=0.004$), SPIN-LE ($\chi^2(3)=13.28$, $p=0.004$), GDT ($\chi^2(3)=13$, $p=0.004$), PDT ($\chi^2(3)=14.04$, $p=0.003$), TMTF-8 Hz ($\chi^2(3)=10.68$, $p=0.014$), and TMTF-200 Hz ($\chi^2(3)=7.75$, $p=0.05$) performance. Wilcoxon signed rank test was used to compare between different evaluations for different psychophysical tests (Table 10). The results revealed that there is a significant change due to training as post-training scores and further the impact of training retains as reflected in post-training evaluations after 1 week and after 1 month.

Table 10

Wilcoxon signed rank test outcome for different test across different evaluations among children with CAPD trained using Non-speech based stimuli with Earobics

Tests	Evaluations	Post-training	1 week after training	1-month after training
SPIN-RE	Pre-training	-2.38*	-2.21*	-1.82
	Post-training		-1.73	-2.23*
	1 week after training			-1.41
SPIN-LE	Pre-training	-2.41*	-2.21*	-2.03
	Post-training		-1.73	-2.00*
	1 week after training			-1.41*
GDT	Pre-training	-2.36*	-2.20*	-2.02*
	Post-training		-1.78	-2.02*

	1 week after training			-1.21
PDT	Pre-training	-2.36*	-2.20*	-2.02*
	Post-training		-2.20*	-2.02*
	1 week after training			-1.48
TMTF-8 Hz	Pre-training	-2.36*	-1.57	-1.48
	Post-training		-2.20*	-2.02*
	1 week after training			-0.94
TMTF-200 Hz	Pre-training	-1.69	-1.15	-0.36
	Post-training		-2.02*	-2.02*
	1 week after training			-1.48

*p<0.05

Effect of training using CBAT between Groups using Behavioural measures

There were four groups (Group I, Group II, Group III, & Group IV) trained using CBAT with different combination of the training module. They were evaluated before and after CBAT training, 1 week after cessation of the training and 1 month after cessation of the training. The different evaluations consisted of SPIN, GDT, PDT and TMTF-8 Hz and TMTF-200 Hz. Kruskal Wallis H test was done to check between groups comparison for each test. Results revealed statistically no significant differencein the amount of improvement or long term retention between the groups on SPIN, GDT, PDT, TMTF-8 Hz and TMTF-200 Hz (p>0.05). The details of the Kruskal Wallis H test outcome is mentioned in the Appendix-A.

Effect of training using CBAT on Sp-ABR

The speech-evoked ABR were obtained from both ears of all children of all the four training groups. They were analysed for latencies ofwave V and wave A, slope of V-A complex and amplitudes of fundamental frequency (F0), first harmonics (H1) and higher harmonics (H2). The results of these parameters for each of the groups and inter-group comparisons are described below:

Effect of training using speech based stimuli (without Earobics) on Sp-ABR.

For the speech based training, the children (N = 7) received training using CBAT. The descriptive statistical analysis was done to obtain mean, standard deviation and median of the various measures in the pre-training and post-training electrophysiological output.Table 11 shows mean, standard deviation and median values of latencies ofwave V and wave A, slope of V-A complex and amplitudes of F0, H1 and H2 of both ears of the participants in this training group.

Table 11.

Mean, standard deviation and median of latencies ofwave V and wave A, slope of V-A complex and amplitudes of F0, H1 and H2 of Sp-ABR in children with CAPD who underwent training using speech based stimuli (Without Earobics)

		Pre-training		Post-training	
		Mean ± SD	Median	Mean ± SD	Median
RE	Wave V latency (in ms)	6.32± 0.21	6.20	6.25± 0.14	6.20
	Wave A latency (in ms)	7.28± 0.27	7.20	7.33± 0.28	7.37
	Slope V/A (in µV/ms)	0.39± 0.11	0.37	0.30± 0.11	0.31

	F0 amplitude (in µV)	10.6± 10.4	7.45	6.95± 2.2	6.70
	H1 amplitude (in µV)	1.63± 0.37	1.59	1.61± 0.50	1.44
	H2 amplitude (in µV)	0.56± 0.11	0.55	0.53± 0.15	0.53
LE	Wave V latency (in ms)	6.48± 0.39	6.37	6.40± 0.35	6.37
	Wave A latency (in ms)	7.44± 0.39	7.37	7.46± 0.45	7.37
	Slope V/A (in µV/ms)	0.38± 0.11	0.36	0.38± 0.06	0.38
	F0 amplitude (in µV)	5.56±1.93	5.11	4.55± 1.41	4.80
	H1 amplitude (in µV)	1.21 ± 0.25	1.2	1.24 ± 0.37	1.22
	H2 amplitude (in µV)	0.49± 0.15	0.44	0.40± 0.09	0.40

Note: SD: standard deviation;RE: Right ear; LE: Left ear

The Wilcoxon signed ranks test was performed for finding out the changes, if any, in the latencies, slope or amplitude of speech ABR after training. In the right ears, the results revealed no significant difference between pre-training and post-training for wave V latency [Z = -1.63, $p > 0.05$], wave A latency [Z = -1.63, $p > 0.05$],F0 amplitude [Z = -1.01, $p > 0.05$], H1 amplitude [Z = -0.33, $p > 0.05$] and H2 amplitude [Z = -1.52, $p > 0.05$]. However, the slope of the V/A showed statistically significant differences after training compared to before training [Z = -1.99, $p<0.05$].Similar result found in left ear for wave V latency [Z = -1.46, $p > 0.05$], wave A latency [Z = -0.84, $p > 0.05$], V/A slope [Z = -0.08, $p > 0.05$], F0 amplitude [Z = -1.18, $p > 0.05$], H1 amplitude [Z = -0.67, $p > 0.05$] and H2 amplitude [Z = -1.18, $p > 0.05$]. Thus there was no significant effect of speech-based training without Earobics on speech evoked ABR.

Effect of training using speech-based and Earobics-basedstimuli on Sp-ABR.

For the speech-based and Earobics-based stimuli, 7 children with CAPD underwent CBAT. The pre- and post-training speech evoked ABR were recorded and analyzed. The descriptive statistical analysis was done to obtain mean, standard deviation and median of the various measures in the pre-training and post-training electrophysiological output. Table 12shows mean, standard deviation and median values of latencies ofwave V and wave A, slope of V-A complex and amplitudes of F0, H1 and H2 of both ears of the participants in this training group.

Table 12.

Mean, standard deviation and median of latencies ofwave V and wave A, slope of V-A complex and amplitudes of F0, H1 and H2 of Sp-ABR in children with CAPD who underwent training using speech based stimuli with Earobics

		Pre-training		Post-training	
		Mean ± SD	Median	Mean ±SD	Median
RE	Wave V latency (in ms)	6.31± 0.26	6.37	6.32± 0.46	6.12
	Wave A latency (in ms)	7.49± 0.65	7.37	7.44± 0.67	7.03
	Slope V/A (in µV/ms)	0.39± 0.09	0.43	0.39± 0.07	0.39
	F0 amplitude (in µV)	10.93±3.74	11.20	9.45±3.87	7.40
	H1 amplitude (in µV)	1.51± 0.56	1.43	1.53± 0.40	1.46
	H2 amplitude (in µV)	0.48± 0.16	0.46	0.50± 0.13	0.49
LE	Wave V latency (in ms)	6.41± 0.36	6.37	6.33± 0.46	6.03
	Wave A latency (in ms)	7.52± 0.58	7.53	7.52±0.60	7.37
	Slope V/A (in µV/ms)	0.38± 0.04	0.38	0.36± 0.09	0.38

F0 amplitude (in µV)	9.44±5.36	8.12	8.18± 2.94	9.01
H1 amplitude (in µV)	1.44± 0.60	1.28	1.41± 0.46	1.35
H2 amplitude (in µV)	0.49± 0.16	0.48	0.47± 0.22	0.53

Note: SD: standard deviation; RE: Right ear; LE: Left ear

The Wilcoxon signed ranks test was performed for finding out the changes, if any, in the latencies, slope or amplitude of speech ABR after training. In the right ears, the results revealed no significant difference between pre-training and post-training for wave V latency [Z = -0.10, $p > 0.05$], wave A latency [Z = -0.42, $p > 0.05$], V/A slope [Z = -0.42, $p > 0.05$], F0 amplitude [Z = -1.18, $p > 0.05$], H1 amplitude [Z = -0.16, $p > 0.05$] and H2 amplitude [Z = -0.52, $p > 0.05$]. Similar result found in left ear for wave V latency [Z = -0.73, $p > 0.05$], wave A latency [Z = -0.10, $p > 0.05$], V/A slope [Z = -0.33, $p > 0.05$], F0 amplitude [Z = -0.33, $p > 0.05$], H1 amplitude [Z = -0.33, $p > 0.05$] and H2 amplitude [Z = -0.8, $p > 0.05$]. Thus there was no significant effect of speech-based and Earobics-based training on speech ABR.

Effect of training using non-speech based stimuli (without Earobics) on Sp-ABR.

Seven children with CAPD underwent training using non-speech-based stimuli. The pre- and post-training speech evoked ABR were recorded and analyzed. The descriptive statistical analysis was done to obtain mean, standard deviation and median of the various measures in the pre-training and post-training electrophysiological output. Table 13 shows mean, standard deviation and median values of latencies ofwave V and wave A, slope of V-A complex and amplitudes of F0, H1 and H2 of both ears of the participants in this training group.

Table 13.

Mean, standard deviation and median of latencies ofwave V and wave A, slope of V-A complex and amplitudes of F0, H1 and H2 of Sp-ABR in children with CAPD who underwent training using non-speech-based stimuli without Earobics

		Pre-training		Post-training	
		Mean ± SD	Median	Mean ± SD	Median
RE	Wave V latency (in ms)	6.42± 0.29	6.37	6.36± 0.20	6.37
	Wave A latency (in ms)	7.42± 0.38	7.37	7.27± 0.33	7.37
	Slope V/A (in µV/ms)	0.38± 0.11	0.41	0.40± 0.11	0.43
	F0 amplitude (in µV)	6.43±2.04	6.91	7.47±2.76	8.42
	H1 amplitude (in µV)	1.51± 0.49	1.37	1.56± 0.24	1.50
	H2 amplitude (in µV)	0.55± 0.11	0.51	0.49± 0.17	0.49
LE	Wave V latency (in ms)	6.41± 0.29	6.37	6.32± 0.15	6.37
	Wave A latency (in ms)	7.49± 0.43	7.37	7.30± 0.28	7.37
	Slope V/A (in µV/ms)	0.41± 0.14	0.41	0.44± 0.1	0.43
	F0 amplitude (in µV)	7.79± 3.70	6.7	6.82± 2.85	6.89
	H1 amplitude (in µV)	1.32± 0.15	1.35	1.46± 0.22	1.41
	H2 amplitude (in µV)	0.45± 0.13	0.44	0.53± 0.06	0.57

Note: SD: standard deviation; RE: Right ear; LE: Left ear

The Wilcoxon signed rank test was performed for finding out the changes, if any, in the latencies, slope or amplitude of speech ABR after training. In the right ears, the results revealed no significant difference between pre-training and post-training for wave V latency [Z = -0.81, $p > 0.05$], wave A latency [Z = -1.26, $p > 0.05$], V/A slope [Z = -0.50, $p > 0.05$], F0 amplitude [Z = -0.94, $p > 0.05$], H1 amplitude [Z = -0.33, $p > 0.05$] and H2 amplitude [Z = -0.93, $p > 0.05$].

Similar result found in left ear for wave V latency [Z = -0.73, $p > 0.05$], wave A latency [Z = -1.35, $p > 0.05$], V/A slope [Z = -0.59, $p > 0.05$], F0 amplitude [Z = -1.01, $p > 0.05$], H1 amplitude [Z = -0.67, $p > 0.05$] and H2 amplitude [Z = -1.69, $p > 0.05$]. Thus there was no significant effect of non-speech-based training without Earobics on speech ABR.

Effect of training using non-speech-based and Earobics-based stimuli on Sp-ABR.

For the non-speech-based and Earobics-based stimuli, 7 children with CAPD underwent training. The pre- and post-training speech evoked ABR were recorded and analyzed. The descriptive statistical analysis was done to obtain mean, standard deviation and median of the various measures in the pre-training and post-training electrophysiological output. Table 14shows mean, standard deviation and median values of latencies ofwave V and wave A, slope of V-A complex and amplitudes of F0, H1 and H2 of both ears of the participants in this training group.

Table 14.

Mean, standard deviation and median of latencies ofwave V and wave A, slope of V-A complex and amplitudes of F0, H1 and H2 of Sp-ABR in children with CAPD who underwent training using non-speech-based and Earobics-based stimuli

		Pre-training		Post-training	
		Mean ± SD	Median	Mean ± SD	Median
RE	Wave V latency (in ms)	6.52± 0.37	6.57	6.36± 0.46	6.39
	Wave A latency (in ms)	7.53± 0.63	7.37	7.29± 0.54	7.39
	Slope V/A (in µV/ms)	0.31± 0.16	0.36	0.38± 0.17	0.41
	F0 amplitude (in µV)	9.27 ±7.63	8.36	8.06±5.07	6.97
	H1 amplitude (in µV)	1.36± 0.45	1.27	1.45± 0.44	1.62

	H2 amplitude (in µV)	0.43± 0.17	0.47	0.45± 0.18	0.49
LE	Wave V latency (in ms)	6.50± 0.44	6.37	6.33±0.38	6.37
	Wave A latency (in ms)	7.51± 0.55	7.53	7.41± 0.3	7.37
	Slope V/A (in µV/ms)	0.33± 0.11	0.28	0.32± 0.14	0.4
	F0 amplitude (in µV)	6.83±4.82	6.27	8.18±2.80	8.87
	H1 amplitude (in µV)	1.07± 0.43	1.27	1.16± 0.46	1.25
	H2 amplitude (in µV)	0.45± 0.15	0.40	0.43± 0.12	0.38

Note: SD: standard deviation; RE: Right ear; LE: Left ear

The Wilcoxon signed ranks test was performed for finding out the changes, if any, in the latencies, slope or amplitude of speech ABR after training. In the right ears, the results revealed no significant difference between pre-training and post-training for wave V latency [Z = -1.26, $p > 0.05$], wave A latency [Z = -1.44, $p > 0.05$], V/A slope [Z = -1.19, $p > 0.05$], F0 amplitude [Z = -0.67, $p > 0.05$], H1 amplitude [Z = -0.16, $p > 0.05$] and H2 amplitude [Z = -0.33, $p > 0.05$]. In the left also there were no significant difference between pre- and post-training findings for wave V latency [Z = -1.75, $p > 0.05$], wave A latency [Z = -0.67, $p > 0.05$], V/A slope [Z = -0.16, $p > 0.05$], F0 amplitude [Z = -1.18, $p > 0.05$], H1 amplitude [Z = -0.12, $p > 0.05$] and H2 amplitude [Z = -0.33, $p > 0.05$]. Thus there was no significant effect of non-speech-based and Earobics-based training on speech ABR.

Effect of training using CBAT on Sp-LLR

The speech-evoked LLR were obtained from both ears of all children of all the four training groups. They were analyzed for latencies ofP1, N1, P2 and N2 and peak-to-peak amplitudes of P1-N1, N1-P2 and P2-N2.The results of these parameters for each of the groups and inter-group comparisons are described below:

Effect of training using speech based stimuli (without Earobics) on Sp-LLR.

For the speech based training, the children (N = 7) received training using CALT. The descriptive statistical analysis was done to obtain mean, standard deviation and median of the various measures in the pre-training and post-training electrophysiological output. Table 15shows mean, standard deviation and median values of latencies ofP1, N1, P2 and N2 and peak-to-peak amplitudes of P1-N1, N1-P2 and P2-N2 of both ears of the participants in this training group.

Table 15.

Mean, standard deviation and median of latencies ofP1, N1, P2 and N2 and peak-to-peak amplitudes of P1-N1, N1-P2 and P2-N2of Sp-LLR in children with CAPD who underwent training using speech-based stimuli

		Pre-training		Post-training	
		Mean ± SD	Median	Mean ± SD	Median
RE	P1 latency (in ms)	95.37± 16.87	92.86	71.51± 10.43	71
	N1 latency (in ms)	147.28±24.63	144.91	122.75± 10.33	124.09
	P2 latency (in ms)	191.60± 36.82	180.31	178.79± 18.10	175.10
	N2 latency (in ms)	259.11± 36.08	261.5	235.02± 27.25	224.03
	P1-N1 amplitude (in µV)	3.21± 1.47	2.49	3.65± 1.70	3.38
	N1-P2 amplitude (in µV)	1.69± 0.98	1.68	2.28±1.83	2.52
	P2-N2 amplitude (in µV)	6.98± 4.68	6.98	4.44± 3.48	3.86
LE	P1 latency (in ms)	91.51± 11.71	94.94	79.02± 11.39	75.16

N1 latency (in ms)	135.53± 8.19	133.46	126.76±16.28	130.31
P2 latency (in ms)	180.44± 23.66	176.11	182.18±16.26	178.22
N2 latency (in ms)	274.58± 42.30	260.46	244.09± 42.69	225.07
P1-N1 amplitude (in µV)	4.02± 1.95	3.42	3.59± 2.28	2.86
N1-P2 amplitude (in µV)	2.10± 1.92	2.02	2.31± 1.39	1.58
P2-N2 amplitude (in µV)	7.24± 3.94	7.85	4.42± 3.14	3.90

Note: SD: standard deviation.

Wilcoxon signed ranks test was performed for latencies of wave P1, N1, P2, and N2 and peak-to-peak amplitudes of P1-N1, N1-P2 and P2-N2. In right ear,the post-training latencies of P1 [Z = -2.37, p<0.05]and N2 [Z = -2.20, p<0.05] were significantly shorter than pre-training latencies. However, there was no significant difference between pre-training and post-training latencies for N1[Z = -1.85, p>0.05],and P2 [Z = -1.35, p > 0.05]. Significant differences before and after training were also not noticed for P1-N1 amplitude [Z = -0.84, p>0.05], N1-P2 amplitude [Z = -0.84, p>0.05] and P2-N2 amplitude [Z = -1.85, p>0.05]. In the left ears, there was a significant difference between pre- and post-training latencies of P1 [Z = -2.37, p< 0.05] and N2 [Z = -2.36, p< 0.05] but notforN1 [Z = -1.36, p>0.05] and P2 [Z = -0.10, p>0.05] latency. Further, there was significant difference between pre-training and post training peak-to-peak amplitudes only for P2-N2 [Z = -2.19, p<0.05]. There were no significant differences noticed for P1-N1 [Z = -0.5, p>0.05]and N1-P2 [Z = -0.01, p> 0.05] amplitude. Figure 5 shows the median pre- and post-training latencies and peak-to-peak amplitudes of both ears.

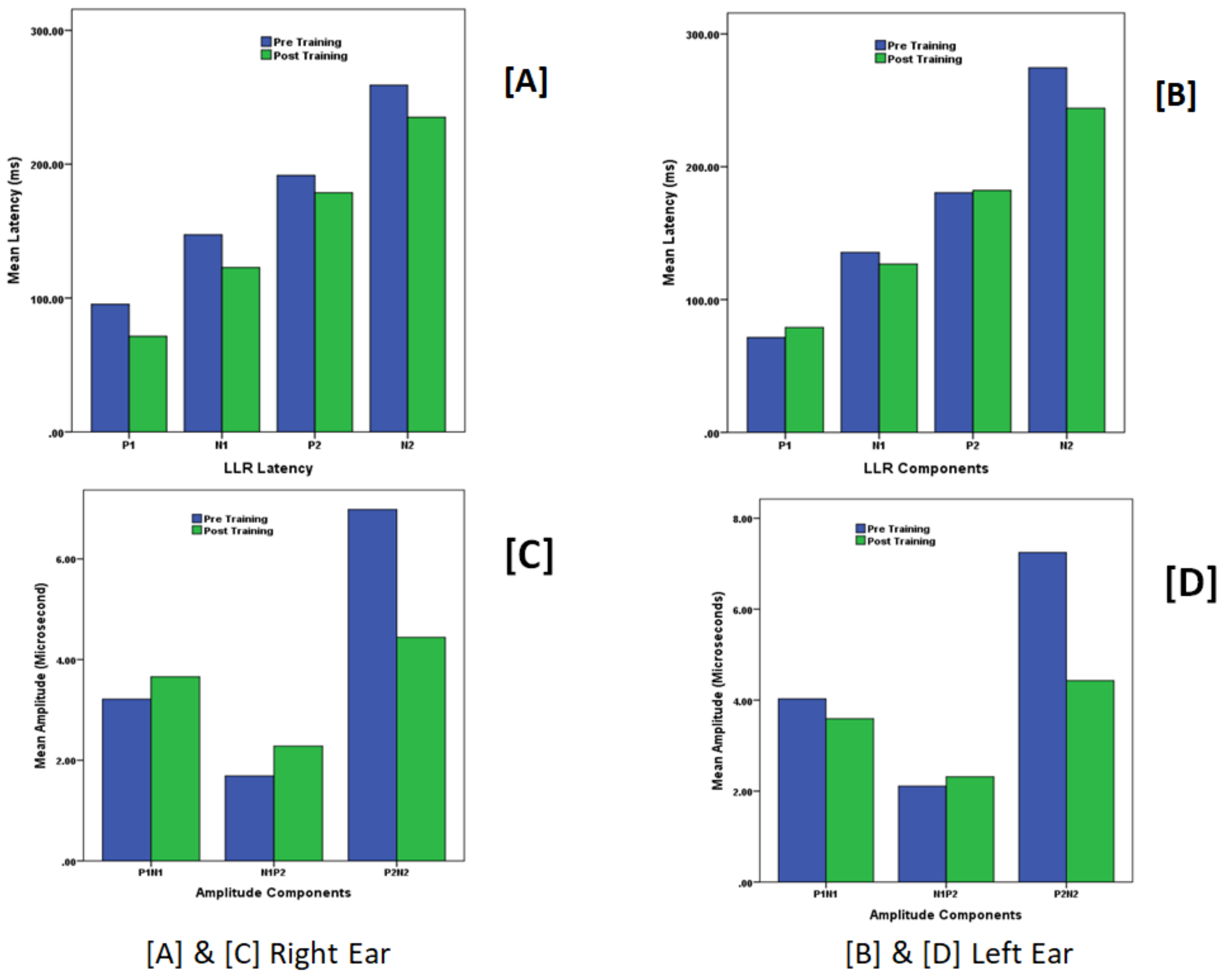


Figure 5: Median pre- and post-traininglatencies and peak-to-peak amplitudes of speech evoked LLR in children with CAPD who underwent training using speech-based stimuli. Panels 'A' and 'C' represent latencies and amplitude respectively of right ear whereas 'B' and 'D' represent latencies and amplitudes respectively of left ear.

Effect of training using speech-based and Earobics-based stimuli on Sp-LLR.

For the speech-based and Earobics-based training, the children with CAPD (N = 7) received training using CALT. The descriptive statistical analysis was done to obtain mean, standard deviation and median of the various measures in the pre-training and post-training electrophysiological output. Table 16 shows mean, standard deviation and median latencies ofP1, N1, P2 and N2 and peak-to-peak amplitudes of P1-N1, N1-P2 and P2-N2 of both ears of the participants in this training group.

Table 16.

Mean, standard deviation and median of latencies ofP1, N1, P2 and N2 and peak-to-peak amplitudes of P1-N1, N1-P2 and P2-N2of Sp-LLR in children at risk for CAPD who underwent training using speech-based and Earobics-based stimuli

		Pre-training		Post-training	
		Mean ± SD	Median	Mean ± SD	Median
RE	P1 latency (in ms)	73.50±13.66	76.99	73.17±13.60	78.58
	N1 latency (in ms)	122.21±8.23	123.05	117.88± 11.18	118.16
	P2 latency (in ms)	181.96±22.73	181.35	173.11±25.04	171.98
	N2 latency (in ms)	249.61±20.77	247.97	239.11±29.13	244.85
	P1-N1 amplitude (in µV)	4.52±2.93	4.43	3.27± 2.14	3.25
	N1-P2 amplitude (in µV)	5.59± 2.99	4.95	4.38± 3.09	4.58
	P2-N2 amplitude (in µV)	6.70±3.11	5.14	7.75±2.36	7.01
LE	P1 latency (in ms)	77.38±11.26	81.74	70.18±14.52	76.20
	N1 latency (in ms)	122.37±9.61	121.33	111.47± 14.17	120.97
	P2 latency (in ms)	184.67±18.39	178.33	173.64±22.05	167.78
	N2 latency (in ms)	249.24±23.26	246.93	233.31±28.41	240.65

P1-N1 amplitude (in µV)	4.28±3.07	3.85	3.59±2.14	2.96
N1-P2 amplitude (in µV)	3.76±3.80	2.58	4.92±2.97	4.20
P2-N2 amplitude (in µV)	6.54±2.90	6.21	7.16±3.07	7.40

Note: SD: standard deviation.

The Wilcoxon signed ranks test was performed for latencies of wave P1, N1, P2, and N2. Intheright ears, there was no significant difference between pre-training and post-training for wave P1 latency [Z = -0.01, $p>0.05$], wave N1 latency [Z = -0.93, $p>0.05$], wave P2 latency [Z = -1.35, $p>0.05$], and wave N2 latency [Z = -1.35, $p> 0.05$]. In the left ears,there was no significant difference between the pre- and post-training latencies of waves P1 [Z = -1.85, $p> 0.05$], waves N1 [Z = -1.75, $p>0.05$]and wave N2 [Z = -1.69, $p> 0.05$]. Nonetheless, significant shortening of latencies after training than before was observed for the waves P2 [Z = -2.20, $p< 0.05$].Figure 6 shows the median pre- and post-training latencies of various LLR peaks and the outcome of the Wilcoxon signed rank test.

The Wilcoxon signed ranks test was performed for peak-to-peak amplitude of P1-N1, N1-P2, & P2-N2 for right ear and left ear. In the right ears, there was no significant difference between pre-training and post-training peak-to-peak amplitude of P1-N1 [Z = -1.35, $p>0.05$], N1-P2 [Z = -1.69, $p>0.05$] and P2-N2 [Z = -0.33, $p>0.05$]. In the left ears, the peak-to-peak amplitude of N1-P2 complex [Z = -1.99, $p< 0.05$]was significantly larger after training when compared to the pre-training values, although there was no significant difference between pre- and post-training peak-to-peak amplitude for the wave complexes of P1-N1 [Z = -0.67, $p> 0.05$] and P2-N2 [Z = -0.67, $p> 0.05$]. Figure 6 shows the median pre- and post-training peak-to-peak amplitudes of various LLR peak complexes.

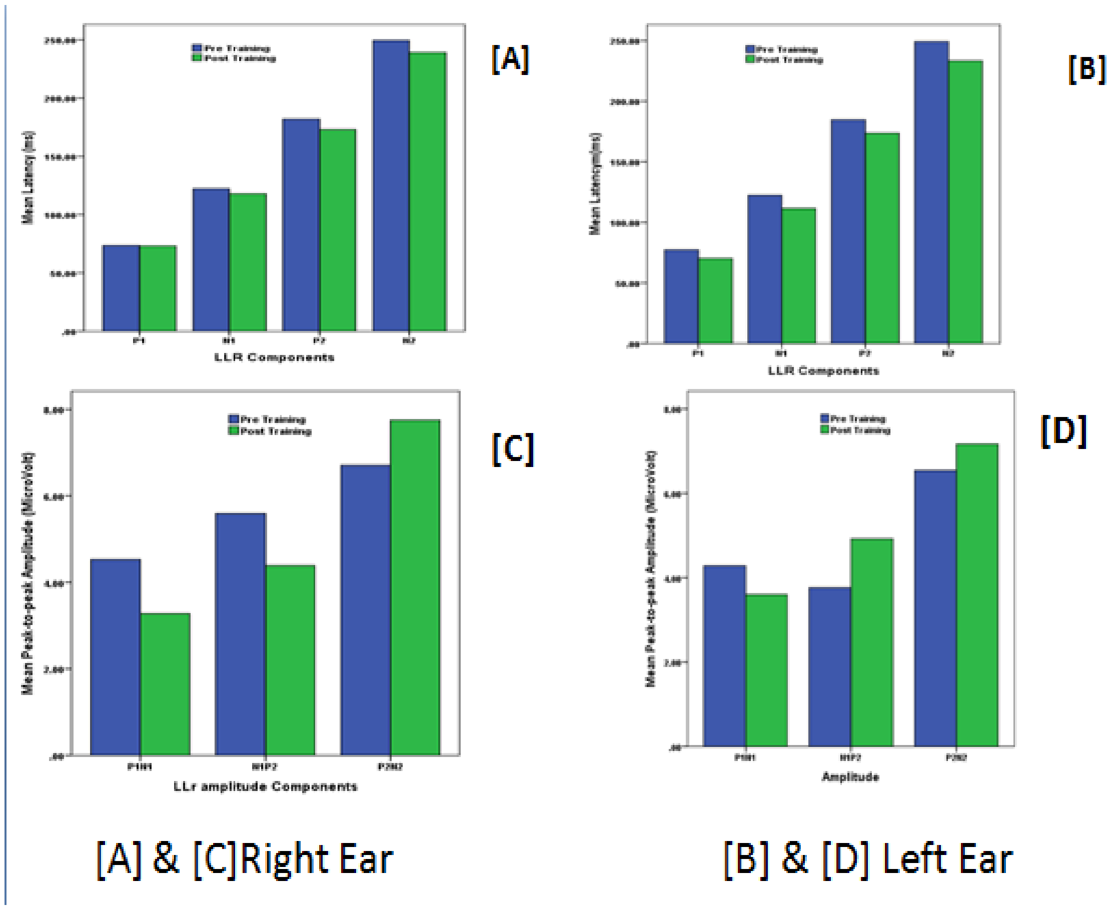


Figure 6: Median pre- and post-training latencies (A&B) and peak-to-peak amplitudes (C&D) of speech evoked LLR in children with CAPD who underwent training using speech-based and Earobics-basedstimuli. Panels ‘A’ and ‘C’ represent latencies and amplitude respectively of right ear whereas ‘B’ and ‘D’ represent latencies and amplitudes respectively of left ear.

Effect of training using non-speech based stimuli (without Earobics) on Sp-LLR.

For the non-speech-based training, the children with CAPD (N = 7) received training using CALT. The descriptive statistical analysis was done to obtain mean, standard deviation and median of the various measures in the pre-training and post-training electrophysiological output. Table 17shows mean, standard deviation and median latencies ofP1, N1, P2 and N2 and peak-to-peak amplitudes of P1-N1, N1-P2 and P2-N2 of both ears of the participants in this training group.

Table 17.

Mean, standard deviation and median of latencies ofP1, N1, P2 and N2 and peak-to-peak amplitudes of P1-N1, N1-P2 and P2-N2of Sp-LLR in children at risk for CAPD who underwent training using non-speech-based stimuli

		Pre-training		Post-training	
		Mean ± SD	Median	Mean ± SD	Median
RE	P1 latency (in ms)	77.98±6.74	78.25	72.44±8.49	72.24
	N1 latency (in ms)	127.72±15.38	117.81	125.90± 10.13	129.30
	P2 latency (in ms)	206.23±26.95	215.67	204.75±20.13	206.83
	N2 latency (in ms)	276.06±30.55	274.35	259.33±13.31	257.49
	P1-N1 amplitude (in µV)	4.35±2.73	3.25	4.70±2.50	3.68
	N1-P2 amplitude (in µV)	3.12±2.13	4.14	3.53±3.76	2.27
	P2-N2 amplitude (in µV)	5.67±2.04	5.23	4.61±3.79	2.81
LE	P1 latency (in ms)	78.65±10.24	78.58	75.52±7.95	73.83
	N1 latency (in ms)	130.16±27.59	119.90	120.81±7.22	121.98
	P2 latency (in ms)	211.73±25.64	207.34	198.29±24.57	194.88
	N2 latency (in ms)	280.38±31.19	273.19	261.78±15.04	266.71
	P1-N1 amplitude (in µV)	4.57±2.49	3.52	3.63±1.52	3.53
	N1-P2 amplitude (in µV)	3.36± 2.22	3.60	3.50±2.23	3.57
	P2-N2 amplitude (in µV)	6.23±4.26	5.12	5.34±3.22	6.04

Note: SD: standard deviation.

The Wilcoxon signed ranks test was performed for latencies of wave P1, N1, P2, and N2. In right ear there was no significant difference between pre-training and post-training latencies of waves P1 [Z = -1.43, p>0.05], N1 [Z = -0.33, p>0.05], P2 [Z = -0.50, p> 0.05] and N2 [Z = -1.57, p>0.05]. Left ear showed a similar trend with no significant difference between the pre- and post-training in latencies of waves P1 [Z = -1.01, p>0.05], N1 [Z = -0.50, p>0.05], P2 [Z = -0.94, p>0.05] and N2 [Z = -1.69, p>0.05].

The Wilcoxon signed ranks test was also performed forpeak-to-peak amplitude. In right ear there was no significant difference between pre-training and post-training for peak-to-peak amplitude of P1-N1 [Z = -0.16, p> 0.05], N1-P2 [Z = -0.01, p> 0.05], and P2-N2 [Z = -1.01, p> 0.05]. Left ear also showed similar results with no significant difference in peak-to-peak amplitude of P1-N1 [Z = -0.67, p>0.05], N1-P2 [Z = -0.67, p> 0.05] and P2-N2 [Z = -0.84, p>0.05]. Figure 7 shows the median pre-training and post-training latencies and amplitudes of various LLR components.

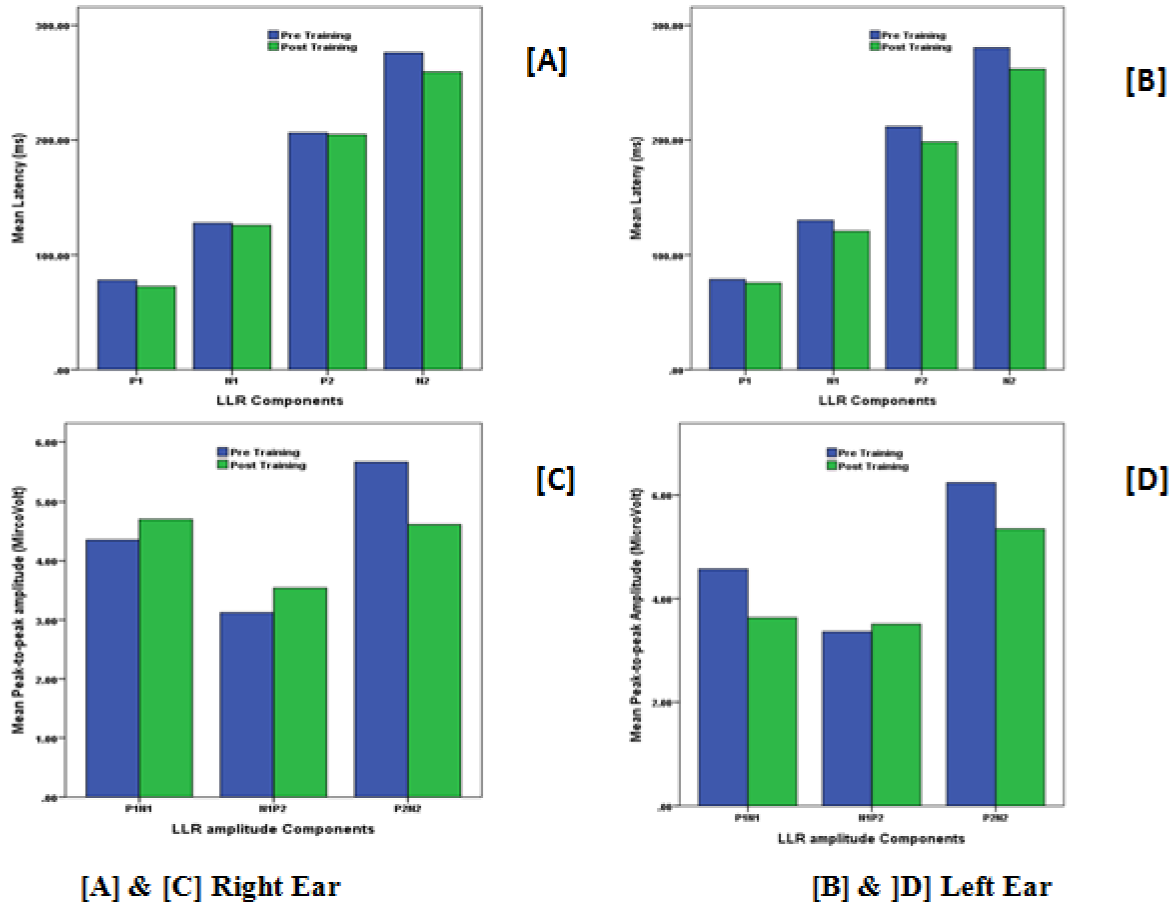


Figure 7: Median pre- and post-training latencies (A & B) and peak-to-peak amplitudes (C & D) of speech evoked LLR in children at risk for CAPD who underwent training using non-speech-based stimuli. Panels 'A' and 'C' represent latencies and amplitude respectively of right ear whereas 'B' and 'D' represent latencies and amplitudes respectively of left ear.

Effect of training using non-speech-based and Earobics-based stimuli on Sp-LLR.

For the non-speech-based and Earobics-based training, the children with CAPD (N = 7) received training using CALT. The descriptive statistical analysis was done to obtain mean, standard deviation and median of the various measures in the pre-training and post-training electrophysiological output. Table 18 shows mean, standard deviation and median latencies ofP1, N1, P2 and N2 and peak-to-peak amplitudes of P1-N1, N1-P2 and P2-N2 of both ears of the participants in this training group.

Table 18.

Mean, standard deviation and median of latencies ofP1, N1, P2 and N2 and peak-to-peak amplitudes of P1-N1, N1-P2 and P2-N2of Sp-LLR in children at risk for CAPD who underwent training using non-speech-based stimuli

		Pre-training		Post-training	
		Mean ± SD	Median	Mean ± SD	Median
RE	P1 latency (in ms)	82.16±16.50	90.78	77.41±10.21	76.20
	N1 latency (in ms)	126.63±24.18	118.16	114.60±13.20	117.84
	P2 latency (in ms)	194.54±24.41	184.66	177.17±15.98	178.22
	N2 latency (in ms)	256.25±17.10	261.47	231.7±19.67	232.36
	P1-N1 amplitude (in µV)	2.54±2.09	1.61	2.09±0.66	1.85
	N1-P2 amplitude (in µV)	2.95±2.17	2.29	2.61±1.67	2.02
	P2-N2 amplitude (in µV)	3.39±2.58	2.08	4.32±1.53	4.07
LE	P1 latency (in ms)	81.89±18.10	90.78	75.94±13.20	76.20
	N1 latency (in ms)	126.31±28.70	133.99	116.64±9.88	117.84
	P2 latency (in ms)	196.06±23.77	194.85	176.90±8.58	176.14
	N2 latency (in ms)	255.57±13.96	251.16	228.69±10.39	231.32
	P1-N1 amplitude (in µV)	3.00±1.95	2.67	3.52±2.07	4.25
	N1-P2 amplitude (in µV)	3.69±3.63	2.12	3.17±2.44	2.75
	P2-N2 amplitude (in µV)	4.39±2.20	4.16	4.74±2.14	5.11

Note: SD: standard deviation.

Wilcoxon signed ranks test was performed for latencies of wave P1, N1, P2, and N2. In the right ears, there was no significant difference between pre-training and post-training for P1 latency [Z = -1.01, $p > 0.05$], N1 latency [Z = -1.18, $p > 0.05$], and P2 latency [Z = -1.69, $p > 0.05$]. However, there were significant changes noticed after training for N2 latency [Z = -2.19, $p < 0.05$] in comparison of pre-training score. Likewise, there was no significant difference between pre- and post-training latencies of P1 [Z = -1.52, $p > 0.05$], N1 [Z = -1.18, $p > 0.05$] and P2 [Z = -1.85, $p > 0.05$] latency. However, there was a significant shortening of latencies of N2 [Z = -2.36, $p < 0.05$] in the post-training recordings than pre-training ones. Figure 8 shows the median pre- and post-training latencies of various LLR peaks and the outcome of the Wilcoxon signed rank test.

The Wilcoxon signed ranks test was performed for comparison of peak-to-peak amplitude between pre- and post-training evaluations for each ear. In the right ears, there was no significant difference between pre-training and post-training peak-to-peak amplitude of P1-N1 [Z = -0.33, $p > 0.05$], N1-P2 [Z = -0.33, $p > 0.05$], and P2-N2 [Z = -0.84, $p > 0.05$]. Likewise, there was no significant change in peak-to-peak amplitude of P1-N1 [Z = -0.84, $p > 0.05$], N1-P2 [Z = -0.50, $p > 0.05$], and P2-N2 [Z = -0.33, $p > 0.05$] of left ears following training using non-speech-based and Earobics-based stimuli. Figure 8 the median pre- and post-training peak-to-peak amplitudes of various LLR peak complexes and the outcome of the Wilcoxon signed rank test.

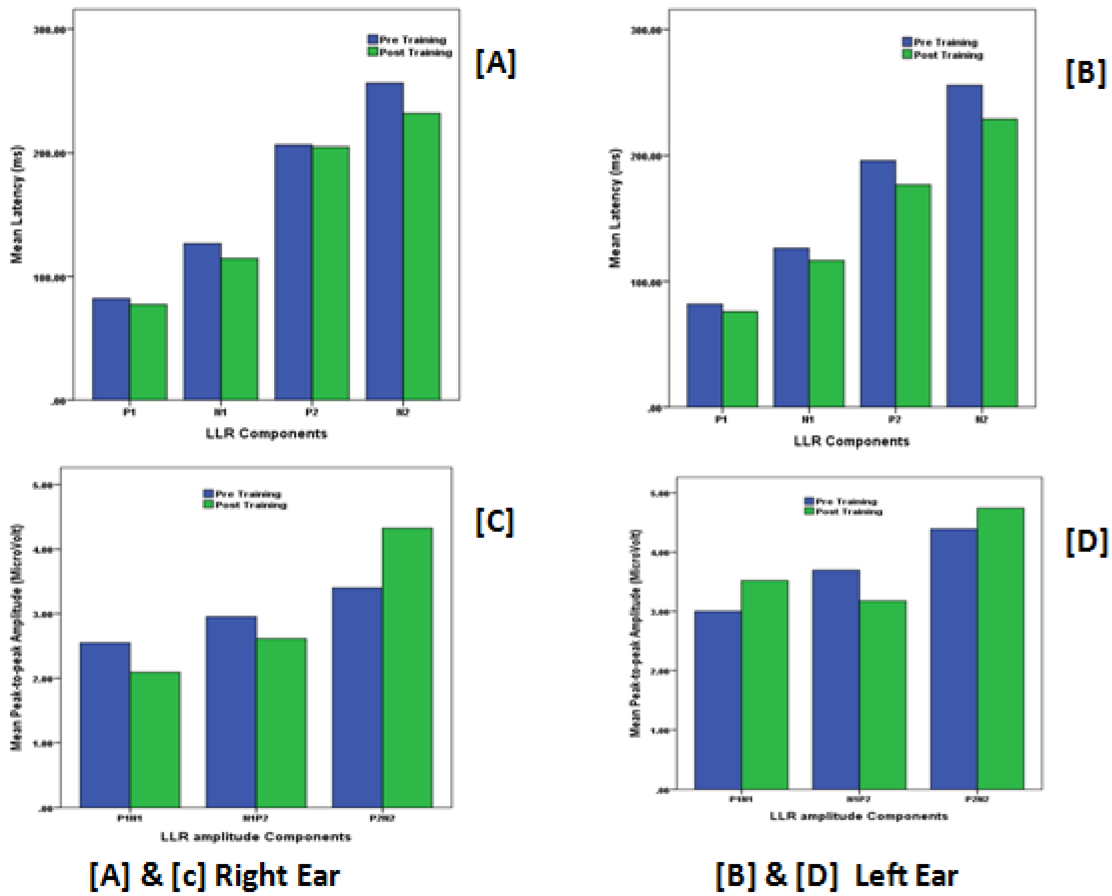


Figure 8: Median pre- and post-training latencies (A & B) and peak-to-peak amplitudes (C & D) of speech evoked LLR in children at risk for CAPD who underwent training using non-speech-based and Earobics-based stimuli. Panels ‘A’ and ‘C’ represent latencies and amplitude respectively of right ear whereas ‘B’ and ‘D’ represent latencies and amplitudes respectively of left ear

Effect of training using CBAT between Groups using Electrophysiological measures

There were four groups (Group I, Group II, Group III, & Group IV) trained using CBAT with different combination of the training module. They were evaluated before and after CBAT training using speech evoked ABR and speech evoked LLR. The different parameters of the speech evoked ABR i.e. wave V, wave A, wave V/A slope, amplitude of f0, H1 and H2 and Speech evoked LLR i.e. latency of wave P1, N1, P2, N2 and amplitude of P1N1, N1P2, and

P2N2 for both right ear and left ear were measured. Kruskal Wallis H test was done to check between groups comparison for different parameters of each test i.e. spABR and spLLR. Results revealed no statistically significant differences in the amount of improvement between groups for any parameters of spABR and spLLR at 0.05 levels (Appendix B). Since there were no statistical difference observed between groups across different evaluations, Mann Whitney U test was not performed further.

DISCUSSION

The present study was aimed to find the utility of CBAT using psychophysical and electrophysiological tests. The result found in the present study for psychophysical and electrophysiological was different in terms of statistical measures. Overall, study reported the psychophysical tests (SPIN, PDT, TMTF& GDT) was effective in predicting the effect of CBAT then electrophysiological tests (sp-ABR &sp-LLR).

The psychophysical measures (SPIN, PDT, TMTF& GDT)as an outcomes after computer based training

Present study showed there was a better performance for all the psychophysical tests after computer based auditory training. The effect of training was retained even after withdrawal of training as per tests carried out after 1 week and 1 month cessation of training. This indicates that there was an improvement in auditory processing ability for children with CAPD and the effect of training sustained at least up to 1 month after cessation of the training. The auditory abilities like auditory closure, temporal resolution, and frequency resolutions showed improvement as per the tests SPIN, GDT, PDT as well as TMTF assessed the above domain.

There are several studies reported similar finding in children with auditory processing disorders (Musiek&Schochat, 1998; Putter-Katz et al., 2002; Miller et al., 2005; Musiek, 2006; Johnston et al., 2009; Alonso &Schochat, 2009; Maggu&Yathiraj, 2011; Tawfik, Hassan, &Mesallamy, 2015;Loo, Rosen, &Bamiou, 2016)and in co-morbid disorders like learning impairment and/or reading difficulties (Merzenich et al., 1996; Kujala et al., 2001; Hayes et al., 2003; Gillam et al., 2008). Musiek and Schochat in 1998 reported a single child of 15 years diagnosed as APD with spelling difficulties and recommended for training on several domains.

This child underwent APD training using both speech and non-speech based task focused on intensity, frequency, temporal, and dichotic speech perception based task almost for 6 weeks (3 hours/week at clinic & 1 hour/week at home). They measured binaural integration, temporal processing and auditory closure abilitiesbefore and after auditory training. They reported improvement in all APD domains with greatest improvement in auditory closure abilities. Alonso and Schochat in 2009 assessed the efficacy of formal auditory training in children with CAPD by adopting the auditory training procedure (both speech and non-speech based task) customized by Musiek and Schochat in 1998. They also reported significant improvement in all behavioural measures (SSI-ICM, speech in noise, directed attention non-verbal dichotic test, and SSW) after auditory training.Later, Musiek in 2006 reported that auditory training had little effect on simple stimuli (pure tone) but show more impact on complex stimuli like speech which indicates simple stimuli does not trigger much to the brain function than do complex stimuli. As author reported brain is plastic which engages more areas of the brain activation using complex stimuli and more the brain is engaged more there would be an improvement for the task. Similarly study done by Miller et al in year 2005 identified 7 children with auditory processing disorders and recruited for different types of training (FastForWord, Earobics, and games/ traditional worksheets) for 4-6 weeks (100 minutes per day, 5 days/week). The reported all children showed improvement with training irrespective of types of training on SCAN-C and SSW test immediately after intervention. To check the retention of training effect, 4 children were evaluated even after 4-6 months cessation of training and showed sustained improvement on SCAN-C and SSW test. In another study done by Putter-Katz et al in year 2002 recruited 20 children with APD and they further made two groups based on performance in different behavioural APD tests. Group 1 APD children were those having poor SPIN and MLD scores and group 2 children were having poor scores in speech-in-noise test, DDT and MLD test. Both the groups were exposed to environmental modification & teaching suggestions (decreased background noise, preferential seating, and use of tape-recorder), remedial techniques (listening and comprehension activities in noise and competing verbal stimuli, selective and divided attention task) and compensatory strategies (auditory closure, speech reading and selective listening). Results showed improvement on speech-in-noise test for group 1 and improvement in all tests for group 2. Study done by Johnston et al in 2009 identified 10 APD children and fitted with FM system for 5 months and compared with 13 typically developing children. They reported improvement in speech perception in quiet and in noise in children with APD with the uses of FM system in classroom as well as at home. In another study done by Sharma, Purdy and Kelly in 2012 were compared intervention approaches used for children with auditory processing disorders. Children with APD were randomly selected for one of the groups for either top down training, bottom up training and use of FM systems. They were assessed for auditory processing, language and reading ability before and after training. They reported positive outcomes with both the approaches as well as with use of FM systems in trained group. However, positive outcomes were not only limited to the areas specifically targeted by the interventions as reported. Maggu and Yathiraj in 2011 investigated efficacy of noise desensitization training in children with poor speech-in-noise scores. They reported significant improvement in speech perception scores among post-training group compare to control group. In a large sample, a study done by Tawfik et al in year 2015 to assess the long term effect of auditory training program on children with APD. They enrolled 30 children with APD and reported improvement in temporal processing and temporal resolution abilities. Further, they reported retention of the changes up to 42 months among children with APD. In a similar line, Loo and colleagues in year 2016 trained children with CAPD for 12 weeks using computer based auditory training and reported significant improvement in speech perception in noise abilities. Further, they also reported retention of the effect among these trained children up to 3 month after the cessation of auditory training.

Study done by Merzenich et al in 1996 were identified 22 children with language learning impairment in the age range of 5-10 years and acoustic modification training was given only for 11 children with learning problems for 5 weeks (3 hours/week) and remaining 11 children served as control group. They reported significant changes in the speech discrimination and language comprehension abilities after acoustic modification training compared to control group. In another study by Kujala et al in 2001 identified 48 children with reading delay and given pattern recognition training using non-linguistic task for 7 weeks (20 minutes/week) and compared with 24 children with reading delay served as control group. They reported higher reading skills among those children with reading delay underwent training. Similarly, Hayes et al in 2003 recruited children with learning problems for Earobic training for 8 weeks. They reported improvement in sound blending abilities among learning problems children compared to control group. Study done by Gillam et al in 2008 identified 216 children with language impairment and randomly assigned to four grouped based on mode of training (Fast ForWord language, academic enrichment, computer-assisted language intervention and individualized language intervention). They were given training for 6 weeks (5 days/week, 1 hour 40 minutes per day) and results showed gain in language and temporal processing task among all groups. However, there were no differences observed between treatments provided to different groups. It probably indicates irrespective of kind of training it does makes positive changes in ability of the language learning. In another study by McArthur et al in 2008 identified children with specific language impairment/specific reading disorders and given non-speech and speech sound training. They were assessed for frequency discrimination, vowel discrimination, and consonant-vowel discrimination. Results showed improvement in language, spelling skills and auditory processing abilities among trained group. Study done by Strehlow et al (2006) reported improvement in auditory processing and reading skills based on temporal processing test in children with specific reading disorders children after attending non-speech and speech sound training.

Agnew et al (2004) incorporated auditory duration judgment (accuracy task) in a study to assess the effectiveness of Fast ForWord intervention on the auditory processing abilities of poor academic performers. Children were significantly more accurate on the auditory judgment task after FFW intervention than they were before. Although it is not feasible to tease out a maturation or learning effect because of repeated measures in this study (as there was no untrained comparison), the authors reported that there were no analogous improvements in the visual domain after FFW training, indicating that the intervention induced changes in auditory processes per se but not in general attention processes. In another study by Marler et al. (2001) provided FFW training for two children with LLI (Language learning impairment) to improve the auditory temporal processing abilities and two children with LLI underwent Laureate Learning Systems (LLS) training. They had considered typically developing children as a control group. They used simultaneous and backward masking for evaluation of the effect of training. During pre-training evaluation, three children showed elevated backward masking thresholds in comparison with typically developing children. The training was given for 4 weeks and both the groups showed progressively better simultaneous and backward masking thresholds. The authors concluded that the improvement showed was may be due to practice or maturation effect, as improved masking thresholds was noted even in typically developing children.

Overall behavioural measures showed improvement with training among children with auditory processing disorders irrespective of different types of stimuli (both speech and non-speech based task) used for auditory training. Similar observation is noticed even in co-morbid conditions like children with learning impairment, specific reading disorders, specific language impairment with auditory processing disorders showed improvement with speech and non-speech based tasks. Hence, to conclude behavioural measures are sensitive enough to tap the changes if any among children with auditory processing disorders provided intervention.

The electrophysiological measures in finding outcomes of auditory training

The electrophysiological measures in the present study did show the significant changes in predicting the effect of CBAT and complementing the outcomes measured using psychophysical test. There were two electrophysiological tests i.e. sp-ABR and sp-LLR were used to check the effectiveness of CBAT intervention at sub-cortical and cortical level. The parameters of sp-ABR (wave V, wave A, V/A slope, F0, H1, and H2) and sp-LLR measured were latency of P1, N1, P2 and N2 as well as peak-to-peak amplitude of P1-N1, N1-P2, and P2-N2. Though the differences in mean thresholds were noticed to be better in different parameters of sp-ABR and sp-LLR, it was statistically significant only for few latency and amplitude measures of sp-LLR in both ears. The above finding is indicating probably more plastic nature of the brain at cortical level but not at sub-cortical or brainstem level. This could also be because of lesser duration of training imparted in present study may be a contributing factor for not reflecting changes at sub-cortical or brainstem level as even in literature most of the studies mentioned minimum 8 weeks of training instead of 4 weeks. Present study impartedcomputer based auditory training only 4 weeks due to limited available resources as well as time constraint.

There are several studies using electrophysiological test estimated the benefit derived due to training for children with auditory processing disorders (Filippini et al., 2012; Schochat et al., 2010; Jirsa, 1992)and /or co-morbid disorders like learning impairment and or reading disorders (Kujala et al., 2001; Hayes et al., 2003; Russo et al.2005, Warrier et al., 2004; Stevens et al., 2008). There are several studies carried out by Kraus, Tremblay and colleges to estimate the efficacy of auditory discrimination training among children and adults demonstrating listening difficulties (Kraus et al., 1995; Kraus, 1999; Tremblay. Kraus, Carrell, & McGee, 1997; Tremblay, Kraus, & McGee, 1998; Tremblay, Kraus, McGee, Ponton, & Otis, 2001; Tremblay & Kraus, 2002).

Filippini et al in 2012 provided formal auditory training to group of children with APD and language impairment and compared with untrained group. They adopted the auditory training procedure which includes both speech and non-speech based stimuli used by Musiek and Schochat, 1998. They noticed improvement in performance as a reduction (better) of the latency of the ABR to complex sound in background noise. In contrast, study done by Yencer in 1998 checked effectiveness of auditory training (auditory integration therapy) on 12 children with auditory processing disorders using latency measures of click evoked ABR. There were 12 children without APD each served as trained and untrained control group for the comparison. Children with APD were given training for one hour per day for the total duration of 10 days. They reported no significant differences in latency measures of click evoked ABR in trained group when compared with both untrained and trained control group. Hence study done by Yencer (1998) is in agreement with present studywhereas it contrasts the finding of Musiek and

Schochat (1998) study. The differences in finding could be because of amount of training and type of population targeted in both the studies.

Hayes et al (2003) identified 27 children with learning problems and given training using Earobics software for 8 weeks. Earobics software uses both speech and non-speech based stimuli and customized as simple to complex task. They estimated the effectiveness of training using click evoked ABR, speech evoked ABR and speech evoked cortical potential in quiet and in noise before and after Earobic training for both trained and untrained group. The results shows that the speech evoked cortical responses in noise were more robust (in terms of latency and amplitude) among trained group in comparison to untrained group. In addition they also noticed good correlation between speech evoked cortical potential recorded in presence of noise with speech-in-noise behavioural measures. However, they did not notice any changes in latencies of click evoked and speech evoked ABR in both trained and untrained children with learning problems. Study done by Russo et al in 2005 provided training to children with learning problems and evaluated the effectiveness of Earobics training using speech evoked ABR and speech evoked cortical responses in quiet and noise. They reported improvement in auditory processing skills after Earobics training based on changes noticed speech evoked ABR and cortical responses. In addition, there were changes improvement noticed in phonological skills in trained children compared to untrained children. Study done by Warrier et al in 2004 identified children with learning problems and provided Earobics training and measured changes using speech evoked cortical potentials in quiet and in noise. They also reported improvement in auditory processing skills based on changes noticed in speech evoked cortical potential and such changes were not noticed in untrained group. In another study done by Steven et al in 2008 assessed FFW training effectiveness using speech evoked cortical potential on children with specific language impairment (SLI) and typically developing children (TDC). They reported significant positive improvements in auditory processing skills and language skills in both the trained groups (SLI & TDC) compared to untrained group. The changes due to training were reflected in speech evoked cortical potentials parameters measured before and after training in both the groups. In contrast, Jirsa (1992) reported no changes in N1 and P2 latency of ALLR before and after individualized listening training among children with auditory processing disorders. Prior to intervention, both the experimental training group and the untrained APD control group showed delayed N1 and P2 latencies relative to the typically developing control group. The experimental training group received individualized training that focused on intensive listening exercises for auditory memory, auditory discrimination, attention, and language comprehension. There were improvements in performances after individualized listening training only on behavioural tests. However, same author reported improvement in P300 latency and amplitude after individualized listening training to experimental trained group in comparison to untrained APD and control group. In a similar line, McArthur et al in 2010 assessed effectiveness of computer based training on children with SLI or SRD using ALLR. They also reported no significant changes in N1-P2 measures after 6 weeks of training when compared with untrained group.

Among electrophysiological studies, apart from speech evoked ABR and ALLR, there are studies done using auditory middle latency responses (AMLR), mismatch negativity (MMN) and P300 to evaluate the efficacy of training on these populations. Study done by Kujala et al in 2001 were reported significant increase in amplitude of MMN after pattern recognition training among children with specific reading disorders compared to untrained group. In another study done by Alonso and Schochat in 2009 trained children with learning problems for 8 weeks using non-speech and speech based tasks and monitored progress with P300 evoked potential. They reported significant improvement in latency of P300 but no changes in amplitude of P300 after training compared to untrained control group. Similarly, Schochat et al in 2010 reported significant changes after non-speech based training in Na-Pa amplitude of AMLR. However, no changes in Pa latency measures of AMLR reported in children with learning problems when compared with untrained control group.

Study done by Kraus et al (1995) trained participants with normal peripheral and central hearing using auditory discrimination training protocol and obtained pre- and post-training behavioural and electrophysiological measures. The training stimuli were discrimination of two synthesized /da/ tokens that differed in the onset frequencies of the second and third formants transition. Training were given for a one week for one hour per day and participants were asked to determine whether two successive tokens were the same or different. The discrimination of /da/ tokens increased from 56% pre-training to 67% post-training. This behavioural increased were reported to be persistent one month following the termination of training. Further, following training, MMN showed larger duration and amplitude for most of the participants. In another study by Tremblay et al (1997) tried to determine to what extent discrimination training with one set of tokens would transfer to another set of tokens not used in the training. The training continuum used was labial consonants i.e. two consonant-vowel continua with voice onset time (VOT) of different but similar durations. The post training evaluation includes both labial and alveolar continua for both behavioural and electrophysiological measures. Post-training results showed improvement in discrimination of both the tokens in training group, though effect was smaller with alveolar tokens. Similarly, MMN responses showed an increase in area and duration for both the labial and alveolar VOT. Further, increase in duration of MMN was noticed to be greater over the left frontal lobe. The increased duration of MMN in the left hemisphere reflects the greater benefit of training to this hemisphere probably due to the greater activity in the left frontal lobe because of the linguistic nature of the stimuli. In spite of MMN response has reflected some promise as a research tool, still it has to show high clinical utility (Tremblay et al., 2001; Tremblay and Kraus, 2002). Due to the above fact, Tremblay and colleges (2001, 2002) reported utility of N1-P2 components of ALLR as electrophysiological outcome measures and suggested to be later is more clinically feasible than the earlier one.

The present study showed no significant differences for different components of sp-ABR such as wave V, wave A, V/A slope, F0, H1 and H2 for group I, II, III, and IV of both ears except V/A slope of right ear in group IV. The above finding showed unlike the difference noticed using psychoacoustic measures, sp-ABR did not reflect the changes because of computer based training irrespective of speech and/or non-speech based stimuli. In contrast literature do report the changes at brainstem level due to training in children with auditory processing disorders (Filippini et al., 2012; Schochat et al., 2010) and /or co-morbid disorders (Kujala et al., 2001; Hayes et al., 2003; Russo et al.2005, Warrier et al., 2004; Stevens et al., 2008). It is presumed that probably the amount of training imparted in present study was not sufficient enough to reflect the changes at brainstem level. As reported in literature, most of the studies checked the effectiveness of auditory training using FFW, Earobics or any customized training at least for 8 weeks with duration of 50 minutes session per week (Hayes et al, 2003;Fillippini, 2012, Krishnamurti et al, 2013). Hayes et al in 2003 reported about 35 to 40 hoursoftraining sessions for 8 weeks period to see the changes due to training in children with learning problems. In another study reported byKrishnamurti et al in 2013 provided training using Earobics for 50 minutes per session, 5 days per week for duration of 8 weeks in children with APD and noticed significant improvement after training. In contrast study done byYencer in 1998 reported no improvement with one hour per day training for duration of 10 days using sp-ABR. Hence, lesser amount of training could be the reason in the present study for no significant changes noticed in different parameters of sp-ABR in both ears.

The long latency responses used in the present study do reflect significant changes due to training for group I, II and IV in terms of shorter latency and larger amplitude. However, group III did not show significant changes for either latency or amplitude measures of sp-LLR. As described earlier the changes observed with sp-LLR could be because of the more plastic nature of the brain at cortex irrespective of the stimuli used for the training. However, it is noticed that the changes are more evident among group I and II participants where speech based stimuli wasused instead non-speech based stimuli used in group III and IV. The significance of speech versus non-speech based stimuli used for training is justified by Musiek in 2006. Since the non-speech based stimuli like pure tone which is simple task does not trigger so effectively as using speech based stimuli. Another factor could be the less amount of training even for sp-LLR to show no improvement due to training. Several studies reported more amount of training which reflected changes in the cortical potential (Jirsa, 1992; Hayes et al, 2003). Study done by Jirsa in 1992 were provided 45 minutes of session twice in weeks for duration of 14 weeks to see the changes due to training in children with APD. Similarly, Hayes et al reported one hour of training sessions for a period of 8 weeks for children with learning problems to see the changes due to training. In contrast, McArthur et al in 2010 reported no significant changes in sp-LLR measures when training was given only for 6 weeks among children with language impairment.

Overall studies showed mixed finding with electrophysiological measures (ABR, AMLR, ALLR, MMN, and P300) in terms of assessing effectiveness of training on auditory processing disorders children with and without learning impairment. Most of the studies using click evoked ABR and sp-ABR did not reflect changes due to training in children with APD. In contrast, late potentials like ALLR, MMN and P300 do reflect changes in cortical structures due to training. Probably it could be because of more plastic nature of the cortical structures as evident with late potentials. Since a large portion of the training exercises focused on improving the acoustic representation of sound, physiological measures that are sensitive to acoustic processing have been used to quantify training related changes in the brain. Cortical auditory evoked potential using complex sounds helps in physiological detection of sounds whereas MMN reflects physiological discrimination and sensory memory of two sounds (Naatanen&Picton, 1987; Naatanen, 1990). In addition, training related changes in the MMN also represents improved neural representation of the trained acoustic cues, which in turns contributes to improve perception.

In summary, present study supports the improvement noticed using computer based auditory training in terms of behavioural measures as well as electrophysiological measures in terms of morphology, amplitude and latencies of sp-ABR and sp-LLR. Present study did not show any differences statistically across groups which indicate alike performance for each group. However, the above finding needs to be validated on larger population and researchers should have untrained group to estimate the benefit derived due to training and not changes occurred due to learning or maturation over time.

SUMMARY AND CONCLUSION

The study was intended to see the impact of computer based auditory training for children with CAPD using electrophysiological study and psychophysical measures. There were 28 children with CAPD in the age range of 8-12 years were considered for the computer based auditory training. The training was provided total 12 sessions in the duration of 5 weeks. The psychophysical and electrophysiological measures were done to find the outcome of the pre and post training. Psychophysical measures used were SPIN, GDT, PDT and TMTF as well as electrophysiological measures used were Sp-ABR and Sp-LLR. The training material used were Earobics, CALT and non-speech stimulus, these were focusing on the stimulation of the different auditory processing. The some are auditory closure, temporal resolution and pitch resolution. This study emphasis on the plasticity exist which shows the improvement in the child with CAPD when the proper stimulation is providing.

All the psychophysical measures in the present study predicted the outcomes of computer based auditory training in children with CAPD, whereas the improvement significant in most of the tests. Even though significant difference did not observe in some tests, but still there was an improvement. From this it can be stated that improvement was seen in terms of auditory closure, temporal resolution and frequency resolution. Hence, present study concluded that the computer based auditory training is an effective training module for the children with CAPD. There was an improvement in performance of psychophysical tests after the CBAT for children with CAPD. At the same time these psychophysical measures are effective measure in providing the information about even small amount of benefits with the training then the electrophysiological assessment.

In electrophysiological tests,Speech evoked LLR showed significant improvement in children with CAPD after CBAT in terms of better (shorter) latency and larger amplitude measures. Whereas speech evoked ABR showed no significant improvement in children with CAPD after the CBAT. This could be due to the lesser duration (amount) of training provided. This amount of training is failed in bringing improvement in the sub-cortical structures whereas cortical structures do reflect changes in electrophysiological tests.

Overall the present study provides the utility of computer based training in children with central auditory processing disorders based on both behavioural and electrophysiological measures. Further, present study will help for future research where the clinician can formulate similar training module with increase in duration of training for other group of population with larger sample size.It will help in understanding the changes if any due to auditory training at sub-cortical and cortical levels in these individuals.

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Appendix A

Kruskal Wallis H Test behavioural measures outcome

	SPIN RE (E2-E1)	SPIN LE (E2-E1)	SPIN RE (E3-E1)	SPIN LE (E3-E1)	SPIN RE (E4-E1)	SPIN LE (E4-E1)
Chi-Square	.433	2.938	.575	2.480	.136	1.911
df	3	3	3	3	3	3
Asymp. Sig.	.933	.401	.902	.479	.987	.591

	GDT (E2-E1)	GDT (E3-E1)	GDT (E4-E1)	PDT (E2-E1)	PDT (E3-E1)	PDT (E4-E1)
Chi-Square	1.505	1.184	1.926	2.232	2.205	1.937
df	3	3	3	3	3	3
Asymp. Sig.	.681	.757	.588	.526	.531	.586

	TMTF200 (E2-E1)	TMTF200 (E3-E1)	TMTF200 (E4-E1)	TMTF8 (E2-E1)	TMTF8 (E3-E1)	TMTF8 (E4-E1)
Chi-Square	2.009	2.331	4.211	4.495	1.711	5.549
df	3	3	3	3	3	3
Asymp. Sig.	.570	.507	.240	.213	.635	.136

Appendix B

Kruskal Wallis H Test (Different parameters of Speech evoked ABR) outcome

	Wave V RE	Wave V LE	V/A Slope RE	V/A Slope LE	f0 RE	f0 LE
Chi-Square	2.518	.858	6.475	.681	2.840	3.144
df	3	3	3	3	3	3
Asymp. Sig.	.472	.836	.091	.878	.417	.370

	H1 RE	H1 LE	H2 RE	H2 LE
Chi-Square	.510	6.309	1.782	6.309
df	3	3	3	3
Asymp. Sig.	.917	.098	.619	.098

Kruskal Wallis H Test (Latency measures of Speech evoked LLR) outcome

	P1 RE	P1 LE	N1 RE	N1 LE	P2 RE	P2 LE	N2 RE	N2 LE
Chi-Square	8.610	1.651	2.435	.425	2.437	3.861	1.527	1.929
df	3	3	3	3	3	3	3	3
Asymp. Sig.	.035	.648	.487	.935	.487	.277	.676	.587

Kruskal Wallis H Test (Amplitude measures of Speech evoked LLR) outcome

	P1N1 RE	P1N1 LE	N1P2 RE	N1P2 LE	P2N2 RE	P2N2 LE
Chi-Square	3.162	1.868	3.832	3.605	4.427	5.327
df	3	3	3	3	3	3
Asymp. Sig.	.367	.600	.280	.307	.219	.149