SPEECH IDENTIFICATION WITH SINGLE CHANNEL MULTICHANNEL AND CHANNEL FREE HEARING AIDS

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CERTIFICATE

This is to certify that this dissertation entitled ***"Speech Identification with Single Channel Multichannel and Channel-free Hearing Aids"*** is the bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student (Registration No. 05AUD001). 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.

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DECLARATION

This is to certify that this dissertation entitled ***"Speech Identification with Single Channel Multichannel and*** *Channel-free* ***Hearing*** *Aids"* is the result of my own study under the guidance of Dr. K. Rajalakshmi, Reader in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted in any other university for the award of any diploma or degree.

Mysore

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DEDICATED

TO

Grand parents

&

My Family

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INTRODUCTION

The last decade has seen numerous and significant improvements in the technology of hearing aids. With the advancement of digital technology, digital hearing aids have become increasingly common. Modern digital signal processing technology includes non-linear, adaptive, multiple channels/bands, speech enhancement, noise reduction, feedback management etc. The issue regarding the ideal number of channels has been a hot topic in rehabilitative amplification for over a decade. Despite the ongoing debate, conventional wisdom indicates more number of channels in digital hearing aid is better and they have seen a surge in the number of channels in commercially available instruments over the last few years.

Compression is one of such technology which helps to optimize the dynamic range of the individual with hearing impairment. Compression is nothing but a nonlinear amplifier which automatically adjusts its gain depending upon the incoming signal. Such a signal processing feature helps to improve the perception in hearing impaired individual by normalizing the loudness increasing the sound comfort and by reducing the inter-syllabic and inter-phoneme intensity difference (Dillon, 2001). Although compression technology helps the hearing impaired individual to perceive better, but the benefit that compression provides, partly depends on the way it is implemented in hearing aids. Broadly, based on the implementation of number of compression circuit in the hearing aids, it can be classified into either single channel or multichannel hearing aid.

In single channel compression, the entire dynamic range is optimized across the full range of frequencies by a single compressor. In multichannel compression hearing aids, this dynamic range is optimized at discrete frequencies by using multiple compressors. Currently, hearing aids with 1 to 20 channels are commercially available. Over the decades attempts have been made to investigate if increasing the channel helps the hearing impaired individual to perceive better. It may appear that the larger the number of channels, the better the compensation for individual hearing impairment. However, increased numbers of channels may also have drawbacks, worthy of consideration.

Yund and Buckles (1993) measured speech discrimination for 8 channel compression and linear amplification. As the signal to noise ratio (SNR) decreased, the speech identification became relatively better in multi-channel compared to linear amplification. Yund and Buckles (1995) reported that speech identification scores improves as the number of channel increases from 4 to 8 and did not vary significantly between 8 to 16 channels. On contrary, Bustamante and Braida (1987) reported that multi-channel amplification reduces the speech intelligibility in hearing impaired individuals. These findings are also supported by Drullman and Smoorenberg (1997). Hickson (1994) have reported that the performance with 4 channel hearing aid is similar to that of single channel hearing aid.

Studies have revealed equivocal results about the advantages and disadvantages of multichannel hearing aid. The recent technology has introduced a channel free hearing aid that promises to reduce the speech cue distortion and improve speech identification.

NEED FOR THE STUDY

Advantages of multichannel hearing aid

Relative to single channel compression, multi channel compression can increase intelligibility because it increases the audibility of speech.

Disadvantage of multichannel hearing aid

Unfortunately, multichannel compression also decreases some of the essential differences between different phonemes. Because compressor gives less amplification to intense signals than to week signals, multichannel compressors tends to decrease the height of spectral peak and to raise the floor of spectral valleys. That is, they partially flatten spectral shapes. Spectral peaks and valley give speech sound much of their identity. Spectral flattening makes it harder for the hearing aids were to identify the place of articulation of consonants (De Gennaro, Braida, Durlach, 1986; Lindholm, Dorman, Taylor, Hannley, 1988; & Lippmann, Braida, Durlach 1981).

Considering these opposing effects of multichannel compression, it is not surprising that some experiments have shown multichannel compression to be better than single channel compression (Kiessling & Steffens, 1991; Moore & Glasberg,1986, 1988) and some have failed to show any advantage for multi channel compression.(Moore, Peters & Stone, 1998; Plomp, 1976; and Walker, Byrne & Dillon, 1984). Multichannel decrease speech intelligibility for normal hearing people (Drullman, Festen,& Plomp,1994; Hohmann&Kollmeier,1995; Yund & Buckles, 1995). If high compression ratio is used in multi channel compression hearing aid, intelligibility is also decreased for hearing impaired listeners (Bustamante& Braida, 1987; De Gennaro, Braida & Durlach, 1986; Drullmann & Smoorenburg, 1997; Plomp, 1976).

Whether the positive effects of multichannel of compression outweigh the negative effects depends on how much audibility is achieved in the reference condition. A net advantage for multichannel compression is thus least likely for sounds that in the single channel condition are comfortably loud and have been amplified by an appropriate gain frequency response shape. So, there is a dearth of studies comparing single channel and multichannel compression and showing equivocal results. So, further research is needed in the area to overcome the ambiguity that is seen in the literature. The emergence of new techniques such as channel free hearing aids necessitates it to be validated along with the existing techniques such as single channel and multichannel. Hence current study was undertaken.

AIMS OF THE STUDY

- To compare the speech identification score with the single channel, three channel, eight channel and channel free hearing aid in quite condition.
- To compare the speech identification scores with the single channel, three channel, eight channel and channel free hearing aid in different noise condition.

REVIEW OF LITERATURE

Hearing loss involves a multifaceted loss of hearing ability. People with sensoryneural hearing loss faces problem of decreased audibility, decreased dynamic range, decreased frequency resolution and decreased temporal resolution. Any of this problem in combination cause decrease in intelligibility. So to improve the intelligibility of speech sound hearing aid is used so that mentioned problem can be ruled out. In this consideration hearing aids are developed with new and newer technology day by day to maintain the natural speech spectrum in the impaired ear. Trend of hearing aid advances from linear to digital technology with different algorithm and circuits.

With a linear hearing aid, a constant gain is applied to all input levels until the hearing aid's saturation limit is reached. Because daily speech includes such a wide range of intensity levels, from low-intensity consonants such as /f/ to high-intensity vowels such as /i/, and from whispered speech to shouting, the benefit of a linear hearing aid is restricted when the amplification needed to make low-intensity sounds audible amplifies high-intensity sounds to the point of discomfort. Smaller the dynamic range in a sensory neural hearing impaired listener the more difficult it is to make speech audible in variety of situations.

To solve this problem, most hearing aids now offer some forms of compression in which gain is automatically adjusted based on the intensity of the signal. The higher the input intensity, the more gain is reduced. High-intensity signals (such as shouted speech) the compression ratio in each channel (Souza and Turner, 1999). The higher the compression ratio, greater the effect on the speech level distribution. Even for a single-channel compressor, the speech level distribution is unevenly affected across frequency (Verschuure et al., 1996).

Speech Intelligibility in quiet

Humes et al. (1999) took 55 hearing-impaired adults with linear peak clipping (fit according to linear, NAL-R targets) and two-channel WDRC aids (fit according to nonlinear, DSL [i/o] targets). All patients wore the linear aids for 2 months, followed by the WDRC aids for 2 months. At the end of each 2- month trial period, a battery of outcome measures were completed that included word recognition in quiet and in noise at various presentation levels; judgments of sound quality; and subjective ratings of hearing aid benefit. In general, results showed better speech intelligibility with the WDRC aid at all but high-level inputs. Patients also reported that the WDRC hearing aids provided greater ease of listening for low level speech in quiet. The authors attributed these results to the greater gain at low input levels provided by the WDRC circuit and the higher DSL target gain levels for the WDRC aid.

Flynn, Davis, & Pogash (2004) took twenty-one children with severe hearing loss for a study to comparing performance on measures of audibility, speech understanding (in quiet and noise) and listening situations between the children's current analog hearing aids and a test hearing aid with multiple-channel non-linear compression. Results were obtained from the children at 2 weeks, 8 weeks, 6 months and 12 months following the fitting of a multiple-channel non-linear hearing instrument. Compared with the children's own hearing instruments, the test instruments provided improved audibility, improvement in speech understanding in quiet and noise, and an improvement in listening skills. They found that there is improvement in speech identification score in quiet condition with multichannel hearing aid.

Speech intelligibility in noise

An important issue is the ability of compression amplification to improve speech intelligibility in noise. Although initially expected as a benefit of nonlinear amplification, compression does not appear to provide substantial benefit in noise compared to linear amplification (eg, Boike and Souza, 2000a; Dreschler et al., 1984; Hohmann and Kollmeier, 1995; Kam and Wong, 1999; Nabelek, 1983; Stone et al., 1997; van Buuren et al., 1999; van Harten-de Bruijn et al., 1997). This is certainly not the case when compared to a directional microphone (Ricketts, 2001; Valente, 1999; Yueh et al., 2001).

Some investigators have suggested that the modulation properties of the background noise may influence the benefit of compression (Boike and Souza, 2000b; Moore et. al., 1999; Stone et al., 1999; Verschuure et. al., 1998). Specifically, compression may improve intelligibility when the background noise is modulated instead of unmodulated

Bentler and Duve (2000) tested a variety of hearing aids that represented advances in amplification technology during the 20th century. Among the devices were a linear peak clipping analog aid, a single-channel analog compression aid, a two-channel analog WDRC aid, and two digital multichannel WDRC aids, all in behind the-ear versions. Each device was fit using its recommended prescriptive procedure: NAL-R for the linear aid, FIG6 for the single-channel compression hearing aid, and the manufacturers' proprietary fitting algorithms for the remaining devices. Despite the differences in circuitry, speech recognition scores in quiet and in noise were similar across devices. The exception was poorer performance at very high speech levels (93 dB SPL) for the linear aid.

Moore and his colleagues (eg, Laurence et al., 1983; Moore and Glasberg, 1986; Moore et aL, 1985, 1992) worked extensively with an amplification system that applies a first-stage, slow acting compression with a compression threshold of 75 dB SPL to compensate for overall level variations, followed by fast-acting compression amplifiers, acting independently in two frequency channels. Results showed improved speech reception threshold in quiet and in noise (Moore, 1987) and improved speech intelligibility, particularly at low input levels (Moore and Glasberg, 1986; Laurence et al., 1983) when compared to linear amplification or to slow-acting compression.

Effect of multichannel compression on speech cues

With a large number of compression channels, relative differences in level across frequency (ie, spectral peak-to-valley differences) will be reduced. Therefore, use of more than two or three channels may substantially reduce the frequency distinction in the speech signal, potentially degrading temporal and spectral cues (Bustamente and Braida, 1987; Dreschler, 1992; Moore and Glasberg, 1986). Any negative effects of increasing numbers of channels are likely to have the greatest consequences for sounds that carry pertinent information in the spectral domain; among them, vowels or the nasal consonants /m, n, ŋ / (Kent and Read, 1992). For example, the most important cue for vowel identity is detection of spectral peaks relative to the surrounding frequency components. Even if overall audibility of the sound is improved, these changes may reduce intelligibility. Differences in the number of channels could explain differences in results between investigators who demonstrate improved vowel intelligibility using WDRC with a small number of channels (eg, Dreschler et at., 1988b and 1989; Stelmachowicz et al., 1995) and those who show a detrimental effect (Franck et. al. 1999) showed vowels were harder to identify via an eight-channel compression hearing aid than with a single-channel compression hearing aid. In a review of published data on multichannel amplification prior to 1994, Hickson (1994) concluded that the best results were obtained with compression systems having three or fewer channels. For speech intelligibility in general, recent data suggest that multichannel systems with up to four channels are equivalent to, but not superior to, single-channel systems (eg, Keidser and Grant, 2001b; van Buuren et al., 1999).

For studies that demonstrated improved performance with greater number of channels, the advantage appears to be one of improved audibility rather than the number of channels per se. For example, Yund and Buckles (1995b) demonstrated improved nonsense syllable recognition in noise as the number of channels increased from four to eight. Comparison of consonant confusions and frequency response for the different numbers of channels were consistent with improved high-frequency audibility. The authors note that results of multichannel compression experiments should be interpreted in the context of the stimuli used. In this case, no additional improvement was seen with more than eight channels, perhaps because the eight-channel system already provided sufficient information for recognition of high-frequency consonants. Similarly, Braida et al., (1982) pointed out that some early studies showed a large advantage for multichannel compression provided improved high-frequency audibility relative to a linear condition.

For most audiometric configurations, two channel or three-channel compression hearing aids seem to offer a good compromise between customized manipulation of the hearing aid response and providing coherent spectral contrast. For more unusual audiometric configurations (i.e., rising or cookie bite audiograms), larger numbers of channels are appealing. Available data on larger number of channels is mixed, although larger number of channels should be most advantageous when adequate frequency shaping is provided (Crain and Yund, 1995); when adding more channels improves speech audibility over a smaller number of channels; and when compression ratios are low enough to avoid distortion of speech components (Yund and Buckles, 1995b).

Larger numbers of channels also have potential benefits for feedback cancellation. The audibility advantage of multi channel compression may be most effective for listeners with a mild-to-moderate loss (Yund and Buckles, 1995a).

When vowels, diphthongs and other phonemes are processed by a multichannel instrument, their key formant sounds may be managed and resolved by different channels, receiving more or less amplification and compression than was originally present and intended. This possible outcome distorts relationships among formants. and potentially other key features of vowel, phoneme and word recognition. Spectral cues in general, are perhaps the most relevant feature for speech reception. Distorted spectral coding appears to be related to reduce speech perception in noise, whereas distorted intensity and temporal cues are not (van Schijndel et al, 2001). Another consideration is that the number of channels, compression ratios, and their time constants (attack and release times) all interact. Taken to an extreme, a large number of channels with high compression ratios can result in an amplified signal (Plomp, 1988). stripped of many of the identifiable speech elements. This effect is known as "spectral smearing." Because of the distorted formant information, spectral smearing is most deleterious to "place" of consonant articulation (e.g. difficulty discriminating between /b/, /d/ and /g/), and increases susceptibility to noise (Boothroyd et al, 1996).

Boothroyd and colleagues (1996) found that "Spectral smearing with bandvvidths of 707 and 2000 Hz elevates phoneme recognition threshold in noise by about 13 and 16 dB respectively". In addition, spectral smearing has greater degradation on word, rather than phoneme performance due to the non-linear relationship between these two measures. This implies that the real-world deleterious effect on speech-in-noise would likely be extreme. In fact, spectral smearing alone can reduce phoneme recognition to only 12% (Boothroyd et al.. 1996). This finding is consistent with the results of van Schijndel et al. (2001) who found that distorted coding of spectral cues was the main factor associated with reduced speech discrimination in noise for hearing impaired subjects. Distorted coding of spectral cues had greater negative impact than did distorted temporal or distorted intensity cue coding. When the input signal is broken into channels, the spectro-temporal characteristics become distorted and important speech transition information is lost, which has been found to impair speech understanding (Boothroyd et al, 1996).

Perception through Channel free hearing aid

This unique processing strategy satisfies the frequency-specific compressive requirements of sensorineural hearing loss, while retaining the intra-signal spectral contrasts important for formant. phoneme and speech recognition. Continuously Adaptive Speech Integrity (CASI) offers unique frequency shaping for optimal hearing-loss appropriate frequency response curves. Flexible input-dependent filter characteristics are applied to the whole signal, allowing frequency-dependent compression, without splitting the signal into channels and incurring the consequent spectral smearing potentially present in many-channel instruments. In addition, this unified signal processing occurs perceptually instantaneously, with appropriate gain characteristics calculated and applied to each incoming signal. CASI analyses incoming signals according to their intensity and dominant spectral elements, and calculates the corresponding gain characteristic to be applied. Spectral characteristics of speech are maintained resulting in more "natural" sounding amplification. Additionally, because CAS1 maintains the natural signal structure, adaptation time may be less for the patient using CASI than for those using more typical multi-channel amplification (Yund and Buckles, 1995). We believe CASI offers the benefits of multi-channel processing, without the above-described drawbacks.

METHOD

Present study was designed to compare the hearing aid performance across the channel in quiet and different noise condition.

Subject

Twelve participants (9 men and 3 women) with age range 35 to 60 years (mean age of 48.5), with conformed diagnosis of sensory neural hearing loss participated in the study. They had audiometric 3 frequency average pure-tone thresholds (500, 1000 and 2000 Hz) in the range of 41 to70 dB HL with speech identification score of greater than 50%. Tympanometry results indicated no middle ear pathology. All of them were first time hearing aid users. All the participants were native Kannada speakers (Language spoken in Karnataka state of India).

Instrumentation

Calibrated two channel diagnostic audiometer (OB922) was used for estimation of pure tone thresholds. Calibrated GSI-tympstar middle ear analyzer was used for Immittance measurements.

A single channel (Terra), Three Channel (Cielo), Eight Channel (Syncro), channel free (Symbio XT 110) hearing aids were used for the purpose of comparison of performance. Hearing aids were programmed with NOAH based Connexx 5.3 (Terra and Cielo), Genie 6 (Syncro) and (Symbio) Oasis plus 7 software. Hearing aids were connected with the computer using HiPro.

Stimuli were played in laptop 44.1 kHz sampling rate and 32 bit software using Cyberlink Power DVD Ultra software. Stimuli were routed through the OB922 two channel audiometer to the two sound calibrated Martin audio Cl 15 speakers.

Stimuli

The speech stimuli used in the present study was taken from bi-syllabic wordlist in Kannada, developed by Yathiraj and Vijaylakshami (2005). This test contains four word lists, each with 25 bi-syllabic words, which are phonetically balanced and are equally difficult. All the four lists were selected for the present study. The words were spoken in conversational style by a female native speaker of Kannada. They were digitally recorded in an acoustical treated room, on a data acquisition system using 44.1 kHz sampling frequency and 32-bit analog to digital converter.

All the word lists were mixed with speech babble (Anitha and Manjula, 2005) at +10 dB and 0 dB SNR. The speech babble is mixed with words with reference to RMS amplitude by program written in MATLAB 7.

Procedure

Puretone thresholds were obtained using modified Hughson and Westlate procedure (Carhart and Jerger, 1959), across octave frequencies from 250 to 8000 Hz for air conduction and 250 to 4000 Hz for bone conduction.

Tympanometric measurements were done using 226 Hz probe tone. This was done to rule out conductive hearing loss due to middle ear pathology. Appropriate probe tips were used to obtain hermetic seal and comfortable pressure for the subject. The parameters documented were types of tympanogram and acoustic reflex thresholds agreeing with ear canal volume, acoustic admittance and the tympanometric peak pressure. The results were also correlated with the ENT findings.

Hearing aids were programmed on the basis of audiometric thresholds with the default gain provided by software. Syncro and Cielo had noise management technology. While programming these noise management options were switched off in order to avoid any unwanted effect on result. All the hearing aids were switched to Omni directional microphone mode as there was no need of noise reduction during the testing

Test was done in acoustically treated room with noise with in permissible limits as per ANSI (1991) specification. Subjects were seated at distance of one meter and at 45° azimuths from the speakers. First the testing was done in unaided condition and later in aided condition. In the aided condition, hearing aids were selected randomly for fitment and testing. Stimuli were played on a laptop at 44.1 kHz sampling rate with 32 bit operating system and were routed through the two channel audiometer (OB922). The intensity level was maintained at 40dBHL throughout the testing and inter stimulus interval was kept constant at 5 seconds. Written responses were obtained from the subjects, but in case the subjects were illiterate, the responses were scored by Kannada speaker.

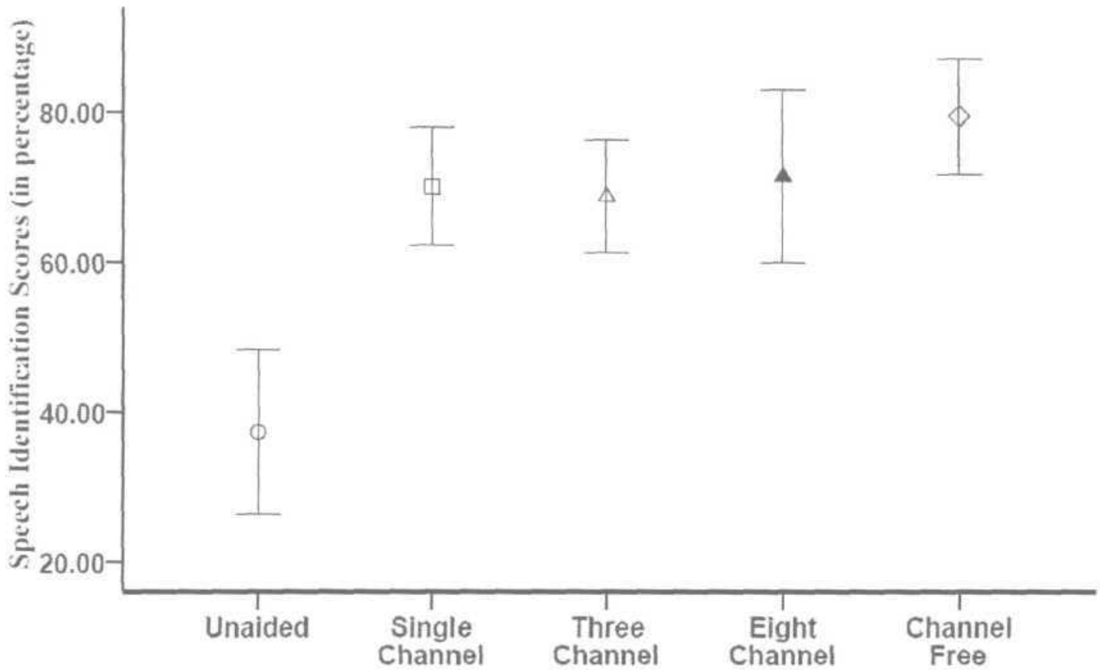
RESULT AND DISCUSSION

Analysis

To investigate the aims of the present study, statistical analysis using SPSS software (version, 15.0) was carried out for the data obtained. The statistical analysis includes descriptive statistics, univariate ANOVA for across hearing aids, SNR and Age.

A. Speech Identification score in Quiet

The speech identification scores of 12 subjects (15 ears) in unaided condition and aided condition are presented in Figure 1. A repeated measure of ANOVA was performed to assess the significant difference across conditions (unaided and 4 aided conditions). Results showed a significant difference across conditions ($F(4, 39.3) = 14.7$, $p<0.01$). Scheffe Post Analysis of variance reveled significant difference between unaided condition and aided conditions ($p<0.01$) but difference in mean across different channel hearing aids data did not reach the significance. However, from the figure it is observed that channel free hearing aid had higher scores compared to other different channel hearing aids.



Figurel. Speech identification scores in quiet condition.

Condition	Mean Score (in %)	Standard Deviation (in %)
Unaided	37.33	19.80
Single channel	70.00	14.14
Three channel	68.66	13.55
Eight Channel	71.33	20.65
Channel Free	79.33	13.87

Table: 1. Mean speech identification scores of the unaided and four aided quiet condition.

B. Speech Identification Scores in Noise

Figure -2 Shows the percentage of speech identification score in quiet, +10 dB SNR and 0 dB SNR conditions for various channel hearing aids (1 Channel, 3 Channel and 8 Channel) and channel free hearing aid. It can be observed that participants performed better with channel free and 8 channel hearing aid than single and 3 channel hearing aid in all the conditions (quiet and +10dB & OdB SNR). Furthermore, it is also clear from the figure 2 that channel free hearing aid and 8 channel show better performance in all the conditions. Participants performed better with channel free in quiet and OdB SNR conditions than 8 channel hearing aid.

Repeated measures ANOVA were performed to assess the significant difference across hearing aid in quiet and two different SNR conditions. Repeated measures ANOVA reveled significant main effect of quiet and two SNR conditions (F (1.67, 112) =143.05, p<0.01), but no significant interaction was observed (F (4.8, 96.6) =0.283, p=0.98). To see the significant difference across different channel hearing aids and channel free hearing aid, Post Hoc analysis of variance was performed and results reveled the mean difference across different channel hearing aid and channel free hearing aid did not reach significant difference (p>0.05).

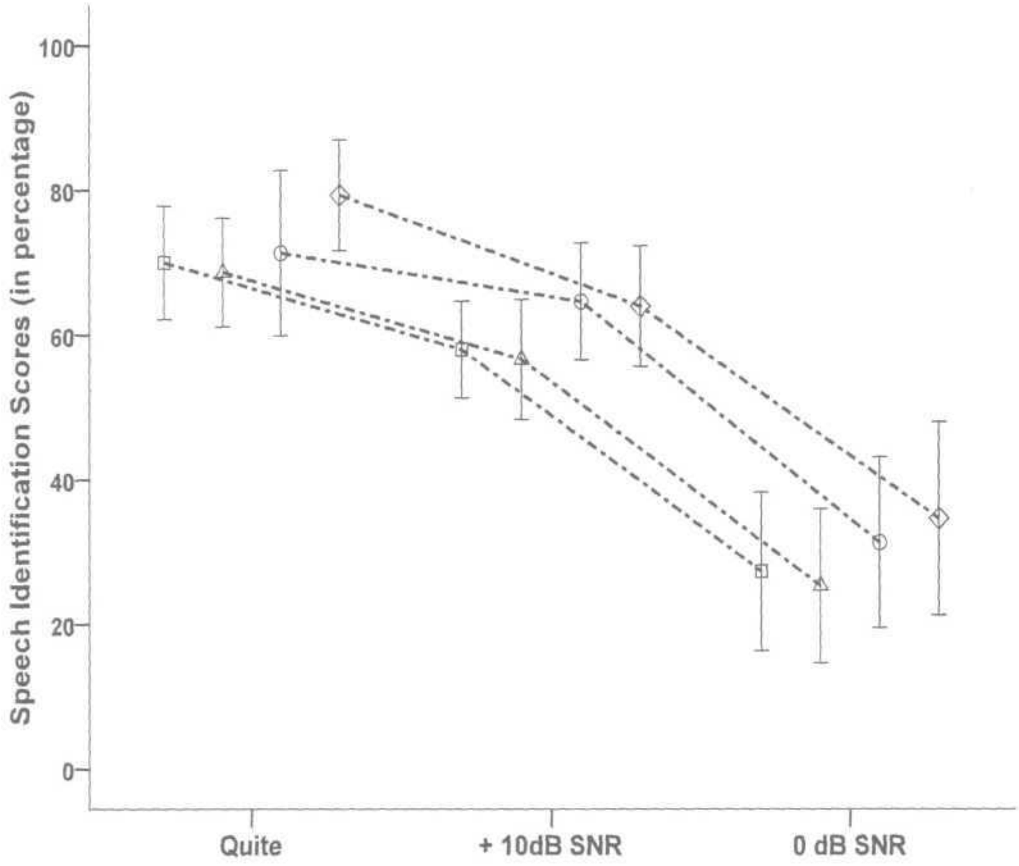


Figure: 2 Speech identification scores in noise condition.

(Square - Single channel, Triangle - Three channel, Circle - Eight channel, Diamond- Channel-free)

	Quiet condition		**+10** dB SNR		0 dB **SNR**	
	Mean (in %)	Standard Deviation (in%)	Mean (in %)	Standard Deviation (in %)	Mean (in %)	Standard Deviation (in%)
Single channel	70.00	14.14	58.00	12.07	27.33	19.80
Three channel	68.66	13.55	56.66	14.96	25.33	19.22
Eight Channel	71.33	20.65	64.66	14.57	31.33	21.33
Channel Free	79.33	13.27	64.00	15.02	34.66	18.16

Table: 2. Mean scores of the aided condition in quiet and different signal to noise ratio.

Discussion

A. Performance in quiet condition

Aided response with different hearing aids is better than in the unaided condition. Results of the present study reveled that no significant difference across hearing aids used in this study. All though the mean scores did not reach the significance, there is difference in mean scores across hearing aids. Furthermore, more variability in the scores was observed, which would have lead to no significant difference across hearing aids. One another is the age range studied in the present study, could have contributed for variability in the scores.

The performance with multichannel hearing aids was almost similar to that observed in single channel and 3 channel hearing aid. A number of investigators reported no significant improvement in speech identification by increasing the numbers of channels in multichannel hearing aid (Louise M. H. HicksonLouise M. H. Hickson, 9994). Souza, (2002) reported that multichannel hearing aids with fast compression time constants, distorts some speech cues, offsetting the benefits of improved audibility. In the present study, multichannel we used syllabic compression was used, which has fast attack and release time constants, which could have caused the distortion and lead to the much variability in performance. Anna O'Brien, (2002) has provided the explanation for the poorer performance observed across studies in multichannel hearing aids. She said that, theoretically, when vowels, diphthongs and other phonemes are processed by a multichannel instrument, their key formant sounds may be managed and resolved by different channels, receiving more or less amplification and compression than was originally present and intended. This possible outcome distorts relationships among formants, and potentially other key features of vowel, phoneme and word recognition (see Figure-3). As observed in the figure-3, an annotation described by the Dillon, (2001) shows that in stimulus /ii/ the spectral difference is lost and formant frequencies are distorted.

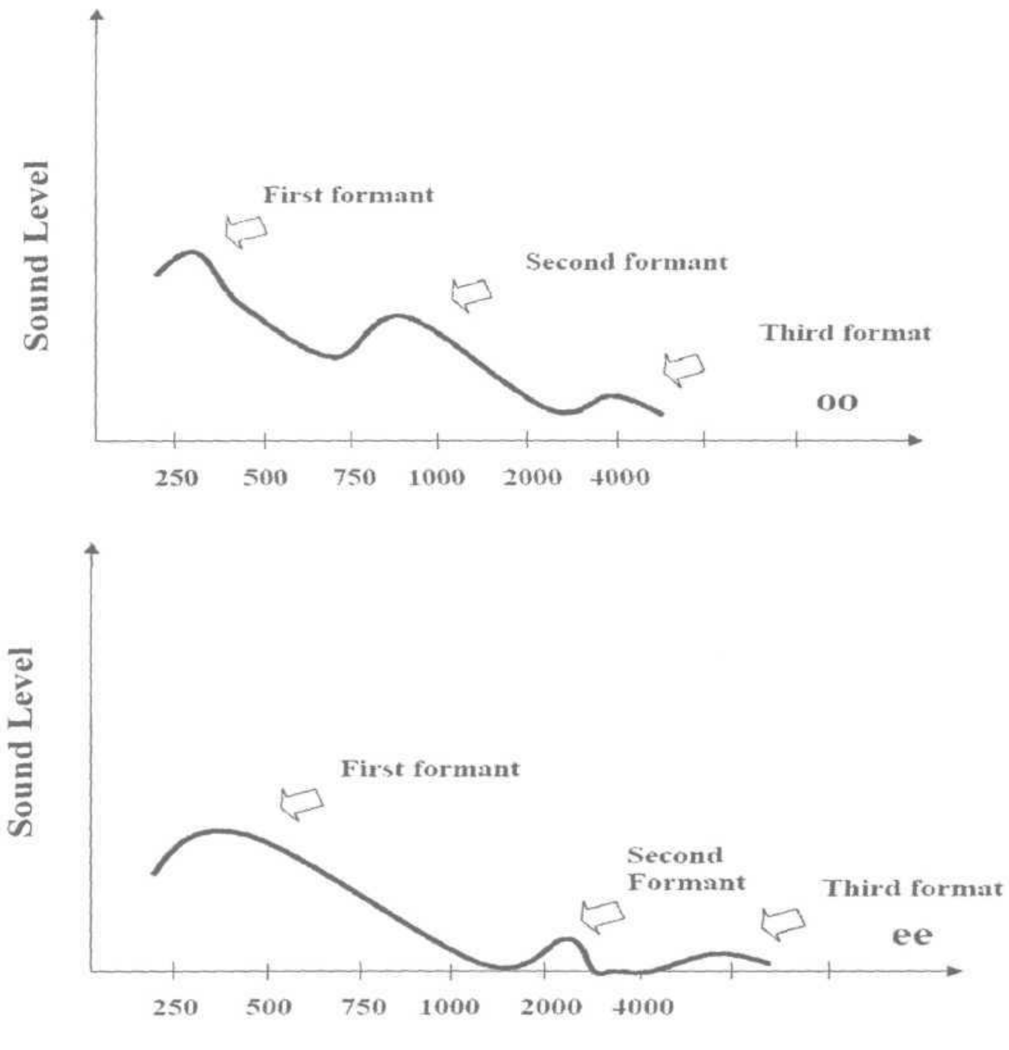


Fig: 3. Annotated diagram of vowel spectra.

In addition, another consideration is that the number of channels, compression ratios, and their time constants (attack and release times) all interact. Taken to an extreme, a large number of channels with high compression ratios can result in an amplified signal (Plomp, 1988), stripped of many of the identifiable speech elements. This effect is known as "spectral smearing." Because of the distorted formant information, spectral smearing is most deleterious to "place" of consonant articulation (e.g. difficulty discriminating between /b/, /*d1* and /g/), and increases susceptibility to noise (Boothroyd et al, 1996)."

The mean scores of channel free hearing aid were 10% higher compared to other multichannel and single channel hearing aids. Similar to the present study, Dillon et al., (2003) showed that the performance of subjects in quiet, impulse noise, for male voice, and female voice was better with channel free hearing aid compared with multichannel hearing aids. He has also shown that internal noise and distortion seen in the channel free hearing aid is less than those observed with multichannel hearing aid, he said that low distortion and less internal noise would have contributed for the better performance in channel free hearing aid. CASI offers unique frequency shaping for optimal hearing-loss appropriate frequency response curves. Flexible input-dependent filter characteristics are applied to the whole signal, allowing frequency-dependent compression, without splitting the signal into channels and incurring the consequent spectral smearing potentially present in many-channel instruments.

B. Performance in Noisy condition

Results revealed that mean performance dropped significantly in noise for all hearing impaired subjects. No significant effect of channel was observed. The drop in performance across hearing aids may due to the poorer performance of hearing impaired subjects in adverse conditions. From Fig. 2 it can be noted that channel free and 8 channel hearing aid performed better in two noise conditions. In addition, channel free provided the better performance in 0 dB SNR condition compared to 8 channel hearing aid. No significant difference was observed in the present study. This may be due to large variability in data, because of the small number of subjects and age range studied in the present study (30-68 years).

A number of investigators reported that performance with 8 channel hearing aid is better than single to 6 channel hearing aids (Yund and Buckle, 1994). More number of channels will provide the possibility of better fit to the individual hearing impairment. The greater the number of channels and the narrower the channels, the greater the likelihood that important frequency components of the signal will fall into channels which do not include higher-intensity components of the noise of the signal itself. It is important that a signal component as a positive signal-to-noise ratio (S/N) within a channel because only then can the signal component determine the amplification in the channel, be amplified appropriately and become useful to the subject. Whenever the S/N is negative in the channel, the noise controls the amplification and the signal and noise components are amplified less than would have been appropriate for the signal component alone. In the multichannel compression haring aids with few broad channels.

however, a signal component may be amplified too little (i.e., "masked electronically") due to the presence of a noise component which would not have masked it perceptually had the signal and noise components been amplified appropriately in two separate channel (Stone et. al.,1999).

Although, number of studies has shown that multichannel hearing aid performance is better, other group of researchers has shown that there is variability due to sensory neural hearing loss (Yund, Simon, & Efron, 1987). It is because of the speech distortions that are caused by the type of compression and time constants applied in the multichannel hearing aids. That is when the input signal is broken into channels, and applying compression and fast time constants, the spectro-temporal characteristics become distorted and important speech transition information is lost, which has been found to impair speech understanding (Boothroyd et al, 1996). In the present study also mean scores were higher but there was more variability (SD) indicating not all subjects improved with 8 channel hearing aid. Lippmann (1978) reported a deterioration of the scores when the signal was compressed with the noise, Barfod (1978) also obtained equivalent scores in his study.

Performance of channel free hearing aid was higher with less variability compared to the multichannel hearing aid. Similar results have been reported by Dillon, (2002). Because, the channel free hearing aid utilizes recently developed technology, Continuously Adaptive Speech Integrity (CASI). This strategy offers unique frequency shaping for optimal hearing-loss appropriate frequency response curves. Flexible input-dependent filter characteristics are applied to the whole signal, allowing frequency-dependent compression, without splitting the signal into channels and incurring the consequent spectral smearing potentially present in many-channel instruments. CASI analyses incoming signals according to their intensity and dominant spectral elements, and calculates the corresponding gain characteristic to be applied. Spectral characteristics of speech are maintained resulting in more "natural" sounding amplification. So the reduced spectral smearing and frequency dependent compression would have improved the performance of subjects with channel free hearing aid.

One important observation made in the study was that channel free hearing aid showed better performance over the eight channel hearing aid in 0 dB SNR and quiet condition. There was no difference in performance between eight channel and channel free hearing aid in 10 dB SNR. Bear and Moore, (1993) and Ter Krause, (1993) have shown that no effect of spectral smearing on speech identification scores in normal hearing subjects in quiet, but it has significant effect in adverse conditions. They further said that poor frequency resolution observed in cochlear hearing loss subjects effects identification scores in noise rather in quiet. From the above it is understood that in the adverse conditions (like 0 dB SNR) the amount of spectral information utilized for understanding the speech is more compared to the conditions like 10 dB SNR and quiet conditions. In the multichannel hearing aids, there is temporal distortion and spectral smearing. Small improvement observed for channel free hearing aid may be due to the reduced spectral smearing and temporal distortions, which would have affected the speech identifications scores in multichannel hearing aids.

To conclude, performance of subjects with channel free hearing aid was better in quiet and noise conditions. Performance of multichannel hearing aids only showed better performance only in noise but no difference in performance between single and three channel hearing aid. So increasing the number of channels improves performance only in noise.

SUMMARY AND CONCLUSION

In recent years a number of studies focused on studying the improvement in performance with multichannel hearing aids. The results of these studies are inconclusive, few have shown that increasing the number of channels improves the speech perception (Kiesseling & Steffens, 1991; Moor & Glasberg, 1998) but others have conflicting results that increasing the numbers of channels and applying the channel specific compression may lead to distortion of speech cue and impairs the performance (Bustamente, & Braida, 1987; De Gennaro, Braida, & Durlach, 1986). In addition, there introduced a new technology, channel free hearing aids, which reduces the distortion in speech that may be introduced by multichannel hearing aid. So the present study is aimed at studying the performance of hearing impaired individuals with single, three channel, 8 channel and channel free hearing aid.

Aims of study

- To compare the speech identification score with the single channel, three channel, eight channel and channel free hearing aid in quite condition.
- To compare the speech identification scores with the single channel, three channel, eight channel and channel free hearing aid in different noise condition.

In present study four hearing aids (single channel, three channel, eight channel and channel free) were used for comparing the speech identification scores of twelve Kannada speaking subjects. All subjects were first time hearing aid users and had moderate to moderately severe sensory neural hearing loss. Speech identification scores were obtained with the Kannada phonetically balance word list (Yathiraj and, Vijayalakshmi 2005) presented in quiet and + 10 dB and 0 dB signal to noise ratio condition.

Result indicates that there is no statistically significant difference between all the hearing aids. The mean scores of the channel free hearing aids in quiet were higher than the other hearing aids used in the present study. In noise condition, both multichannel and channel free hearing aids provided the higher performance than other two hearing aids. But the performance variability in multichannel hearing aid is higher in 0 dB SNR condition. But both multichannel and channel free hearing aids provided the good performance over other two in 10 dB SNR condition.

It can be concluded that multichannel hearing aid may provide better performance in noise than in quiet, when compared to single and three channel hearing aids. Performance with channel free hearing aids was higher in quiet as well as in noise. Results of the present study suggest that channel free hearing aids would be a better option over the multichannel hearing aids. However, these results can not be generalized, as there were less number of subjects and more variability in score.

FUTURE DIRECTIONS TO RESEARCH

1) Future investigators should study on large number of population.
2) Studies should be carried by varying the different parameters in multichannel and Channel free hearing aids.
3) Studies can be carried out on subjects with different degrees, configurations and type of hearing impairment.

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Appendix

Phonemically Balanced Word List Developed by Yathiraj and Vijayalakshmi (2005).

rait̪a	tʃukki	huḷu	va:tʃu
anna	hagga	su:dzi	hoṭṭe
mola	bat̪t̪a	roṭṭi	doṇi
tʃa:ku	mantʃa	gu:be	vadzra
t̪uti	bekku	akka	va:ṇi
me:ke	lo:ta	e:ḷu	t̪ale
ha:vu	ba:la	vi:ṇe	kat̪t̪e
kat̪t̪u	dze:bu	d̪imbu	me:dzu
bi:ga	mandi	vaḍe	na:ji
o:d̪u	noṇa	go:li	ba:lu
baḷe	maḷe	ha:lu	ni:li
mu:ru	ṭi:vi	amma	gombe
ra:ṇi	d̪i:pa:	dzana	ka:ge
t̪apa:	rave	ravi	ad̪u
t̪a:ra:	moḷe	t̪ande	d̪ra:kṣi
brʌṣu	railu	rakṭa	bægu
hasu	ka:ru	sut̪t̪u	kaṣṭa
dzade	d̪ivja	ja:va	paisa
nalli	a:ru	tʃandra	mara
kivi	pu:ri	ja:ke	hu:vu
varṣa	had̪d̪u	ʃa:le	t̪innu
ja:ru	suṣma	aid̪u	iḍli
d̪a:na	t̪a:ji	nad̪i	ke:ḷu
ʃæmpu	d̪ana	uppu	sara
ili	ʃa:lu	kriṣna	pad̪a