Perspective Article

Management of Auditory Processing Disorders: The Indian Scenario

Asha Yathiraj

JAIISH(2015)
Vol 34, pp. 8-16

Affiliations

Department of Audiology, All India Institute of Speech and Hearing, Mysore, India

Corresponding Author

Asha Yathiraj
Department of Audiology, All India Institute of Speech and Hearing, Mysore, India
Email:asha_yathiraj@rediffmail.com

Key Words

Direct remediation
Auditory Integration
Auditory Separation / Closure
Temporal Integration
Temporal Patterning

Abstract

It is essential that individuals diagnosed to have an auditory processing problem (APD) be provided appropriate management in order to overcome their difficulty to the maximum extent possible. The positive impact of training on individuals with APD has been demonstrated in studies carried outside India as well as within India. In India, studies on the management of APD have primarily focused on deficit specific therapy. These studies have demonstrated positive outcomes for therapy provided for auditory processes such as auditory integration, auditory separation / closure training, temporal integration, and temporal patterning. Deficit specific training has been noted to be useful not only in children but also in older adults with APD. Along with such training, the use of compensatory and coping strategies is recommended to help individuals with APD deal with difficulties faced in day-to-day situations. The article provides an overview of the studies carried out in India regarding APD management.

The ultimate goal of screening and diagnostic assessment for auditory processing disorders (APD) is to determine effective management strategies. Management of individuals with auditory processing problems is required to enable them to lead a life that is as fulfilling as possible despite the presence of auditory processing difficulties. The management techniques vary depending on whether the individual has a condition requiring medical/surgical intervention or a condition that does not. Audiological intervention is majorly provided for conditions where medical/surgical intervention is not warranted.

The percentage of children with APD or with symptoms of APD in India is similar to that reported in Western literature. Chermak and Musiek (1997) reported that in school-going children the prevalence of APD was 2 to 3%. Likewise, in India, the prevalence of school-going children who are at-risk for APD was found to be 3.2% (Muthuselvi & Yathiraj, 2009). The figure obtained in the latter study was based on information obtained from 3120 school-going children using the 'Screening checklist for auditory processing (SCAP)' (Yathiraj & Mascarenhas, 2003, 2004). It has also reported that children with learning disability have abnormal representation of auditory stimuli in the central auditory nervous system despite normal peripheral auditory system (Cunningham, Nicol, Zecker, & Kraus, 2000; Hayes, Warrier, Nicol, Zecker, & Kraus, 2003). It has been observed that 3 to 7% of all school-aged children exhibit some form of learning disability (Bellis, 1996). Similarly, in India it has been found that the percentage of children found to have dyslexia ranges from 3% (Ramaa, 1985) to 7.5% (Nishi, 1988). Due to the high percentage of children with symptoms of APD, it is essential that provision be made to reduce the negative impact of the condition.

To prevent the dropout of these children from school, it is essential to identify them and provide rehabilitation. The positive impact of training has been demonstrated in studies carried outside India (English, Martonik, & Moir, 2003; Katz & Burge, 1971; Katz, Chertoff, & Sawusch, 1984) as well as within India (Maggu & Yathiraj, 2011a; Maggu & Yathiraj, 2011b; Priya & Yathiraj, 2009; Yathiraj & Mascarenhas, 2003, 2005; Yathiraj & Priyadarsini, 2009). These studies have highlighted that appropriate and systematic training can bring about changes that enable the individuals diagnosed to have APD to perform not very different from those diagnosed to not have the condition.

Management Trends for APD

In the Western world in the '80s and early '90s, with the exception to a few researchers such Katz and Burge (1971), individuals with APD were recommended to avoid situations that involved utilizing auditory processes that were deficit. Thus, individuals were often informed to avoid noisy situations, as difficulty in listening in the presence of noise was considered a major difficulty. However, since the mid '90s, this approach has changed worldwide, including India. The current focus is to train individuals with APD to enhance their abilities by stimulating the deviant auditory process. This change in the overall training method stems from the findings of studies on neural plasticity. Three types of neural plasticity were described by Scheich (1991). These included developmental plasticity, compensatory plasticity and learning related plasticity. While all three types of plasticity probably did play a role in the success of a training programme, learning related plasticity was considered to play a major role. Researchers have demonstrated that appropriate auditory stimulation can result in changes in the neural auditory system (Edeline, Pham, & Weinberger, 1993; Edeline & Weinberger, 1993; Linkenhoker & Knudsen, 2002; Recanzone, Schreiner, & Merzenich, 1993). Thus, acoustic stimulation or the lack of it can alter brain plasticity.

Two major trends in the management of individuals with APD have been recommended in literature. These include the bottom-up and top-down approaches. The bottom-up therapy programme usually involved providing auditory training activities to tap auditory processes that were found to be deviant on evaluation. In addition, it included measures to improve signal-to-noise ratio either through the use of assistive devices or reduce noise and reverberation. In contrast, a top-down therapy program focuses on improving the individual's abilities to utilise rules of language and cognition abilities. With considerable emphasis being given to deficit based therapy (Bellis, 2003; Chermak & Musiek, 1997; Chermak & Musiek, 1992; Katz & Burge, 1971), as well as evidence of its positive impact, the bottom-up approach has gained more impetus in the recent past. Deficit based therapy has also been referred to as direct remediation therapy.

Deficit specific intervention of APD is based on three primary assumptions. First assumption is that certain basic auditory skills or processes underlie more complex listening, learning and communication utilities. The second assumption underlying the utility of deficit-specific intervention for APD is that through the use of different diagnostic tests it is possible to identify the auditory processes that are dysfunctional in a given individual. According to Domitz and Schow (2000), and Schow, Seikel, Chermak, and Berent (2000), no single test is sufficient to diagnose APD. Rather, the use of a combination of tests that assess multiple auditory processes was indicated. A final assumption important to the utility of deficit-specific intervention for APD was that training on the specific deficient auditory processes would result in an improvement in those functions that the individual experiences difficulties. Thus, it can be construed that in order to provide appropriate remediation, it is essential to initially detect the auditory process or processes that is/are defective. This would serve as a guideline in planning an intervention programme. It has also been recommended by the American Speech-Language-Hearing Association (1996) and Smoski, Brunt, and Tannahill (1992) that information gathered from checklists and questionnaires used to identify children at-risk for APD could provide insights regarding functional deficits and assist in planning habilitation programmes. The use of such checklists and questionnaires are recommended only in the absence of facilities to provide diagnostic test information.

According to Chermak and Musiek (1992), management of APD requires a comprehensive approach, given the range of listening and learning deficits associated with this complex and heterogeneous group of disorders. Further, Ferre (1998) opined that effective management for APD must include modification of a client's environment to minimize auditory overload and maximize coping, teaching and usage of compensatory strategies. The use of coping strategies by the client, direct therapeutic techniques designed to improve the deficient auditory (and / or other related) skills was also suggested.

Direct therapeutic techniques aim at alleviating specific auditory processing problems that an individual may have. The purpose of direct remediation activities is to maximize neuroplasticity and improve auditory performance by changing the way the brain processes auditory information (Bellis, 1996; Chermak & Musiek, 1997). Besides improving the targeted auditory process, auditory training is known to improve basic auditory skills such as auditory vigilance, temporal and spectral detection and discrimination, and inter-hemispheric transfer. Typically, direct remedial training involves providing auditory training for a specific auditory process that is found to be defective in order to stimulate its use.

It is generally hypothesised that providing deficit specific training through direct remediation would also help in speech perception. This in turn would improve the individual's communication and learning skills. Depending on the specific auditory process that is found to be defective, direct therapy is provided for auditory integration, auditory separation / closure training temporal processing and / or auditory interaction. In addition, training is also given for specific acoustical parameter, phoneme synthesis and multi-modality inter-hemispheric stimulation.

APD Management Techniques Used in India

In keeping with the changing trend in the rest of the world, management procedures for individuals with auditory processing problems have also changed in India over the years. In the '80s, practicing audiologists recommended that individuals with APD should avoid noisy situations. Additionally, individuals with symptoms of APD were counselled regarding the availability of FM systems that would enable them to hear better in the presence of noise. Research in the area of APD management was non-existent in India at that period of time. Thus, audiologists in India followed the recommendations made by researchers in the Western world. The earliest publication regarding a systematic training programme for auditory processing problems in India was by Shivashankar (1998). He described two training programmes, 'Controlled auditory signal presentation strategies' and 'Auditory perceptual training' developed earlier by him along with Shashikala. These training programmes were designed for individuals with aphasia having symptoms of auditory processing. However, no evidence was provided regarding the utility of the techniques.

Yet another document that described different techniques to provide training for children with APD was developed by Delcy (2001) under the guidance of Yathiraj. This independent project describes a host of techniques as guidelines for clinicians to utilise with individuals having APD. These recommendations were based on ideas available in literature as well as based on the suggestions of the guide.

The first empirical evidence of an APD management programme in India was in a project by Yathiraj and Mascarenhas (2003) that was later published (Yathiraj & Mascarenhas, 2005). This study utilized multiple techniques depending on the deficit demonstrated by the children. This included phoneme synthesis training along with auditory integration, auditory separation and recognition of low redundancy speech, auditory memory (recall and sequencing) and duration pattern recognition. Subsequent to this study, several others ensued, substantiating the utility of deficit specific/direct remedial training. Given below are descriptions of the studies that have provided direct remediation for different auditory processes in India with a brief link with the status in other parts of the world.

Auditory Integration Training

To improve performance of children who demonstrated difficulty on a dichotic listening task, several methods have been tried and found to be effective. This includes practice on the staggered spondaic word test, a dichotic procedure (Minetti & McCartney, 1978), dichotic off set training (Katz et al., 1984), and the use of auditory stimulation to the ear that has depressed dichotic scores (English et al., 2003).

Priya and Yathiraj (2009) evaluated the utility of a dichotic-offset training material developed by Yathiraj (2006) on 12 children aged 7 to 12 years. The training material consisted of 12 dichotic word lists with six lists each having 10 word pairs. The material had 6 offset lags that progressed from an easy condition to difficult conditions (500 ms, 300 ms, 200 ms, 100 ms, 50 ms, & 0 ms). The participants selected for the study underwent education in English medium schools for at least 3 years. They had normal pure-tone, immittance, speech identification, as well as normal intelligence and no speech production problems. The children were included in the study only if they failed SCAP (Yathiraj & Mascarenhas, 2003, 2004) and the Dichotic CV test developed by Yathiraj (1999) and/or the Dichotic Digit test developed by Shivashankar and Herlekar (1991). The children were divided into an experimental and control group with 6 children each. The children in the experimental group received therapy for 10 to 15 sessions, depending on the progress made by them, while the control group received no therapy. The training commenced with the largest offset lag (500 ms) and the lag time was progressively reduced. A child was required to obtain a double-correct score (responses correct in both ears) of approximately 70% to progress to the next lower lag time. If the double-correct scores obtained did not reach the 70% criteria the lists were presented again in a randomized order. Throughout the training the children were provided feedback whether their responses were correct or incorrect. The training continued until the child was able to respond to the target criteria with the 0 ms lag lists. The utility of the dichotic off-set training was established by comparing the baseline performance on the dichotic digit and dichotic CV tests (evaluation-1) with post training evaluations (evaluation-2). The control group was evaluated 15 days following the initial evaluation. A statistically significant ($p < 0.05$) improvement was evident in the experimental group but not in the control group. The improvement was more evident for the dichotic CV test than for the dichotic digit test. Further, the two groups were found to perform similarly prior to the training on both dichotic tests. However, following the training, the control group showed a significant difference on the dichotic CV ($p < 0.05$) test but not on the dichotic digit test ($p > 0.05$). This lack of improvement in the dichotic digit test was ascribed to the test being influenced by auditory memory, thereby tapping both auditory integration and auditory memory. On the other hand, this influence was not observed for the dichotic CV test that tapped only auditory integration. It was concluded that the dichotic offset training programme developed by Yathiraj (2006) was useful in improving auditory integration.

It was also demonstrated by Yathiraj and Priyadarsini (2009) that a whole-brain activity could improve auditory integration. Children aged 7 to 12 years, who passed a screening checklist for auditory processing (Yathiraj & Mascarenhas, 2003, 2004) were selected for the study. Sixteen children, who were provided abacus training in centers running the programme for a duration ranging from 6 months to 2 years, were compared with 8 age and gender matched children who did not undergo such training. The children attended the abacus training programmes to improve their mathematical abilities. As part of the training, coordinated movements of the fingers of both hands were required for calculation of numbers dictated to them. The auditory integration performance of the children was evaluated using the dichotic digit test developed by Shivashankar and Herlekar (1991) and the dichotic CV test developed by Yathiraj (1999). The children who underwent the abacus training were found to obtain significantly higher scores on the dichotic CV test compared to the children who had not undergone such training. However, on the dichotic digit test, although the children who underwent training obtained higher scores than those who did not, the difference was not significant. It was concluded that a dichotic test that has less redundancy, such as the dichotic CV test, is able to detect the subtle improvement in performance in auditory integration following diotic training that involved intensive auditory stimulation.

Thus, the studies demonstrate that improvement in auditory integration can be brought about through auditory integration stimulation using dichotic off-set training or intensive diotic listening training. While the study by Yathiraj and Priyadarsini (2009) was done on children who were not at-risk for auditory processing disorders, it is possible that similar or greater improvement may be seen also in children with auditory integration problems.

Auditory Separation / Closure Training

One of the main difficulties seen in individuals with problems in auditory separation / closure is perception in the presence of noise. To deal with such problems, as early as 1971, Katz and Burge advocated the use of noise desensitization to help such individuals. They used speech-in-noise desensitization therapy in 49 children with APD. This was done over 8 sessions of 30 minutes each. It was found that children who were exposed to speech under controlled noise conditions were able to develop a greater tolerance for background noise and showed a greater ability to respond correctly to speech under noise conditions. This was observed in the 31 children who were tested using a stereo test and 28 children who were evaluated using a monaural test.

In India the earliest report of an auditory separation programme was developed by Shivashankar and Shashikala described by Shivashankar (1998). The programme, 'Auditory Perceptual Training', was developed to improve auditory perception and attention in patients with mild Wernicke's or conduction aphasia having fine deficits in auditory perception. The patients were required to indentify digits or words in the presence of a background passage presented through a tape recorder. To make the task easier, initially the gender of the speaker presenting the signal differed from that of the speaker reading the background passage. In addition, the background signal was spoken in a secondary language of the patient and the foreground signal spoken in his/her primary language. Further, the foreground signal progressed from two digits to four digits. The patient was required to either verbally repeat or write down the words. Once the patient could accomplish the easier task, the contrasts between the foreground and the background stimuli were gradually reduced one-by-one. Initially, the speaker contrast was withdrawn by using a single speaker, followed by the language contrast wherein only the primary language of the patient was used. Once the patient was able to carry out the task using four digits, the foreground stimuli were replaced with words and the task was carried out using a similar technique. Although no statistical information was provided, the authors reported that the outcome of the programmes was promising.

The effect of noise desensitisation therapy has also been demonstrated in a study by Maggu and Yathiraj (2011b). Ten children (8 years to 11 years) who were referred on SCAP and failed a speech-in-noise test were studied. While five of them received 15 to 20 sessions of therapy lasting 20 to 30 minutes daily, five were not provided any form of therapy. Six hierarchical levels of noises and signal-to-noise ratios were used to provide the noise desensitization training. The noise types included a quiet situation, environmental noise (fan noise) presented at +15 dB SNR, speech noise presented at +10 dB SNR, + 5 dB SNR and 0 dB SNR, as well as multi-speaker babble presented at 0 dB SNR. The children were tested initially to establish their baseline performance using three different speech tests (2 monosyllabic word tests & 1 sentence test). The experimental group was revaluated soon after the training programme and the control group was evaluated 3 weeks after the initial evaluation. The experimental group demonstrated significant improvement in scores following training ($p < 0.05$). No change in performance was observed in the control group. Additionally, the two groups did not differ in performance during the first evaluation, but in the second evaluation the experimental group had significantly higher scores than the control group (p ¡ 0.05). This confirmed the utility of the technique. It was postulated by Maggu and Yathiraj that similar to what happens in tinnitus retraining therapy (Jastreboff & Hazel, 2004), noise desensitisation training probably prevented noise from reaching the limbic and autonomic nervous system. This would have prevented it being perceived and thus not allowing it to interfere with the speech signal.

In an earlier study Yathiraj and Mascarenhas (2003, 2005) holistic training was provided to 5 children who were referred on SCAP and were diagnosed to have APD. The children were considered to have APD if they failed one or more of four APD diagnostic tests (Dichotic CV, Speech-in-noise, Duration Pattern Test, Auditory sequencing test). The children were provided thirty sessions of therapy, each lasting 45 minutes, five days a week. The training was given by one of the experimenters for the auditory processing deficits that they demonstrated. Table 1 shows the training that was provided for the different deficits that were utilised. Besides the different procedures used, training was also provided utilised different signal-to-noise ratios. The post therapy scores on the diagnostic tests revealed that there was a significant improvement in the performance of the children for all the tests that were administered, including the speech-in-noise test. For the Dichotic CV test and Auditory sequencing test the improvement was significant at the 0.01 level, while for the Speech-in-noise test and Duration Pattern Test it was significant at the 0.05 level. This indicated that providing children with deficit specific therapy did bring about an improvement in their auditory performance. The interview with the parents and the class teachers of the children revealed that there was a generalization of the skills that were taught during the therapy to the home and school situations. As the training was provided along with several other techniques, it was difficult to pinpoint which of the several techniques used brought about the improvement seen in the children. However, the study by Maggu and Yathiraj (2011b) that specifically evaluated the effect of noise desensitisation proved that such activities can bring about improvement in auditory separation / closure.

Temporal Processing Training

As per the report by the American Speech-Language-Hearing Association (2005), auditory signals have different temporal components that include temporal integration, temporal discrimination, i.e. temporal gap detection, temporal ordering, and temporal masking. Temporal cues are reported to be important for speech perception (Gordon-Salant & Fitzgibbons, 1993; Liégeois-Chauvel, de Graaf, Laguitton, & Chauvel, 1999; Lisker & Abramson, 1964; Shannon, Zeng, Kamath, Wygonski, & Ekelid, 1995; Summerfield, 1982; Tyler, Summerfield, Wood, & Fernandes, 1982).

Early training programmes for temporal processing problems reported in literature focused on manipulating specific components of speech signals. This was noted to result in better perception of speech. Tallal and Piercy (1974) observed that children with language impairments required longer cues when compared to a matched group of normal children. They noted that when the initial portion of the speech signal was prolonged, normal perception occurred. Two treatment programs developed to address deficit in central auditory temporal processing skills are Sloan's Phonemic Training Program (1986) and the Fast ForWord Program developed by Tallal and colleagues (Scientific Learning Corporation, 1997).

In India, research for temporal processing problems has been carried out using non-speech based stimuli. Shivashankar (1998) described of a temporal based training program to improve auditory processing developed by Shivashankar and Shashikala. The programme titled 'Controlled Auditory Signal Presentation Strategies' was reported to be tried on patients with Wernicke's aphasia. The technique started with non-linguistic auditory material. Initially, the patient was required to match the number of times they heard taps being presented by a clinician seated in front of them. Once the patient was able to achieve this target, the training was done with only auditory cues being provided. Following this the patient was expected to match signals hummed by the clinician, similar to the pitch pattern and duration pattern test. The hummed stimuli, presented in triads, initially varied in pitch (e.g. low-low-high, high-low-high, etc) and later varied in duration (e.g. long-short-long, short-long-long, etc). Subsequently, linguistic units were utilised in place of the hummed stimuli. The authors however did not report of the utility of the technique used by them.

Using the principles of the duration pattern test, Maggu and Yathiraj (2011a) developed temporal patterning training material. The duration of the tones ranged from 250 ms to 500 ms. The 250 ms duration tone was constant and the variable tone was decreased gradually in 5 duration steps (500 ms, 450 ms, 400 ms, 350 ms, & 325 ms). This was done for three different frequency tones (250 Hz, 1 kHz, & 4 kHz) representing low, mid and high frequency signals. To vary the difficulty of the training programme, the tasks were hierarchically graded, commencing with 2-tone duration discrimination, and progressing to 3 and 4-tone duration discrimination. For each of the tasks, one stimulus had a duration that was different from the remain-

Table 1: Therapy activity based on process deficiency

Test Failed	Process	Therapy
Dichotic CV	Auditory integration	Auditory closure and Dichotic offset training
Speech-in-noise	Low redundancy speech and auditory separation	Noise desensitization
Duration Pattern Test	Duration pattern recognition	Duration pattern training for verbal and non verbal stimuli
Auditory Sequence Test	Auditory memory and sequencing	Memory games and memory enhancing devices

ing.

Maggu and Yathiraj evaluated 10 children who were referred on SCAP and had poor scores as per the norms given by Gauri (2003) for the duration pattern test. The children, aged 8 to 13 years, were randomly assigned to an experimental and a control group, with equal number of children in each group. While the children in the experimental group received 19 to 25 sessions of training over a period of a month, those in the control group did not. The baseline performance of all the children was obtained on five different processes / higher cognitive skills (temporal patterning, temporal resolution, auditory separation, binaural integration, and auditory memory & sequencing). In addition to the duration pattern test that was used to evaluate temporal patterning, temporal resolution was assessed using the 'Gap Detection Test' developed by Shivaprakash (2003); auditory separation using the 'Speech perception in noise' test developed by Yathiraj, Vanaja, and Muthuselvi (2010b); binaural integration using the Dichotic CV test developed by Yathiraj (1999); and auditory memory and sequencing using the 'Revised Auditory Memory and Sequencing Test developed by Yathiraj, Vanaja, and Muthuselvi (2010a). The baseline performance was compared with the response obtained after of the training in the experimental group and 3 to 4 weeks after the baseline performance in the control group. Significantly better performance was obtained in the experimental group on the tests that tapped temporal patterning and auditory memory and sequencing ($p < 0.05$). No such difference was seen in the control group. Additionally, significantly better performance was seen in the experimental group compared to the control group on these two processes ($p < 0.05$) in the second evaluation but not in the first evaluation ($p > 0.05$). It was inferred that temporal pattern training brought about improvement not only in the process that was directly targeted (temporal patterning) but also in higher cognitive skills (auditory memory & sequencing). Further, maintenance of performance was observed one month following the cessation of therapy in two of the participants from the experimental group who were randomly selected for retesting. The improvement in auditory memory and sequencing of speech stimuli following training with non-speech stimuli highlighted the positive impact of non-verbal training material on verbal performance. The study revealed that training in one auditory process (temporal patterning) does not necessarily bring about improvement in other auditory processes (temporal resolution, auditory separation, & binaural integration). This indicates that in children, training requires to be given separately for each auditory process that is found to be defective.

In a study currently under review by Vaidyanath under the guidance of Yathiraj, an auditory temporal resolution training program was developed for adults. The same was tested on 20 older adults aged 55 to 75 years who had poor scores on a temporal resolution test. The training material consisted of gaps embedded in four different kinds of noise (broadband noise, 500 Hz, 1000 Hz, & 2000 Hz narrow band noise). The entire auditory temporal resolution training material was divided into four levels (Level I to Level IV) to form a hierarchy of activities that varied in complexity. The complexity varied in terms of the duration of noise in which the gap was embedded (300 ms in level 1 & 200 ms in the remaining levels), the number of choices from which the discrimination had to be done (2 choices in levels 1 & 2, 3 choices in level 3 & 4 choices in level 4), as well as the duration of the gap that were inserted at the centre of the noise segments (varied gradually from 30 ms to 3 ms within & across levels). Following training, gap detection thresholds were found to improve significantly. Maintenance of the improvement was observed one month after the termination of therapy. Further, in addition to improvement in the process in which training was provided, there was improvement in other processes / higher cognitive abilities (Gap-In-Noise, Gap Detection, Duration Pattern, Dichotic CV, Speech-Perception-in-Noise, and Auditory memory span) as well as cortical responses (N1 latency of late latency response). Thus, it was inferred that in adults, training in one auditory process does bring about improvement in the other auditory processes. Furthermore, it was noted that improvement was seen not only in behavioural responses, but also in specific electrophysiological responses.

Acoustical Parameter Training

Several researchers have utilized training activities that focus on the acoustical parameters of acoustical signals. The parameters include frequency, intensity and/or temporal cues. Although the training provides focus on specific acoustical cues, the activities indirectly tapped specific processes, especially those related to temporal cues. Discrimination training of frequency and intensity has been found to be effective by several studies that used mismatched negative responses (MMN). These studies were mainly done by Kraus, Tremblay and colleagues from 1995 onwards (Kraus, McGee, Carell, King, & Tremblay, 1995; Tremblay, Kraus, Carrell, & McGee, 1997; Tremblay et al., 2001; Tremblay & Kraus, 2002; Tremblay, Kraus, & McGee, 1998). The studies by Tremblay also demonstrated that generalization to untrained speech sounds was possible. In addition to MMN, the effectiveness of speech discrimination has also been demonstrated using functional magnetic resonance imaging (fMRI) by Jäncke, Gaab, Wüstenberg, Scheich, and Heinze (2001).

In India, Vanaja and Sandeep (2004) recorded Auditory Late Latency Responses and Mismatch Negativities to speech and tonal stimuli, in a group of 15 children with learning disability. Auditory training was given to 2 of these children who had abnormal electrophysiological responses. They were trained to discriminate pure-tones differing in frequency, intensity and duration. The training was carried out until the children discriminated a difference of 50 Hz, 2 dB HL and 50 ms, respectively. Post-therapy electrophysiological recording showed a reduction in latency for all the ALLR waves in both the subjects. In one of the subjects, in whom MMN could be recorded for both speech and non-speech stimuli, the post therapy latencies were shorter than the pre therapy recordings. In the second subject, post-therapy MMN, recorded for speech stimuli, showed reduced latencies compared to the pre-therapy recordings but no response was obtained for tonal stimuli. Although done on a small group, the study does add to the corpus of findings, substantiating that auditory training does enhance auditory responses, especially for speech based sounds.

Phoneme Synthesis Training

Phonemic synthesis has been another technique used with children having learning disability or auditory processing problems (Katz & Wilde, 1994). Bellis (1996) reported that the purpose of phoneme training is to help a child learn to develop accurate phonemic representation and to improve speech-to-print skills. Phonemic synthesis is considered to involve the blending of discrete phonemes into the correctly sequenced, and co-articulated sound patterns (Katz & Harmon, 1981). Sloan (1998) reported that consonant discrimination training not only teaches the child to discriminate speech sounds correctly, but also helps the child know when he/ she has perceived a sound incorrectly or is unsure.

In India Yathiraj and Mascarenhas (2003, 2005) utilized phoneme synthesis training along with other procedures, depending on the processes that were defective. The other techniques used along with phoneme synthesis included auditory integration, auditory separation and recognition of low redundancy speech, auditory memory (recall and sequencing) and duration pattern recognition. The phoneme synthesis techniques aimed to enable the children to break words heard by them into their constituent speech sounds as well as blend speech sounds to make words. Several activities were utilised to enable the children to meet this target. As the procedure was used along with several other techniques, the utility of phoneme synthesis training in isolation could not be ascertained. However, from the findings of the study it was clear that the holistic training programme was useful in bringing about improvement in four auditory processes / higher cognitive skills that were evaluated (auditory integration, auditory separation / closure, duration pattern recognition, & auditory memory and sequencing).

The studies using direct remedial procedures indicate that the techniques are very promising. A few studies also indicate that training in one process does result in improvement in other processes / higher cognitive functioning, as well as to real life situations. However, such generalization does not occur to all processes. The improvement with direct remediation was observed to take place in children and in older adults with symptoms of APD. Thus, it can be observed from the studies done using direct remedial training is a useful bottom-up approach.

Top-Down Approaches

The majority of the training programmes researched in India have focused more on bottom-up techniques. Not much research has been reported regarding specific top-down approaches. A few of the top-down approaches that have been reported specifically for those with APD include the use of metalinguistic and metacognitive strategies. Metalinguistic linguistic strategies refer to the abilities of a person to use appropriate higher-order linguistic rules in difficult listening situations. Similarly, metacognitive strategies refer to the abilities of a listener to plan and use ways to get a better understanding of what is spoken. It enables them to extract information from spoken communication

(Chermak & Musiek, 1992). Although metalinguistic and metacognitive strategies have been utilized in clinical practice for children with APD in India, there is no research that has reported of the utility of specific strategies. However, there is report of one study utilizing auditory memory, a higher cognitive skill, in addition to other activities to provide training to children with APD (Yathiraj & Mascarenhas, 2003, 2005). The objective of the training was to improve both memory as well as sequencing abilities. Several activities were used utilized to tap auditory memory and sequencing, which were described in their 2003 report.

Conclusions

While there are several techniques / approaches that have been recommended to train individuals with APD, in India the training programmes have been restricted majorly to the auditory processes that have been discussed above. The choice of selecting the above processes stems for research showing that these auditory processes are the ones that are majorly affected (Katz, 1992; Musiek, Geurkink, & Kietel, 1982; Muthuselvi & Yathiraj, 2009; Welsh, Welsh, & Healy, 1980). Further, it has been reported that improvement in academic and language skills occur following APD intervention, indicating that generalization of activities takes place to non-therapy situations (Chermak, Curtis, & Seikel, 1996). Yathiraj and Mascarenhas (2003) also reported that the deficit specific training provided to children with APD resulted in a generalization of the skills taught to their home and school situations.

From the literature in India as well as other parts of the world, it is evident that direct remedial training procedures do bring about marked improvement in the performance of children identified to have APD. Besides providing direct remedial training, recommendations regarding environment modification, to enhance auditory perception, continue to be used. Further, compensatory and coping strategies are recommended to be utilized to help individuals with APD deal with difficulties faced in day-to-day situations. A combination of all these techniques would result in individuals with APD leading a more fruitful life and learn to cope better in real life situations.

References

American Speech-Language-Hearing Association. (1996). *Central auditory processing: Current status and implications for clinical practice.*

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

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 to practice* (2nd ed.). New York: Thomas Delmar Learning.

Chermak, G., & Musiek, F. (1997). *Central auditory processing disorders: New perspectives.* San Diego: Singular Pub.

Chermak, G. D., Curtis, L., & Seikel, J. A. (1996). The effectiveness of an interactive hearing conservation program for elementary school children. *Language, Speech, and Hearing Services in Schools, 27*(1), 29-39.

Chermak, G. D., & Musiek, F. E. (1992). Managing central auditory processing disorders in children and youth. *American Journal of Audiology, 1*(3), 61-65.

Cunningham, J., Nicol, T., Zecker, S., & Kraus, N. (2000). Speech-evoked neurophysiologic responses in children with learning problems: development and behavioral correlates of perception.*Ear and Hearing, 21*(6), 554-568.

Delcy, J. (2001). *Handout for management of CAPD.* (Masters in Speech and Hearing), University of Mysore, Mysore.

Domitz, D. M., & Schow, R. L. (2000). A new CAPD battery–multiple auditory processing assessment: factor analysis and comparisons with SCAN. *American Journal of Audiology, 9*(2), 101.

Edeline, J.-M., Pham, P., & Weinberger, N. M. (1993). Rapid development of learning-induced receptive field plasticity in the auditory cortex. *Behavioral Neuroscience, 107*(4), 539.

Edeline, J.-M., & Weinberger, N. M. (1993). Receptive field plasticity in the auditory cortex during frequency discrimination training: selective retuning independent of task difficulty. *Behavioral Neuroscience, 107*(1), 82.

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

Ferre, J. (1998). The M3 model for treating central auditory processing disorders. In M. Masters, N. Stecker & J. Katz (Eds.), *Central auditory processing disorders: Mostly management* (pp. 103-116). Boston: Allyn and Bacon.

Gauri, D. T. (2003). Development of norms on duration pattern test. (Masters in Speech and Hearing), Master?s independent project submitted to the University of Mysore, Mysore, India. Retrieved from http://203.129.241.86:8080/digitallibrary/HomeAtoZ.do?alphabet=D&recordPage=8&currentPage=1

Gordon-Salant, S., & Fitzgibbons, P. J. (1993). Temporal Factors and Speech Recognition Performance in Young and Elderly Listeners. *Journal of Speech, Language, and Hearing Research, 36*(6), 1276-1285.

Hayes, E. A., Warrier, C. M., Nicol, T. G., Zecker, S. G., & Kraus, N. (2003). Neural plasticity following auditory training in children with learning problems. *Clinical Neurophysiology, 114*(4), 673-684.

Jäncke, L., Gaab, N., Wüstenberg, T., Scheich, H., & Heinze, H. J. (2001). Short-term functional plasticity in the human auditory cortex: an fMRI study. *Cognitive Brain Research, 12*(3), 479-485.

Jastreboff, P., & Hazel, J. (2004). *Tinnitus Retraining Therapy: Implementing the Neurophysiological Model.* New Delhi: Cambridge University Press.

Katz, J. (1992). *Classification of auditory processing disorders.* Central auditory processing: A transdisciplinary view, 81-91.

Katz, J., & Burge, C. (1971). Auditory perception training for children with learning disabilities. *Menorah Medical Journal, 2,* 18-29.

Katz, J., Chertoff, M., & Sawusch, J. R. (1984). Dichotic training. *Journal of Auditory Research, 24*(4), 251-264.

Katz, J., & Harmon, C. (1981). Phonemic synthesis: Testing and training. In K. R (Ed.), *Central auditory and language disorders in children* (pp. 145-157). Houston

College-Hill Press.

Katz, J., & Wilde, L. (1994). *Handbook of Clinical Audiology.* In J. Katz & W. L. Gabbay (Eds.), *Auditory processing disorders* (4th ed.). Baltimore: Williams & Wilkins.

Kraus, N., McGee, T., Carell, T. D., King, C., & Tremblay, K. (1995). Central auditory system plasticity associated with speech discrimination training. *Journal of Cognitive Neuroscience, 1195*, 25-32.

Liégeois-Chauvel, C., de Graaf, J. B., Laguitton, V., & Chauvel, P. (1999). Specialization of Left Auditory Cortex for Speech Perception in Man Depends on Temporal Coding. *Cerebral Cortex, 9*(5), 484-496.

Linkenhoker, B. A., & Knudsen, E. I. (2002). Incremental training increases the plasticity of the auditory space map in adult barn owls. *Nature, 419*(6904), 293-296.

Lisker, L., & Abramson, A. S. (1964). A cross-language study of voicing in initial stops: Acoustical measurements. *Word, 20*(3), 384-422.

Maggu, A., & Yathiraj, A. (2011a). Effect of temporal pattern training on specific central auditory processes. *Student Research at AIISH Mysore, (Articles based on Dissertation done at AIISH), IX,* 18-27.

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

Minetti, S. B., & McCartney, J. H. (1978). The effects of practice on 8-10-yr-old children using the Staggered Spondaic Word Test. *The Journal of Auditory Research, 18*(4), 293-298.

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

Muthuselvi, T., & Yathiraj, A. (2009). Utility of the screening checklist for auditory processing (SCAP) in detecting (C)APD in children. *Student Research at AIISH Mysore (Articles based on dissertation done at AIISH), VII,* 159-175.

Nishi, M. M. (1988). *A study of cognitive development of learning disabled children.* (Masters in Education), University of Mysore, India, Mysore.

Priya, G., & Yathiraj, A. (2009). Effect of temporal based training in children with an auditory processing disorder. *(Articles based on dissertation done at AIISH), V,* 138-147.

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

Recanzone, G. A., Schreiner, C., & Merzenich, M. M. (1993). Plasticity in the frequency representation of primary auditory cortex following discrimination training in adult owl monkeys. *The Journal of Neuroscience, 13*(1), 87-103.

Scheich, H. (1991). Auditory cortex: comparative aspects of maps and plasticity. *Current Opinion in Neurobiology, 1*(2), 236-247.

Schow, R. L., Seikel, J. A., Chermak, G. D., & Berent, M. (2000). Central auditory processes and test measures: ASHA 1996 revisited. *American Journal of Audiology, 9*(2), 63.

Shannon, R. V., Zeng, F.-G., Kamath, V., Wygonski, J., & Ekelid, M. (1995). Speech Recognition with Primarily Temporal Cues. *Science, 270*(5234), 303-304.

Shivaprakash, S. (2003). *Gap detection test - Development of norms.* (Independent project submitted as part of Masters degree in Speech and Hearing), University of Mysore, Mysore, India. Retrieved from http://203.129.241.86:8080/digitallibrary/AuthorTitle.do?jAuthor=Shivaprakash,%20S

Shivashankar, N. (1998). Aphasia rehabilitation. In A. Taly, N. Shivaraman & T. Murli (Eds.), *Neurorehabilitation: Principles and practices* (pp. 174-189). Bangalore: NIMHANS.

Shivashankar, N., & Herlekar, G. (1991). Dichotic Digit test in Intracranial lesions. *Journal of the Indian Speech and Hearing Association, 8,* 67-71.

Sloan, C. (1998). Management of auditory processing difficulties: A perspective from speech-language pathology. *Seminars in Hearing, 19,* 367-378.

Smoski, W. J., Brunt, M. A., & Tannahill, J. C. (1992). Listening characteristics of children with central auditory processing disorders. *Language, Speech, and Hearing Services in Schools, 23*(2), 145.

Summerfield, Q. (1982). Differences between spectral dependencies in auditory and phonetic temporal processing: Relevance to the perception of voicing in initial stops. *The Journal of the Acoustical Society of America, 72*(1), 51-61.

Tremblay, K., Kraus, N., Carrell, T. D., & McGee, T. (1997). Central auditory system plasticity: Generalization to novel stimuli following listening training. *Journal of the Acoustical Society of America, 102,* 3762-3773.

Tremblay, K., Kraus, N., McGee, T., Ponton, C., Otis, & Brian. (2001). Central Auditory Plasticity: Changes in the N1-P2 Complex after Speech-Sound Training. *Ear and Hearing, 22*(2), 79-90.

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

Tremblay, N., Kraus, N., & McGee, T. (1998). The time couruse of auditory perceptual learning: neurophysiological changes during speech sound training. *Neuroreport, 9*(16), 3557-3560.

Tyler, R. S., Summerfield, Q., Wood, E. J., & Fernandes, M. A. (1982). Psychoacoustic and phonetic temporal processing in normal and hearing impaired listeners. *The Journal of the Acoustical Society of America, 72*(3), 740-752.

Vaidyanathan R. (2016). Efficacy of temporal processing training in older adults. Doctoral dissertation in Audiology, submitted to the University of Mysore, Mysore, India.

Vanaja, C. S., & Sandeep, M. (2004). *Auditory long latency responses in children with learning disability.* All India Institute of Speech and Hearing. Mysore. Retrieved from http://203.129.241.86:8080/digitallibrary/HomeGuideTitle.do?jGuide=NA

Welsh, L., Welsh, J., & Healy, M. (1980). Central auditory testing and dyslexia. The *Laryngoscope, 90*(6), 972-984.

Yathiraj, A. (1999). Dichotic CV test. Mysore, India: All India Institute of Speech and Hearing.

Yathiraj, A. (2006). Dichotic off-set training material Mysore, India: All India Institute of Speech and Hearing.

Yathiraj, A., & Mascarenhas, K. (2003). *Effect of auditory stimulation in central auditory processing in children with CAPD.* Mysore: All India Institute of Speech and Hearing, ARF Project.

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

Yathiraj, A., & Mascarenhas, K. (2005). Effect of Auditory Stimulation in Central Auditory Processing in Children with APD. *The Journal of the Indian Speech and Hearing Association, 19,* 16-25.

Yathiraj, A., & Priyadarsini, K. (2009). Effect of Training on Dichotic CV and Dichotic Digit Scores. *Journal of the Indian Speech and Hearing Association, 23,* 74-80.

Yathiraj, A., Vanaja, C. S., & Muthuselvi, T. (2010a). *Revised Auditory Memory and Sequencing Test in Indian-English Developed as part of the project 'Maturation of auditory processes in children aged 6 to 10 years' completed in 2012.* Department of Audiology, Mysore, India: All India Institute of Speech and Hearing.

Yathiraj, A., Vanaja, C. S., & Muthuselvi, T. (2010b). *Speech-in-noise test in Indian-English (SPIN-IE) Developed as part of the project 'Maturation of auditory processes in children aged 6 to 10 years' completed in 2012.* Department of Audiology, Mysore, India: All India Institute of Speech and Hearing.