EMOTION PERCEPTION IN COCHLEAR IMPLANT USERS, HEARING AID USERS AND NORMAL HEARING CHILDREN

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A Dissertation Submitted in Part Fulfillment for the Degree of

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ALL INDIA INSTITUTE OF SPEECH AND HEARING

MANASAGANGOTHRI

MYSORE-570006

June 2011

Dedicated to my dearest Amma, Appa and Cma…

Certificate

This is to certify that this dissertation entitled **"Emotion perception in cochlear implant users, hearing aid users and normal hearing children"** is a bonafide work in part fulfillment for the degree of Master of Science (Audiology) of the student (Registration No. 09AUD030). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore

June, 2011

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Declaration

This dissertation entitled **"Emotion perception in cochlear implant users, hearing aid users and normal hearing children"** is the result of my own study under the guidance of Prof. Asha Yathiraj, Professor of Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore　　　　　　　　　　　　　　　　Registration No.09AUD030

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

It is well established that speech is unique to humans and it is the most common mode of communication. Humans use speech to convey their attitude and emotions. Emotions have been noted to be identified on the basis of the conjunction of three criteria: regulator of social and interpersonal behaviour, primarily through their multi expressive channels, like language; regulate the flow of information and the selection of response processes or outputs of the organism, like cognition; and unlike language and cognition, regulate behaviour through a noncodified, prewired communication process (Izard, Kagan & Zajonc, 1984).

Auditory and visual cues are reported to be important in the perception of a speaker's emotional state. The auditory perception of emotion in the vocal expressions of others is noted to be vital for accurate understanding of emotional messages, which in turn shapes listeners' reactions and subsequent speech production (Banse & Scherer, 1996). In determining emotion, nonverbal behaviours are also observed to be of utility. Information about a speaker's intonation, facial expression, and gestures also add to or change the meaning of spoken discourse. Although, such nonverbal actions are considered to have multiple functions, their major function is the expression of emotion (Patterson, 1995; Feldman, Tomasian, & Coats, 1999; Bavelas & Chovil, 2000; Creusere, Alt & Plante, 2004).

Right from infancy, those with normal hearing are able to recognize emotions through facial and vocal expressions (Montague & Andrews, 2002). Further, the ability of normal hearing children to perceive emotions purely through the auditory modality was demonstrated by Peters (2006). Children aged 6-12 years were to able to distinguish emotions such as angry, scared, happy, and sad.

Studies have been reported that adults with normal hearing were able to recognize the emotional state of a speaker based only on auditory cues (Pereira, 2000a; Peters, 2006). This was attributed to the acoustic distinctiveness of different emotions. Banse and Scherer (1996), Williams and Stevens (1972) found that anger was characterized by a high average fundamental frequency, large range of fundamental frequency, high average intensity and a high rate of speech. In contrast, sadness was characterized by a low average fundamental frequency, low average intensity, long duration, and a slow rate of speech. Banse and Scherer (1996) concluded that auditory perception of the emotion was based primarily upon the acoustic cues such as fundamental frequency characteristics, average intensity, and the intensity changes along the utterance; the energy distribution in the spectral range, specifically the ratio between the energy in the high frequencies and the energy in the low frequencies; the formant location; and finally, the duration of the production or the rate of speech.

Persons with hearing impairment have been noted to be at a greater disadvantage than those with normal hearing at understanding emotion because of an inability to perceive all of the subtle changes that convey emotion. Among the profoundly hearing impaired persons, it has been observed by Most, Weisel and Zaychik (1993) that some could perceive acoustical changes that occurred in frequency, time, and intensity components of a speech signal, whereas others could only perceive changes in the time and intensity components. Further, it has also been reported that auditory perception of emotions by children, youth, and adults with hearing loss who use hearing aids have lower performance in comparison to individuals with normal hearing (Rigo & Liberman, 1989; Most, Weisel, & Zaychik, 1993; Shinall, 2005).

The studies on perception of emotion by cochlea implants show that they too perform poorer when compared to normal hearing listeners (Peters 2006; Most & Aviner, 2009; Hopyan, Gordon & Papsin, 2011). Hopyan, Gordon and Papsin (2011) revealed that children using cochlear implant were able to correctly distinguish happy versus sad music well above chance levels, but performed poorer on this task when compared to their typical hearing peers. The authors concluded that the children with cochlear implant show the ability to perceive emotion in music but do so less accurately than typically hearing peers.

Need for the study:

Emotional perception in pre-lingual implantees has not been studied extensively. Among the few studies done, many of them have compared emotion perception between individuals with normal hearing sensitivity and cochlear implant users (Peters 2006, Hopyan, Gordon & Papsin 2011). Whereas, only a very few investigators had compared emotional perception between cochlear implant users and hearing aid users (Most & Aviner, 2009). Hence, there is a need for more studies to compare emotion perception between cochlear implant users and hearing aid users in the pre-linguistic population.

Intonation is found to be one of the major cues for perception of emotion (Scherer & Oshinsky, 1977). It is also known that intonation patterns used across languages differ (Khan, 2011). It is noted that studies on emotion perception in cochlear implant users mainly were carried out in western countries using English. Hence, there is a need to evaluate difficulty in the perception of emotions in cochlear implant users in Indian languages. This would throw light on whether the perception of emotions differs across different language groups of cochlear implant users.

Previous studies used only a small number of test items to test emotion perception (House, 1994; Pereira, 2000a; Peters, 2006). Hence there is a need for a comprehensive study which compares the performance of emotion perception using more number of sentences through which reliable responses could be got.

Aim of the study:

The present study aimed to compare emotion perception through the auditory mode in children with normal hearing sensitivity with two groups of children having hearing impairment (cochlear implant users and hearing aid users). Besides comparing the children with hearing impairment with normal hearing children, the study aimed to compare the perception of the two groups with hearing impairment i.e. those using hearing aid and those using cochlear implants. The study also proposed to compare the perception across four different emotions i.e. happy, sad, neutral and question/interjection.

CHAPTER 2

REVIEW OF LITERATURE

The word emotion is derived from the Latin word ‘emovere’ meaning ‘to move out’. There are six basic emotions that have been studied. They are happiness, anger, fear, sadness, disgust, and surprise. All other emotions are considered varieties of these basic emotions (Robbins, Judge, & Sanghi, 2010). Each emotion has been noted to be characterized by physiological and behavioural qualities, including those of movement, posture, voice, facial expression, and pulse rate fluctuation (Duclos et al., 1989). According to Tomkins’s theory of emotions (1962), each basic emotion can vary in intensity and consists of a single brain process, whose triggering produces all the various manifestations of emotion, including its facial and vocal expression, changes in peripheral physiology, subjective experience, and instrumental action. As they have a single cause, these components tightly cohere in time and were intercorrelated in intensity. Banse and Scherer (1996) considered that the perception of emotion in the vocal expressions of others is considered vital for accurate understanding of emotional messages, which in turn shapes listeners’ reactions and subsequent speech production.

Acoustic correlates of emotions:

Several studies have been conducted to determine the acoustic correlates of emotions. Darwin (1998) gave a comprehensive description of the vocal sounds associated with emotion and reported that the fundamental frequency (F0) of speech varied with simulated expressions of contempt, anger, fear, grief, and indifference. It was also found that F0–related measures, such as mean F0 and overall pitch contour, were also influenced by emotions. Further, listeners were found to make reasonably accurate inferences about talkers' emotions from hearing such cues in speech samples.

It was reported that the emotions can be categorized into as three dimensions, arousal (intensity dimension), pleasure (positive or negative) and power (potency dimension) (Davitz, 1964). Using the above categories, Pereira (2000b) investigated emotion perception in 31 normal hearing subjects. The utterances having four types of emotions were studied. These included happiness, sadness, two forms of anger (hot and cold) and a neutral state. The task given was to rate each of the utterances using three of the above categories. The result showed that the concept of the dimensions of emotion was useful to describe and distinguish emotions. They also found that emotion with a similar level of arousal, and sometimes a similar level of power, shared acoustic characteristics in terms of F0 range and mean, and particularly intensity mean.

In another study, Williams and Stevens (1972) attempted to identify and measure those parameters in a speech signal that reflected the emotional state of a speaker. Comparison was made between a real-life situation and a simulated situation. It was reported that anger, fear, and sorrow situations tended to produce characteristic differences in contour of fundamental frequency, average speech spectrum, temporal characteristics, precision of articulation, and waveform regularity of successive glottal pulses.

It has been noted by Pereira and Watson (1998) that acoustic analysis of emotion using material consists of two semantically neutral utterances portraying three emotions: anger, happiness and sadness and a neutral tone. The fundamental frequency, duration and an estimate of sound intensity were analyzed. The results showed that the contour of the fundamental frequency was most revealing, showing differences between anger and happiness. Also the mean fundamental frequency differentiated between cold anger and hot anger. Further, they showed that hot anger and happiness had a fundamental frequency with a large range and high mean in contrast to the more subdued emotions of sadness, and neutral voice.

Scherer and Oshinsky (1977) reported that fast tempo, large pitch variation, sharp envelope, a few harmonics, and moderate amplitude variation were the acoustic parameters of a speech signal depicting happy. These signals could be used to differentiate happiness from sadness which had a slow tempo, low pitch level, a few harmonics, round envelope, and pitch contour down.

The acoustic properties of speech associated with four different emotions (sadness, anger, happiness, and neutral) intentionally expressed in speech by an actress was also described by Yildirim et al. (2004). The results revealed that happiness/anger and neutral/sadness shared similar acoustic properties in this speaker. Speech associated with anger and happiness were characterized by longer utterance duration, shorter inter-word silence, higher pitch and energy values with wider ranges, showing the characteristics of exaggerated or hyperarticulated speech. In contrast, (House, 1994, and Pereira, 2000b) found some of these acoustic properties to be different. They found a happy utterance to be shorter in duration than a sad one.

In general, across studies on the acoustic properties of emotional speech, there is considerable overlap in acoustic properties that denote different emotions. Yildirim et al. (2004) also found that RMS energy, inter-word silence, and speaking rate were useful in distinguishing sadness from the other emotions they examined. It is clear from the literature acoustic correlates of emotion that mean F0, overall pitch contour, tempo, harmonics and duration are found to be important to distinguish emotions.

Development and perception of emotions in individuals with normal hearing:

It has been shown that the development of perception of emotion is important for understanding communication intent, social competence and social adjustment (Nowicki & Mitchell, 1998). Montague and Andrews (2002) investigated person familiarity in infants. It was found that infants begin to recognize emotions through their parents' facial as well as vocal expressions. Russell, Bachorowski, and Dols (2003) observed that prosodic cues that signal a talker's emotional state are particularly important for auditory perception of emotion. When talking to infants, adults were noted to use 'infant-directed speech' that exaggerates prosodic features, compared with 'adult-directed speech'. Infant-directed speech was such that it attracted the attention of infants, provides them with reliable cues regarding the talker's communicative intent, and conveying emotional information that plays an important role in their language and emotional development.

Most children have been observed to discriminate the facial expressions for happiness, sadness, anger, and fear, by the preschool years (Izard, 1971; Odom & Lemond, 1972). Shaffer and Kipp (2010) reported that at birth, emotions such as contentment, disgust, distress, interest could be perceived by children. Emotions like anger, fear, joy, sadness and surprise were acquired by 2-7 months whereas embarrassment, envy, guilt, pride, shame by 12-24 months. As the children grew older, they became better at correctly identifying emotion and sarcasm. According to Dimitrovsky (1964), children aged 5 to 12 years of age become increasingly accurate at labeling affect.

The performance on perception of emotion (angry, scared, happy, and sad) by children with normal hearing sensitivity, aged 6-12 years, was studied by Peters (2006). Three semantically neutral sentences, appropriate in vocabulary and syntax for the children were used. The number of correct responses to the presentations was greater than 90% in children with normal hearing.

The perception of emotions by adults has been also investigated. Pereira (2000a) examined the perception and expression of emotion in 40 normal hearing subjects. Two semantically neutral utterances, spoken in two productions by two actors (one male, one female) in the emotions of cold anger, hot anger, happiness, sadness and neutrality were considered. The normal hearing individuals obtained 85% correct scores in identifying the emotions.

The importance of acoustic cues in the perception of emotions was demonstrated by Luo, Fu and Galvin (2007). Eight normal hearing adults were evaluated for their perception of vocal emotions (angry, anxious, happy, sad, and neutral). When the overall amplitude cues were preserved, normal-hearing listeners achieved near-perfect performance (89.8%). Removing the overall amplitude cues significantly worsened the mean performance of normal hearing participants (87.1%).

The review of literature reveals that emotions can be perceived by normal hearing individuals from a very young age. There however appears to be a developmental trend.

Perception of emotions in individuals with hearing impairment:

Persons with hearing impairment are at a greater disadvantage than those with normal hearing at perceiving emotions. In order to identify emotions auditorily, it is considered necessary to perceive subtle acoustic changes. Among those with profound hearing impairment, some have been found to perceive acoustical changes that occur in the frequency, time, and intensity components of the speech signal, whereas others could only perceive changes in the time and intensity components (Most, Weisel, & Zaychik, 1993). Difficulties in perceiving information about the speaker's emotional state has been noted to lead to a lack of awareness of the individual's impact upon others, a lack of empathy, and social skills that are not adapted to the situation (Mellon, 2000).

Moore (1996) found that most of the acoustic information about emotions such as F0 is located in the low frequency range, and many individuals with hearing impairment have residual hearing in this range. However, along with the audibility, impaired psychoacoustic abilities such as frequency resolution, frequency discrimination, or temporal resolution, were thought to hamper information on emotion.

Studies on the auditory perception of emotions by children, youth, and adults with hearing loss who use hearing aids have reported of lower performance in these individuals in comparison to those with normal hearing (Most, Weisel, & Zaychik, 1993; Rigo & Liberman, 1989; Shinall, 2005). A study by Rigo and Liberman (1989) reported a negative correlation between the identification of emotions and the degree of hearing loss in the lower frequencies, whereas on the other hand Most, Weisel and Zaychik (1993) did not report such a correlation. All the persons with hearing loss who participated in the latter study received low auditory scores in emotion perception, without any correlation to the degree of hearing loss. The difference in the results was due to the subject criteria where Most and others included participants with severe and profound hearing loss, whereas those examined by Rigo and Liberman had a wide range of hearing loss ranging from mild and moderate to severe degrees.

Studies on the perception of emotions through the visual mode in individuals with hearing impairment provided different results. Some of the studies reported similar performance in individuals with hearing impairment to that of individuals with normal hearing (Dyck, Farrugia, Shochet, & Brown, 2004; Hosie, Gray, Russell, Scott, & Hunter, 1998; McCullough, Emmorey, & Sereno, 2005). Whereas, other studies revealed that the individuals with hearing impairment performed poorly through the visual mode also (Dyck & Denver, 2003; Most, Weisel, & Zaychik, 1993). Most of the research findings did not report any significant correlation between the degree of hearing loss and the ability to accurately identify facial expressions (Dyck & Denver, 2003; Most, Weisel, & Zaychik, 1993).

Andrews and Lennon (1991) reported that the lower performance of children with hearing impairment when perceiving emotional information was due to the ability to perceive emotions which develops along with spoken language. The infants could identify emotions more easily by watching facial expression while hearing matching vocalization. In addition, Rigo and Liberman (1989) speculated that individuals with hearing impairment might focus upon the mouth in order to speech-read, and therefore, miss information around the eyes that might be relevant to emotions. Reports by Most, Weisel, and Zaychik (1993) and Rigo and Liberman (1989) indicated that similar to individuals with normal hearing, those with hearing loss exhibited better perception of emotions through the visual mode and the combined auditory-visual mode than the perception through the auditory mode. However, in contrast to hearing individuals, the level of emotion perceived by individuals with hearing loss through the combined auditory–visual mode did not exceed that of emotions perceived through the visual mode.

This indicated that they did not benefit from the addition of auditory information to the visual mode.

Engen, Engen, and Blackwell (1983) showed that even children with hearing impairment, who could only hear lowest frequencies at high intensities, were able to perceive differences in intonation and to categorize them according to sentence type.

Most and Frank (1991) studied the relationship between the perception and production of intonation, where 22 children with hearing-impairment (aged 9–13 yrs) with a hearing loss of 80 dB or greater were recruited. Three tasks of intonation perception and production were carried out. The tasks consisted of imitation of intonation contours, discrimination of intonation contours, and reading of short sentences with various intonation contours. Acoustic analysis was done to assess performance on the speech production task. The data suggested a relationship between imitation and discrimination of intonation contours. Also, greater accuracy in perception and production of intonation was demonstrated for falling than for rising contours.

The ability of pre-kindergarten students having normal hearing and impaired hearing to identify emotion in speech through audition was studied by Shinall (2005). Identification and discrimination of emotions were evaluated. For the discrimination task, five of the six pre-kindergarten students with normal hearing were able to perform above chance (50%) which showed that they were able to discriminate these emotions through audition alone. The students with hearing impairment had more difficulty than the children with normal hearing. The overall averages were 74% correct for the students with hearing impairment and 94% correct for the students with normal hearing. The listener's age did seem to affect the results of the students' scores for this task. For both the students with normal hearing and impaired hearing, the identification task was more difficult than the discrimination task. The normal hearing students did better than chance with an average of 80% correct while for the students with hearing impairment, the overall average was near chance with an average of 46%. This showed that the students with normal hearing were able to identify emotion better than were the students with impaired hearing.

It is clear from the literature that emotion perception is affected in children and adults with hearing impairment. The poorer performance has been attributed to the inability of those with hearing impairment to utilize subtle acoustic cues to differentiate emotions auditorily. It was also observed that children with hearing impairment are unable to utilize emotions visually also.

Perception of emotions in individuals using Cochlear Implants and hearing aids:

The amplification options available for individuals with hearing loss are hearing aids and cochlear implants. Recent digital hearing aids help individuals with hearing impairment improve their hearing and speech comprehension. Likewise, cochlear implant technology has opened up rehabilitation options for the use of spoken language among individuals with severe to profound hearing loss. The use of the cochlear implants has shown that it increases the audibility of the speech signal and consequently enables better speech perception compared to those with a similar degree of hearing loss but who use hearing aids (Blamey et al., 2001; Calmels et al., 2004; Gestoettner, Hamzavi, Egelierlier, & Baumgartner, 2000; Mildner, Sindija, & Zrinski, 2006).

Hopyan, Gordon and Papsin (2011) conducted a study to determine whether children who had been deaf from infancy and were experienced cochlear implant users had acquired the ability to identify emotion in musical phrases. The participants were 18 unilateral cochlear implant users, aged 7-13 years, with a mean activation age of 2-9 years. In addition, 18 age and gender matched controls were studied. The participants were asked to judge 32 brief musical excerpts as happy or sad by pointing to simple graphics of a smiling or frowning face. The results revealed that children using cochlear implants were able to correctly distinguish happy versus sad music well above chance levels, but performed more poorly on this task than their peers with typical hearing. The age at which the cochlear implant was activated and the time following cochlear implant activation was both not correlated with outcome measures. The authors concluded that the children with cochlear implants show the ability to perceive emotion in music but do so less accurately than typically hearing peers.

The results of a study by House (1994) suggested that implant users perceive mood by using intensity as the primary cue, fundamental frequency as a strong secondary cue, and spectral and voice source characteristics as weak secondary cues. These cues were, however, misinterpreted, especially when the emotions were similar. The author concluded that adult cochlear implant users confused happiness with anger and sadness with neutrality. These confusions reflected the use of intensity as a primary cue to detecting emotion in speech. The results also indicated that these cochlear implant users also attended to fundamental frequency as a cue to perceive emotion. This was evident from their responses which showed that they could differ from sadness and neutrality from anger as the intended mood. These three mood types were noted to have more similar F0 contours relative to the wide range in F0 excursions found in happy speech.

It is known that F0 range, F0 mean, and F0 variation are important for perception of emotion. Several studies have investigated cochlear implant users' perception of indexical information about the talker in speech. Fu, Chinchilla, Nogaki, and Galvin (2005) found that voice gender identification of cochlear implant users' was nearly perfect (94% correct) when there was a sufficiently large difference (~100 Hz) in the mean overall fundamental frequency (F0) between male and female talkers. When the mean F0 difference between male and female talkers was small (~10 Hz), performance was significantly poorer (68% correct). In the same study, voice gender identification was also measured in normal hearing subjects listening to acoustic cochlear implant simulations, in which the amount of available spectral and temporal information was varied. The results for normal hearing subjects listening to cochlear implant simulations showed that both spectral and temporal cues contributed to voice gender identification and that temporal cues were especially important when the spectral resolution was greatly reduced. Compared to voice gender identification, speaker recognition was much more difficult for cochlear implant users.

Pereira (2000a) also examined the perception and expression of emotion in speech in post-lingually deafened adults which was compared with the perception by normal hearing subjects. The results revealed that subjects who wore both hearing aids and cochlear implants consistently confused happiness with anger and sadness with neutrality. They suggested that intensity was being used as a primary cue for identifying emotion since higher intensities were common to both happiness and anger, while lower intensities were common to neutral and sadness.

Similar results were obtained by Schorr (2005) and Peters (2006). Schorr (2005) recruited 39 children with cochlear implants, aged five through fourteen years, and assessed them with tasks that measured the processing of basic social and emotional stimuli. An age and sex matched group of 37 normal hearing peers was assessed for control purposes. A list of the non-linguistic emotional sounds (four negative, four positive, and four neutral stimuli) was used for the identification task. Sounds (e.g. cries, giggles, gasps) were delivered via loud speakers in a quiet room to individual participants at approximately 75 dB SPL. The participants were asked to report or imitate the sounds they heard as a positive, negative, or neutral sound. Responses were accepted verbally or by pointing to a positive, neutral, or negative icon. The result indicated that participants with cochlear implants were less accurate than participants with normal hearing in identification of emotion-eliciting sounds. The result of this study shed light on the subtle effects of auditory deprivation during early childhood and the clearly ongoing effects of decreased auditory perception.

The ability of adult cochlear implant users to perceive emotion through speech alone was also studied by Peters (2006). The method used was the same as that they had used earlier on the children. The number of correct responses to the presentations by adult cochlear implant users ranged from 40.7% to 92.8%.

The ability of 26 paediatric cochlear implantees to produce and perceive speech intonation contrasts, in comparison with their age-matched peers with normal hearing was investigated by Peng, Tomblin and Turner (2008). They also studied the relationships between intonation production and perception in cochlear implant users and normal hearing individuals. It was found that both the production and the perception scores were significantly lower in the cochlear implant group than those with normal hearing.

An attempt was made by Luo, Fu and Galvin (2007) to study the effect of the number of channels and cut-off frequency in the perception of vocal emotions (angry, anxious, happy, sad, and neutral) in normal-hearing listeners and cochlear implant users. When the overall amplitude cues were preserved, normal-hearing listeners achieved near-perfect performance, whereas listeners with cochlear implant recognized less than half of the target emotions. Removing the overall amplitude cues significantly worsened the mean performance of normal hearing participants and the cochlear implant users. Further, both cochlear implant and normal-hearing performance significantly improved as the number of channels or the envelope filter cutoff frequency was increased from 1 to 8 and 50 to 400 Hz respectively. The results suggested that spectral, temporal, and overall amplitude cues each contributed to vocal emotion recognition. The poorer cochlear implant performance was attributed to the lack of salient pitch cues and the limited functional spectral resolution.

Most and Aviner (2009) evaluated the benefits of cochlear implants to perceive emotion in participants differing in their age of implantation. The findings of the cochlear implant group were compared with hearing aid users and adolescents with normal hearing. The emotion perception was examined by having the participants identify happiness, anger, surprise, sadness, fear, and disgust. The emotional content was placed upon the same neutral sentence. The stimuli were presented in auditory, visual, and combined auditory–visual modes. The results revealed better auditory identification by the participants with normal hearing in comparison to all groups of participants with hearing impairment. No differences were found among the groups with hearing impairment in each of the 3 modes. Although auditory–visual perception was better than visual-only perception for the participants with normal hearing, no such differentiation was found among the participants with hearing impairment. The results question the efficiency of some currently used cochlear implants in providing the acoustic cues required to identify the speaker's emotional state.

It is clear from the above studies that emotion perception is affected in children with hearing impairment. This was observed in those using hearing aids as well those using cochlear implants. Most of the studies compared the performance of those using hearing aids or cochlear implants with that of normal hearing individuals. However, relatively few studies compared perception of emotions by hearing aid users with that of cochlear implant users.

CHAPTER 3

METHOD

The study aimed to determine the abilities of children using cochlear implants to perceive different emotions through the auditory mode. Their perception was compared with that of children using hearing aids, and children with normal hearing children.

Participants:

The study comprised of a clinical group and a control group who had been exposed to Kannada from early childhood. The clinical group consisted of twenty-two children in the age range 5 years to 17 years. All the participants had congenital severe or profound bilateral, sensorineural hearing loss. Among the twenty-two participants, twelve used cochlear implants and twelve used binaural digital hearing aid. The clinical group had at least one year of experience with their devices. The two clinical groups were matched in terms of their listening age with the device worn by them (cochlear implant/hearing aid). Both groups had aided audiograms within the speech spectrum.

Twelve normal hearing children in the age range of 5-6 years served, as the control group. It was ensured that these children had no history of hearing loss and had normal pure-tone thresholds.

Table 1: Details of the clinical groups

Sl. No	Age in years	Gender	Device used	Experience with the device (years)
1	8	Female	Sprint	2
2	12	Female	Sprint	2.5
3	11	Female	Freedom	2.5
4	13	Female	Sprint	2.5
5	9	Female	Sprint	3
6	6	Female	Freedom	2.5
7	17	Male	Esprit 3G	7
8	10	Female	Freedom	2
9	8	Female	Freedom	3
10	6	Female	Esprit 3G	3
11	5	Female	CP810	2
12	10	Female	Sprint	4
13	5	Female	Siemens Infinity Pro SP	4
14	6	Female	Siemens Intus SP	3.5
15	6.5	Male	Canta 280	3
16	8	Female	Siemens Infinity Pro SP	4
17	8	Female	Electone Eclipse 2 SP	3.5
18	10	Male	Siemens Infinity Pro SP	6
19	11	Male	Siemens Infinity Pro SP	5

20	10	Male	Siemens Infinity Pro SP	5
21	9	Male	Starkey EB01312	6
22	12	Female	Siemens Infinity Pro SP	5
23	13	Female	Siemens Infinity Pro SP	7
24	17	Female	Siemens Infinity Pro SP	11

Equipment:

The perception testing was carried out using an Intel Core 2 Duo laptop loaded with Adobe Audition (version 3). The output from the laptop was calibrated using a sound level meter (834 - Larson Davis make) having a half-inch free-field microphone (2540 - Larson Davis make). The calibration was done in a sound treated room with the Sound Level Meter kept one meter away from two external speakers (Creative SBS15). The speakers were placed side by side at 0^0 azimuth with reference to the sound level meter. The volume control of the speakers and the computer software were manipulated such that the output was 60 dB SPL. The settings were noted and used throughout the evaluation process.

Material:

The 'Auditory Perception Test of emotions in Kannada sentences' developed by Agarwal and Yathiraj (2007) was used to evaluate emotion perception. The test depicted four emotions (neutral, happy, sad and interjection/questioning) using ten Kannada sentences and five practice items (Appendix I). All the sentences used for the test permitted the use of the four emotions semantically. A female whose mother tongue was

Kannada, served as the speaker. The test had been recorded using a sampling rate of 44100 Hz with 32 bits, and was stored in a CD.

Prior to obtaining the data on the target group, the appropriateness of the material was checked on twenty native adult speakers of Kannada. These adults were required to indicate as to whether each of the sentences could be used to represent the four different emotions. It was confirmed that the four emotions could be used for day-to-day communication, without altering the syntactic structure of each sentence.

Further, the adults had to listen to the sentences that were randomized and indicate the emotion that was represented using the 4-choice closed-set tasks. The participants had to point to one among the four pictures portraying the emotions happy, sad, neutral and interjection (Appendix II). As 90 % of the participants could correctly identify each emotion, the pictures were retained without any modification.

Initially, pictures representing the emotions were shown to 20 young adults to confirm that the pictures represented the emotion that they were supposed to do so. The participants were expected to identify the emotion that each picture depicted. 90 % of the young adults could correctly identify the emotions.

Test environment:

The emotion perception testing was done in a quiet room, free from any distractions and adequately lit. The participants were comfortably seated 1 meter away from the speakers which were placed in front of the participant at 0^0 azimuth.

Procedure for identification of emotion:

A board, with the pictures of faces portraying the emotions was placed in front of the participants. The participants were instructed to listen to the audio stimuli depicting the four emotions and point to one of the pictures placed in front of them that depicted the emotions. The task was also demonstrated by the experimenter using the practice items. Prior to administering the test items, the participants carried out the task using the same practice items.

The participant heard all ten test items, with each item having four emotions. The forty test items were presented in a random order to prevent them from guessing. It was ensured that the children were attentive prior to the presentation of the stimuli. If required, the children were given breaks in between the session. The entire testing was done in one session. Social reinforcement and tangible reinforcement were provided for the participants.

Scoring: Each correct response was given a score of '1' and an incorrect response was given a score of '0'. The responses of each of the participants were tabulated.

Analyses:

The data thus obtained were subjected to statistical analysis using SPSS (Version 18.0) software. Multiple analysis of variance test was done to compare the performance of the participants having normal hearing with those having hearing impairment. Further, the comparison was done between the normal hearing participants and the subgroups of the participants having hearing impairment (Cochlear implant users and hearing aid users). In addition, a comparison was also done between the two subgroups of participants with hearing impairment.

CHAPTER 4

RESULTS AND DISCUSSION

The present study aimed at comparing the perception of four different emotions in cochlear implant users, hearing aid users and normal hearing children. The analyses were done to get a *comparison of performance across the participants* wherein children having normal hearing were compared with children using hearing aids as well as with those using cochlear implant; and the two groups with hearing impairment (cochlear implant users and hearing aid users) were also compared. In addition, a *comparison of perception of four different emotions* was also carried out for the different participant groups.

Comparison of performance across participants:

Initially, descriptive statistics were carried out to determine the difference in the performance between the *participants having normal hearing and those with hearing impairment*. From Table 2 it is evident that the mean scores of the participants with normal hearing were higher when compared to the participants with hearing impairment. Also the variability in scores among the normal hearing group was lesser when compared to the two groups with hearing impairment. This is evident from the standard deviation provided in Table 2. The scores obtained by the two subgroups of individuals with hearing impairment were lower than that of the normal hearing group. However, the mean and the standard deviation scores obtained by the *participants using cochlear implants and hearing aids* were comparable. This was observed for each of the four emotions that were evaluated.

Table 2: Mean scores and SD for all four emotions across groups

Emotions	Group	Mean	Std. Deviation
Happy	CI users	6.00	2.663
	HA users	6.92	0.996
	Normal hearing	9.17	0.835
Neutral	CI users	7.17	1.850
	HA users	6.75	2.301
	Normal hearing	9.58	0.793
Sad	CI users	8.33	1.614
	HA users	8.50	1.382
	Normal hearing	9.92	0.289
Interjection	CI users	6.00	1.128
	HA users	5.58	1.505
	Normal hearing	9.00	0.603

Maximum score = 10; CI = cochlear implant; HA = Hearing aid

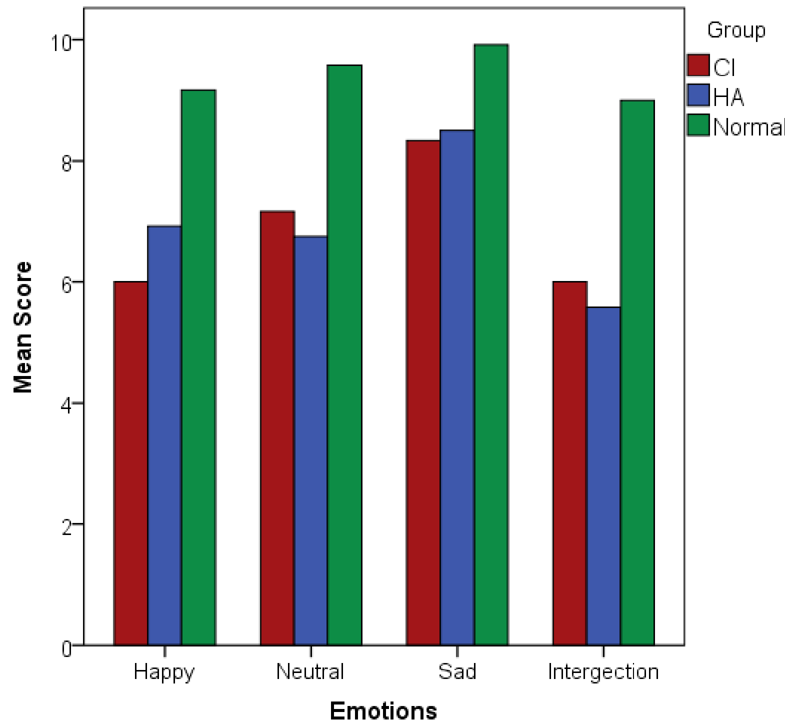

Figure 1: Mean perception scores of four emotions across participant groups

To see if the performance among the groups differed significantly, repeated measures ANOVA was done. A significant main effect was observed between groups [$F = 25.71$, $p < 0.001$] and between emotions [$F = 16.785$, $p < 0.001$]. As there was a significant main effect between groups, Duncan's Post Hoc test was done. The results showed that there was a significant difference between the normal hearing group and those with hearing impairment ($p < 0.05$). In contrast, there was no significant difference between the two groups with hearing impairment ($p > 0.05$).

The results of the study show that the performance of individuals with normal hearing is better than the groups having hearing impairment. This demonstrates that despite the children with hearing impairment having aided audiograms within the speech spectrum, they were unable to utilize acoustic cues in a manner similar to that done by normal hearing individuals.

Several studies on the auditory perception of emotions by children, youth, and adults with hearing impairment who use hearing aids have reported lower performance in comparison to individuals with normal hearing (Rigo & Liberman, 1989; Most, Weisel, & Zaychik, 1993; Shinall, 2005). Also, individuals with normal hearing are known to perform better than cochlear implant users (Pereira, 2000; Peters, 2006; Luo, Fu & Galvin, 2007).

The findings of the present study concur with that reported in literature, confirming that irrespective of whether the children with hearing impairment used cochlear implants or hearing aids, they were unable to perceive emotions like their normal hearing peers. The hearing impairment probably resulted in them perceiving acoustic cues that are essential for them differentiate the emotions, in a distorted manner.

Comparison of perception of different emotions:

As the repeated measures ANOVA revealed that there was a significant difference between emotions [$F = 16.785$, $p < 0.001$], MANOVA was done to check how the three groups of participants perceived each of the four emotions. The results shown in Table 3 confirmed that there was a significant difference in the perception of all four emotions, when the three participant groups were combined.

Table 3: Comparison of emotions with groups combined.

Emotions	**F**	**Level of Significance**
Happy	10.886	0.000
Neutral	9.012	0.001
Sad	5.926	0.006
Interjection	32.060	0.000

Duncan's Post Hoc test was done to check how each of the groups perceived the four different emotions. The results showed that individuals with normal hearing perceived each of the emotions significantly better than the groups using cochlear implantation and hearing aids. This was seen for all four emotions at the level of 0.05. However, there was no significant difference between those using cochlear implantation and those using hearing aids with regard to their perception of each of the emotions ($p > 0.05$). The mean scores shown in Table 2 confirm this.

The results bring to light that the normal hearing group perceive each of the emotions significantly better than the two groups with hearing impairment. Further, it is also highlighted that emotion identification by cochlear implant users and hearing aid users was comparable. This reveals that by using cochlear implants, children with profound hearing impairment can perform similar to those with lesser degrees of hearing impairment who use hearing aids. However, neither of these technologies enables them to perceive like normal hearing children.

Previous studies have shown the advantage of cochlear implants mainly for the perception of segmental features of speech (Calmels et al., 2004; Gestoettner et al., 2000). However, the advantage of cochlear implants in relation to the perception of suprasegmental features has not been conclusive. Some research has shown that perception of suprasegmental features improves after implantation (Huang, Wang, & Liu, 1995; Waltzman & Hochberg, 1990). Other studies, however, did not show an advantage of cochlear implants over hearing aids (Boothroyd & Eran, 1994; Lee, Hasselt, Chiu, & Cheung, 2002; Most & Peled, 2007). Furthermore, some of these studies have even demonstrated poorer performance by cochlear implant users in comparison to hearing aid users in the perception of intonation (Boothroyd & Eran, 1994; Most & Peled, 2007) and in the perception of syllable stress (Most & Peled, 2007).

Thus, the findings of the present study highlights that using a cochlear implant does not result in perception similar to normal hearing individuals. However, it enables the users to perceive emotions through the auditory modality in a manner similar to those with lesser degrees of hearing impairment who use hearing aids.

Comparison of performance within each group across emotions:

To check within each participant group, the significance of difference in perception across the four emotions, one-way ANOVA was done. A significant difference was seen in all three groups in the way they perceived emotions {cochlear implant users [$F = 5.366$, $p < 0.05$], hearing aid users [$F = 9.8$, $p < 0.001$], individuals with normal hearing [$F = 5.088$, $p < 0.05$]}. The mean values depicted in Table 4 also indicate the difference in scores obtained in the perception of emotions by the three different groups.

Table 4: Mean scores and SD for all the four emotions within each group

	Emotions	Mean	Std. Deviation
Cochlear implant users	**Happy**	6.00	2.6
	Neutral	7.17	1.8
	Sad	8.33	1.6
	Interjection	6.00	1.1
Hearing aid users	**Happy**	6.92	0.9
	Neutral	6.75	2.3
	Sad	8.50	1.3
	Interjection	5.58	1.5
Normal hearing children	**Happy**	9.17	0.8
	Neutral	9.58	0.7
	Sad	9.92	0.2
	Interjection	9.00	0.6

Further, pair-wise comparison was done which revealed, as shown in Table 5 that among the cochlear implant users, the emotions sad and interjection were significantly different ($p < 0.05$) whereas the other two emotions did not differ significantly. Among the hearing aid users, the emotion happy was significantly different from sad and interjection ($p < 0.05$), neutral from sad ($p < 0.05$), interjection from sad and happy ($p < 0.05$) and the emotion sad from all the other three ($p < 0.05$). The group with normal hearing individuals performed similar to the group using cochlear implantation. Here, the emotions sad and interjection had significant difference ($p < 0.05$) whereas other two emotions did not have any significant difference between them.

Table 5: Comparison of perception across emotions by cochlear implant users, hearing aid users and normal hearing children

		Happy	**Neutral**	**Sad**	**Interjection**
Cochlear implant users	**Happy**	-	-	-	-
	Neutral		-	-	-
	Sad			-	**
	Interjection				-
Hearing aid users	**Happy**	-	-	**	**
	Neutral		-	**	-
	Sad			-	**
	Interjection				-
Normal hearing children	**Happy**	-	-	-	-
	Neutral		-	-	-
	Sad			-	**
	Interjection				-

** $p < 0.05$

The results of the study revealed that the emotion sad was perceived the best and also that it was significantly different from the other three emotions. This occurred for all three participant groups. This shows that the emotion sad had acoustical cues which enabled it to be perceived better when compared the other three emotions.

To determine the acoustic cue that resulted in the better perception of the emotion sad, the waveforms of the stimuli were analyzed using the Adobe Audition software. The average duration of the stimuli having sad emotion was found to be longer when compared to the other three emotions. The emotion sad had a duration ranging from 1.72 to 2.22 seconds (mean = 1.92 seconds), whereas the others had lesser duration [i.e. 1.29 to 1.89 seconds (happy), 1.31 to 1.83 seconds (neutral) and 1.2 to 1.91 (interjection)]. Hence, the duration cue could have helped the participants in identifying the sad emotion better than others.

Earlier studies have also found the utterances of different emotions had varying durations which served as perceptual cues. House (1994) and Pereira (2000b) found a happy utterance to be shorter in duration than a sad one. Also, Yildirim et al. (2004) found that RMS energy, inter-word silence, and speaking rate were useful in distinguishing sadness from the other emotions they examined.

In the present study, all the groups found sadness the easiest to identify and interjection was the most difficult. Sentences depicted happiness and neutral emotions were in-between. Similar result was reported by Most, Weisel and Zaychik (1993), Most and Aviner (2009) and Pereira (2000a). They too observed that the emotion sad was perceived better than the other emotions they used in their study, such as anger, disgust, fear, happiness and surprise.

In contrast with the findings of the present study Luo, Fu and Galvin (2007) reported that the difference between emotions ‘happy’ or ‘angry’ and ‘sad’ or ‘neutral’ were identified better by subjects using cochlear implants. They attributed this better perception to the higher amplitude present in utterances depicting these emotions compared to other emotions such as ‘neutral’ and ‘sad’.

Likewise, Pereira (2000b) found that overall amplitude cues significantly contributed to vocal emotion recognition not only for cochlear implant users but also for normal hearing listeners, even though normal hearing listeners had full access to other emotion features such as pitch cues and spectral details.

Unlike the findings of Luo et al (2007) and Pereira (2000b), it was observed in the present study that both cochlear implant users, hearing aid users and normal hearing group all used duration as major cue to perceive emotions rather than relative intensity. This could be because in the present study the stimuli had been RMS normalized to result in all the utterances having similar loudness.

Further, in the current study it was found that the emotion ‘sad’ has a falling pattern when compared to other emotions. This could have also contributed it being perceived better than the other three emotions. Most and Frank (1991) also observed greater accuracy in perception and production of intonation was for speech signals with falling than for rising contours, in children using hearing aids. The low frequency falling pattern could have possibly enhanced the perception of emotion ‘sad’. Thus it can be construed that the participants in the present study used a combination of duration and frequency contours to help them perceive different emotions.

The results revealed that

- The participants with normal hearing sensitivity performed significantly better than the participants with hearing impairment in the overall perception of emotions (happy, neutral, sad and interjection) as well as the perception of each emotion.

- There was no significant difference in the overall perception of emotions and the perception of individual emotions among the two groups having hearing impairment (cochlear implant group and hearing aid group).
- The emotion sad was perceived best by all the participants and interjection was the poorest in all the groups of participants.

CHAPTER 5

SUMMARY AND CONCLUSION

The auditory perception of emotion in the vocal expressions of a speaker is noted to be vital for accurate understanding of emotional messages, which in turn shapes listeners' reactions and subsequent speech production (Banse & Scherer, 1996). Infants as young as 2-7 months have been found to respond to variations in emotions present in speech utterances (Shaffer & Kipp, 2010). Normal hearing children aged 6-12 years have also been found to perceive emotions such as angry, scared, happy, and sad purely through the auditory modality (Peters, 2006). Similarly, studies have been reported that adults with normal hearing were able to recognize the emotional state of the speaker based only on auditory cues (Peters, 2006; Pereira, 2000). Persons with hearing impairment have been noted to be at a greater disadvantage than those with normal hearing at understanding emotion because of an inability to perceive subtle changes that convey emotion (Most, Weisel, & Zaychik, 1993). It has also been reported that auditory perception of emotions by children, youth, and adults with hearing loss who use hearing aids have lower performance in comparison to individuals with normal hearing (Most et al., 1993; Rigo & Liberman, 1989; Shinall, 2005). The studies on perception of emotion by cochlea implants (CI) show that they too perform poorer when compared to normal hearing listeners (Peters 2006; Most & Aviner, 2009; Hopyan, Gordon & Papsin, 2011).

Emotional perception in pre-lingual implantees has not been studied extensively. Among the few studies done, many of them have compared emotion perception between individuals with normal hearing sensitivity and cochlear implant users (Peters 2006, Hopyan, Gordon & Papsin 2011). Whereas, only a very few investigators had compared emotional perception between cochlear implant users and hearing aid users (Most & Aviner, 2009). Hence, there is a need for more studies to compare emotion perception between cochlear implant users and hearing aid users in the pre-linguistic population.

Intonation is found to be one of the major cues for perception of emotion (Scherer & Oshinsky, 1977). It is also known that intonation patterns used across languages differ (Khan, 2011). It is noted that studies on emotion perception in cochlear implant users mainly were carried out in western countries using English. Hence, there is a need to evaluate difficulty in the perception of emotions in cochlear implant users in Indian languages. This would throw light on whether the perception of emotions differs across different language groups of cochlear implant users.

Previous studies used only a small number of test items to test emotion perception (House, 1994; Pereira, 2000; Peters, 2006). Hence there is a need for a comprehensive study which compares the performance of emotion perception using more number of sentences through which reliable responses could be got.

The present study was undertaken to compare the emotion perception through the auditory mode in children with normal hearing sensitivity with two groups of children having hearing impairment, one using cochlear implant and the other using hearing aid. The study also compared the perception across four different emotions i.e. happy, sad, neutral and question/interjection.

The results of the present study revealed that

- The participants with normal hearing sensitivity performed significantly better than the participants with hearing impairment in the overall perception of emotions (happy, neutral, sad and interjection) as well as the perception of each emotion.

- There was no significant difference in the overall perception of emotions and the perception of individual emotions among the two groups having hearing impairment (cochlear implant group and hearing aid group).

- The emotion sad was perceived best by all the participants and interjection was the poorest in all the groups of participants. The better perception of the sad emotion was because of the combination of duration and frequency contours.

From this study, it is evident that even though the participants with hearing impairment had aided thresholds within the speech spectrum, performed poorer when compared to participants with normal hearing.

Clinical implication

- Based on the findings of the present study, it can be inferred that children with hearing impairment need to be provided training to perceive emotions through their auditory modality. Though they have aided audiograms within the speech spectrum, they are unable to perform like their normal hearing peer group. With the help of auditory training, focusing on aspects related to the perceptions of emotions, they may perceive these aspects clearer. Hence, it is important to include tasks related to perception of emotion in the aural rehabilitation and speech intervention programs for pre-lingually deafened children who use cochlear implant and/or hearing aids.

- This study also adds information to the literature.

Future direction

- A study comparing other emotions which are not included in the study could be carried out.
- Also, perception of emotion across participants with different native language could be carried out.

CHAPTER 6

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APPENDIX- 1

Test items:

1. EªÀvÀÄÛ ¸ÀÆÌ¯ï E®è.
2. £Á¼É gÀeÁ EzÉ.
3. PÉA¥ÀÅ §¸ÀÄì §AvÀÄ.
4. £À£ÀUÉ PÁ¬Ä¯É E®è.
5. aPÀÌ £Á¬Ä EzÉ.
6. PÀ¥ÀÅöà PÁUÉ EzÉ.
7. zÉÆqÀØ ªÀÄgÀ EzÉ.
8. E°è ªÀÄ£É EzÉ.
9. £À£ÀUÉ ¹» EµÀÖ.
10. ¥Á¥ÀÅUÉ ºÁ®Ä ¨ÉÃPÀÄ.

Practice items:

1. Dl ¸ÁªÀiÁ£ÀÄ EzÉ.
2. £À£Àß ºÀvÀæ ¨ÉPÀÄÌ EzÉ.
3. EzÀÄ ¨ÉÃ¹UÉ PÁ®.
4. FUÀ ªÀÄ£ÉUÉ ºÉÆÃUÉÆÃt.
5. £À£Àß ºÀvÀæ ¥ÀÅ¸ÀÛPÀ EzÉ.

APPENDIX- 2

Neutral

Happy

Sad

Interjection