Effect of Number of Channels of Hearing Aids on the Speech Perception in Individuals with Different Degrees of Sloping Hearing Losses

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Abstract

Single-channel hearing aids amplify sound alike across all the frequencies whereas Multi-channel hearing aids amplify different frequency components of sound differentially. The reports in the literature are equivocal regarding the effect of increasing the number of channels of hearing aid on speech perception by individuals with hearing impairment. Some studies have found improvement, some worsening and various other studies have shown improvement only up to a limited number of channels. However, these studies have neither specifically targeted the sloping hearing loss population, who are most likely to benefit from increasing number of channels nor have they used high frequency word lists to check for the performance change. So, the present study aimed at determining the effect of number of channels of hearing aids on the speech perception in individuals with different degrees of sloping hearing losses using the conventional as well as high frequency word lists. The participants in the study included 30 post-lingual Kannada speaking individuals with hearing impairment in the age range of 18 to 55 years. They were equally divided into three groups based on the configuration of hearing loss (flat, ski-slope and precipitous slope). The degree of hearing loss was between mild and severe hearing loss. Results revealed increase in the speech perception scores with increase in the number of channels of the hearing aid. The effects were more pronounced for the sloping hearing loss configurations where better results were noticed with 8-channel hearing aid. So, it can be said that individuals with high frequency sloping hearing loss configurations are likely to benefit with multi-channel compression hearing aids, especially with more than 4-channel systems.

Key words: *multichannel hearing aid, sloping hearing loss*

Introduction

The sensori-neural hearing loss results in loss of audibility, coupled with an uneven distortion of the audibility of the ear to different frequencies. Hearing aids are designed and fitted to lessen the problems faced by individuals with hearing impairment. The hearing aid technology allows for the sound to be amplified alike across the frequencies, as in single channel, or different frequency components of sound to be amplified differentially, as in multichannel hearing aid.

In a single channel system, the dynamic range is optimised across the full range of frequencies by a single processor, which means that single-channel compression systems vary gain across the entire frequency range of the signal. Thus, they cannot accommodate variations in the listener's dynamic range that may occur for different frequency regions. Many listeners with a sloping loss have a normal or near normal dynamic range for low-frequency sounds but a sharply reduced dynamic range for high frequency sounds where hearing loss is more severe. Upon improvement of an intense low frequency sound, most hearing aids, would decrease overall gain and cause high frequency sounds to become inaudible (Kuk, 1996), thus resulting in decreased speech identification. In contrast, multi-channel hearing aids split the incoming signal into different frequency bands and each band of signal passes through a different amplification channel. The gain compression is performed independently in each channel prior to summing the output of all channels. Hence, no such issue of inaudibility of one sound due to another sound is likely to come into the picture. In a multi-channel compression hearing aid, the incoming speech signal is filtered into two or more frequency channels. Compression is then performed independently within each channel prior to summing the output of all channels. Thus, the speech perception would still be better in the sloping hearing loss cases.

There are several reports in literature that have tried to explore the effect of increasing the number of channel of hearing aid on speech perception. The opinions regarding the usefulness are divided with some showed improvement (Barford, 1978; Yund & Buckles, 1995), some showing improvement upto only a small number of channels (Hickson, 1994; Keidser & Grant, 2001; Van Buuren, Festen, & Houtgast, 1999) where as other showing worsening of the scores (Bustamante and Braida, 1987). However, all the above studies either used severe degrees of hearing losses or specifically

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did not use participants with high frequency sloping hearing losses. So, the present study aimed at finding the effect of increasing the number of channels of hearing aids on the speech perception in individuals with flat and sloping hearing loses with different degrees of slopes.

Method

Present study was designed to compare the speech identification performance between single channel and multi channel hearing aid in different degrees of sloping hearing loss cases.

Participants

Thirty post lingual Kannada speaking individuals with mild to severe sensori-neural hearing loss in the ear to be tested (either symmetrical or asymmetrical hearing loss) and in the age range of 18 to 55 years were recruited for the study. They were also required to have at least 50% speech identification scores. The participants were split into three equal groups based on the audiogram configuration [Flat (difference between the maximum and the minimum thresholds with in 20 dB), Ski sloping (falls from low to high frequency at a rate of approximately 5-10 dB), steeply or precipitous sloping (threshold increases approximately at the rate of 15-20 dB per octave)].

Stimulus

Recorded version of phonemically balanced word list in Kannada developed by Yathiraj and Vijayalakshmi (2005) was used in this study. The speech material consisted of 4 phonetically balanced word lists and each list had 25 words. Also recorded version of a high frequency-Kannada speech identification test (HF KST) word list developed by Mascarenhas and Yathiraj (2002) was used. All the words were presented through a CD.

Instrumentation and Test procedure

A calibrated diagnostic audiometer Madsen Orbiter OB922 Version 2, with TDH-39 supra-aural ear phones housed in MX-41 cushions and Radio ear B-71 bone-vibrator, was used for obtaining air conduction and bone-conduction thresholds respectively. The same audiometer with loudspeakers placed at 45^{o} azimuth was used for the hearing aid trial. A GSI Tympstar middle ear analyser was used for immittance evaluation to rule out middle ear pathology.

The present study used three different hearing aids of MicroTech Company that were similar in all other regards except the number of channels (Vector 4-double channel, Vector 8-four channel, and Vector 16-eight channel). The hearing aids were connected to a Pentium 4 computer using appropriate cables and a Hi Pro box and programming was done using NAL-NL1 gain prescription formula. The hearing aids were switched to directional mode and other additional features were turned off. The participants were seated at an azimuth of 45° from the loud speakers and the stimulus was routed to the sound field condition through the audiometer. The hearing aid selection for the study was completely randomized to avoid adulteration of results due to order effect. The subjects were required to give written responses and in case of illiterate clients, native Kannada speaker noted down the responses.

Results and Discussion

The present study was aimed at finding the usefulness of increasing the number of channels of hearing aids on speech perception in varying degrees of sloping hearing losses. The obtained data was analyzed using SPSS software Version 15.0.

Speech Identification scores for the Phonemically Balanced word list

The Mean and standard deviation for the speech identification scores using the P.B word list for the three groups across the hearing aids were calculated. The mean and standard deviation for the speech identification scores are given in Table 1. The table revealed a trend towards increase in the speech identification scores with increase in the number of channels within each hearing loss group. It can also be seen that the increase in scores with increase in number of channels was greater for the two sloping hearing losses compared to the flat hearing loss group.

Further analysis was done using mixed ANOVA to see the interaction effect for 3 channels and three groups. Mixed ANOVA showed a significant interaction for the three channels of the hearing aid [$F(2, 54)=40.41$, $p<0.05$] but it revealed no significant interaction between the channel and the three groups [$F(4, 54)=1.106$, $p>0.05$]. Further, mixed ANOVA also revealed no significant interaction of the three groups [$F(2, 27)=0.158$, $p>0.05$]. Since the channel showed a significant interaction, a Bonferroni post hoc analysis was done to see the group wise differences. The details of Bonferroni post hoc analysis are given in Table 2. The table shows that there was significant channel interaction observed between 2-4, 2-8, and 4-8 channels of the hearing aids.

Table 1: Mean and standard deviation (S.D.) of speech identification scores of PB list

Number of Channels of Hearing Aid	HEARING LOSS					
	Flat Hearing Loss		Moderately Sloping Hearing Loss		Steeply Sloping Hearing Loss	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
2 channel	83.20	13.20	80.00	10.83	83.60	9.32
4 channel	87.50	9.96	91.20	7.49	90.00	6.59
8 channel	93.60	8.044	96.00	5.96	96.40	5.14

Table 2: Results of the Bonferroni post hoc analysis for the PB words

	4 channel	8 channel
2 channel	p<0.05	p<0.05
4 channel		p<0.05

So, an overall trend for increase in the speech scores for the PB word list with the increase in the number of channels was found. This was irrespective of degree of the slope of hearing loss. These findings are consistent with reports in literature (Barfod, 1978; Yund & Buckles, 1995) which also tend to suggest likewise performance improvement with increase in number of channels up to 8. The present finding could be attributed to maintenance of required audibility in each channel as required by the configuration of hearing loss. Venema (2000) postulated that a multichannel compression hearing aid may be better able to accommodate the variations in hearing threshold at each frequency thereby providing more appropriate and accurate, required audibility for each of the frequencies. Souza and Turner (1998) also reported the improvement in speech identification scores with increase in number of channels to increased audibility. However, there are also reports in literature which suggest that the speech perception scores improved with increase in number of channel only up to 3 or 4 and did not show further improvement (Hickson, 1994; Keidser & Grant., 2001; Van Buuren et al., 1999). Villchur (1978) explained this finding of no improvement to poor post compression frequency equalization for some hearing aids, also the difference between the study and those reported in literature could be attributed to use of different compression ratio in the preview of different channels by the two set of studies.

Speech Identification scores for the high frequency word list

Mean and standard deviation for the speech identification score of high frequency word list for the three groups across three hearing aids was calculated. The mean standard deviation for the speech identification scores are given in table 3. Table 3 reveals a trend towards increase in speech identification scores with increase in the number of channels for all the three groups. A comparison of the groups shows better scores for flat configuration compared to the other two whereas the scores for the other two groups (moderately sloping, steeply sloping) were comparable. It can also be seen that the change in performance with increase in number of channels, though noticed for all the three groups, was a lot higher for the moderately sloping and sharply sloping hearing loss groups (nearly 19% and 21%) as opposed to only 14% for the flat configuration group.

Mixed ANOVA was done to see the interaction effect for 3 channels and three groups. Mixed ANOVA showed a significant main effect for the three channels of the hearing aid [F(2, 54)=105.61, p<0.05], and it showed an interaction between channel and group [F(4, 54)=2.62, p<0.05]. Further, mixed ANOVA also showed significant interaction for the three groups [F(2, 27)=14.77, p<0.05]. The Bonferroni post hoc analysis was done to see the pair-wise comparison for the channels. The details of the Bonferroni post hoc analysis are given in Table 4.

The Duncan's post hoc test was done to see the group differences. Duncan's post hoc analysis revealed a significant difference between flat hearing loss and moderately sloping hearing loss groups (p<0.05), whereas it revealed no significant difference between moderately sloping and sharply sloping hearing loss groups (p>0.05). The Duncan's post hoc analysis also revealed a significant difference between flat and sharply sloping hearing loss groups (p<0.05).

Since there was an interaction between channel and group, repeated measure ANOVA was done to see which of the groups or channels were significantly different. For the flat configuration group, repeated measures of ANOVA revealed a significant difference for the channels. The Bonferroni pair-wise comparison was done to see the group-wise differences for the channels. The result of the analysis has been portrayed

Table 3: Mean and standard deviation (S.D.) of speech identification scores of high frequency word list.

Number of Channels of Hearing Aid	HEARING LOSS					
	Flat Hearing Loss		Moderately Sloping Hearing Loss		Steeply Sloping Hearing Loss	
	Mean (% scores)	S.D.	Mean (% scores)	S.D	Mean (% scores)	S.D.
2 channel	76.50	8.18	48.00	18	44.50	9.26
4 channel	80.50	9.84	59.00	17.6	51.50	13.13
8 channel	90.00	6.23	67.50	17.6	65.50	11.89

Table 4: Results of the Bonferroni post hoc analysis for the HF words

	4 channel	8 channel
2 channel	$p<0.05$	$p<0.05$
4 channel		$p<0.05$

Table 5: Bonferroni pair wise comparison for flat hearing loss, moderately sloping hearing loss, and steeply sloping hearing loss

Flat Hearing loss group		
No. of channels	4 channel	8 channel
2 channel	$p>0.05$	$p<0.05$
4 channel		$p<0.05$

Moderately sloping hearing loss group		
No. of channels	4 channel	8 channel
2 channel	$P<0.05$	$p<0.05$
4 channel		$p>0.05$

Steeply sloping hearing loss group		
No. of channels	4 channel	8 channel
2 channel	$p>0.05$	$p<0.05$
4 channel		$p<0.05$

in Table 5. It is evident from the table that there was significant difference between 2-channel and 8-channel hearing aids and also between 4-channel and 8-channel hearing aids ($p<0.05$). However, there was no evidence of a significant difference for a comparison between 2-channel and 4-channel hearing aids. Likewise, there was also a significant difference for the channels for moderately sloping and steeply sloping hearing loss configurations which necessitated the need of a Bonferroni pair-wise comparison and the results are shown in Table 5.

Mixed ANOVA revealed a significant main effect for the groups. To understand the main effect, multiple analysis of variance (MANOVA) was done to see for which of the channels there was a group difference. MANOVA revealed a significant difference for the 2-channel hearing aid [$F(2, 27)=18.34$, $p<0.01$], 4-channel hearing aid [$F(2, 27)=11.73$, $p<0.01$] and 8-channel hearing aid [$F(2, 27)=11.26$, $p<0.01$].

Duncan's post hoc analysis was done to see for which of the channels the groups were different. The Duncan's post hoc analysis revealed a significant difference between the flat hearing loss configuration and the moderately sloping hearing loss configuration ($p<0.05$) for 2-channel hearing aid. It also revealed a significant difference between the flat hearing loss configuration and the sharply sloping configuration ($p<0.05$), however, there was no evidence of a significant difference between the sharply sloping and the moderately sloping configurations of hearing loss ($p>0.05$) using a 2-channel hearing aid. Likewise, for 4-channel and 8-channel hearing aids also, there was no significant difference between sharply sloping and moderately sloping configurations ($p>0.05$), however the difference was significant ($p<0.05$) when these two were compared with the flat hearing loss configuration.

So, use of high frequency word list showed slightly different result to the PB word list. Here, there was no significant change in the speech perception scores with increase in number of channels from 2 to 4. However, there was a significant change (increase) in the scores with increase in number of channels to 8. There are no reports in literature that have reported about the effect of number of channels of hearing aids on the speech perception when using the HF wordlist. The present findings could probably be attributed to the frequency configuration of the HF word list itself. The wordlist (HF and PB word list) used in the present study was constructed with the use of phonemes that had maximum energy concentration beyond 1000 Hz. The two channel hearing aid in the present study had a cut-off frequency of 1000Hz. So, comparing with the frequency composition of the word list, the hearing aid effectively had only one channel to process the high frequency word list. This would mean that the required accuracy of audibility for the moderately sloping and steeply sloping hearing loss configurations would not be achieved. It is also a known fact that high frequencies are important for speech discrimination and low frequencies for the audibility of the speech sound (Dubno, Dirks, & Schaefe, 1989). So, if the accurate amplification is not achieved in the high frequencies, it would result in poor speech discrimination and thereby in poorer speech identification scores.

A similar scenario would be portrayed by the use of 4-channel hearing aid. In the present study, the four channel hearing aid had less than 500 Hz, 500-1000 Hz, 1000-2000 Hz and 2000-4000 Hz as the different compression channels. Again a similar comparison with the frequency composition of the high frequency word list shows that the hearing aid in question effectively had only two channels to process the speech sound of high frequency word list. This should have, in essence, resulted in slightly better performance compared to two channels, which was exactly the case in the present study. However the present study didn't show the difference between two and four channel hearing aids to produce statistically significant difference for the high frequency word list this could be attributed to the addition of only one extra effective channel in the zone which had the high energy concentration (high frequency zone beyond 1000 Hz). This produced slight betterment of scores for four channel hearing aid. However, this could not be appreciated statistically.

The 8-channel hearing aid of the present study had five different frequency channels (1000-1500 Hz, 1500-2000 Hz, 2000-3000 Hz, 3000-4000 Hz, and 4000-6000 Hz) beyond 1000 Hz. This would mean a lot better and more accurate fitting of thresholds in high frequencies and thereby produce better scores than two and four-channel hearing aids. The results of the present study complied with this logical view.

Conclusions

It can be concluded that increasing the number of channels produce better speech perception scores at least till 8. The effects are better for the sloping hearing loss configurations where better results were noticed with 8-channel hearing aid. So, it can be said that individuals with high frequency sloping hearing loss configurations are likely to benefit with multi-channel compression hearing aids.

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