Emotion Perception in Cochlear Implant Users, Hearing Aid Users and Normal Hearing Children

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Abstract

Perception of emotions through the auditory modality is an essential component of communication. It is known to help in the perception of pragmatic component of a message being transmitted. The present study aimed to compare the perception of four different emotions through the auditory mode in children with normal hearing sensitivity with that of two groups of children having hearing impairment (cochlear implant users and hearing aid users). In addition, 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 compared the perception across the four different emotions i.e. happy, sad, neutral and interjection. 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). Also 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 attributed to contrastive acoustical features present in the signals.

Key words: *Emotion perception, cochlear implant users, hearing aid users*

Introduction

It is well established that humans use speech to convey their attitude and emotions. Emotions have been considered necessary to regulate social and interpersonal behaviour, the flow of information and the selection of response processes or outputs of the organism, and 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' reaction 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 in 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 to12 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, 2000; Peters, 2006). This was attributed to the acoustic distinctiveness of different emotions. Pereira (2000), who examined 40 normal hearing subjects, found that they could perceive with 85% accuracy, 5 emotions (cold anger, hot anger, happiness, sadness and neutrality) spoken in two semantically neutral utterances.

Persons with hearing impairment have been noted to be at a disadvantage in perceiving emotions because of their inability to perceive subtle acoustic signals that convey emotion. It has been observed by Most, Weisel and Zaychik (1993) that some individuals with profound hearing impairment could perceive acoustical components of frequency, time, and intensity in a speech signal, whereas others could only perceive changes in the time and intensity. It has also been reported that auditory perception of emotions by children, youth, and adults with hearing loss who use hearing aids was lower compared to individuals with normal hearing (Rigo & Liberman, 1989; Most, Weisel & Zaychik, 1993; Shinall, 2005).

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The studies on perception of emotion by cochlear implants show that they too perform poorer when compared to normal hearing listeners (Peters 2006; Most & Aviner, 2009; Hopyan, Gordon & Papsin, 2011). Most and Aviner (2009) evaluated the benefit of cochlear implants in the perception of emotions (happiness, anger, surprise, sadness, fear, and disgust) in participants differing in their age of implantation. The findings of the cochlear implant users were compared with hearing aid users and adolescents with normal hearing. The results revealed better auditory identification by the participants with normal hearing in comparison to the participants with hearing impairment. 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.

From the literature on the perception of emotions, it is apparent that studies regarding perception in pre-lingual cochlear implantees have not been studied extensively. Among the few studies done, the focus has been in comparing emotion perception between individuals with normal hearing sensitivity and cochlear implant users (Peters 2006, Hopyan, Gordon & Papsin 2011). Investigations dealing with the comparison between cochlear implant users and hearing aid users are sparse (Most & Aviner, 2009). Hence, there is a need to study this aspect.

Further, earlier studies have used only a small number of test items to evaluate emotion perception (House, 1994; Pereira, 2000; Peters, 2006). It is essential that a comprehensive study be conducted which compares the performance of emotion perception using a larger number of test items.

It is also known that intonation patterns used across languages differ (Khan, 2011). The published literature on emotion perception in cochlear implantees has primarily been done using English. Hence, there is necessary to evaluate the difficulties in the perception of emotions in cochlear implant users in different languages, including Indian languages. This would throw light on whether the perception of emotions differs across different language groups of cochlear implant users.

The present study aimed to compare emotion perception through the auditory mode in children having 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 aspires to compare the perception across four different emotions i.e. happy, sad, neutral and question/interjection.

Method

Participants

The participants 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, sensori-neural 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. Details regarding the clinical group are provided in Table 1. Twelve normal hearing children in the age range of 5 to 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.

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. 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 CD version of the test, which had been recorded using a sampling rate of 44100 Hz with 32 bits, was used.

Prior to obtaining the data on the target group, the appropriateness of the material was checked on twenty native young-adult speakers of Kannada. Initially, pictures representing the emotions were shown to them 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, hence the pictures were not altered.

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

Further, the 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. In addition, the young-adults had to listen to the sentences that were randomized and indicate the emotion that was represented using a 4 - choice closed-set tasks. The participants had to point to one among the four pictures portraying the emotions happy, sad, neutral and interjection. 90% of the participants could correctly identify each emotion, confirming that the test items could be retained without any modification.

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^o 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.

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^o 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. 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 short breaks in between the session. The entire testing was done in one session. Social reinforcement and tangible reinforcement were provided for the participants.

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 and subjected to statistical analyses. Besides descriptive statistics, repeated measures ANOVA was done. 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 across the four different emotions* was also carried out for each participant groups. MANOVA was also done to check how the three groups of participants perceived each of the four emotions.

Results and Discussion

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.

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 across different emotions

As the repeated measures ANOVA revealed that there was a significant main effect with groups and emotions combined [$F=16.785$, $p<0.001$], 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.

Duncan's Post-Hoc test was done to check how each of the groups perceived the combined scores of 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

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

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

Table 3: Comparison of emotions with groups combined

Emotions	F	p
Happy	10.886	0.000
Neutral	9.012	0.001
Sad	5.926	0.006
Interjection	32.060	0.000

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 perception across emotions within each group

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 [$F=9.8$, $p<0.001$]; normal hearing individuals [$F=5.088$, $p<0.05$]}. The mean values depicted in Table 2 also indicate the difference in scores obtained in the perception of emotions by the three different groups.

Further, pair-wise comparison was done which revealed (Table 4) 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 4: 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 (2000) 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 (2000). 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 (2000) 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 (2000), 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.

Conclusions

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 each emotion 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 emotion 'sad' was probably on account of the contrastive acoustic cues got from the duration and frequency contours.

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.

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