Pitch perception in individuals with sensorineural hearing loss with and without dead regions

Palash Dutta & K Rajalakshmi*

Abstract

It has been suspected that a pure tone might be perceived as noise like when the tone produces maximum excitation in a region of the cochlea where there is extensive or complete loss of inner hair cell (IHC) and /or neural function which is referred to as a dead region (DR). It is defined as region in the cochlea where IHCs and /or neurons are functioning so poorly that a tone producing peak vibration in that region is detected by off place listening (i.e. the tone is detected at a place where the amount of basilar membrane vibration is lower but IHCs and neurons are functioning more effectively). In this study total 17 sensorineural hearing loss individuals with and without dead region were taken. They were divided into two groups- subjects having sensorineural hearing loss with dead region and without dead region. For detection of dead regions psychophysical tuning curves (PTCs) was established using a procedure which is similar to the physiological determination of a tuning curve on the basilar membrane or in the auditory nerve. TEN (Threshold-Equalizing Noise) test was also used which is relatively fast and simple test. If the subjects had dead region or not then pitch matching experiment was carried out. For the pitch matching task subjects were asked to match the perceived pitch of a variable pure tone with that of another pure tone that was fixed in frequency. The results reveal that pitch perception in individuals with sensorineural hearing loss with dead region is different than in those individuals having sensorineural hearing loss without dead region. The result also shows that if sensorineural hearing loss is accompanied with dead region (DR) then there is broader auditory filter and hence pitch matching is difficult.

Introduction

A sinusoid is usually perceived by people with normal hearing as having clear tonal quality and a distinct single pitch; hence sinusoids are often called pure tones. However some people with hearing impairment report that pure tones sound highly distorted and noise like (Florentine & Houtsma, 1983; Moore et al. 1985; 1977b; Murry & Byrere, 1986; Huss & Moore, 2005). From the audiogram it is difficult to predict whether or not a person will experience such a percept. It has been suspected that a pure tone might be perceived as noise like when the tone produces maximum excitation in a region of the cochlea where there is extensive or complete loss of inner hair cell (IHC) and/or neural function which is sometimes referred to as a dead region (DR) (Florentine & Houtsma, 1983; Moore et al, 1985; Huss & Moore, 2005). A DR can be defined as a region in the cochlea where IHCs and/or neurons are functioning so poorly that a

* Reader in Audiology, All India Institute of Speech and Hearing, Mysore, India
e-mail: rajrose2000@yahoo.com

tone producing peak vibration in that region is detected by off-place listening (i.e. the tone is detected at a place where the amount of basilar-membrane vibration is lower but the IHCs and neurons are functioning more effectively; Moore, 2004). The extent of a DR can be defined in terms of the characteristic frequencies (CFs) of the IHCs and/or neurons immediately adjacent to the DR (Moore, 2001). DRs can be diagnosed and localized using psychophysical tuning curves (PTCs) (Florentine & Houtsma, 1983; Turner et al. 1983; Moore et al. 2000; Moore & Alcantara, 2001; Huss & Moore, 2003; Kluk & Moore, 2005) and using the threshold-equalizing noise (TEN) test (Moore et al, 2000; 2004; Huss and Moore, 2003).

The Pitch of a pure tone may be determined by the auditory system from the distribution of activity or excitation along the basilar membrane or in the auditory nerve (place theory) (Helmholtz, 1863; von Bekesy, 1960; Siebert, 1968, 1970) or from temporal information derived from patterns of phase locking in the auditory nerve (Siebert, 1970; Moore, 1973; Goldstein & Srulovicz, 1977; Srulovicz & Goldstein, 1983).

In principle, theories of pitch perception can be evaluated by studying pitch perception for people with hearing impairment (Moore & Carlyon, 2005). Studies investigating pitch perception in subjects with low-frequency DRs have suggested that a tone with a frequency falling in a DR is often perceived with a low pitch that is roughly “normal” (Florentine & Houtsma, 1983; Turner et al., 1983). Pitch shifts were much smaller than would be predicted based on the place where the tone was assumed to be detected (Just outside, the boundary of the DR). The results were interpreted as indicating that the pitch of a low frequency tone is predominantly derived from the temporal pattern of neural firing evoked by the tone.

The results obtained by Florentine and Houtsma (1983) and by Turner et al. (1983) were mostly based on pitch matches using tones at and within about 2 octaves of the edge frequency of the DR. It is possible that the analysis of information about pitch carried by interspike intervals is optimized when place and temporal information is consistent (Evans, 1978). For example, the analysis of temporal information may depend upon differences in the phase of the response at different points along the basilar membrane (Loeb et al., 1983; Shamma & Klein, 2000; Carney et al., 2002). The processing of temporal information could be disrupted when the propagation time of the traveling wave along the basilar membrane deviates from normal as may happen in hearing impaired ears (Ruggero et al., 1996). When a tone produces peak vibration in a DR perception of the tone depends on the spread of vibration to an adjacent functioning region of the cochlea. At that region, the traveling wave pattern and specifically the relative phase of the response at different places, might differ markedly from the pattern occurring around the place where peak vibration occurs. This might markedly disrupt the processing of temporal information.

It remains unclear as to what determines the pitch when either temporal and place information become weaker and what happens when temporal and place codes give conflicting information about pitch. The presence or absence of dead regions can have serious implications for the fitting of hearing aids. Amplification over a frequency range corresponding to a dead region may not be beneficial because amplified frequency components would be detected and analyzed in frequency channels that normally respond to other frequencies.

The present study aimed to investigate the pitch perception in individual with and without dead regions in subjects with sensorineural hearing loss and whether there is relationship between dead region and perceived pitch. The study also investigated whether there is any relationship between the extent of DRs and pitch shift.

Method

Participants

Participants were divided into 2 groups. In first group 7 subjects having sensorineural hearing loss without dead region were taken. In the second group 10 subjects having sensorineural hearing loss with dead region were taken. Sensorineural hearing loss without dead region group subjects had no significant history of neurological disorders. Subject had pure tone threshold more than 40 dBHL in frequency ranges 250 Hz to 4000 Hz and immittance screening revealed no middle ear pathology. Subjects' air bone gap was less than 10 dBHL at all frequencies from 250 Hz to 4000 Hz. Subject had pure tone average more than or equal to moderate degree of hearing loss and immittance screening revealing no middle ear pathology.

Instrumentation

A calibrated two channel diagnostic audiometer MA-53 was used for testing the subjects. An immittance audiometer (GSI-33) used for evaluation of middle ear function. Tape recorder with CD for TEN test was connected to a two channel diagnostic audiometer for presenting the stimulus. Test was carried out in an air conditioned sound treated double room set up with ambient noise levels within permissible limits (Re: ANSI 1991, as cited in wilber, 1994).

Test materials

TEN test CD was used for the purpose of diagnosing dead region in subjects with sensorineural hearing loss.

Procedure

1) Pure Tone average: Pure tone thresholds were obtained at octave frequencies between 250 Hz and 8000 Hz for air conduction stimuli and between 250 Hz to 4000 Hz for bone conduction stimuli using modified Hughson Westlake method (Carhart & Jerger, 1959).

2) Tympanometry: Tympanometry and reflexometry were carried out to rule out any middle ear pathology.

3) Psychophysical tuning curves: Psychophysical tuning curves (PTCs) (Chistovich, 1957; Small, 1959) were measured using a procedure which is similar to the physiological determination of a tuning curve on the basilar membrane (Sellick, et al., 1982) or in the auditory nerve (Kiang, Watanabe, Thomas & Clark, 1965). The signal was a sinusoid which was presented at a level 10 dB above the absolute threshold. In a given run the signal frequency was fixed. The masker was an 80 Hz wide band of noise with variable center frequency. The exact masker frequencies were chosen individually for each subject so as to define the position of the tip of the tuning curve with reasonable accuracy. Several signal frequencies were used for each subject; they were chosen to cover a range including any suspected dead region. For each of several masker center frequencies the level of the masker needed just to mask the signal was determined.

4) TEN (Threshold-Equalizing Noise) **test:** For detection of dead regions TEN test was used which is relatively fast and simple test (Moore, et al. 2000). The test makes use of a masking noise called "threshold-equalizing noise" (TEN) which is spectrally shaped.

Absolute thresholds and masked thresholds in TEN were measured using manual audiometry with the procedure proposed by Carhart and Jerger (1959). The TEN from the CD was fed to one of the tape inputs on OB 922 audiometer and the sinusoidal test signal was fed to the other. TEN and signal levels were controlled by the use of the level controls on the audiometer. The noise and sinusoidal signal were mixed using the audiometer, and stimuli were delivered using TDH - 39 earphones supplied with audiometer. Each ear of each subject was tested separately.

Pitch-matching Procedure

For the pitch matching task subjects were asked to match the perceived pitch of a variable pure tone with that of another pure tone that was fixed in frequency. The two tones were presented alternatively. Matches were made within the same ear to estimate the reliability of matching. The subject was instructed to say 'same' or 'different' in the perceived pitch of variable tone with that of fixed frequency tone. The procedure was carried out for frequencies at 250, 500, 1000, 2000 & 4000 Hz. Data was tabulated in terms of the perceived pitch at the above frequencies. The extent of pitch matching was noted down for each frequency in all the subjects.

Results and discussion

There were 10 subjects with sensorineural hearing loss with dead region and 7 sensorineural hearing losses without dead region in the present study.

A) Group analysis

Table 1a &1b: Cross tabulation with respect to fixed and variable frequency in SNHL without dead region

1(a) Right ear

Fq. In Hz	250	500	1000	2000	4000
250	7	0	0	0	0
500	0	7	0	0	0
1000	0	0	7	0	0
2000	0	0	0	7	0
4000	0	0	0	0	7

fixed frequency is shown in the first column and variable frequencies in other 5 columns

Number of subjects perceiving each fixed frequency and variable frequency are presented as a cross table for both the groups and both the ears. Since we are dealing with frequency data test of significance were not suitable and there was possibility of one person perceiving in more than one way and because of this constraint the analyses were restricted to graphical representation.

1 (b) Left ear

Fq. In Hz	250	500	1000	2000	4000
250	7	0	0	0	0
500	0	7	0	0	0
1000	0	0	7	0	0
2000	0	0	0	7	0
4000	0	0	0	0	7

Fixed frequency is shown in the first column and variable frequencies in other 5 columns

Table 2a & 2b: Cross tabulation with respect to fixed & variable fq in SNHL with dead region

2(a) Right ear

Fq. In Hz	250	500	1000	2000	4000
250	10	1	1	-	-
500	-	10	1	-	-
1000	1	2	9	4	2
2000	1	2	4	10	9
4000	-	1	3	8	9

2(b) Left ear

Fq. In Hz	250	500	1000	2000	4000
250	10	1	1	-	-
500	-	10	2	-	-
1000	-	1	10	4	3
2000	1	1	3	9	7
4000	-	1	3	7	9

Fixed frequency is shown in the first column and variable frequencies in other 5 columns

Number of subjects was converted as percentage since the subject size was not similar in both the groups. For the first group sensorineural hearing loss without dead region 7 subjects were taken and for second group sensorineural hearing loss with dead region 10 subjects were taken.

1) Sensorineural hearing loss without dead region right ear group and left ear group

It can be observed from the graph that all 7 subject with sensorineural hearing loss without dead region in both right ear and left ear fixed frequency same as variable frequencies at all frequency levels. None of the subject perceived in any other frequency level.

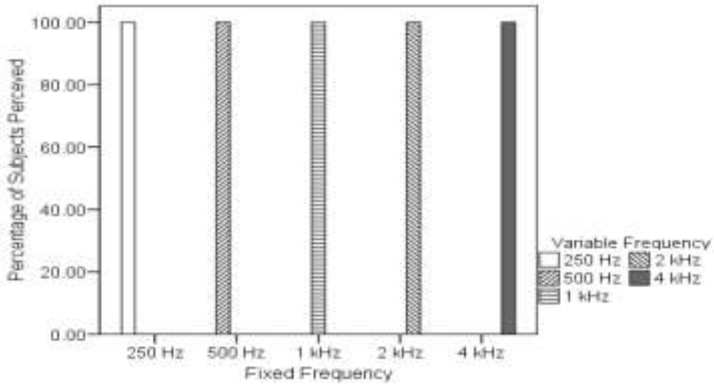

Figure 1: Sensorineural hearing loss without dead region (Right ear)

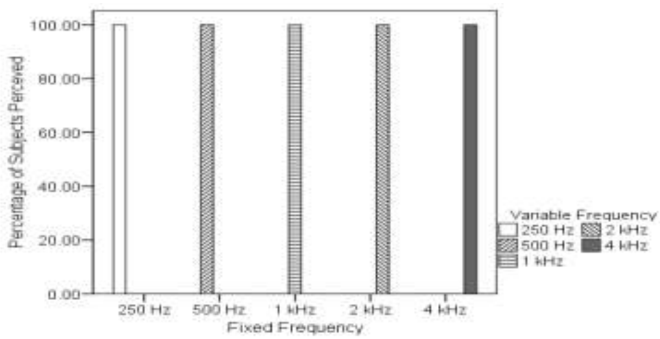

Figure 2: Sensorineural hearing loss without dead region (Left ear)

2) Sensorineural hearing loss with dead region right ear group and left ear group

It can be noticed that in each fixed frequency we can find subjects who perceived in other variable frequencies but most of the subjects could perceive at the same frequency.

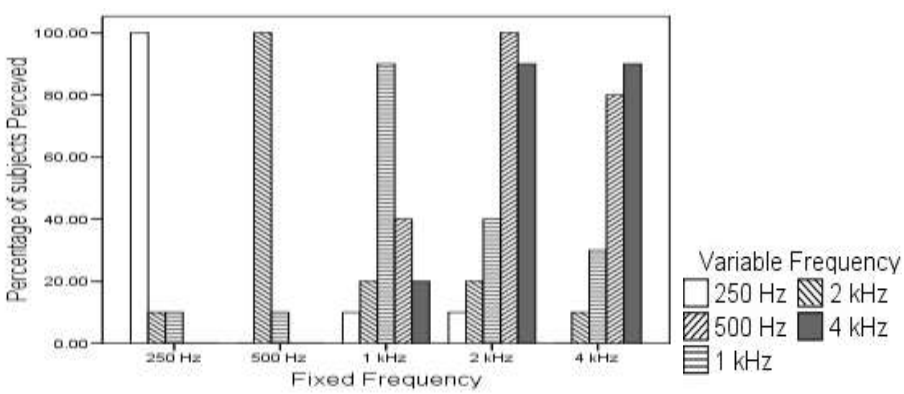

Figure 3: Sensorineural hearing loss with dead region (Right ear)

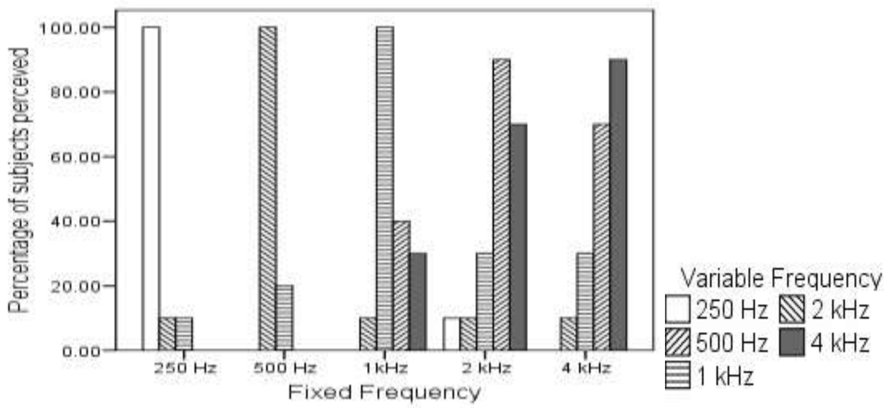

Figure 4: Sensorineural hearing loss with dead region (Left ear)

Cochlear hearing loss results in a variety of changes in the way that sounds are represented in the auditory system. For such changes are especially relevant for the perception of pitch. There may be regions within the cochlea where the inner hair cells (IHCs) and/or neurons are completely nonfunctional. These are referred to as dead regions. The peak in the neural excitation pattern may occur at a place very different from that normally associated with that frequency. The place theory predicts that the perceived pitch of the tone in such a case should be very different from normal.

The result of present study indicated that pitch perception in individual with sensorineural hearing loss with dead region is different than the sensorineural hearing loss without dead region. The result in pitch shifts are for two reasons. The first applies when the amount of hearing loss varies with frequency and especially when the amount of inner hair cell (IHC) damaged varies with characteristic frequency. When the IHC transduction efficiency is reduced and so a given amount of basilar membrane (BM) vibration leads to less neural activity than when the IHCs are intact. When IHC damage varies with characteristic frequency the peak in the neural excitation pattern evoked by a tone will shift away from a region of greater IHC loss. Hence the perceived pitch is predicted to shift away from that region. Early studies of diplacusis (De Mare, 1948; Webster & Schubert, 1954) were generally consistent with this prediction, showing that when a sinusoidal tone is presented in a frequency region of hearing loss, the pitch shifts towards a frequency region where there is less hearing loss. An alternative way in which pitch shifts might occur is by shifts in the position of the peak excitation on the BM.

The results of the present study indicated that the tips of tuning curves shifted towards lower frequencies in case of sensorineural hearing loss with dead region. This means that the maximum excitation at a given place is produced by a lower frequency. The results also showed shift of pitch toward higher frequency (upward) but some cases showed shift towards lower frequency. The peak of the BM response in an impaired cochlea would be shifted towards the base –i.e toward place normally responding to higher frequencies. Gaeth and Norris (1965) and Schoeny and Carhart (1971) reported that pitch shifts were generally upwards regardless of the configuration of loss. However it is also clear that individual differences can be substantial and subjects with similar patterns of hearing loss (absolute thresholds as a function of frequency) can show quite different pitch shifts. Huss, et al. (2001) and Huss and Moore (2005) obtained pitch matches and octave matches for subject with an extensive high frequency dead region. For tones whose frequency fell well within the dead region the perceived pitch was shifted upwards although it was also unclear.

The result of the present study indicated that frequency discrimination is poor for the individual with sensorineural hearing loss with dead region. The frequency of pure tones may be represented in terms of phase locking (a temporal representation) for frequencies below about 5000 Hz and purely spectrally (a place representation) for higher frequencies.

The precision of phase locking can be reduced (Wolf et al. 1981; Miller, et al. 1999), although this has not always been found. According to temporal theory reduced precision of phase locking should adversely affect frequency discrimination.

The propagation time of the traveling wave along the basilar membrane and the relative phase of the response at different places may differ from normal because of loss of the active "mechanism", structural abnormalities or both (Ruggero, 1994; Ruggero et al. 1996). This could adversely affect mechanisms for pitch perception based on cross-correlation of the outputs of different points on the basilar membrane (Loeb et al. 1983; Shamma, 1985; Shamma and Klein, 2000).

It has been proposed that the frequency discrimination of steady pulsed tones by normally hearing listeners is largely based on temporal information (cues desired from phase locking) for frequencies upto 4 to 5 KHz (Moore, 1973, 1974, 2003; Goldstein and Srulovicz, 1977; Sek & Moore, 1995; Micheyl, et al. 1998, Heinz, et al. 2001). Above 4 to 5 KHz, frequency discrimination is thought to depend mainly on place based changes in the excitation pattern (Moore, 1973b; Sek & Moore, 1995) although residual phase locking may play some role (Heinz, et al. 2001).

The results clearly indicated that if sensorineural hearing loss is accompanied with dead region (DR) then there is broader auditory filter. If there is no dead region the auditory filter shape is narrow which might indicate that hair cell in that region could be functioning. It can be expected that the perception of pitch might be more affected by the relative phase of the component in a dead region than the without dead region.

For such DR cases frequency selectivity is reduced. Auditory filters are broader than normal (Pick et al. 1977; Glasberg & Moore, 1986; Moore, 1998). Hence the excitation pattern evoked by a sinusoid is also broader than normal. According to place theory this should lead to impaired frequency discrimination of sinusoids. Reduced frequency selectivity also presumably leads to a reduced ability to resolve partials in complex tones and this might adversely affect the perception of the pitch of complex tones and also pure tone. For subjects with broad auditory filters even the lower harmonics would interact at the outputs of the auditory filters giving a potential for strong phase effects. Changes in phase locking and in cochlear traveling wave phase could also lead to less clear pitches and poorer discrimination of pitch.

In the present study subjects of sensorineural hearing loss with dead region reported that they did not perceive distinct pitch but sounded like noises. There have been a few studies of pitch perception in people with hearing losses that increase abruptly at high frequencies, who probably had dead regions at high frequencies. These subjects often report that high frequency sinusoids do not have distinct pitch but sound like noises or buzzes (Villchur, 1973; Moore et al. 1985b; Murray & Byrne, 1986). Subjective reports that pure tones sound noise like may be taken as a hint that a dead region is present but ratings of the clarity of the tonal percept cannot be used as a reliable indicator of dead regions. A sensorineural hearing loss involves not only a reduction of sensitivity but also a set of supra threshold impairments that distort the perception of sounds: listeners may suffer increased susceptibility to forward and backward masking, making it more likely that vowels will mask energy in weaker adjacent consonants; auditory filters are often broader than normal, leading to increased masking by background noises and by echoes in reverberant rooms; in extreme cases, even in quiet anechoic environments, difficulties may be experienced in detecting changes in the pitch of a talker's voice and in determining the spectral shape of speech sounds; the ability to analyze the temporal fine structure of the output of auditory filters may also be reduced leading to difficulties in following rapid changes in amplitude**,** frequency and pitch and exacerbating the effects of noise.

Conclusions

From the result we can conclude that pitch matches are often erratic and frequency discrimination is poor for tones with frequencies falling in a dead region. This indicates that such tones do not evoke a clear pitch sensation. The shifted pitches found for some subjects indicate that the pitch of low frequency tones is not represented solely by a temporal code. Possibly there needs to be a correspondence between place and temporal information for a “normal” pitch to be perceived.

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Effect of Dichotic Offset Training (Dot) in Children with an Auditory Processing Disorder

Priya G & Asha Yathiraj*

Abstract

Management of children with auditory processing disorders had gained wide importance in recent years. Various studies in the literature have shown that training children with central auditory processing problems using deficit specific intervention results in the improvement of auditory skills. The present study aimed at finding out the effectiveness of Dichotic Offset Training in children with auditory processing disorder. Twelve children who failed a screening checklist and the Dichotic CV and/or the Dichotic Digit test were included in the study. Six of them in the experimental group received Dichotic Offset Training using the training material developed by Yathiraj (2006). The children in the control group did not receive any training. The results revealed that there was statistically significant improvement after training in dichotic CV test. In dichotic digit test statistically significant improvement was seen in right ear single correct scores alone and not for left ear single correct score and double correct scores. Thus training children with binaural integration deficits using dichotic Offset Training was found to be effective.

Introduction

Auditory stimulation is so essential to development of humans that any interruption in this decoding process may have adverse effects on the overall maturation of an individual. The presence of an auditory processing problem can disrupt the decoding of auditory signals (Hanson & Ulvestad, 1979). The current definition of (C)APD explicitly recognizes both the auditory nature of the disorder and the inherent non-modularity of the central auditory nervous system. ASHA (2005) defined central auditory processing as “the perceptual (i.e., neural) processing of auditory information in the central nervous system (CNS) and the neurobiologic activity that gives rise to the electrophysiologic auditory potentials”. It includes neural mechanisms that underlie a variety of auditory behaviours including localization/lateralization, performance with degraded or competing acoustic signals, temporal aspects of audition, auditory discrimination and auditory pattern recognition.

Recent reports suggest that auditory training (AT) can serve as a valuable intervention tool particularly for individuals with language impairment and central auditory processing disorder (C)APD (Chermak & Musiek, 2002). Musiek, Shinn and Hare (2002) noted that the use of AT for treatment of APD is different from the classic use of AT. Most important to this

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* Professor of Audiology, All India Institute of Speech and Hearing, Mysore, India
e-mail: ashayathiraj@rediffmail.com

difference is that AT applied to APD is targeting the brain as the main site of mediation and the brain, unlike the auditory periphery is plastic.

Training for auditory integration is one such formal training program (Katz, Chertoff & Sawusch, 1984; English, Martonik & Moir, 2003). It has been shown that providing deficit specific therapy does result in improvement in auditory processing (Katz et al., 1984; Putter-Katz et al., 2002; English et al., 2003).

Binaural integration (BI) is the ability of a listener to process information presented to both ears at the same time. Poor performance in binaural integration has been found to result in difficulty in hearing in the presence of background noises or difficulty listening to two conversations at the same time (Bellis, 1996). An individual with deficit in binaural integration has been reported to have difficulty in integrating or processing information from more than one source at a time.

Binaural integration and binaural separation tasks are considered warranted when deficits are identified during dichotic evaluations. Musiek and Schochat (1998) used auditory training which involved directing the stimuli to the stronger ear at a reduced level. This sound field condition provided more cross-over between signals and greater demands on the patient than if the task was conducted under earphones. It was suggested by Musiek et al. (2002) that this procedure can also be modified using temporal offsets that lag in the poorer ear which improves the poorer ear performance.

One form of remediation for individuals with binaural integration problems is dichotic offset training, originally proposed by Rudmin and Katz (1982, cited in Katz et al., 1984). The main objective of Dichotic Offset Training (DOT) was to train the child to differentially integrate the two different stimuli which were separately given to both ears. Katz et al., (1984) studied 10 children aged 7-10 years who demonstrated difficulty on a dichotic test (SSW). They were given DOT for 15 one-hour sessions using different offset conditions (500, 100, 300, 200, 100 and 0 msec). A consistent pattern of improvement was documented for Staggered Dichotic Digit Test (SDD). However, they found a lack of statistically significant improvement on the SSW and Speech-in-Noise tests. They suggested that a battery of auditory training tasks is likely to be more beneficial than training any single skill.

Musiek and Schochat (1998) reported a case study of a 15 year old patient who demonstrated bilateral mild deficits on dichotic digits test and moderate bilateral deficits on the frequency pattern test and the compressed speech with reverberation test. A 6-week auditory training program was given that included three 1-hour sessions per week along with home training. Post auditory training performance showed higher scores on all central auditory tests.

A study by English et al., (2003) described another form of treatment for children with deficit in dichotic learning skill. Ten children with reduced left ear Dichotic Digit Test (DDT) scores (in the age range of 5 years 10 months to 10 years 9 months) were taken as subjects. They received additional auditory training in conjunction with the left-ear-only stimulation. The training was given for 1 hour a week for 10 to 13 weeks. It was found that for most subjects providing auditory stimulation to the left ear only improved left ear dichotic deficits as measured by the dichotic digit test. From the above studies it is evident that different forms of training can be provided which would result in an enhancement in dichotic performance. Both dichotic offset training as well as stimulation of the deviant ear have shown to bring about improvement in auditory integration.

According to Rupp and Stockdell (1978) 15 to 20% of school age population have some type of language/learning disorder, 70 percent of these have 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) APDs. In India it has been found that 3% of the children were found to have dyslexia (Ramaa, 1985). Since many of the school going children have this problem there is a need to find appropriate treatment procedures to help them develop their auditory skills and perform better academically. Many intervention procedures have been reported in literature but their efficacy has not been studied. Hence there is a need to study the effectiveness of an auditory training procedure which would enhance auditory perception. The aim of the present study is to determine the effectiveness of Dichotic Offset Training in children with low scores on the Dichotic CV and the Dichotic Digit tests.

Method

Participants

Two groups of participants were included in the present study, an experimental group and a control group. All the participants who were in the age range of 7-12 years had studied in an English medium school for at least 3 years. They had normal pure tone, immittance and speech identification findings. Further, they had normal IQ and no speech problems. Only those who failed the 'Screening Checklist for Auditory Processing' (SCAP) developed by Yathiraj and Mascarenhas (2002), the Dichotic CV test developed by Yathiraj (1999) and/or the Dichotic Digit test developed at AIISH were included in the study. The participant selection criteria for the control group were the same as the experimental group. While the experimental group received dichotic offset training the control group did not.

Instrumentation

A calibrated dual channel audiometer (Orbiter 922) was utilized for pure tone testing and for presenting the Dichotic CV and Dichotic Digit tests. To rule out any middle ear pathology a calibrated immittance meter (GSI Tympstar) was used. An audio CD player (Philips) was used to present test stimuli during evaluation while a portable audio CD player (Sony) with head phones was used during the training sessions.

Test Environment

All the evaluations were carried out in a two room situation which was acoustically treated as per ANSI (1991). Training was given in a quiet, distraction free environment.

Material Used

To select the participants the 'Screening Checklist for Auditory Processing' (SCAP) developed by Yathiraj and Mascarenhas (2002) was used. Further, to determine their binaural integration abilities they were evaluated utilizing the 'Dichotic CV test' developed by Yathiraj (1999) using the norms developed by Krishna (2001) and the 'Dichotic Digit test' developed at AIISH, with the norms obtained by Regishia (2003). The dichotic offset material developed by Yathiraj (2006) was used for the training. It consisted of 12 dichotic word lists with six lists having monosyllables without blends and six lists having monosyllables with blends. Each list had 10 word pairs. The material had 6 offset lags (500 ms, 300 ms, 200 ms, 100 ms, 50 ms and 0 ms). Each offset lag consisted of 4 word lists, two having a right ear lag and two with a left ear lag. Prior to administering the dichotic material the familiarity of the words was checked on ten children in the age range of 7 to 7 years 11 months. In addition the intelligibility of the recorded material which had been done on a computer by a female speaker with a sampling rate of 16 KHz was checked on ten adults. The material was found to be familiar to children as well as intelligible to adults.

Procedure

Participant Selection Procedure

The initial selection of the participants was done by screening for children using the 'Screening Checklist for Auditory Processing' (SCAP), developed by Yathiraj and Mascarenhas (2002). The checklist was administered by teachers who had a good knowledge about the abilities of the children. Twelve of those children who had scored less than 50% were taken for further evaluation. They were evaluated using dichotic CV and dichotic digit test. Half of the participants were administered the Dichotic CV first while the other half the Dichotic Digit test. Only those who failed these two tests were included in the study. The initial dichotic test scores also served as the baseline evaluation.

Baseline Evaluation (Evaluation I)

The Dichotic CV test which consisted of 30 pairs of CV segments was administered at 50 dB HL. The children had to repeat the phonemes and the responses were written down by the clinician. The scores obtained were compared with the norms developed by Krishna (2001). Of the twelve children who were administered the test ten failed the Dichotic CV test.

The Dichotic Digit Test was presented at 40 dB SL. The children were instructed to repeat all the numbers heard regardless of the order and the responses were written down. The norms developed by Regishia (2003) were used to decide whether a child passed or failed a test. Eleven out of the twelve children failed the test.

Dichotic Offset Training:

Six of the children who failed either of the above tests were given training using the Dichotic Offset Training (DOT) material developed by Yathiraj (2006) using an audio CD player with headphones. The training was started with the easier offset lag (500 ms) and once a child obtained approximately 70% double correct scores the next lower lag material was used. If the double correct scores obtained did not reach the 70% criteria the lists were presented again in a randomized order. Gradually the offset lag was reduced and the task was made more difficult. Each child was trained using all the lag times with both monosyllable lists without and with blends. Throughout the training the children were provided feedback regarding their performance (a head nod for every correct response). On completion of the 0 ms lag lists therapy was stopped. The number of sessions required by the children varied between 10 to 15 sessions depending on the abilities of the child.

Post therapy evaluation (Evaluation II)

After completion of the 0 ms lag therapy, post therapy evaluation was done for the experimental group. For the control group evaluation II was done 15 days after evaluation I. These evaluations were done using the dichotic CV and dichotic digit test and the single correct and double correct scores were obtained. The scores obtained from evaluation I and II were tabulated and scored.

Results and discussion

A comparison of the scores obtained in I and II evaluations were done separately for the experimental group and control group and also across groups. In addition a comparison of dichotic offset scores obtained during therapy by the experimental group, was carried out.

I a) Comparison of evaluations I and II in the experimental group

The scores obtained by the experimental group during evaluation I (pre training evaluation) and evaluation II (post training evaluation) on the dichotic tests were compared using the Wilcoxon Signed ranks test. The results revealed a statistically significant difference between the evaluation I and II scores following the dichotic offset training in the experimental group. The test scores were statistically significant at 0.05 levels for both single correct and double correct scores in the dichotic CV test. For the dichotic digit test, the scores were statistically significant only for the right ear single correct scores at a 0.05 level of significance. The left single correct scores and double correct scores did not show any statistically significant improvement (Table 1 & Figure 1).

Table 1: Comparison of pre and post test scores in the experimental group

Test	Score type	Mean pre therapy score	Mean post therapy score	z value
Dichotic CV	Right single correct	8.7	15.5	-2.201*
	Left single correct	13.3	23.2	-2.01*
	Double correct	1.8	10.8	-2.207*
Dichotic digit	Right single correct	14.4	22.0	-2.201*
	Left single correct	18.2	24.3	-1.577
	Double correct	1.7	7.5	-1.826

* Significant at 0.05 level

The results revealed that the dichotic offset training given to children who had deficit in binaural integration was found to be effective in acquiring that particular auditory skill. The improvement was found to be lesser in the Dichotic Digit test when compared to the Dichotic CV test which may be because the Dichotic Digit test requires auditory memory skills also along with binaural integration.

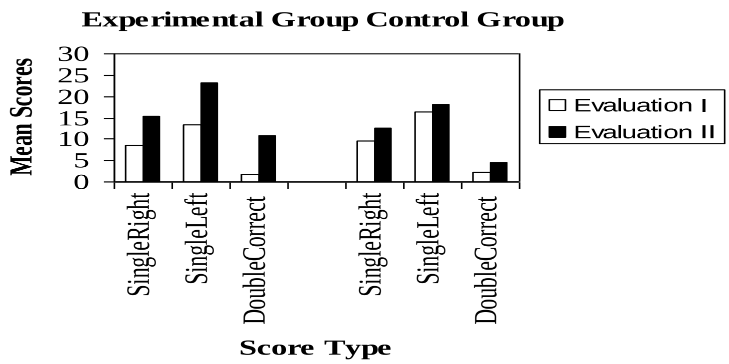

Figure 1: Evaluation I and II for Dichotic CV test for the experimental & control Group

I b) Comparison of evaluations I and II done in the control group

The scores obtained by the control group during evaluations I and II were compared using the Wilcoxon Signed rank test for both Dichotic CV and Dichotic Digit test. The results revealed that there was not much improvement seen in the Dichotic CV and Dichotic Digit test scores for the control group who did not receive any training. The Z scores obtained shows that the difference in the scores was not statistically significant (Figure 2).

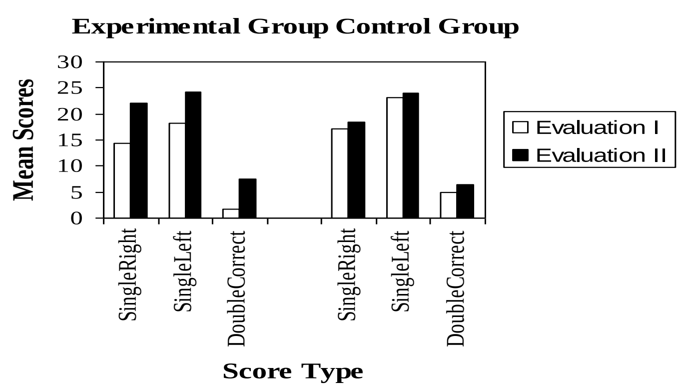

Figure 2: Evaluation I and II for the Dichotic Digit Test for experimental and control group

Thus it can be construed that without Dichotic Offset Training the individuals with poor auditory integration skills do not show any marked variation in their performance. The finding of the present study is similar to that of Katz et al., (1984) who also reported that children who did not receive Dichotic Offset Training did not show an improvement in performance. Besides the improvement seen using Dichotic Offset Training a study by English et al., (2003) showed that even training those with poor dichotic scores in one ear resulted in improvement in dichotic scores. In their study the poorer ear was stimulated and improvement was seen in left ear alone.

II) Comparison of evaluation I and II across groups

The scores obtained were compared between the experimental and control groups, separately for evaluations I and II (Table 2). For evaluation I the mean scores for both the groups did not vary much for the Dichotic CV and the Dichotic Digit test. However, for evaluation II, there were variations in the mean scores for the Dichotic CV test but not much for the Dichotic Digit Test.

To compare the mean scores between the experimental and control groups for evaluations I and II, non-parametric Mann-Whitney test was carried out. From Table 3 it is evident that there was no significant difference between the experimental and control group for evaluation I in the Dichotic CV and the Dichotic Digit Test. However in evaluation II there was a statistically significant difference across the groups in the Dichotic CV test. The left single correct score showed a significant difference at the 0.05 level whereas the right single correct score and double correct score showed a significant difference at 0.1 level.

Table 2: Mean and standard deviation scores for both the groups on I and II evaluations

Evaluation	Test	Score Type	Experimental group		Control group	
			Mean	SD	Mean	SD
Evaluation I	Dichotic CV	RE	8.7	4.5	9.6	3.9
		LE	13.3	7.7	16.3	6.6
		DC	1.9	3.6	2.3	4.8
	Dichotic digit test	RE	14.4	5.0	17.1	4.7
		LE	18.2	10.2	23.3	4.9
		DC	1.7	2.4	4.8	8.7
Evaluation II	Dichotic CV	RE	15.5	3.3	12.5	2.3
		LE	23.2	2.7	18.2	4.5
		DC	10.8	5.0	4.7	4.4
	Dichotic digit test	RE	22.0	3.2	18.4	4.5
		LE	24.3	4.3	24.1	5.9
		DC	7.5	8.4	6.5	7.3

The Dichotic Digit test did not show any significant difference when compared across the groups. Thus it can be concluded that following training the experimental group showed a significant difference which was not observed in the control group on a test that purely tapped auditory integration (dichotic CV). In contrast, the test that tapped both auditory integration and auditory memory (dichotic digit test) did not show such an improvement.

Table 3: Comparison of mean scores across the groups

Test	Group	Score Type	Evaluation I Mean scores	Significance	Evaluation II Mean scores	Significance
Dichotic CV	Experimental	RE	8.666	NS	15.500	0.124**
	Control	RE	9.583		12.500	
	Experimental	LE	13.333	NS	23.166	0.036*
	Control	LE	16.333		18.166	
	Experimental	DC	1.833	NS	10.833	0.091**
	Control	DC	2.333		4.666	
Dichotic Digit Test	Experimental	RE	14.416	NS	22.000	NS
	Control	RE	17.083		18.416	
	Experimental	LE	18.166	NS	24.250	NS
	Control	LE	23.250		24.083	
	Experimental	DC	1.666	NS	7.500	NS
	Control	DC	4.833		6.500	

* Significant at 0.05 level; ** Significant at 0.1 level

III) Comparison of dichotic offset scores in the experimental group:

The scores obtained by the experimental group during the dichotic offset training were also analyzed. The scores obtained at each of the lag times for the monosyllables without blends (Figure 3) and with blends (Figure 4) were analyzed. The double correct scores obtained during the therapy sessions were compared across various offset lags. This was done separately for the training material having a right lag and that having a left lag. For each of the conditions the baseline scores obtained at the start of the training were compared with the scores obtained at the end of the training for a particular lag time.

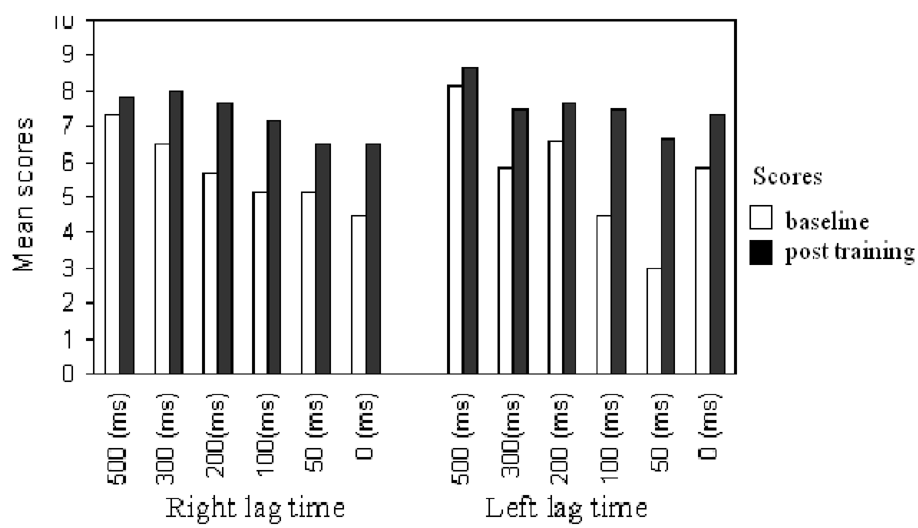

Figure 3: Double correct scores for monosyllables without blends, for varying lag times

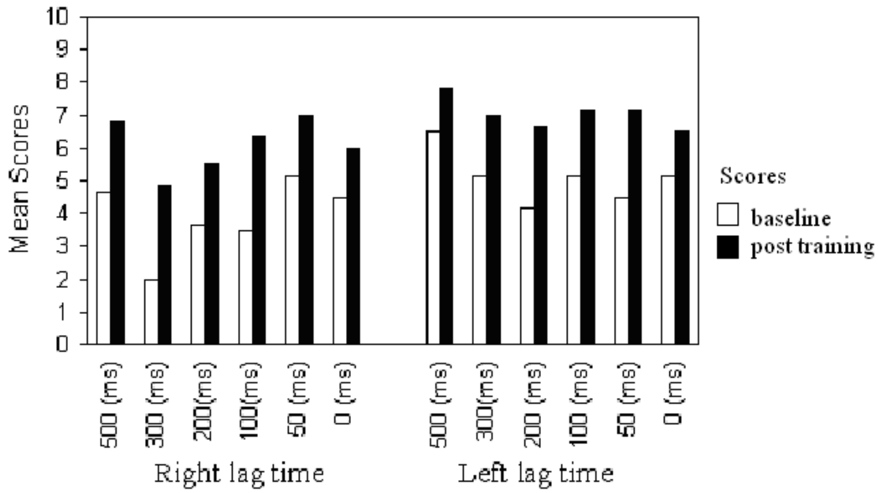

Figure 4: Double correct scores for monosyllables with blends, for varying lag times

From Figures 3 and 4 it can be observed that for all the lag conditions, material type (non-blends and blends) and ear of lag, there was an improvement in performance with training. The improvement seen during therapy was greater for the monosyllables without blends than for the monosyllables with blends. The Mann-Whitney test was carried out to check for overall changes between the baseline performance and the post therapy scores for each lag time. A statistically significant response was observed only for the 100 msec lag time. For other lag times, though there was an improvement, it was not statistically significant.

Conclusion

Based on the results of the present study it can be concluded that the Dichotic Offset training (DOT) is found to be effective in helping the children with deficits in binaural integration. No significant improvement was found for the control group in both the Dichotic CV and Dichotic Digit tests. The experimental group showed significant improvement ($p < 0.05$) in both the single and double correct scores in the Dichotic CV test following training. In the Dichotic Digit test the significant improvement was found only for right ear single correct score ($p < 0.05$) and not for left ear single correct and double correct score. It can be concluded that the improvement is more for a dichotic test that taps only binaural integration and not a test that taps both binaural integration and auditory memory.

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