EFFECT OF DIFFERENT COMPRESSION PROCEDURES ON AIDED SPEECH IDENTIFICATION SCORES IN INDIVIDUALS WITH VARYING DEGREES OF HEARING LOSS

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Abstract

The aim of the present study was to determine the effect of different types of compression on aided speech identification scores (ASIS) in a group of individuals with hearing impairment of varying degrees. The ASIS were determined at two presentation levels (40 and 70 dB HL) in a quiet environment, for three types of compression (i.e., Dual compression only, Syllabic compression only and a combination of both Dual and Syllabic compression across the frequency channels). Ten ears in each degree of hearing loss (Moderate, Moderately Severe, and Severe), a total of 30 ears, were taken in the present study. ASIS were determined by using phonemically balanced word list developed by Yathiraj and Vijayalakshmi (2005). The results of the present study indicated that there was a significant improvement in ASIS for the compression procedure in which a combination of the two procedures was used. However, there was no significant difference when any one of the compression procedures was used individually in all the frequency channels across various degrees of hearing loss. This indicates that the consonant to vowel ratio is more enhanced in the combined compression procedure than when only one of the compression procedures is used. There was also a significant improvement for a higher presentation level when compared to a lower presentation level irrespective of the compression procedure used. This could be attributed to the better audibility of the speech.

Key words: *Aided Speech Identification Scores, Syllabic compression, Dual compression, Consonant to vowel ratio.*

Hearing loss is a form of sensory impairment that affects many individuals across the world. Sensorineural hearing loss is most common form, which is usually irreversible and results in decreased audibility, decreased dynamic range, decreased frequency resolution, and decreased temporal resolution (Dillon, 2001). This form of hearing impairment can be usually fitted with amplification devices such as hearing aids and/or cochlear implants. With the advancement in the hearing aid technologies there are now many options available in the same hearing aid to improve the perception of speech in individuals with hearing impairment.

The audibility of a signal can be compensated by just providing amplification to the incoming signals. However, it is observed that, most of the individuals with hearing impairment are not satisfied with their hearing aids, moderate to intense sounds cause discomfort though soft sounds are audible, which were not audible before. This is often referred to as 'reduced dynamic range'. This reduction in their dynamic range may be due to loss of cochlear compression. This would be due to acoustic trauma or cochlear injury (Ruggero, 1996; Robles & Ruggero, 2001). Thus, reduction in dynamic range associated with loudness recruitment or softness imperceptions cannot be compensated with fixed gain linear amplification hearing aids due to inconvenience in selection of desired gain (Chaudhari, 2002).

Also, linear hearing aids amplify all the sounds present in the environment equally, which leads to increase in background noise and thus, decreases the speech perception abilities. In the past, this issue was controlled by peak clipping strategies, where the output of the hearing aids was not over-amplified. However, this in turn distorted louder sounds. Later, hearing aids used dynamic range compression, which addressed the issue of full-range amplification by providing amplification based on the level of the input signal (Amlani, 2008).

With advent of technology, digital hearing aids at present, has the facility to be programmed, and thus allows the user to adjust the equalization of their hearing aids to meet their particular needs. Some of these hearing aids also featured noise reduction and feedback suppression; however, the limitations of analog signal processing meant that these devices were quite crude. The most advanced hearing aids featured multi-band processing schemes that incorporated wide dynamic range compression and adaptive time constants for the compression to further improve sound quality (Amlani, 2008). These hearing aids also has ability to divide the signal into many components based on frequency, intensity or time and apply different processing techniques to

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manipulate the signal, resulting in precise tuning of the signal to benefit the individuals with hearing impairment.

Compression amplification is most beneficial to the hearing aid users, but there is no consensus as to which form of compression is most beneficial. Single-channel compression is substantially better than those without compression. However, there is only a modest improvement of two-channel compression systems over single-channel compression (Young & Buckles, 1995), and ambiguous results with respect to the use of many compression channels.

Wide dynamic range circuits provide relatively more gain for low input sound levels and less gain for high input sound levels. Phonemic, syllabic and slow-acting compressions are sub-categories of WDRC. The goal of phonemic and syllabic compression is to reduce the amplitude differences between individual phonemes or syllables of speech, respectively (Moore, Johnson, Clark, & Pluvinage, 1992; Mare, Dreschler, & Verschuure, 1992; Hickson, 1994; Dillon, 2001). This would result in improved audibility of low-intensity speech sounds, such as most consonants, without over amplification of the high intensity speech sounds, such as most vowels. Phonemic and syllabic compressors must act quickly in order to adapt to the varying input levels of different speech segments. Attack times are often less than 5 ms, and release times may range from 50 ms to 200 ms. Attack and release times are not faster than this because the sum of the attack and release times should be at least 5 times longer than the period of the lowest frequency of the input signal in order to avoid waveform distortion (Moore & Glasberg, 1986).

On the other hand, dual compression has both syllabic and Automatic volume control algorithm. In this algorithm, short and long attack and release times are used depending on the level and time course of the input signal, exploiting the advantages of both compression procedures (syllabic and AVC). Gain reduction with short time constants reacts quickly to sudden, loud sounds and quickly turns to the original level after the loud sound is over. Thus the desired soft signal occurring after the loud sound is not affected. In contrast, if the criterion sound level is presented for a longer time, the long time constants are activated. The gain of the hearing instrument is adjusted only to slow changes to the average input level and the natural loudness variations in speech levels are preserved (Moore, Glasberg & Stone, 1991).

Several researchers have studied various perceptual benefits of various attack and release times which showed varied results. When the perceptual rating was measured, many preferred slow-acting release times in presence of certain background noises, but not for other noise background (Neuman, Bakke, Mackersie, Hellman & Levitt, 1995). Bentler and Nelson (1997) reported that there is no effect of various combinations of phonemic, syllabic and slow-acting compressors on nonsense syllable identifications in noise, perceived intelligibility, or hearing aid usage time. Jenstad and Souza (2005) studied the acoustic effects of release time on vowel-consonant nonsense syllables. They reported that faster release times were associated with a larger difference between the WDRC processed and unprocessed signals. Also, shorter release times were associated with a larger difference in level between the consonant and vowel segments. Both of these results indicate that faster release times led to more effective compression for nonsense speech syllables.

Comparison of the dual and syllabic compression was made by many researchers to determine which one would be more appropriate to improve the speech identification ability of individuals with hearing impairment. Geetha (2005) compared the effect of syllabic and dual compression on speech identification scores among individuals with mild to moderately severe sensorineural hearing loss. The results of this study reported that there was no significant difference in speech identification scores with either types of compression but the subjective preference was towards dual compression. Similar findings were also obtained with different degrees of hearing loss (Sarathy, 2010).

Need for the Study

Various research studies have revealed that, there is not much difference observed among the two compression procedures though the dual compression is meant to improve the speech perception ability than the syllabic compression. Research studies have indicated that the syllabic compression or dual compression alone has not brought changes in speech perception abilities. Investigators have evaluated the efficiency of two compression procedures either using either of the procedure alone or a comparison of the two. This lack of consensus among the compression procedures, would leave a question whether, any further modifications or different combination of these compression procedures would improve the speech perception abilities. Hence, the current study was taken up to determine the speech identification abilities with the combination of these two procedures where in dual compression for the low frequency bands and syllabic compression for the high frequency bands were incorporated.

Objectives

The objective of the present study is twofold, the first is to study the effect of compression procedures on speech perception in individuals with different degree of hearing loss and to compare the speech identification scores obtained using different compression procedures at different presentation levels in individuals with different degree of hearing loss.

Method

Participants

The participants with sensori-neural hearing loss were divided into three groups namely moderate, moderately-severe and severe based on the degree of hearing loss having taken ten ears in each group. The age range of participants was from 31 to 57 with mean age of 44 years. The participants in the moderate group had hearing thresholds of 41 to 55 dB HL, moderately-severe group had thresholds of 56 to 70 dB HL and severe group had thresholds of 71 to 90 dB HL. The mother tongue of all the participants was Kannada. All the participants were naive hearing aid users.

Stimulus

Phonemically balanced word lists developed by Yathiraj and Vijayalakshmi (2005) were used for the study. The word list consists of four lists with 25 words in each list. The words were randomized using random tables to obtain eight lists which were used in this study.

Instrumentation

A non-linear digital behind-the-ear hearing aid with the following features was selected in the present study. The hearing aid had four compression channels with the facility to select dual or syllabic compression in each of the channels. The hearing aid also had an option to program for individuals with hearing impairment of various degrees. The hearing aid could accommodate three programs in which different compression procedures could be stored by keeping all other parameters constant.

A Pentium IV Computer along with Hi-Pro device and programming cables was used for connecting the hearing aid to the computer and to program. NOAH-2 and Connexx (V5.0a) softwares were used to program the hearing aid. The stimulus was presented through Adobe Audition V3.0 connected to an audiometer from the computer through an auxiliary cable. The stimulus was presented through loudspeakers at 45 degree azimuth and speech identification scores for different compressing conditions were determined.

Procedure

The pure tone thresholds (from 250 Hz to 8 KHz for air conduction and from 250 Hz to 4 KHz for bone conduction) of the test ear were fed into the NOAH fitting software. The subject was fitted with the digital hearing aid on the test ear using a custom ear mold. The hearing aid was connected to the HI-PRO that was in turn connected to a computer with the programming software. The hearing aid was detected by the Connexx software after switching the hearing aid "on" and both the volume control and the acclimatization level was set at two. The default prescriptive formula used was NAL-NL1.

The hearing aid was programmed for the first fit condition and the compression option was first set to the dual compression in the low frequency channels and the syllabic compression in the high frequency channels and this first program was named as P1. In the 2nd program (P2), compression method was set to dual compression in all the frequency channels and in 3rd program (P3), it was set to syllabic compression in all the frequency channels. The compression threshold and the compression ratio values set by the software, i.e. default settings were unchanged.

The aided speech identification scores were determined at two presentation levels (40 dB HL and 70 dB HL) using the word lists developed by Yathiraj and Vijayalakshmi (2005) in all the three programs. The order of administration of P1, P2, and P3 were randomized across all the 3 groups. The subject was instructed to provide a verbal response for all the stimuli presented and the correct responses were scored. The speech identification scores were tabulated and subjected to statistical analysis.

Results and Discussion

The speech identification scores for three programming conditions (P1, P2, & P3) at two presentation levels were noted for all the three groups. The data obtained from the thirty ears with different degrees of hearing loss was tabulated and analyzed using Statistical Package for Social Sciences, (SPSS, V17) to determine the effect of different compression procedures on speech identification scores across different degrees of hearing loss and also to determine the effect of different compression procedures on speech identification scores at different presentation levels. Thus mean and standard deviation of speech identification scores of all the three groups were obtained, which is shown in Table 1 and these results were compared across the groups.

Table 1: *Mean and Standard deviation of aided speech identification scores at different compression procedures used in the three groups at presentation levels of 40 and 70 dB HL.*

S.No	Degree of Hearing Impairment	Compression Procedure	Presentation Level (dB HL)	Mean (SIS)	Standard deviation
1.	Moderate	P1	40	88.4	2.27
			70	91.2	1.69
		P2	40	68.8	4.13
			70	75.60	2.95
		P3	40	68.0	3.77
			70	76.0	3.71
2.	Moderately Severe	P1	40	85.6	5.4
			70	90	4.71
		P2	40	66.6	5.51
			70	73.8	5.85
		P3	40	70.8	4.64
			70	74	6.11
3.	Severe	P1	40	66.4	6.59
			70	72.4	4.69
		P2	40	50.8	5.01
			70	56.8	5.59
		P3	40	50.4	6.02
			70	57.6	7.82

Repeated measures of ANOVA was done for the tabulated speech identification scores, the results revealed that there was no significant difference with regard to the speech perception abilities in P2 and P3 programs, i.e., there was no significant difference in speech identification scores between the dual compression only and the syllabic compression only condition across the frequency channels. There was also no significant difference in speech identification scores across different degrees of hearing loss over these two compression procedures. These results are in support of that reported by Geetha (2004) and the results across different degrees of hearing loss were also consistent with the study reported earlier by Sarathy (2010). These results are also supported by the findings of the study done by Bentler and Nelson (1997), who also reported no effect of various combinations of phonemic, syllabic and slow-acting compressors on nonsense syllable identification in both quiet and noise. Sarathy (2010) also reported similar findings. In contrary, to these findings, Moore et al. (1991) reported that the speech identification scores were better for dual time constant compression compared to adaptive compression. However, these authors fail to explain the reason for their results.

However, there was a significant difference in speech identification scores for the combined compression procedure when compared with that of either dual only or syllabic only condition [$F_{(2,27)} = 419.04$, $p<0.01$]. The same was found to be true at two presentation levels. There was a significant difference in speech identification scores between P1 & P2 and between P1 & P3 at 40dB and at 70 dB HL. Fig. 1 shows that participants in all the three groups performed better when combined compression was used than when single compression was utilized at 40 dB HL.

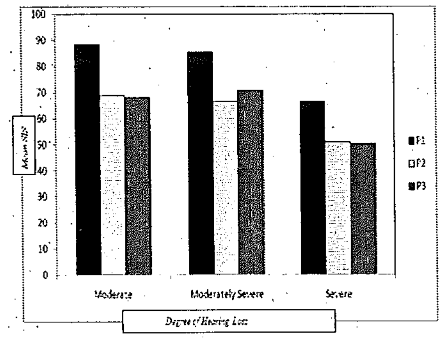

Figure 1: *Mean speech identification scores of individuals with hearing impairment with various degrees of hearing loss at 40 dB HL presentation level using three compression procedures*

Similar results were obtained at 70 dB HL as illustrated by Fig 2.

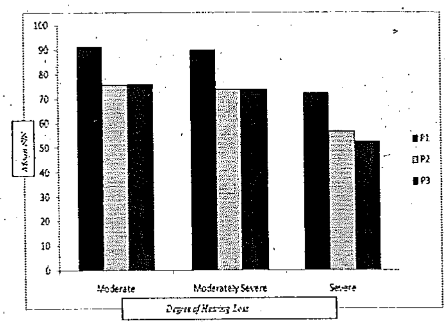

Figure 2: *Mean speech identification scores of individuals with hearing impairment with various degrees of hearing loss at 70 dB HL presentation level using three compression procedures*

Boneferroni multiple comparison tests at a significance level of 5% was also done to determine which of the two groups differ significantly. The results of Bonferroni multiple comparison tests revealed that there was a significant difference in speech identification scores between the combined compression method with that of the single compression method across the frequency channels. Duncan post hoc analysis revealed that the three groups (moderate, moderately-severe, and severe) differed significantly from each other in the combined compression method.

The results of the present study also revealed that individuals belonging to all the three groups performed better at 70 dB HL when compared to 40 dB HL irrespective of the compression procedure used. This could be related to better audibility of the sounds that made perceive speech better at high intensity levels. There was also a significant difference in speech identification scores across different degrees of hearing loss which could be related to the more audibility at high presentation level. This finding is in contrary to the study done by Moore et al. (1991), who reported that there is no significant difference in speech identification scores at high presentation levels (70dB HL) compared to low stimulus presentation levels (40 dB HL).

The results of the present study has revealed that the speech identification scores for the combined compression method (Dual compression at low-frequency channels and Syllabic compression at high-frequency channels) is significantly higher than that of the either of the two other compression procedures presented alone across all the frequency channels. With this type of combined compression procedure the short duration portion of the speech signals (i.e., consonantal part) will be enhanced (in both the channels), whereas the vowel part (which is longer in duration than consonants) will not be enhanced to the same extent as that of the consonantal part. The reasons that the vowels are more concentrated in lower frequencies and are longer in duration. Thus, the vowel part will not be amplified to the same extent as that of the consonant. This in turn increase the consonant-to-vowel (CV) ratio with the combination of the both the compression procedures, and thus, increase the speech identification abilities. Hickson, Thyer and Bates (1999) reported that CV ratio will be generally increased with compression, compared to linear amplification, and that the effects will be greatest for amplification with compression in the high-frequency channel. This finding is in contrary to study by Souza (2002) who states that acoustically, the amplitude contrast between the C and V is significantly altered by WDRC. The WDRC reduces the vowel level and increases the consonant level relative to the original speech token. The difference in results could be due the difference in types of compression used.

This is also true at different presentation levels (i.e., both at 40 dB HL and 70 dB HL). The results can be better explained at 70 dB HL, as the compression would have worked above the compression knee point. Hearing aid used in the present study had knee point around 62 to 66 dB HL, so the high presentation level (70 dB HL) was above the knee point and the low presentation level was below the knee point. Unexpectedly, there was a significant improvement in speech identification scores of individuals with cochlear hearing loss.

Conclusions

The present study made an attempt to find out the effect of different combination of compression procedures on speech perception across varying degrees of hearing impairment. The results showed that the speech identification scores for the combined compression method (Dual compression at low-frequency channels and Syllabic compression at high-frequency channels) is significantly higher than that of the either of the two other compression procedures (Dual compression and Syllabic compression) utilized alone across all the frequency channels in individuals with moderate, moderately-severe and severe hearing loss. Also, in individuals with moderate, moderately-severe and severe hearing loss, similar performance is obtained in speech identification scores when only dual compression and only syllabic compression was used across the frequency channels. In addition, it was found that individuals belonging to all the three groups performed better at 70 dB HL when compared to 40 dB HL in speech identification task.

Implications of the study

As the combined compression in digital hearing aids improves speech perception in individuals with hearing impairment, the combined compression is to be used clinically. As the performance in this condition is much better, there will be more acceptance and better adoptability with the amplification. This results in optimum use of hearing aids. Thus, helping Audiologists to achieve the main goal of rehabilitation.

References

Amlani, A. M. (2008). Multichannel Compression Hearing Aids: Perceptual Considerations. *The ASHA Leader*. Retrieved on December, 15, 2010, from http://www.asha.org/Publications/leader/2008/080304/f080304b.htm

Bentler, R. A., & Nelson, J. A. (1997). Assessing release-time options in a two-channel AGC hearing aid. *American Journal of Audiology, 6*, 43–51.

Chaudhiri, S. (2002). Hearing aids: Speech processing techniques. *Hearing Aid Journal, 16(4)*, 72-76.

Dillon, H. (2001). Hearing Aids. *Forlaget Thieme.* Boomerang Press, Sydney.

Geetha, C. (2005). *Effect of syllabic and dual compression on speech identification scores.* Unpublished Masters Dissertation, University of Mysore.

Robles, L., & Ruggero, M.A.(2001). Mechanics of the mammalian cochlea. *Physiological. Review, 81*, 1305–1352.

Ruggero, M. A. (1996). The effects of acoustic trauma, other cochlear injury, and death on basilarmembrane responses to sound. *Scientific Basis of Noised-Induced Hearing*, 23–35.

Moore, B. C. J., Glasberg, B., & Stone, M. (1991). Optimization of slow acting automatic gain control system for use in hearing aids. *British journal of audiology, 25 (3)*, 171-182.

Moore, B. C. J., Johnson, J. S., Clark, T. M., & Pluvinage, V. (1992). Evaluation of a dual-channel full dynamic range compression system for people with sensorineural hearing loss, *Ear and Hearing, 13*, 349–370.

Mare, M. J., Dreschler,W. A., & Verschuure, J. (1992). The effects of input-output configuration in syllabic compression on speech perception, *Journal of Speech and Hearing. Research, 35*, 675–685.

Hickson, L. M. H. (1994). Compression amplification in hearing aids, *American Journal of Audiology, 3*, 51–65.

Hickson, L., Thyer, N., & Bates, D. (1999). Acoustic analysis of speech through a hearing aid: consonant-vowel ratio effects with two-channel compression amplification, *Journal of American Academy of Audiology, 10(10)*, 549-556.

Moore, B. C. J., & Glasberg, B. R. (1986). A comparison of two-channel and single-channel compression hearing aids, *Audiology, 25*, 210–226.

Neuman, A. C., Bakke, M. H., Mackersie, C., Hellman, S., & Levitt, H. (1995). Effect of release time in compression hearing aids: Paired-comparison judgments of quality, *The Journal of the Acoustical Society of America, 98*, 1471–1478

Sarathy, K. (2010). Effect of Syllabic and Dual Compression on Speech Identification Scores Across Different Degrees of Hearing Loss, Unpublished Masters Dissertation, University of Mysore.

Souza, P.E. (2002). Effects of compression on speech acoustics, intelligibility and sound quality. *Trends in Amplification, 6 (4)*, 131- 165.

Jenstad, L. M., & Souza, P. E. (2005). Quantifying the effect of compression hearing aid release time on speech acoustics and intelligibility, *Journal of Speech, Language, and Hearing Research, 48*, 651–667.

Yathiraj, A., & Vijayalakshmi, C. S. (2005). Phonemically Balanced Word List in Kannada. Developed in Department of Audiology, All India Institute of Speech and Hearing, Mysore.

Yund, E. W, & Buckles, K. M. (1995). Enhanced speech perception at low signal-to-noise ratios with multichannel compression hearing aids. *Journal of the Acoustical Society of America, 97*, 1224-1240.