EFFECT OF TEMPORAL PATTERN TRAINING ON SPECIFIC CENTRAL AUDITORY PROCESSES

Register No: 09AUD003

A dissertation submitted as part of fulfilment of final year

Master of Science (Audiology)

University of Mysore, Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING,

MANASAGANGOTHRI, MYSORE - 570006

June, 2011

CERTIFICATE

This is to certify that this dissertation entitled '***Effect of temporal pattern training on specific central auditory processes',*** is a bonafide work submitted in part of fulfilment for the degree of Master of Science (Audiology) of the student Registration No.: 09AUD003. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any diploma or degree.

Mysore

June, 2011

Dr. S. R. Savithri

Director

All India Institute of Speech and Hearing,

Manasagangothri, Mysore -570006.

CERTIFICATE

This is to certify that this dissertation entitled '***Effect of temporal pattern training on specific central auditory processes',*** has been carried out under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other university for the award of any diploma or degree.

Mysore

June, 2011

Dr. Asha Yathiraj

Guide

Professor of Audiology,

Department of Audiology,

All India Institute of Speech and Hearing,

Manasagangothri, Mysore -570006.

DECLARATION

This is to certify that this master's dissertation entitled '***Effect of temporal pattern training on specific central auditory processes',*** is the result of my own study under the guidance of Dr. Asha Yathiraj, Professor of Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other university for the award of any diploma or degree.

Mysore **Register No. 09AUD003**

June, 2011

Dedicated to

The wonderful subject

(C)APD

Acknowledgments

I would like to extend my prayers and regards to ***Late. Dr. Vijayalakshmi Basavaraj*** *under whose umbrella we have grown gracefully.* ***Madam****, may your soul rest in peace.*

"Teachers lead a person from darkness to light". Words would fall short while I thank ***Prof. Asha Yathiraj****, my guide, my mentor and my inspiration. Madam, I have learnt a lot from you. Thank you for opening the doors of this wonderful subject of (C)APD to me. Thank you for showering all your support and blessings on me.*

I would like to thank ***Prof. S. R. Savithri****, Director, AIISH, for permitting me to carry out this research.*

"Parents are the first teachers for a child". I am thankful to **mumy** *and* ***daddy*** *for providing me with love, affection and quality life. I promise, I will never let you down.*

"Having elder siblings is a boon. You can always learn from their experiences". I am thankful to

my brothers ***Atul*** and ***Amit*** *for their support and care they have shown on me.*

Thanks to the newer members of the family, my ***bhabhis*** *(Shivali and Jyoti) and of course my cute little nephews,* ***Daksh*** *and* ***Divyan.***

Six years in AIISH went in a flash. This would not have been possible without you ***Bhanu****. Thanks for being there in the ups and downs of my life. Thanks for your inexplicable support, both intellectually and emotionally.*

Thanks to ***Brajesh sir*** *for his kind support and guidance in all aspects of life. I have been glad to see through life from your lens. Thank you sir.*

Thanks to ***Biswajeet*** *bhai and* ***Sasmita*** *bhabhi for their support and experienced advices from time to time. You guys made my life simpler. Cheers!*

Thanks to the person who spurred my interest in research for the first time, ***Yatin Mahajan****, my senior, my ally. Thanks Yatin bhai for being there in need.*

*Thanks to Akshay C (****Acky****), Chandan* ***(kaati****), Satbir (****baba****) for the wonderful times we spent together (both on and off the field ;-). God bless you. All the best!*

Shruti *and* ***Varsha****, the duo have played true friends' part whenever I needed them. Thanks to them. We will always cherish these memories.*

Thanks to the tiny tots, ***Ishu, Varun, Uday, Punsiba, Supreet*** *for making life better in here.*

It would go incomplete without mentioning the most happening names of my AIISH life. Thanks ***Muksi, Keerthi and Suman*** *for making the things electrifying in its true sense. You guys rock!!*

Thanks to ***Bharath*** *(audiologist turned engineer) for his technical support from time to time. Cheers ;-)*

I am thankful to ***Ms. Vasanthalakshmi*** *in helping me tackle statistics.*

Thanks to the ***parents*** *for letting their* ***children*** *to participate in this study. Thanks for their co-operation. This work was not possible without their help.*

Thanks to all my classmates for their help and support.

Table of contents

List of Tables

List of figures

INTRODUCTION

Central auditory processing disorder (C)APD is reported to be a complex and heterogenous group of disorders usually associated with a range of listening and learning deficits despite normal hearing sensitivity (Chermak & Musiek, 1992).According to ASHA (2005), the (Central) auditory processes include the auditory mechanisms that underline several abilities or skills. These include sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of audition such as temporal integration, temporal discrimination (e.g. temporal gap detection), temporal ordering, temporal masking, as well as auditory performance with degraded acoustic signal. Deviancy in any of these skills has been noted to result in a (C)APD. Dawes and Bishop (2007) reported that this deviancy in turn could bring about listening difficulties which would result in academic, behavioural, and social difficulties.

Chermak and Musiek (1992) proposed that the management of (C)APD should include modification of the environment, use of compensatory strategies and direct remediation. Environmental modifications included noise abatement, enhanced signal quality via assistive listening technology, changes in the listener's oral presentation and classroom seating options. Compensatory strategies such as addition of visual cues, instructional modifications and changes in the curriculum or assessment process were noted to be useful in children with (C)APD. It was reported that direct remediation activities or deficit-specific intervention programmes should be designed using linguistic or non-linguistic stimuli to improve specific auditory processes.

Direct remediation methods have been divided broadly into two types by Chermak and Musiek (1997) i.e. top-down therapy and bottom-up therapy. According to Ferre (2006),*top-down therapy* is reported to involve the use of the whole gestalt, following which the information is analyzed and broken down into its component parts. Here, functional communication is the goal or focus and so emphasis is on comprehension and taking-in the whole acoustic stimulus as a unit. Top-down approaches, according to Bellis and Anzalone (2008), address higher level central resources such as language, cognitive, memory, and related functions, along with environmental modifications. Richard (2006) reported that a top-down approach is mostly used by the speech-language pathologists.

Further, Richard (2006) opined that a *bottom-up* approach is closely aligned to the perspective of audiological management of (C)APD. For this approach to be used, it was considered necessary that an individual must be aware of the introduction of an acoustic stimulus in the environment. This acoustic stimulus was processed at different hierarchical levels in the auditory system and finally translated using a linguistic code to attach a meaning to the auditory signal. According to Bellis and Anzalone (2008), bottom-up approaches focus on access to and acquisition of the auditory signal and include auditory training as well as environmental modifications to improve the listening environment.

Formal and informal auditory training is yet another way in which direct remedial techniques have been classified for individuals with (C)APD. The classification was proposed by Musiek (1999). Formal auditory training procedures were expected to be conducted by audiologists in a clinic or lab setting that enabled control over stimulus generation and presentation. On the other hand, informal auditory training procedures were activities that could be used in everyday settings that were functionally significant to the patient. This was considered to complement formal auditory training.

Bellis (2003) suggested that intervention for (C)APD should arise logically from the nature of an individual's auditory deficit related to functional difficulties and sequelae. This has also been called as deficit-specific intervention.

Bellis recommended several activities which alleviate a particular central auditory deficit. Training activities that tapped deficits in auditory closure, binaural integration/separation and temporal patterning were proposed. In addition, activities such as missing word exercises, missing syllable exercises, missing phoneme exercises, speech-in-noise training and vocabulary building were also suggested. For binaural integration and separation deficits, activities such as dichotic listening training and localization training were put forth. Bellis advocated activities such as prosody training and temporal patterning training that were considered beneficial in overcoming deficits in temporal patterning.

Several authors (English, Martonik & Moir, 2003; Maggu & Yathiraj, 2011; Priya & Yathiraj, 2007; Putter-Katz et al., 2002) have noted improvement in individuals with (C)APD with the use of deficit specific intervention. The improvement was confirmed using imaging (Temple et al., 2003), electrophysiological (Jirsa, 1992) and behavioural measures (Maggu & Yathiraj, 2011;Musiek, 1999; Musiek & Schochat, 1998; Priya & Yathiraj, 2006; Yathiraj & Mascarenhas, 2003).

Musiek, Shinn and Hare (2002) opined that temporal processing abilities form the foundation of auditory processing, specifically with respect to speech perception.

According to Musiek and Chermak (1995) and Musiek, Pinheiro and Wilson (1980), these abilities include discrimination of differences in auditory stimuli, sequencing of auditory stimuli, gestalt pattern perception, and trace memory. Bellis (2003) found these abilities to be responsible for recognition of the acoustic contour and utilization of the prosodic aspects of speech.

Need for the study

According to Rupp and Stockdell (1978) between 15 % to 20% of school-age population has some type of language/learning disorder, 70% of these had some form of auditory impairment. Further, Chermak and Musiek (1997) estimated that as many as 2% to 5% of the school-age population exhibit (C)APD. In India, 3% of the children have been found to have dyslexia (Ramaa, 1985).A temporal processing disorder has been observed to be one of the most frequently occurring subtype of (C)APD (Chermak & Musiek, 1997; Musiek, Geurkink, Kietel & Hanover 1982; Muthuselvi & Yathiraj, 2009). Muthuselvi and Yathiraj (2009), who studied 3120 school-going children, observed that 6.9% of them were at-risk for (C)APD. They further found that in the 42 at-risk children evaluated on diagnostic tests, binaural integration was most affected (38%), followed by auditory memory (35%), temporal processing (14.2%-16.2%), auditory closure (14-19%) and binaural interaction (2.3%).

Musiek et al. (1982) found that 72.7% of their clients with (C)APD had temporal processing deficit. According to Bellis (2003), children with temporal processing disorders have been shown to have deficits in acoustic contour recognition and thus difficulty recognizing and using prosodic aspects of speech.

Several training procedures have been carried out in the past to improve temporal processing abilities (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, 2002; Yathiraj & Mascarenhas, 2003;). Some studies have used speech based training programmes (Ferre, 1997; Tallal et al., 1996; Temple et al., 2003; Turner & Pearson, 1999) while others have used a combination of speech and tone (Merzenich et al., 1996; Yathiraj & Mascarenhas, 2003). However, there are relatively few studies that have used only tone based material for training (Bellis & Anzalone, 2008; Vanaja & Sandeep, 2002).

Activities such as two-tone ordering and consonant-vowel sequencing have shown improvement in the temporal aspects (Merzenich et al., 1996). Vanaja and Sandeep (2002) studied the impact of discrimination training using pairs of tones differing in durations on long latency response and mismatched negativity responses. However, they did not study the impact of the training on other central auditory processes. Evidence of a speech based training activity improving other processes has been shown by Battin, Young and Burns (2000). They found that the Fast ForWord (FFW) resulted in improvement in the temporal aspects as well as the other central auditory processes such as auditory figure ground and binaural separation. There is a need to check the impact of a non-speech based temporal processing training programme on temporal processing as well as other auditory processes.

Aims of the study

Thus, the study aimed at testing the efficacy of temporal pattern training directly on temporal processes in children with (C)APD, as well as its impact on other central auditory processes (temporal patterning, auditory separation, binaural integration, temporal resolution and auditory memory and sequencing).

REVIEW OF LITERATURE

The primary goal of diagnosis of (C)APD, according to Bellis (2006), is to demonstrate the presence of a disorder and know about the nature of the disorder in order to carry out a deficit specific intervention. (C)APD rehabilitation has been approached in two ways, as a deficit in a language-based phenomenon (Kamhi, 1981, 1984; Rice, 1983) and as an auditory based deficit (Tallal, Stark, Kallman & Mellits, 1981). The latter involves providing direct remediation.

Effect of direct remediation

The impact of direct remediation has been studied using electrophysiological measures as well as behavioural measures. Elbert, Pantev, Wienbruch, Rockstroh and Taub (1995) suggested that neuroplasticity can be induced through experience and stimulation which could lead to reorganisation of the cortex, improved synaptic efficiency and increased neural density. This in turn, could lead to a cognitive and behavioural change. Tremblay, Kraus, McGee, Ponton and Otis (2001) found a change in the N1-P2 complex after speech sound training was provided for 10 normal hearing young adults. The training consisted of a distinction of voice onset time (VOT) from -20 to -10 msec in a /ba/ syllable. After the training, they observed an improvement in distinction between the two variants, both behaviourally and electrophysiologically. Similarly, Tremblay and Kraus (2002) reported of an increase in the amplitude of P1, N1 after training in the right hemispheric region while P2 amplitude change was noted in both hemispherical locations.

Temple et al. (2003) noticed a change in functional magnetic resonance imaging (fMRI) after training children with dyslexia on a Fast ForWord (FFW) programme. They trained children with dyslexia for 100 minutes a day, five days a week, for a period of one month. They found increased activation in the left temporo-parietal cortex and inferior frontal gyrus after the training. Earlier, Jirsa (1992) carried out a training paradigm consisting of a series of activities tapping different areas such as attention, auditory discrimination, speech-in-noise and auditory memory and found that there was a decrease in P3 latency and increase in P3 amplitude compared to pre-training baseline, reflecting the neuroplasticity.

Besides imaging and electrophysiological studies, there have also been accounts of changes in auditory perception following direct remediation. Tallal et al. (1996) reported that progressive, adaptive, and intensive auditory training improved temporal processing and certain language skills. Likewise, other studies (Maggu & Yathiraj, 2011; Musiek, 1999; Musiek & Schochat, 1998; Priya & Yathiraj, 2006;; Yathiraj & Mascarenhas, 2003)) have reported an improvement in various auditory processes following deficit specific intervention for children diagnosed with (C)APD.

Direct remediation using verbal stimuli

Studies using direct remediation on individuals with (C)APD have utilized verbal as well as non-verbal stimuli. The more recent studies have used more of verbal stimuli when compared to non-verbal stimuli. While some of the studies have focused on providing training for specific auditory processes, others do not.

a) Training for binaural integration

Binaural integration has been described to be the ability of a listener to process information presented to both the ears at the same time. This process also involves working memory and divided attention. Poor performance in binaural integration has been noted to result in difficulty in hearing in the presence of background noises or difficulty in listening to two conversations at the same time (Bellis, 1996).

Binaural integration and separation training tasks are considered warranted when deficits are identified during dichotic evaluations. *Dichotic offset training*(DOT) was a remediation technique suggested by Rudmin and Katz (1982) for individuals with deficits in binaural integration. The main objective of DOT was to train a child to differentially integrate two different stimuli which were separately given to both ears. Katz, Chertoff and Sawusch (1984) administered DOT in 10 children aged 7-10 years who demonstrated difficulty on a dichotic test (SSW). The offset lag was reduced from 500 msec to 0 msec in successive sessions. They were given 15 one-hour training sessions. A significant improvement was found on the SSW and speech-in-noise tests but no improvement was found on a phonemic synthesis test.

It was suggested by Musiek, Shinn and Hare (2002) that the DOT procedure could also be modified using temporal offsets that lag in the poorer ear, which may improve the poorer ear performance. It was opined that, gradually, by using adaptive techniques, the offset differentials may be reduced over multiple practice sessions which would allow an improvement in the performance of the good ear and maintain the improvement of the weak ear at a higher level of performance.

Priya and Yathiraj (2007) carried out DOT on 6 children with binaural integration deficits. The training started with an easier offset lag of 500 msec. When the children obtained 70% on double correct scores, the lag was reduced in order to make the task more difficult. This continued till the stimuli were presented simultaneously. The training was provided for 10-15 one-hour sessions. It was found that there was a significant improvement after the training ($p < 0.05$) in all their subjects.

Another form of training for those with auditory integration problems is based on the findings of Musiek, Shinn and Hare (2002) who found that children with APD demonstrated a left ear deficit on dichotic speech tasks. With this finding, Musiek and Schochat (1998) employed an auditory training program which consisted of activities such as intensity training, frequency training, temporal training and dichotic speech perception training, tapping different processes. Dichotic speech perception training involved directing the *stimuli to the stronger ear* at a reduced level. A higher intensity level was presented to the weaker ear through sound field. This sound field condition was considered to provide more cross-over between signals and greater demands on the patient than if the task was conducted under earphones. The stimuli used were words, sentences and consonant-vowel-consonant (CVC) words. Prior to the training, the patient exhibited unilateral mild deficits on dichotic digits and moderate bilateral deficits on the frequency pattern and compressed speech with reverberation test. This activity in the training programme was conducted for 15 to 20 minutes per session, once or twice per week for a duration of 6 weeks. The authors found an improvement in the left ear scores in a dichotic task following this activity.

A similar form of training, developed for individuals with binaural integration deficits, is *dichotic interaural intensity difference (DIID) training*. The efficacy of DIID has been described by Schochat, Musiek, Alonso and Ogata (2010) and Moncrieff and Wertz (2008). Schochat et al. (2010) studied the effect of an auditory training programme on MLR amplitudes in 30 children with (C)APD. The training programme consisted of a DIID training and was carried out for a duration of 8 weeks. The authors found a significant increase in the MLR amplitude as well as improvement in the behavioural scores following the training. Using the same training material, Moncrieff and Wertz (2008) studied the effect of DIID in two groups of children with (C)APD. The first group consisted of 8 children in the age range of 7 to 13 years who had got lower scores on (C)APD tests. The second group consisted of 13 children with (C)APD, who had a listening comprehension equivalent to first grade student, as measured on Brigance comprehensive inventory of basic skills - revised (Brigance, 1999). They found that in both the groups, there was an improvement in left-ear scores following the DIID training. However, in the first group, 8 to 11 sessions were required, while in the second group, 12 to 24 training sessions were required to bring about an improvement. This difference was attributed to the heterogeneity in factors such as motivation, attention and language skills.

English, Martonik and Moir (2003) studied the effect of *left-ear only stimulation*on 10 children with reduced left ear scores on the dichotic digit test. In addition to dichotic listening deficits, the subjects had problems in auditory discrimination, auditory sequential memory, and temporal resolution. The training continued for one hour per week for 10-13 weeks. It was found that the left-ear only stimulation led to an increase in the left ear scores on the dichotic digit test.

It is thus evident that different techniques have been used to train individuals with auditory integration problems. All the approaches have been reported to result in improvement in auditory integration.

b) Training for auditory figure-ground/auditory separation/auditory closure

Auditory figure-ground refers to the ability of a person to auditorially attend to a designated stimulus and not be distracted by a background noise (Terry, 2001). Figure-ground or competing sound stimuli often represent serious learning problems in individuals. It has been observed that the listener's attention is easily distracted from the signal in the presence of extraneous, irrelevant sounds.

Another difficulty reported to be seen in individuals with a problem in perceiving in the presence of noise is *auditory closure*. It has been defined as the ability of the listener to utilize extrinsic and intrinsic redundancy to fill-in missing or distorted portions of auditory signal and recognize the whole message. Deficit in auditory closure have been found to lead to difficulty in understanding speech in background noise or with unfamiliar speakers (Bellis, 1996).

According to Bellis (1996), the purpose of *auditory closure activities* is to assist children in learning to fill-in the missing parts of a message in order to enable them perceive a meaningful whole. It was suggested that context plays an important role in auditory closure, since prediction of a complete word or message often depends on the surrounding context. Several exercises were suggested by Bellis to treat children with deficit in auditory closure. These included missing word exercises, missing syllable exercises, missing phoneme exercises and vocabulary building. A variety of activities were suggested for each of the above exercises. Suggested activities for the missing word exercises consisted of familiar songs or rhymes, prediction of rhyming words and filling in the missing words. For missing syllable exercises, the proposed activities consisted of presentation of sentences with target word embedded in it, both in quiet and noisy or distracting situations. In order to build vocabulary in children with (C)APD, the activities suggested were reauditorization and derivation of word meaning from the context. Though Bellis suggested several activities to help individuals having difficulty with auditory closure, their utility was not established.

In order to bring about improvement in auditory figure-ground perception, training techniques have been described. According to Heasley (1980), the development of auditory attention and attention span helps the listener to attend to the desired message while ignoring other sounds. It was recommended that initially the child should be asked to listen and repeat two or three words in the presence of soft background noise heard from a record player or radio. Then the task was made difficult by asking the child to repeat short sentences and asking questions in the presence of gradually louder extraneous sounds. The next step was to tell a story in the presence of background sound that could be controlled for loudness or softness, after which questions related to the story were asked. A system of timed reinforcements was recommended. Though Heasley described the training procedures, the outcome from such training was not provided.

Putter-Katz et al. (2002) studied 20 children who had auditory processing problems who complained of difficulty in understanding verbal stimuli in the presence of noise or competing speech. The children were provided 45-minute treatment session per week for over a 4 month period (i.e. 13-15 sessions). The management programme focused on environmental modification techniques, remediation techniques and compensatory techniques. The children, who had deficit only in the speech-in-noise test, showed an improvement of approximately 10% following therapy. However, the improvement was seen only in the right ear and not in the left ear. In contrast, children who had poor performance in both the speech-in-noise test and dichotic listening tasks showed 15% of improvement on auditory separation tasks such as speech-in-noise and competing sentences.

Maggu and Yathiraj (2011) carried out a noise desensitization training programme on 5 children with poor speech-in-noise scores. These children were trained for speech comprehension in the presence of various types of noises for 15-20 sessions with each session lasting for 25-30 minutes. The training paradigm moved from an easier listening condition to a more difficult condition by decreasing the SNR successively. They found a significant improvement in the speech comprehension in the presence of noise, both in sound field and under headphone, following the training.

It can be observed that auditory figure-ground training/auditory separation and auditory closure activities are recommended for individuals who have difficulty in listening in the presence of noise. Several suggestions have been put forth to improve auditory perception for such individuals. However, not all the suggestions have been evaluated to confirm their utilities.

c) Training for temporal processing

A temporal processing disorder is observed to be one of the most noted sub-types of (C)APD (Chermak & Musiek, 1997; Musiek et al., 1982; Muthuselvi

&Yathiraj, 2009). A few training procedures have been carried out in the past to improve temporal processing abilities (Alexander & Frost, 1982; Merzenich et al., 1996; Tallal et al., 1996).

Alexander and Frost (1982) reported about an auditory training programme using decelerated speech that time expanded 60-80 ms the transitions by 60 – 80 ms. It was documented that this technique brought about improvement in auditory discrimination in children with language disabilities.

Tallal et al. (1996) used a similar auditory training paradigm as Alexander and Frost and studied language comprehension in seven children with LLI. They studied the effect of training on them by using temporally modified speech. The children received the training in the form of games. In the first stage, the duration of speech signal was prolonged by 50% while preserving its spectral content and natural quality. In the second processing stage, fast (3 to 30 Hz) transitional elements of speech were differentially enhanced by as much as 20 dB. Training exercises were conducted for 3 hours a day, 5 days a week, at the laboratory. In addition they did homework for 1 to 2 hours a day, 7 days a week, over a 4 week period. The children with LLI were between 1 and 3 years behind their chronological age in speech and language development, based on their pre-training scores. After training, scores improved by 2 years with the children approaching or exceeding normal limits for their age in speech discrimination and language comprehension. A similar study was carried out by Tallal et al. on 22 subjects with LLI and the results were found to be similar as the first study. They demonstrated that training children with speech stimuli in which the brief, rapidly changing components had been temporally prolonged and emphasized, coupled with adaptive training exercises designed to sharpen temporal processing abilities, resulted in a dramatic improvement in receptive speech and language in children with LLI.

Merzenich et al. (1996) studied temporal processing in language learning impaired (LLI) children. For training, two audio visual (AV) games were designed. The first AV game was a perceptual identification task and the second game was phonetic element recognition exercise. The first trial of these games was conducted with seven 5.9 to 9.1 year old children with LLI. Training was given for 19 to 28 training sessions of 20 minutes each conducted over a four week training period. Tallal repetition test (1980) was conducted before and after the training and it revealed a statistically significant improvement in the temporal event recognition and sequencing abilities. A second study by Merzenich et al. was conducted on 11 children with LLI. The pre and post training group differences were again significant. This study strongly indicated that the fundamental temporal processing deficits of children with LLI can be overcome by training.

Using the recommendations of Tallal and group, 'Fast ForWord' (FFW), a commercially available programme that used temporal based activities was developed. This computer software programme was designed to build listening, speaking, and reading skills in children with language learning impairment (LLI) (Scientific Learning Corporation, 1999). The FFW consists of seven computer games which incorporate acoustically modified speech in exercises to improve language decoding skills of children with language learning impairments. It is reported to help them to discriminate subtle sound differences. The signals were digitally manipulated to increase the duration and intensity of certain phonemes or transition elements that have been previously identified to cause processing problems with specific language impairment. Each successive level of the game reduces the parameters by which the signals are modified until the fifth level of each game where the signal reflects the dynamics of normal adult's conversational speech patterns.

The utility of FFW was studied by Turner and Pearson (1999). They reported four case studies of children diagnosed with a language-learning impairment in receptive phonology, listening comprehension, or general language abilities. They used FFW language for one hour and forty minutes, 5 days a week for about a 6 to 8 week period. The training programme consisted of seven individual training exercises consisting of three sound and four word exercises. The sound exercises present auditory information in a pre-word format using different frequencies, times, deviations and phonemes. As a child's performance improved, the degree of speech processing progressed from level 1 to level 5. Level 5 contained natural, unmodified speech. Once a child reached the criteria for dismissal from training, post-evaluation was done. The results demonstrated that FFW did not aid each child in the same area or in the same degree. Some children exhibited great improvement after completing FFW, but other children show only minimal improvement. It was noted that success of a child's participation was based on many factors and the selection criteria were extremely important.

Temple et al. (2003) trained 20 children with dyslexia on FFW for 100 minutes a day, 5 days a week, for almost a month. They found a significant difference between the pre and post training fMRI. Despite these convincing findings, the overall efficacy of FFW has been challenged for several reasons. Friel-Patti, Loeb and Gilliam(2001) and Gilliam, Loeb and Friel-Patti(2001) argued that FFW did not truly train temporal processing. They observed that no clear relationship was established between several indirect measures of temporal processing (eg. perception of backward masked speech) and treatment using FFW.

Musiek (2005) proposed the use of a game called SIMON™ to treat temporal processing deficits. The training involves different stages of difficulty, starting with simple sequencing tasks and progressing to more complicated temporal ordering tasks based on a patient’s success. However, utility of the approach was not reported.

Several programmes have utilized phoneme sequencing and sound blending activities which enhance the speech-sound discrimination as well as patterning skills. Such activities have been included in programmes such as the Phoneme synthesis programme (Katz & Fletcher, 1982), Processing power (Ferre, 1997), and the Lindamood-Bell Phoneme Sequencing (LiPS) programme (Lindamood-Bell Learning Processes, 1998). Bellis (2003) emphasizes the use of a hierarchy of activities from simple discrimination of non-speech stimuli to linguistic stimuli with improvement in the patterning skills of a child with temporal patterning deficit.

From the above studies it is evident that training using temporally altered speech does bring about an improvement in language development. Thus, it can be construed that direct remediation techniques bring about an improvement not only in the process being targeted, but brings about a global improvement in the language development of children having LLI.

Direct remediation using non-verbal stimuli for temporal based training

While most of the studies have focused on speech based training programmes, there are relatively fewer studies which have used exclusively non-speech programmes. Chermak and Musiek (2002) suggested the use of non-speech stimuli for intensity, frequency training and temporal training of individuals with (C)APD. They, however, did not report the outcome of using such training. Musiek and Schochat (1998), in a patient with (C)APD, implemented temporal patterning activities along with other training procedures. They utilized intensity, frequency and temporal training using both non-speech and speech based material. The intensity training consisted of discrimination tasks while temporal training consisted of gap detection training. In the frequency training tasks, the patient was asked to detect the frequency modulations, discriminate among two tones with different frequency modulations and to tell if there was a change when a frequency tone swept from lower to higher frequencies and *vice versa*. These activities were carried out for a duration of 6 weeks. It was observed that the training resulted in improvement of all the processes.

Yathiraj and Mascarenhas (2003) also studied the impact of deficit specific intervention on 5 children with (C)APD. Besides providing training for duration pattern recognition they also imparted training for auditory integration, auditory separation, and auditory memory and sequencing. Training for duration pattern recognition included both non-verbal (pure tones) and verbal material (vowels). They employed DOT for deficits in auditory integration and noise desensitization for deficits in auditory separation. Memory games for auditory memory and sequencing were used. They had found a significant improvement in all the processes following the training procedure. They obtained a significant improvement in auditory integration and auditory memory and sequencing at a 0.01 level and a significant improvement ($p < 0.05$) in duration pattern recognition and auditory separation.

The impact of discrimination training in 2 children with learning disability was studied by Vanaja and Sandeep (2002). They employed pairs of tones differing in durations for training. The latency of long latency response (LLR) and mismatched negativity (MMN) of the children were compared prior to and following therapy. They reported that there was a reduction in latency of LLR and MMN waves in both their participants.

For a child with temporal patterning deficit, Bellis and Anzalone (2008) used a programme in which they varied duration and frequency of a two-tone stimulus in a graded manner. After the training, they found a significant improvement on frequency pattern and also confirmed its maintenance after a year of training. Another non-verbal auditory training procedure was used by Kujala et al. (2001) on 48 children who were 7 years old and at-risk for dyslexia. Training was conducted for 10 minutes twice a week for a total of seven weeks. The training stimuli consisted of sound elements which varied in frequency, intensity or duration. After the training they reported of considerable improvement in the MMN amplitude as well as reading abilities. Thus, studies providing training to improve temporal processing using non-verbal material are relatively few. A few of the studies (Musiek & Schochat, 1998; Yathiraj & Mascarenhas, 2003) have used non-verbal temporal training along with other forms of training, thus making it difficult to conclude about the impact of any once process alone. The studies that have used solely non-verbal temporal based training (Bellis & Anzalone, 2008; Vanaja & Sandeep, 2002) have utilized just one or two participants, thus making it difficult to generalize the findings. Thus, there is a need to study this aspect further.

From the overall review of literature, it is evident that training of children with (C)APD has gained momentum since the last three decades. While several therapy strategies have been suggested for various processing problems, not all of them have been used to confirm their utility. Further, studies substantiating improvement with specific training programmes are relatively few. Hence, there is a need to carry out further studies in this area.

METHOD

The present study was undertaken to investigate the effect of temporal pattern training on various central auditory processes in children with (C)APD. The study was carried out in three stages. In the *first stage*, participant selection and baseline evaluation (evaluation-I) were carried out. In the *second stage*, the participants in the experimental group were provided training while those in the control group were not given any training. In the *third stage*, tests were administered to evaluate the effect of training.

Participants

Two groups of participants, an experimental and a control group, were studied. Each group had five participants whose age ranged from 8 to 13 years. The participants were randomly assigned to the above two groups. The participants included those who did not pass the 'Screening checklist for auditory processing', (SCAP) developed by Yathiraj and Mascarenhas (2002, 2004) and had poor scores on the duration pattern test (DPT) developed by Gauri and Manjula (2003). All the participantsstudied in schools where the medium of instruction was English; had pure-tone air conduction and bone conduction thresholds within 15 dB HL from 250 Hz to 8000 Hz and 250 Hz to 4000 Hz, respectively; had Type A tympanograms and acoustic reflexes present between 90 to 100 dB HL; had speech identification scores above 90% on 'Speech test material in English for Indians', developed by Chandrashekhar (1972); had no report of any speech and language problems; and had Intelligence Quotients between 90 and 110 on the Raven's coloured progressive matrices (Raven, 1956).

The experimental group was provided with the temporal pattern training while the control group was not given any training. A written consent was taken from the caregivers prior to the evaluation.

Material

The training material included non-speech stimuli i.e. tones of 250 Hz, 1kHz and 4 kHz, representing low, mid and high frequency signals. The tones were of different durations with a constant inter-tone interval of 250 msec. A hierarchy of training material developed, consisting of 2-tone, 3-tone and 4-tone activities. The tones were generated using Adobe audition version 3.0 software. The intensity of the signals was maintained at 60 dB SPL. The duration of the tones ranged from 250 msec to 500 msec. The lower limit of 250 msec was selected based on the duration used in the DPT (Gauri & Manjula, 2003). Details of the training material are provided in appendix I.

To determine the minimum temporal difference required by a person for the perception of temporal order among tones, a pilot study was conducted. This was carried out on 5 normal hearing adults and 5 normal hearing children in the age range of 18 to 25 years and 8 to 13 years, respectively. The tones having frequencies of 250 Hz, 1kHz and 4 kHz at 60 dB SPL were generated and presented through Adobe audition version 3.0 software. The participants had to identify the temporal order of the tones. It was found that both groups required at least 75 msec difference between the two tones for perception of temporal order.

Instrumentation

A calibrated dual channel diagnostic audiometer, OB 922 (version 2) with air conduction (TDH-39) and bone conduction (B-71) transducers was used to carry out pure-tone audiometry, speech audiometry and the (C)APD tests. A calibrated immittance meter (GSI Tympstar) was used to ensure the presence of normal middle ear function. The CD version of the test material was played through a Dell Vostro laptop with Intel Celeron processor. Adobe audition 3.0 was used for the presentation of the training material monaurally using headphones. The output level from the headphones was measured using a 'Larson Davis systems 824' sound level meter equipped with a ½" free-field 2540 microphone. The volume control of the software and that of the computer were manipulated so that output from the headphone was approximately 60 dB SPL.

Environment

All the evaluations were carried out in an acoustically treated two-room situation which met the specifications of ANSI S3.1 (1999). The training was given in a quiet, distraction free environment.

Procedure

Stage I

Procedure for selection of participants

Screening for the presence of (C)APD was carried out on school-going children aged 8 to 13 years. Teachers who had taught the children for at least one year were asked to identify those with a suspected (C)APD using the SCAP. The checklist was scored on a two point rating scale. Each answer marked ‘Yes’ was scored ‘1’ and each ‘No’ was scored ‘0’.

Those children who obtained less than 50% scores on the SCAP, the cut-off value that indicates the suspicion of (C)APD, were tested for their temporal patterning skills, using DPT. Their responses were compared with the norms developed by Gouri and Manjula (2003). Those who got scores lower than the normative were included in the study. Baseline evaluation (Evaluation-I) was carried out on these children on 4 additional (C)APD tests to assess different central auditory processes. The tests included SPIN developed by Yathiraj, Vanaja and Muthuselvi(2010) which evaluated auditory separation; Dichotic CV test developed by Yathiraj (1999) to determine auditory integration; Gap Detection Test (GDT)developed by Shivaprakash and Manjula (2003), to obtain the information on temporal processing abilities; and Auditory Memory and Sequencing Test (AMST) developed by Yathiraj and Mascarenhas (2003)to determine auditory memory skills.

The SPIN, Dichotic CV, GDT and AMST tests were administered using the CD version of the tests which were played on a computer. The output from the computer was routed through the audiometer. The outputs of the all tests were presented through the headphones, except AMST which was presented through sound-field speakers.

The *SPIN*testwas presented monaurally at 0 dB SNR at 40 dB SL (ref. SRT). Verbal responses of the participants were noted. A correct response was given a score of ‘1’ and an incorrect response a score of ‘0’. Similarly, in the *GDT*, the signals were presented monaurally at 40 dB SL (ref. PTA). The participants were required to indicate as to which set of noise bursts in a triad contained a gap. The minimum gap duration which the participants were able to detect was compared with norms given by Chermak and Lee (2005). For both these tests (SPIN and GDT), half the participants were initially tested in the right ear while the other half were tested in the left ear, to avoid any ear order effect.

For the*Dichotic CV test*, the stimuli werepresented at 40 dB SL (ref. SRT) and the participants were asked to repeat the syllables which were heard through headphones. Their oral responses were noted by the experimenter. Their right ear, left ear and double correct responses were scored and compared with the norms given by Krishna and Yathiraj (2001).

Stimuli for the *AMST*were presented through a loudspeaker in a sound-field condition at 40 SL (ref. SRT). The loudspeaker was placed at a 45^0 azimuth at a distance of one meter from the head of each participant. The participants were asked to repeat the words heard by them. Their oral responses were later scored by the experimenter. A score of '1' was given for each correctly repeated word to calculate the auditory memory score. Also, sequencing score was calculated by awarding an additional score of '1' when an item was in the correct order. The responses were compared with age appropriate norms developed by Devi, Sujitha and Yathiraj (2008).

Stage II

The children in the experimental group were trained using the hierarchical material that was developed. The training started with easy tasks (level 1a) and gradually proceeded to more difficult tasks (level 3e) (AppendixI). The material was played through a computer loaded with Adobe audition (Version 3.0) software. The participants heard the stimuli through headphones, in a monaural condition at approximately 60 dB SPL. In half the participants, the training commenced in the right ear while for the other half it was commenced in the left ear. This was done to avoid any ear order effect. Only after the completion of training in both the ears at a particular level of difficulty, was the next level of difficulty commenced.

The participants were trained initially using a discrimination task followed by an identification task. This was done at each level of difficulty. In the discrimination tasks, the children had to say whether the tones were same or different while in the identification task they were expected to repeat the pattern of the tones verbally (eg. long-short-long). In order for a child to progress to a higher level of training activity, he/she had to correctly perform on both the discrimination and identification tasks at least 80% of the time.

Stage III

After the training, the experimental group was tested using the same five tests as used in evaluation-I. The control group was also evaluated 3-4 weeks after the initial evaluation. The order in which the tests were administered during evaluation II for each participant was the same as that of evaluation-I. This was adopted to avoid any test order effect.

Test retest reliability

Test-retest reliability was conducted on 40% of participants (2 from each group). All tests were administered on these participants after a period of 1 month after evaluation-II.

Statistical analysis

The scores on the five different processes (auditory separation, binaural integration, temporal resolution, temporal patterning and auditory memory and sequencing) obtained by 10 children with (C)APD were analysed using SPSS (version 19) software. Besides descriptive statistics, Mann Whitney U test was used to compare the performance of the two groups within the two evaluations. Further, in order to compare the scores for each group across the two evaluations, Wilcoxon test was used.

RESULTS AND DISCUSSION

The outcomes of the statistical analyses are compared and discussed in terms of the scores obtained across evaluation I and II; scores obtained across the experimental and control groups; and scores obtained across evaluation II and III.

I) Comparison across evaluation I and II

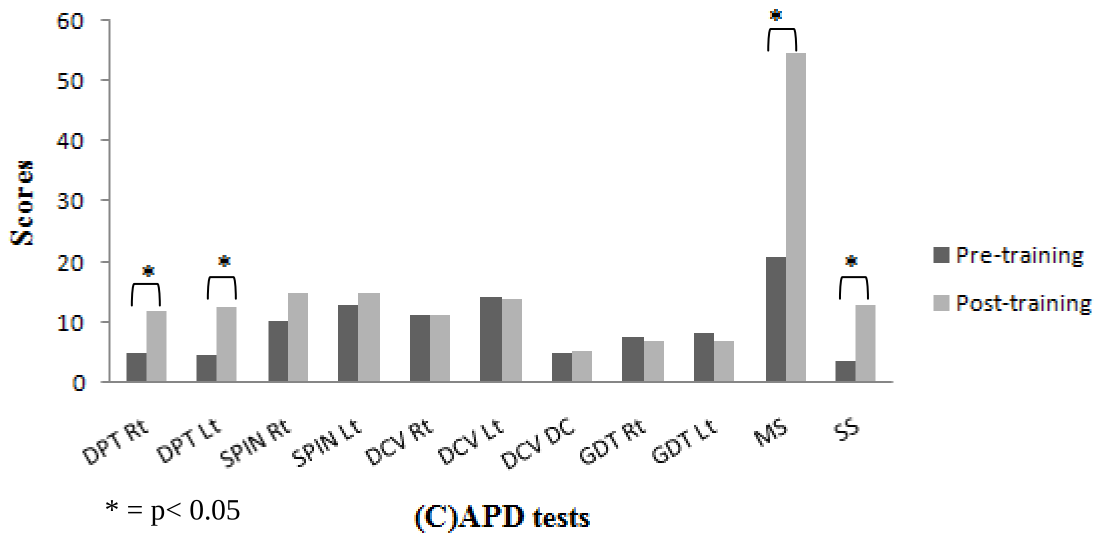
In order to check the impact of training, the scores obtained in evaluation I were compared with that obtained in evaluation II. This was done for each of the groups i.e. those who underwent training (experimental group) as well as those who did not undergo training (control group). It can be observed from Table 1 and Figure 1 that the mean values differed considerably across the two evaluations for the experimental group, but not so for the control group. To check whether these differences were statistically significant or not, Wilcoxon signed ranks test was carried out.

In the *experimental group*, the Wilcoxon signed rank test revealed that there was a significant difference at the 0.05 level for the scores obtained on the DPT and the AMST while there was no significant difference on the other tests (Figure 1). In the *control group*, there was no significant difference between the scores obtained across the two evaluations on all the tests, as per the outcome of the Wilcoxon signed rank test (Figure 2).

Table 1.*Mean and Standard deviation (SD) for each test for evaluation I and II across groups.*

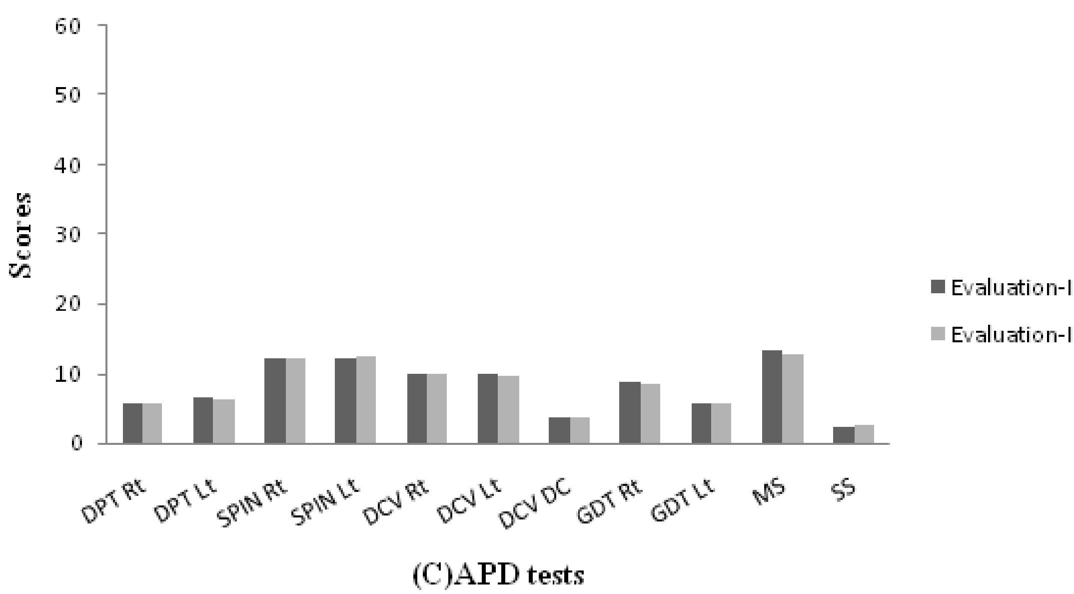
Tests	Ear/ Score	Eval	Experimental group (E)		Control group (C)		E-C difference
			Mean score	**S. D.**	**Mean score**	**S. D.**	
DPT [f]	Right	I	5 (16.6%)	1.87	5.6 (18.7%)	3.04	-2.1%
		II	12 (40%)	2.91	5.6 (18.7%)	3.04	31.3%
	Left	I	4.8 (16%)	2.48	6.4 (21.3%)	1.14	-5.3%
		II	12.6 (42%)	3.28	6.2 (20.6%)	1.3	21.4%
SPIN [¤]	Right	I	10.2 (40.8%)	6.18	12.2 (48.8%)	5.8	8%
		II	15 (60%)	4.79	12.2 (48.8%)	5.8	11.2%
	Left	I	12.8 (51.2%)	7.69	12.2 (48.8%)	4.38	2.4%
		II	15 (60%)	7.71	12.4 (49.6%)	4.15	10.4%
DCV [f]	Right	I	11.4 (38%)	6.22	10 (33.3%)	5.24	4.7%
		II	11.4 (38%)	6.22	10 (33.3%)	5.24	4.7%
	Left	I	14.4 (48%)	6.98	10 (33.3%)	5.09	14.7%
		II	14 (46.6%)	6.70	9.6 (32%)	4.44	14.6%
	DCS	I	5 (16.6%)	4.35	3.6 (12%)	2.88	4.6%
		II	5.2 (17.3%)	4.14	3.6 (12%)	2.88	5.3%
GDT	Right	I	7.6 ms	1.67	8.8 ms	0.89	--NA--
		II	6.8 ms	2.28	8.6 ms	0.89	--NA--
	Left	I	8.2 ms	2.16	5.8 ms	1.30	--NA--
		II	7 ms	2.73	5.8 ms	1.30	--NA--
AMST	MS [α]	I	21 (17.7%)	8.21	13.2 (11.2%)	3.03	6.5%
		II	54.8 (46.4%)	11.5	12.8 (10.8%)	3.19	35.6%
	SS [α]	I	3.6 (3.0%)	1.34	2.4 (2.03%)	2.50	0.97%
		II	12.8 (10.8%)	4.81	2.8 (2.4%)	2.88	8.4%

Note: Eval= Evaluation;Maximum possible score:f =*30*, ¤= 25, α= 118



Note: DPT: Duration pattern test, SPIN: Speech-in-noise test, DCV: Dichotic CV test , GDT: Gap detection test, AMST: Auditory memory and sequencing test,

Figure 1. Comparison of evaluation-I and II within the experimental group

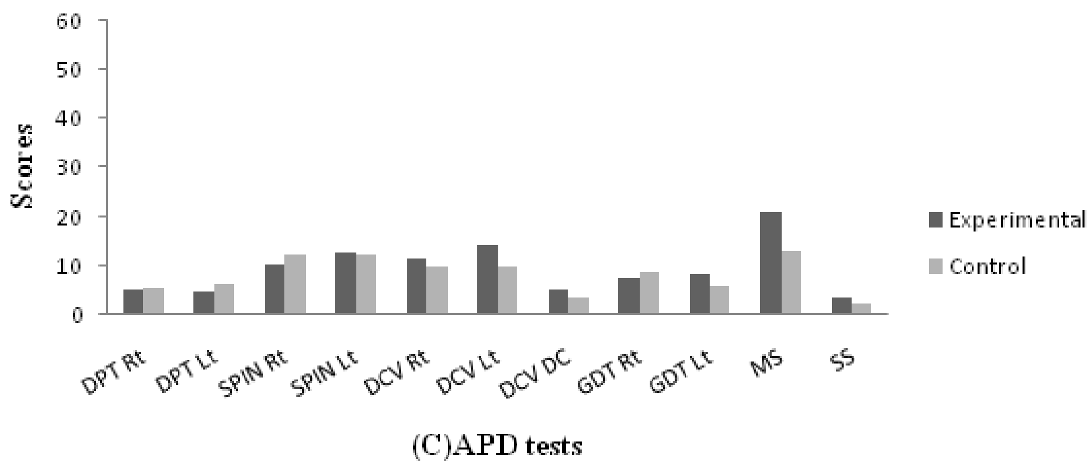


Note: DPT: Duration pattern test, SPIN: Speech-in-noise test, DCV: Dichotic CV test , GDT: Gap detection test, AMST: Auditory memory and sequencing test,

Figure 2. Comparison of scores across evaluation-I and II within the control group

II) Comparison across the experimental and control groups

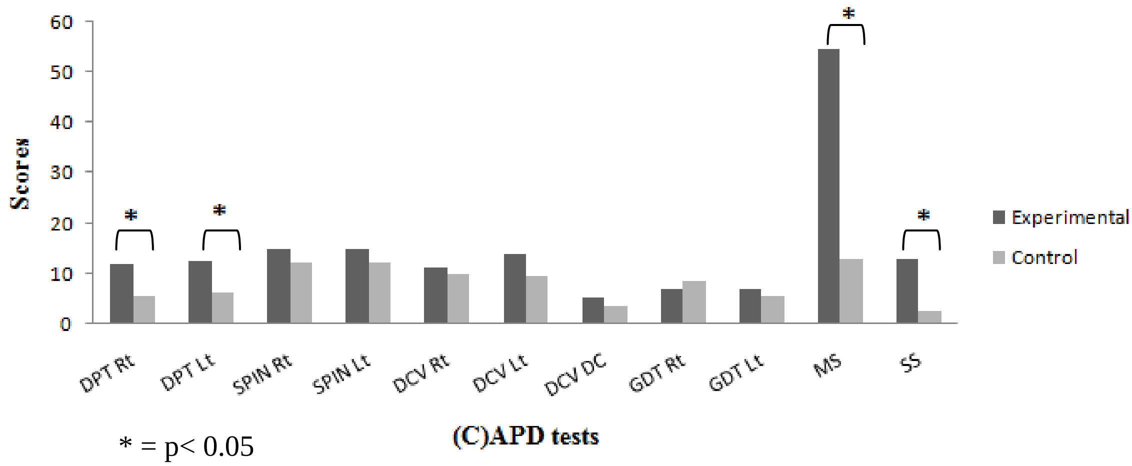
To further ensure that the improvement in the scores for the various processes was due to training, a comparison of both participant groups (experimental & control) was carried out. The two groups were compared on the various tests, before the training (evaluation I) and after the experimental group underwent a training (evaluation II). It is evident from Table 1 and Figure 3 that there was no significant difference between the two groups at the initial stage of the study (evaluation I). However, after training was provided to the experimental group, there was considerable change in the scores of the two groups (Table 1 & Figure 4). Mann Whitney U test was carried out to check whether these differences were statistically significant.



Note: DPT: Duration pattern test, SPIN: Speech-in-noise test, DCV: Dichotic CV test , GDT: Gap detection test, AMST: Auditory memory and sequencing test,

Figure 3. Comparison of scores across experimental and control group for evaluation-I.

The Mann Whitney U test revealed that there was no significant difference between the experimental and control group for any of the tests during the evaluation-I (baseline evaluation). In contrast, there was a significant difference obtained between the two groups after the training paradigm. The significance was noted at the 0.05 level on DPT and AMST. Although improvement appeared on other tests too, it was found to be insignificant.



Note: DPT: Duration pattern test, SPIN: Speech-in-noise test, DCV: Dichotic CV test , GDT: Gap detection test, AMST: Auditory memory and sequencing test,

Figure 4. Comparison of scores across the experimental and control group in the evaluation-II

The positive *impact of temporal pattern training on temporal processing* was evident from the fact that there was a significant improvement in the DPT scores following training. This improvement can be attributed to the implementation of a temporal based deficit specific intervention. This goes to confirm that direct remediation does have an influence on the process being targeted. The finding of the present study is in agreement with that of Bellis and Anzalone (2008) who found considerable improvement in the scores of a participant on a frequency pattern test following temporal pattern training.

The *impact of temporal pattern training on other central auditory processes* was apparent from the significant improvement seen in the scores on the AMST following training. This improvement was seen for both the memory sub-test as well as the sequencing sub-test. It can be construed from this finding that temporal pattern training using non-verbal material, has a positive effect on auditory memory and sequencing. This would have occurred due to the relation between the temporal patterning and auditory memory which has been suggested by several authors (Pinheiro & Musiek, 1985; Benaish & Tallal, 1996). Pinheiro and Musiek (1985) proposed that temporal patterning and auditory memory and sequencing may share the same neurophysiologic process. The relationship between temporal processing and memory was also perceptible from the findings of Benaisch and Tallal (1996). They reported that infants aged 6 to 10 months with a positive family history of language impairment, had poor temporal processing thresholds and recognition memory. These infants had been evaluated to determine their temporal processing threshold, habituation and recognition memory.

The influence of temporal processing on other domains has also been reported in literature. Tallal et al. (1996) noted that temporal processing abilities could be improved through training and this in turn led to an improvement in language and literacy skills. They employed the use of acoustically modified speech and found that this resulted in an improvement in speech discrimination and language comprehension skills.

The findings of studies dealing with individuals with dyslexia also throw light on the association between temporal based training and other processes. Habib et al. (2002) found temporally modified speech to result in improvement in phonological abilities which in turn correlated with temporal order judgment. Likewise, Overy (2003) observed that music training, administered on children having dyslexia with deficits in timing, brought about improvement in other processes. Rapid auditory processing was one of the processes that improved.

Thus, it can be concluded from the findings of the present study and from those discussed above that temporal based training could bring about an improvement in other processes, including auditory memory. The current study reveals that providing temporal based training can bring about improvement in both auditory memory and auditory sequencing. However, such training does not result in improvement in other processes such as auditory integration and auditory separation. It is speculated that these processes are more dependent on acoustic parameters other than temporal cues.

III) Comparison of scores across evaluationsII and III

Four participants, two each from the experimental (participants A and B) and control group (participants C and D) were taken to check the maintenance of training after a gap of 1 month following evaluation-II. It was noticed that the scores on the various tests remained almost constant for the participants from both the groups.

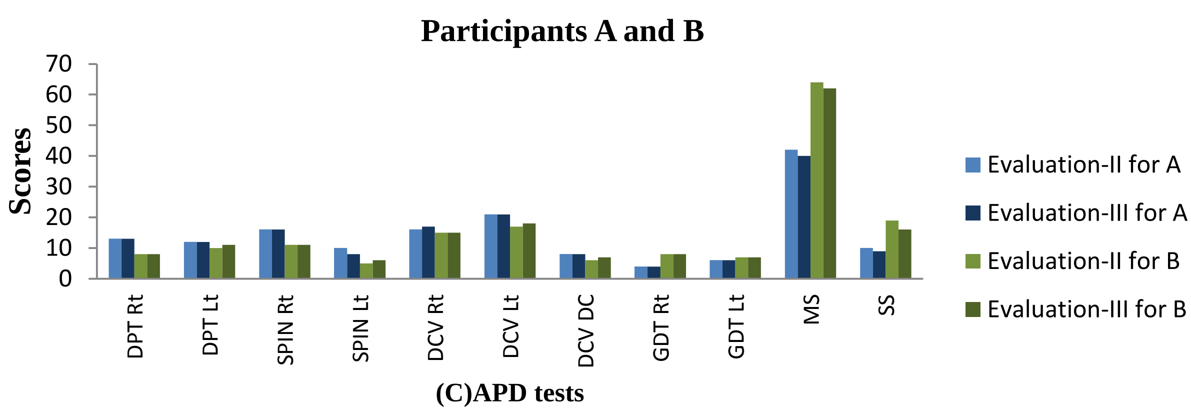


Figure 5. Comparison of scores of participants A and B across evaluation II and III

Figure 5 depicts the scores of two participants from the experimental group who were evaluated on the same set of tests as in evaluation-I and II, after a gap of one month following the training. It can be observed that the effect of training was maintained even after a month of termination of the training. The scores on the various tests remained almost constant.

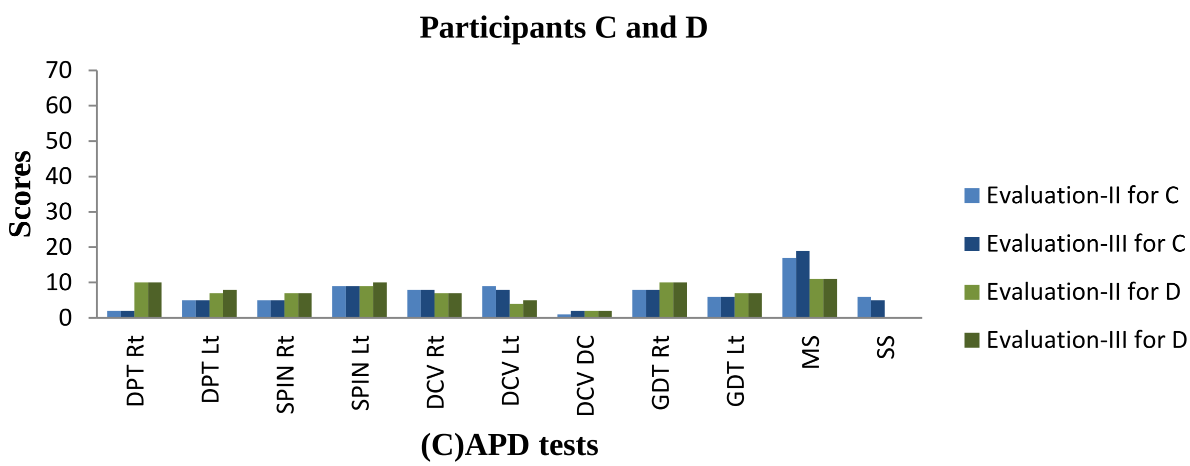


Figure 6. Comparison of scores of participants C and D across evaluation II and II

Similarly, Figure 6 shows the scores of two participants who were randomly selected from the control group. It was found that there was not much change in the scores obtained in evaluation III compared to that obtained in evaluation-II.

The above finding shows that the effect of training is maintained even after one month after the cessation of therapy. From the findings, it can also be noted that without training, scores obtained on different auditory process tests, do not improve. Further, the findings confirm the reliability of the scores obtained in evaluation II.

Thus, from the findings of the present study it can be concluded that the temporal pattern training brings about an improvement in the individuals with deviant temporal processing. Along with the improvement in temporal pattern processing, the training also positively influenced the auditory memory and sequencing abilities of the participants who underwent temporal pattern training, affirming its effect on other central auditory processes. The study also brought to light that the positive effects of training are maintained even after a month following the cessation of the therapy. Hence, it can be construed that temporal pattern training is useful in improving not only temporal processing but also auditory memory and sequencing.

SUMMARY AND CONCLUSIONS

Studies have shown the presence of a notable prevalence of (C)APD in children (Chermak & Musiek, 1997; Muthuselvi &Yathiraj, 2009). To help such children, various strategies have been put forth. Several authors have recommended the use of deficit specific intervention using verbal material (Merzenich et al., 1996; Tallal et al., 1996; Temple et al., 2003; Turner & Pearson, 1999). However, very few studies report the employment of non-verbal material for intervention (Bellis & Anzalone, 2008; Vanaja & Sandeep, 2002).

The present study aimed at studying the effect of temporal pattern training on various central auditory processes in children with (C)APD. Ten children aged 8 to 13 years,who had deviant scores on 'Screening Checklist for Auditory Processing' and duration pattern test, were included in the study. Baseline evaluation (evaluation-I) was done using the gap detection test, speech-in-noise test, dichotic consonant-vowel test and auditory memory and sequencing test. These participants were randomly divided into anexperimental and control group. The experimental group received temporal pattern training while the control group did not receive any training. The training material, consisting of tones of various frequencies, was developed as a part of the study. It contained a hierarchy of activities that were designed after a pilot study. Using the developed material the participants were trained for 19 to 25 sessions, depending upon the abilities of the children.

Wilcoxon signed rank test revealed a significant difference within the experimental group when the scores got on evaluation I (pre-training scores) were compared with the scores got on evaluation II (post-training scores). However, no such difference was observed for the control group who did not undergo any training. Also, Mann Whitney U test was administered between the two groups of participants. This was done separately for evaluation I and evaluation II. It was found that there was a significant difference between the groups in evaluation II, but not in evaluation I. The difference between the groups in evaluation II was attributed to the training the experimental group had undergone.

Thus, from the present study, it can be concluded that:

- Non-verbal auditory training leads to an improvement in central auditory processing,
- Temporal pattern training leads to an improvement in the temporal patterning process and thus is a useful deficit specific intervention strategy,
- Temporal pattern training not only improves the temporal patterning processing but also improves auditory memory and sequencing abilities,
- The improvement in the auditory memory and sequencing scores with temporal pattern training reveals a link between the two processes,
- No improvement was noticed for binaural integration, auditory separation and temporal resolution.

Implications

- This study provides a training paradigm for children with temporal processing deficits.

- This study also helps in understanding the effects on various central auditory processes following training and indicates the linkage between temporal pattern perception and auditory memory.

REFERENCES

Alexander, D. W., & Frost, B. P. (1982). Decelerated synthesized speech as a means of shaping speed of auditory processing of children with delayed language. *Perceptual andMotor skills, 55*, 783-792.

American Speech-Language-Hearing Association (2005). *(Central) auditory processing disorder (technical report).*Retrieved fromhttp://www.asha.org/members/desref-journals/deskref/default.

ANSI S3.1 (1999). American National Standards Institute (1999).*Maximum permissible ambient noise for audiometric test rooms. ANSI S3.1-1999.*New York: American National Institute.

Battin, R. R., Young, M., & Burns, M. (2000). Use of Fast ForWord in remediation of central auditory processing disorders.*Audiology Today, 12*(2), 13-15.

Bellis, T. J. (1996). *Assessment and management of Central Auditory Processing Disorders in the educational setting: from Science to practice.* San Diego, CA: Singular.

Bellis, T. J. (2003). *Central auditory processing in the educational setting: From science topractice* (2nd Ed.). Clifton Park, NY: Thomas–Delmar Learning.

Bellis, T. J., & Anzalone, A., M. (2008). Intervention approaches for individuals with (central) auditory processing disorder. *Contemporary issues in communication science anddisorders, 35,* 143-153.

Benaisch, A. A., & Tallal, P. (1996). Auditory temporal processing thresholds, habituation and recognition memory over the 1st year. *Infant behavior and development, 19(3),* 339-357.

Brigance, A. H. (1999).*Brigance comprehensive inventory of basic skills - revised (CIBS – R)*. Curriculum associates.

Chandrashekar, S. K. (1972).*Development and Standardization of speech test material in English for Indians.* Unpublished Master'sDissertation. University of Mysore, Mysore.

Chermak, G. D., & Lee, J. (2005). Comparison of children's performance on four tests of temporal resolution. *Journal of American Academy of Audiology, 16* (8), 554-563.

Chermak, G. D.,&Musiek, F. E.(1992). Managing central auditoryprocessing disorders in children and youth.*American Journal of Audiology, 1,* 61–65.

Chermak, G. D., & Musiek, F. E. (1997). *Central auditory processing: New perspective.* San Diego: Singular Publishing Group.

Dawes, P., &Bishop, V. M. (2007). The SCAN-C in testing for auditory processing disorder in a sample of British children. *International journal of Audiology, 46,*780-786.

Devi, N., Sujitha, N., & Yathiraj, A. (2008). Auditory memory and sequencing in children aged 6 to 12 years, *Journal of All Indian Institute Of Speech And Hearing,* 27, 95-100.

Elbert, T., Pantev, C., Wienbruch, C., Rockstroh, B. & Taub, E. (1995). Increased cortical representation of the fingers of the left hand in string players. *Science, 270,* 305-306.

English, K., Martonik, J., & Moir, L. (2003). An auditory training technique to improve dichotic listening, *Hearing Journal, 56*(1), 34-38.

Ferre, J. M. (2006). Management strategies for APD. In T. K. Parthasarathy (Ed.). *An introduction to auditory processing disorders in children* (pp. 167-169). New Jersey: Lawrence Erlabaum Associates.

Ferre, J. M., (1997). *Processing power: a guide to CAPD assessment and management.* San Antonio, TX: The psychological corporation.

Friel-Patti, S., Loeb, D., & Gilliam, R. (2001). Looking ahead: An introduction to five exploratory studies in Fast ForWord. *American Journal of Speech-language Pathology, 10*, 195-202.

Gauri, D. T., & Manjula, P. (2003).*Development of norms on duration pattern test.* UnpublishedMaster's independent project submitted to the University of Mysore.

Gilliam, R, Loeb, D., &.Friel-Patti, S. (2001). Looking back: a summary of five exploratory studies of Fast ForWord.*American Journal of Speech-language Pathology, 10*, 269-273.

Habib, M., Rey, V., Daffaure, V., Camps, R., Espesser, R., Joly-Pottuz & Demonet, J. F. (2002).Phonological training in children with dyslexia using temporally modified speech:a three-step pilot investigation. *International Journal of Language and Communication Disorders, 37*(3), 289-308.

Heasley, B. E., (1980).*Auditory processing disorders and remediation*. Springfield: Charles C. Thomas.

Jirsa, R., E. (1992). The clinical utility of P3 AERP in children with auditory processing disorders. *Journal of Speech and Hearing Research,* 35, 903-912.

Kamhi, A. (1981). Non-linguistic symbolic and conceptual abilities of language impaired and normally developing children. *Journal of Speech and Hearing Research, 24,* 446 - 453.

Kamhi, A. (1984). Problem solving in child language disorders: The clinician as clinical scientist. *Language Speech and Hearing Services in Schools, 15,* 226-234.

Katz, J., Chertoff, M., & Sawusch, J. (1984). Dichotic training. *Journal of Auditory Research, 24,* 251-264.

Katz, J., & Fletcher, C. H. (1982).*Phonemic synthesis: blending sounds into words*. Vancouver, WA: Precision Acoustics.

Krishna, G. & Yathiraj, A. (2001).*Dichotic CV test – Revised normative data on children*. Unpublished Master independent Project submitted to the University of Mysore, Mysore.

Kujala, T., Karma, K., Ceponiene, R., Belitz, S., Turkkila, P., Tervaniemi, M., & Naatanen, R. (2001). Plastic neural changes and reading improvement cause by audiovisual training in reading-impaired children. *Proceedings of the National Academy of Sciences of the United States of America, 98*, 10509-10514.

Lindamood Bell-Learning Processes. (1998). *LiPS: Lindamood Phoneme Sequencing program*. San Luis Obispo, CA: Author.

Maggu, A. R., & Yathiraj, A. (2011). Effect of noise desensitization training on children with poor speech-in-noise scores. *Canadian Journal of Speech Language Pathology andAudiology, 35* (1), 56-63.

Merzenich, M. M., Jenkins, W. M., Johnston, P., Schreiner, C., Miller, S. L., & Tallal, P. (1996). Temporal processing deficits of language-learning impaired children ameliorated by training. *Science*, 271, 77-80.

Moncrieff, D. W., & Wertz, D. (2008). Auditory rehabilitation for interaural asymmetry: Preliminary evidence of improved dichotic listening performance following intensive training. *International Journal of Audiology, 47*, 84-97.

Musiek, F. E. (1999). Habilitation and management of auditory processing disorders: overview of selected procedures. *Journal of American Academy of Audiology, 10*, 329-342.

Musiek, F. E. (2005). Temporal (auditory) training for (C)APD. *The Hearing Journal, 58*, 46.

Musiek, F. E.,& Chermak, G. D.(1995). Three commonly asked questions about central auditory processing disorder: management. *American Journal of Audiology,4(1),* 15-18.

Musiek, F. E., Geurkink, N. A., Kietel, S. A., & Hanover, N. H. (1982). Test battery assessment of auditory perceptual dysfunction in children, *Laryngoscope, 92(3),* 251-257.

Musiek, F. E., Pinheiro, M. L., & Wilson, D. H. (1980). Auditory pattern perception in 'split-brain' patients. *Archives of otolaryngology*, 106, 610-612.

Musiek, F. E., & Schochat, E. (1998). Auditory training and central auditory processing disorders: A case study. *Seminars in Hearing, 19*, 357-366.

Musiek, F. E., Shinn, J., & Hare, C. (2002). Plasticity, Auditory training, and Auditory Processing Disorders. *Seminars in Hearing*, *23*(4), 263-275.

Muthuselvi, T., & Yathiraj, A. (2009). *Utility of the screening checklist for auditory processing (SCAP) in detecting (C)APD in children.* Unpublished Master's dissertation, University of Mysore,Mysore.

Overy, K. (2003). Dyslexia and music: From timing deficits to musical intervention. *Annals of New York Academy of Sciences, 999,* 497-505.

Pinheiro, M. L. & Musiek, F. E. (1985). Sequencing and temporal ordering in the auditory system. In: M . L. Pinheiro and F. E. Musiek (Eds). *Assessment of Central Auditory Dysfunction: Foundation and Clinical Correlates.*(pp. 219-228). Baltimore: Williams and Wilkins.

Priya, G., & Yathiraj, A. (2007).*Effect of dichotic offset training (DOT) in children with an auditory processing disorder*. Unpublished Master's Dissertation. University of Mysore, Mysore.

Putter-Katz, H., Said, L. A., Feldman, I., Meran, D., Kushmit, D., Muchnik, C., & Hildesheimer, M. (2002). Treatment and evaluation indices of auditory processing disorders. *Seminars in Hearing, 23* (4), 357-363.

Ramaa, S. (1985).*Diagnosis and remediation of dyslexia.* Ph. D. thesis, University of Mysore, Mysore.

Raven, J. C. (1956).*Coloured progressive matrices*. Lewis and Co.: London.

Rice, M. L. (1983). Contemporary accounts of the cognition/language relationship: Implications for speech-language clinicians. *Journal of Speech and Hearing Disorders, 48,* 347-359.

Richard, G. J. (2006). Language based assessment and intervention for APD. In T. K. Parthasarathy (Ed.). *An introduction to auditory processing disorders in children* (pp. 97-98). New Jersey: Lawrence Erlabaum Associates.

Rudmin, F., & Katz, J. (1982). Dichotic offset and offset parameters on the SSW test. In: D. A. Arnst, and J. Katz (Eds). *The SSW test: Development and Clinical use.* San Diego: College hill press.

Rupp, R.R., & Stockdell, K. G. (1978). *Speech protocols in Audiology.* New York: Grune & Stratton.

Schochat, E., Musiek, F. E., Alonso., R. & Ogata, J. (2010). Effect of auditory training on the middle latency response in childrenwith (central) auditory processing disorder. *Brazilian journal of Medical and Biological Research, 43*(8), 777-785.

Scientific Learning Corporation. (1999). Fast ForWord: Assessment. Retrieved from http://www.scientificlearning.com.

Shiva praskash,S., &Manjula, P. (2003). *Gap Detection Test-development of norms.* Unpublished Master independent Project submitted to the University of Mysore, Mysore.

Tallal, P. (1980). Auditory temporal perception, phonics, and reading disabilities in children,*Brain and Language*, 9, 182-198.

Tallal ,P., Miller, S. L., Bedi, G., Byma, G., Wang, X., Nagarajan, S. S., Schreiner, C., Jenkins,W. M., &Merzenich, M. M. (1996). Language Comprehension in Language LearningImpaired Children Improved with Acoustically Modified Speech, *Science, 271,*81-84.

Tallal, P., Stark, R., Kallman, C.,& Mellits, D.(1981). A re-examination of some non verbal perceptual abilities of language impaired and normal children as a function of age and sensory modality. *Journal of Speech and Hearing Research, 24,* 351 -357.

Temple, E., Deutsch, G., Poldrack, R., Miller, S., Tallal, P., Merzenich, M., & Gabrielli,J. (2003). Neural deficits in children with dyslexia ameliorated by behavioural remediation evidence from functional MRI. *Proceedings of the National Academy* *of Sciences of theUnited States of America, 100*, 2860-2865.

Terry, B. (2001). *Areas of Perception That Affect Learning*. Retrieved from http://www.parentpals.com/gossamer/pages/Detailed/890.html.

Tremblay, K., & Kraus, N. (2002). Auditory training induces asymmetrical changes in cortical neural activity. *Journal of Speech, Language and Hearing Research, 45*(3), 564-572.

Tremblay, K., Kraus, N., McGee, T., Picton, C., & Otis, B. (2001). Central auditory plasticity changes in the N1-P2 complex after speech-sound training. *Ear and Hearing, 22*, 79-90.

Turner, S., & Pearson, D. W. (1999). Fast ForWord language intervention programs: four case studies. *Texas Journal of Audiology and Speech Language Pathology*. Retrieved from http://www.scilearn.com/results/science/articles/main =abstract10_1.

Vanaja, C. S., & Sandeep, M. (2002).Auditory long latency responses in children with learning disability. Departmental project, All India Institute of Speech and Hearing, Mysore.

Yathiraj, A. (1999). The Dichotic CV test. Unpublished material developed by department ofAudiology, All India Institute of Speech and Hearing, Mysore.

Yathiraj, A., & Mascarenhas, K. (2002). Audiological profile of thechildren with suspected auditory processing disorder. Developed as apart of project titled 'Effect of auditory stimulation of central auditoryprocesses in children with CAPD', at the department of audiology, AllIndia Institute of Speech and Hearing, Mysore.

Yathiraj, A., & Mascarenhas, K. (2003). Effect of auditory stimulationin central auditory processing in children with (C)APD, project carriedout at the department of Audiology, All India Institute of Speech andHearing, Mysore.

Yathiraj, A., & Mascarenhas, K. (2004). Auditory profile of childrenwith suspected auditory processing disorder. *Journal of Indian Speechand Hearing Association,18*, 6-14.

Yathiraj, A., Vanaja, C. S., & Muthuselvi, T. (2010). Speech in noise test. Developed as a part of project titled 'Maturation of auditory processes in children aged 6 to 11 years', at the department of audiology, All India Institute of Speech and Hearing, Mysore.

Appendix I

Training material designed for temporal pattern training

Levels	No. of tones	Duration of tones	No. of stimuli	Remarks
1a	Two tones	250 msec, 500 msec	20	Both different
1b	Two tones	250 msec, 450 msec	20	Both different
1c	Two tones	250 msec, 400 msec	20	Both different
1d	Two tones	250 msec, 350 msec	20	Both different
1e	Two tones	250 msec, 325 msec	20	Both different
2a	Three tones	250 msec, 500 msec	20	two similar, one different
2b	Three tones	250 msec, 450 msec	20	two similar, one different
2c	Three tones	250 msec, 400 msec	20	two similar, one different
2d	Three tones	250 msec, 350 msec	20	two similar, one different
2e	Three tones	250 msec, 325 msec	20	two similar, one different
3a	Four tones	250 msec, 500 msec	20	three similar, one different
3b	Four tones	250 msec, 450 msec	20	three similar, one different
3c	Four tones	250 msec, 400 msec	20	three similar, one different
3d	Four tones	250 msec, 350 msec	20	three similar, one different
3e	Four tones	250 msec, 325 msec	20	three similar, one different