Effect of Syllabic and Dual Compression on Speech Identification Scores across Different Degrees of Hearing Loss

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Abstract

The study aimed to investigate effects of compression types (syllabic and dual compression) on speech identification scores (SIS) in two conditions; Quiet condition at 40 dBHL and 70 dBHL of speech and, in the presence of noise (speech noise at 10 dB SNR) at same two intensities. The study was conducted on 20 subjects with sensori-neural hearing loss of various degrees (mild, moderate, moderately severe and severe). Speech identification scores were tested using phonemically balanced wordlist for Kannada speaking individuals developed by Yathiraj and Vijayalakshmi (2005). The results indicated that there was no significant difference in SIS obtained between syllabic and dual compression conditions, in quiet and in noise, at different input levels. Neither syllabic nor dual compression showed significant difference in SIS across different degrees of hearing loss. Higher presentation levels did not degrade the SIS, rather exhibited a better performance across different degrees of hearing loss, in both quiet and noisy conditions. Syllabic and Dual compression alone won't possibly help in improving speech perception as the former acts on the rapidly varying cues within a speech signal as it has short attack and release times whereas the latter adopts the time constant depending on the input signal. Hence, either syllabic or dual compression alone facilitates significant improvement in speech perception through hearing aids.

Key words: *Compression, speech identification scores, hearing loss.*

Across the world many people have different types of hearing impairment. A loss of cochlear compression may underlie many of the difficulties experienced by hearing-impaired listeners. Low-level sounds elicit a narrowly tuned response that grows nonlinearly with level to become more broadly tuned at high levels (Ruggero, Rich, Reico, Narayan & Robles., 1997; Rhode & Recio, 2000). The degree of compression is less for frequencies well below the characteristic frequency (CF) of the recording site (Robles & Ruggero, 2001). This response pattern is vulnerable to acoustic trauma, cochlear injury or death (Ruggero, 1996; Robles & Ruggero, 2001). Direct measurements of basilar membrane motion on acoustically or chemically traumatized cochleae showed reduced sensitivity near characteristic frequency and broadly tuned responses that grow more linearly with level than do the responses of healthy basilar membrane. (Ruggero, 1996; Robles & Ruggero, 2001).

Sound amplification is one of the means to reduce the effects of hearing loss. There are different techniques incorporated in hearing aids depending upon the impairment characteristics. In case of elevated hearing thresholds, frequency selective amplification can be useful. Hearing loss due to reduction in dynamic range associated with loudness recruitment or softness imperception cannot be compensated with fixed gain linear amplification hearing aids due to inconvenience in selection of desired gain (Chaudhari, 2002).

The primary drawback of early analog hearing aids was that sounds were amplified over the full audible frequency range. Across the listening spectrum, those sounds they could still hear well would be amplified together with those they found more difficult to hear, resulting in an uncomfortable listening experience. Furthermore, when users turned up the volume to hear soft sounds, loud sounds were also boosted. Early hearing aids addressed the problem of loud sounds by 'clipping' the output so the sounds were not over-amplified. However, as clipping distorted louder sounds, early analog aids were not effective in more complex listening situations. Later, analog hearing aids used dynamic range compression, which addressed the issue of full-range amplification by providing amplification based on the input signal level (Amlani, 2008).

With drastic improvement in technology, hearing aids had the facility to be programmed, thus allowing 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 analog hearing aids featured multi-band processing schemes that incorporated wide dynamic range compression (WDRC) and sometimes adaptive time constants for the compression to further improve sound quality (Amlani, 2008).

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Digital hearing aids overcome few of the drawbacks and problems faced with analog-based hearing aids. For example, digital devices can divide the sound information into many components based on frequency, time, or intensity and apply different processing techniques to manipulate the signal, resulting in precise tuning of the signal to benefit the hearing-impaired consumer. The ability to address each individual's unique listening environments and specific, unique acoustic needs is a relatively new development. With digital signal processing (DSP), hearing aid technologies have advanced to the point where each individual fitting can be tailored to the individual's acoustic and environmental needs. Indeed, with DSP technology, the sound quality and sound processing ability of hearing aids is tremendous. Some people like sounds quieter, some like them louder, some can tolerate more noise, and some can tolerate less noise. DSP hearing aids allow the audiologist to alter the hearing aids to better fit the patient's needs (Amlani, 2008).

With advancement in digital technology, various types of compression are incorporated in hearing aids. Compression plays a major role in decreasing the range of sound levels in the environment to better match the dynamic range of a hearing impaired person. Compressors can react to a change in input levels within a few thousandths of a second, or they can be so sluggish that they take many tens of seconds to fully react. Fast acting compression with a low compression threshold can be used to increase the audibility of the softer syllables of speech, where as slow acting compression will leave the relative intensities unchanged, but will alter the overall level of a speech signal (Smith, 2006).

Compression amplification is most beneficial to the hearing aid users, but there is no consensus as to which form of compression is most beneficial. Whereas single-channel compression is substantially better than no compression, experimental evaluations of multi-channel compression systems show only a modest improvement of two-channel compression over single-channel compression and ambiguous results with respect to the use of many compression channels. Compression amplification generally works well in quiet, but there are problems with compression amplification in noise. Fine tuning the time course of compression such that gain is reduced very quickly at the start of a strong speech sound (the attack time) but the gain continues unchanged for a short-while after a reduction in speech level (the release time) will improve listening in noisy situations (Levitt, 2004). Compression limiting, automatic volume control (AVC), syllabic compression and dual compression are a few types of compression amplification.

Compression limiting: Involves rapid compression of short duration sounds (< 5 ms) in order to protect the subject from intense sounds. Compression limiting hearing aids have two main features; a high compression 'knee-point' and a high 'compression ratio'. Low-level sounds are amplified linearly, but inputs from moderate to intense sounds are squashed into a narrow range of outputs (Dillon, 2001). A high compression ratio usually is defined as being greater than 5:1 (Dillon, 1988).

Automatic volume control has long attack and release time due to which fast changes in the amplitude of input signal are better preserved. This is possible because adjustments to output signal occur over a longer time course. This preserves the level variations within the speech which is an advantage. However the disadvantage of AVC is that the LDL (loudness discomfort level) may be exceeded because the reduction in gain is slower (Chaudhari, 2002).

Syllabic compression: For individuals with reduced dynamic range it may be difficult to achieve and maintain a volume control setting that makes the weakest sounds of speech sufficiently audible to be understood without the most intense sounds becoming excessively loud. Even when the dynamic range is adequate to hear weak phonemes without intense ones being too loud, there is the potential for the weaker phonemes to be temporally masked by the stronger ones. A potential solution to both these problems is to include a fast acting compressor that increases its gain during weak syllables or phonemes and decrease its gain during intense syllables and phonemes. Such a compression is called syllabic or phonemic compression (Dillon, 2001). Most commercially available hearing instruments have relatively short time consonants with an attack time of 1 to 10 ms and release time of less than 100 ms. The major utility of this is that, the levels are adjusted differently within the syllabic structure of the speech signal.

In dual compression, short and long, attack and release times are used depending on the level and time course of the input signal. It exploits the advantages of both compression procedures (syllabic & AVC). Gain reduction with short time consonants 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 of the average input level and the natural loudness variations in speech levels are preserved (Moore, Glasberg & Stone, 1991).

Hence, the present study aimed to compare the effects of syllabic and dual compression on speech identification scores (SIS) in quiet and background noise condition.

Method

The study was carried out on 40 ears (10 in each category; mild, moderate, moderately severe and severe sensory-neural hearing loss) of 20 subjects who were post-lingually hearing impaired. Participants were in the age range from 20 to 60 years and had hearing loss of either mild, moderate, moderately severe or severe (symmetrical) degree. The air bone gap of less than 10 dB, and normal middle ear functioning on immittance evaluation confirmed sensorineural nature of the hearing loss. Speech identification scores were above 50%, appropriate to pure tone average. The participants were native speakers of Kannada and naive hearing aid users.

The speech identification scores were obtained in six conditions, listed in Table 1.

Table 1. Different conditions used in the study

Unaided condition	Quiet	40 dBHL
		70 dBHL
	Noise (10 dB SNR)	40 dBHL
		70 dBHL
(Aided condition) Syllabic compression	Quiet	40 dBHL
		70 dBHL
	Noise (10 dB SNR)	40 dBHL
		70 dBHL
(Aided condition) Dual compression	Quiet	40 dBHL
		70 dBHL
	Noise (10 dB SNR)	40 dBHL
		70 dBHL

Procedure

Unaided scores were found using five open ended questions and 25 words in Kannada. The words were taken from 'phonetically balanced list for Kannada speaking individuals' developed by Yathiraj and Vijayalakshmi (2005). The questions and paired words were presented at 40 dBHL through the speakers of the audiometer at 45° azimuth. The subjects were made to sit comfortably and were fitted with the hearing aid on the test ear using an appropriately sized ear tip. The hearing aid was connected to Hipro that was in turn connected to a computer with the programming software; Connex (Sifit V 5.0a). Puretone 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 software. The test ear was either the right ear or left ear whichever fulfils the subject selection criteria. Following this, the frequency shaping was selected for fine tuning. The first target gain curve that was set by the software. The fine tuning was based on the subject's needs.

Compression threshold and compression ratio values were kept at default settings and were left unchanged. The only parameter that was changed was the compression type which was either syllabic or dual. Aided speech identification scores were obtained using phonetically balanced list at 40 dBHL through the speakers. For 50% of the subjects in each category (degree of hearing loss), syllabic compression was evaluated first followed by dual compression. The vice versa was done for the rest of the 50% in order to avoid the order effect.

To evaluate the hearing aid performance in noise, speech noise was presented at 10 dB SNR i.e.; the level of speech noise was either 30 dBHL or 60 dBHL and correspondingly the level for speech was 40 dBHL or 70 dBHL. A total of 12 PB word lists were made by iterating the original test (containing 4 word lists) thrice. The 3 order iterations are as follows: Word list presented in the same order (original form), Word list presented in the reverse order (bottom to top), last 10 words were presented first followed by first fifteen words. These 3 iterations were implemented in the four word lists to get a total of 12 PB word lists.

Each word list was presented at each of these 12 conditions. The subject was instructed to repeat the words as he/she heard and the tester noted down the response in a response sheet. In speech identification testing each correct response was given a score of 'one' and total number of correct responses was noted down for each condition, for each subject, across different degrees of hearing loss. The SIS was not converted to percent scores.

Results and Discussion

The 12 different conditions [(unaided, syllabic and dual compression), (quiet & noise) and (40 & 70 dBHL)] of the current study are abbreviated as follows;

Qua40 – Unaided SIS obtained in quiet at 40dB.
Qua70 - Unaided SIS obtained in quiet at 70dB.
Qsy40 - Aided (syllabic compression) SIS obtained in quiet at 40dB.
Qsy70 - Aided (syllabic compression) SIS obtained in quiet at 70dB.
QDu40 - Aided (dual compression) SIS obtained in quiet at 40dB.
QDu70 - Aided (dual compression) SIS obtained in quiet at 70dB.
Nua40 - Unaided SIS obtained in noise at 40dB.
Nua70 - Unaided SIS obtained in noise at 70dB.

Nsy40 - Aided (syllabic compression) SIS obtained in noise at 40dB.
Nsy70 - Aided (syllabic compression) SIS obtained in noise at 70dB.
NDu40 - Aided (dual compression) SIS obtained in noise at 40dB.
NDu70 - Aided (dual compression) SIS obtained in noise at 70dB.

The data obtained from the forty ears with different degrees of hearing loss was tabulated and analyzed using Statistical Package for Social Sciences, (SPSS, version 16) to investigate the following; one, comparison across different degrees of hearing loss, in the above mentioned 12 different conditions and two, comparison between the above mentioned 12 different conditions, across different degrees of hearing loss.

The results of mixed ANOVA for speech identification scores revealed that there was significant difference in speech identification scores across different degrees of hearing losses. (Mild, moderate, moderately severe and severe), [F (3, 36) = 544.978, P<0.001]. There was significant difference in speech identification scores between quiet and noise situations, [F (1, 36) = 859.079, P<0.001], between unaided and aided (syllabic and dual compression), [F (2, 72) = 2338.224, P<0.001], between intensity (40 dBHL & 70 dBHL) [F (1, 36) = 2842.731, P<0.001] across different degrees of hearing loss. Bonferroni multiple comparison tests at 5% level of significance revealed, significant difference in speech identification scores between unaided and aided (syllabic and dual compression) conditions. There was no significant difference in speech identification scores between syllabic and dual compression settings in the aided condition. Duncan post hoc analysis revealed that the four groups (mild, moderate, moderately severe and severe) were significantly different from each other.

The above findings reveal some well known facts like; SIS in quiet were better than in noise. SIS at 70 dBHL were better than at 40 dBHL. SIS in aided conditions were better than in unaided condition.SIS were different across different degrees of hearing loss with mild hearing loss showing better scores followed by moderate, moderately severe and severe hearing losses. The reason could be for mild hearing loss, the threshold ranges from 26-40 dBHL and the presentation levels used were 40 dBHL and 70 dBHL which is well within the participant's thresholds (> 40 dBHL). But, for the other degrees of hearing loss like moderate, moderately severe and severe, it is not so at 40 dBHL. At 70 dBHL, individuals with degrees other than mild exhibited better scores when compared to 40 dBHL, but they could not reach the centum target. This was because of the physiological limitations due to pathological condition, in the anatomical structures; which would lead to distorted speech perception with increase in intensity.

There was no significant difference in SIS between the two aided conditions (syllabic and dual compressions) across different degrees of hearing loss in different conditions which suggests that the variations in the time consonants does not markedly affect speech perception in both quiet and noise conditions. However, as the noise used was speech noise, we cannot generalise this study to a real life noisy situation.

Moore et al. (1991) found good scores for dual time constant compressor compared to adaptive compression but the reasons for this are not clear. Whereas at higher presentation levels there was no significant difference found between the two aided conditions and higher scores were obtained at 70 dBHL when compared to 45 dBHL. on the contrary, Bentler and Nelson (1997) reported no effect of various combinations of phonemic, syllabic, and slow-acting compressors on nonsense syllable identification in noise. The results of these studies support the findings of the present study.

Hence at higher presentation level, speech recognition is not degraded at the same time; compression does not provide a significant benefit over the unaided condition, nor does any difference exists between the performances of different compression types.

Comparison across different degrees of hearing loss, in the above mentioned 12 different conditions

The results of MANOVA for speech identification scores across different degrees of hearing loss, in 12 different conditions revealed the following and is shown in Table 2.

There was significant difference across different degrees of hearing loss in the 12 different conditions. In order to know which groups (different degrees of hearing loss) differed in these conditions. Duncans post hoc analysis was done at 5% level of significance and the results are discussed for each condition independently.

Qua40 (Unaided SIS in quiet at 40 dBHL): There was no significant difference in speech identification scores (SIS) between moderately severe and severe sensorineural hearing loss. Significant difference in speech identification scores (SIS) between Mild and moderate, Mild and moderately severe, Mild and severe, Moderate and moderately severe, Moderate and severe sensorineural hearing loss.

Table 2. F values for 12 conditions across different degrees of hearing loss, using MANOVA

Conditions	F(3,36)	p
Qua40	452.38	0.000
Qua70	777.24	0.000
Qsy40	211.98	0.000
Qsy70	145.46	0.000
QDu40	161.55	0.000
QDu70	97.25	0.000
Nua40	176.38	0.000
Nua70	697.46	0.000
Nsy40	405.29	0.000
Nsy70	261.92	0.000
NDu40	298.92	0.000
NDu70	250.93	0.000

Qua70 (Unaided SIS in quiet at 70 dBHL): There was significant difference in speech identification scores (SIS) across four different degrees of hearing losses.

Qsy40 (Aided (syllabic compression) SIS in quiet at 40 dBHL): There was no significant difference in speech identification scores (SIS) between mild and moderate sensorineural hearing loss. However there was a difference in speech identification scores between other possible pairs.

Qsy70 (Aided (syllabic compression) SIS in quiet at 70 dBHL): There was no significant difference in speech identification scores (SIS) between mild, moderate and moderately severe sensorineural hearing loss. There was significant difference in speech identification scores (SIS) between mild and severe, moderate and severe, moderately severe and severe sensorineural hearing loss.

QDu40 (Aided (dual compression) SIS in quiet at 40 dBHL): There was no significant difference in speech identification scores (SIS) between mild and moderate sensorineural hearing loss. There was significant difference in speech identification scores between moderately severe and severe, mild and moderately severe, mild and severe, moderate and moderately severe, moderate and severe sensorineural hearing loss.

QDu70 (Aided (dual compression) SIS in quiet at 70 dBHL): There was no significant difference in speech identification scores (SIS) between mild, moderate and moderately severe sensorineural hearing loss. There was significant difference in speech identification scores (SIS) between mild and severe, moderate and severe, moderately severe and severe sensorineural hearing loss.

Considering the fact explained by Dillon (2001) that syllabic compression act on the rapidly varying cues within a speech signal as it has short attack and release times. But rapid increase in gain during the pauses in speech will cause greater gain to be applied to background noise than to speech. On the other hand dual compression adopts the time constant depending on the input signal, as a result of which release time is short for brief intense sounds, and becomes longer as the duration of the intense sound increases. Thus long intense sounds (or a succession of several intense sounds, such as syllables in high level speech) will cause the release time to lengthen. This slow release means that the gain will not significantly increase during each brief pause between the syllables or change from syllable to syllable. In terms of amplification there is no difference between both these types of compression. Hence, if we employ only syllabic or dual compression it may not provide enough cues to improve speech perception especially in the noisy situations. In such conditions we may have to enable other parameters like noise reduction or use an expansion circuit to reduce low level noise.

Thus a possible explanation for these kinds of results could be attributed to the intensity reaching the ear and the amount of distortion caused to the incoming signal due to hearing loss. As the degree of hearing loss increases, both spectral and temporal resolution would be affected, thus causing poor processing of low intensity speech sounds and short durational cues (like burst and transition) by the peripheral centres. This in turn affects the overall perception. However higher presentation levels showed no significant difference in SIS across mild, moderate and moderately severe losses. This could be related to the audibility factor, as the low intensity cues are made audible for a higher degree of hearing loss it could perform in par with the lesser degrees of hearing losses.

Souza & Bishop (1999) found that increasing the amount of audible speech information with WDRC has similar effects on consonant recognition for listeners with different degrees of hearing loss. Differences in sentence recognition for listeners with different degrees of loss may be due to processing effects or to differences in available acoustic information for longer segments of WDRC-amplified speech.

Nua40 (Unaided SIS in noise at 40 dBHL): There was no significant difference in speech identification scores (SIS) between moderately severe and severe sensorineural hearing loss. There was Significant difference in speech identification scores (SIS) between, Mild and moderate, Mild and moderately,

Mild and severe, Moderate and moderately, Moderate and severe sensorineural hearing loss.
Nua70 (Unaided SIS in noise at 70 dBHL): There was no significant difference in speech identification scores (SIS) between moderately severe and severe sensorineural hearing loss. There was significant difference in speech identification scores (SIS) between mild and moderate, mild and moderately, mild and severe, moderate and moderately severe, moderate and severe sensorineural hearing loss.

Nsy40 (Aided (syllabic compression) SIS in noise at 40 dBHL): There was a significant difference in speech identification scores (SIS) across four different degrees of hearing losses in all probabilities.

Nsy70 (Aided (syllabic compression) SIS in noise at 70 dBHL): There was no significant difference in speech identification scores (SIS) between mild and moderate sensorineural hearing loss. There was significant difference in speech identification scores (SIS) between moderately severe and severe, mild and moderately severe, mild and severe, moderate and moderately severe, moderate and severe sensorineural hearing loss.

NDu40 (Aided (dual compression) SIS in noise at 40 dBHL): There was significant difference in speech identification scores (SIS) between four different degrees of hearing losses.

NDu70 (Aided (dual compression) SIS in noise at 70 dBHL): There was no significant difference in speech identification scores (SIS) between mild and moderate sensorineural hearing loss. There was Significant difference in speech identification scores (SIS) between moderately severe and severe, mild and moderately severe, mild and severe, moderate and moderately severe, moderate and severe sensorineural hearing loss.

In this study in the aided conditions, types of compression used are syllabic and dual which don't have an effect on continuous type of noise. In noisy conditions there are both audibility and distortion issues, in noisy situations there is distortion of the signal itself with an additional distortion caused due to inadequate spectral and temporal resolution due to hearing loss. This could possibly explain the results of the study as there was significant difference in SIS at the both aided conditions at 40 dBHL. However at 70 dBHL there was no significant difference between mild and moderate degree of hearing loss, which could be attributed audibility factor, as the low intensity cues are made audible; higher degree of hearing loss could perform in par with the lesser degrees of hearing losses.

Staples (2009) reported that the attack and release times can play a significant role in ability to hear in noise. The primary advantage of slow acting compression is that the envelope of speech is maintained close to its original form. This means that the shape of the signal is the same at the output as it was at the input, giving nearly all the amplitude envelope cues necessary for speech understanding. The end-user benefits from this type of compression, by maintaining speech intelligibility in quiet or moderate listening environments. However, in multi-talker noisy environments (the real area of concern for people with hearing impairment), slow acting compression is unable to react quickly enough to provide additional amplification for soft sounds. Multiple talkers in the same environment do not produce steady (e.g., white or pink) noise, since speech is a temporally modulated signal. Background noise thus tends to fluctuate, providing drops or dips in the signal where critical speech elements are available, such as the fundamental frequency. Normal hearing persons can take advantage of these dips to improve speech understanding, and possibly to help distinguish one talker from another. This phenomenon is known as 'listening in the dips'. For example, the fundamental frequency information heard 'in the dips' may provide a grouping cue that makes it easier for target speech and background noise to be streamed into separate tracts (Hopkins & Moore, 2009). People with hearing loss tend to be less successful at taking advantage of dips (Moore, 2008). The ability to use the information in the dips appears to depend on the ability to perceive temporal fine structure (Hopkins & Moore, 2009), and this ability is often degraded in people with hearing loss.

Fast-acting compression may help people to hear the soft sounds in the dips, whereas slow-acting compression is likely unable to respond quickly enough to apply the appropriate gain to these low-level dips (Moore, 2008). Fast-acting compression could provide additional benefit for the more challenging environments by amplifying weaker sounds and making it possible to listen in the dips. The downside of fast-acting compression is that it can distort the temporal envelope of speech and reduce spectral contrasts, thereby degrading speech cues (Moore, 2008). Slow acting compression appears to be a safe option, whereas fast acting compression may involve higher risk but a higher potential reward.

Comparison between 12 different conditions, across different degrees of hearing loss, using paired t test

Individuals with mild sensorineural hearing loss: There was significant difference in SIS between the unaided and aided (syllabic and dual compression) conditions in quiet. There was no significant difference in SIS between the two aided (syllabic and dual compression) conditions in quiet at same as well as different intensities. There was significant difference in SIS between the unaided and aided (syllabic and dual compression) conditions in noise. There was no significant difference in SIS between the two aided (syllabic and dual compression) conditions in noise at same as well as different intensities.

Individuals with moderate sensorineural hearing loss: There was significant difference in SIS between the unaided and aided (syllabic and dual compression) conditions in quiet. But there was no significant difference in SIS between the two aided (syllabic and dual compression) conditions in quiet at same as well as different intensities. There was significant difference in SIS between the unaided and aided (syllabic and dual compression) conditions, between the two aided (syllabic and dual compression) conditions (at different intensities) in noise. There was no significant difference in SIS between the two aided (syllabic and dual compression) conditions in noise at same intensities.

Individuals with moderately severe sensorineural hearing loss: There was significant difference in SIS between the unaided and aided (syllabic and dual compression) conditions, between the two aided (syllabic and dual compression) conditions (at different intensities) in quiet. There was no significant difference in SIS between the two aided (syllabic and dual compression) conditions in noise at same intensities. There was significant difference in SIS between the unaided and aided (syllabic and dual compression) conditions, between the two aided (syllabic and dual compression) conditions (at different intensities) in noise. There was significant difference in SIS between the two aided (syllabic and dual compression) conditions in noise at different intensities (40 and 70 dB HL).There was no significant difference in SIS between the two aided (syllabic and dual compression) conditions in noise at same intensities.

Individuals with severe sensorineural hearing loss: There was significant difference in SIS between the unaided and aided (syllabic and dual compression) conditions in quiet. There was significant difference in SIS between the two aided (syllabic and dual compression) conditions in quiet at different intensities (40 and 70 dB HL).There was no significant difference in SIS between the two aided (syllabic and dual compression) conditions in quiet at same intensities. There was significant difference in SIS between the unaided and aided (syllabic and dual compression) conditions in noise. There was significant difference in SIS between the two aided (syllabic and dual compression) conditions in noise at different intensities (40 and 70 dB HL). There was no significant difference in SIS between the two aided (syllabic and dual compression) conditions in noise at same intensities.

The possible reason for significant difference in SIS between unaided and aided conditions and also for aided conditions (syllabic and dual) at different intensities (40 dB HL and 70 dB HL) could be attributed to the audibility factor as discussed before. The probable explanation for no significant difference in SIS between the aided conditions (syllabic and dual) at same intensities (40 dB HL or 70 dB HL), cannot be explained by the audibility factor as the intensity reaching the ear is same and the results are also showing that compression is not playing a major role to improve speech perception in both quiet and noise situations. As quoted by Dillon (2001), syllabic compression act on the rapidly varying cues within a speech signal as it has short attack and release times but unfortunately rapid increase in gain during the pauses in speech will cause greater gain to be applied to background noise than to speech. Whereas dual compression adopts the time constant depending on the input signal, as a result release time is short for brief intense sounds. But it becomes longer as the duration of the intense sound increases.

Thus long intense sounds (or a succession of several intense sounds, such as syllables in high level speech) will cause the release time to lengthen. This slow release means that the gain will not significantly increase during each brief pause between the syllables or change from syllable to syllable. Thus both the types of compression won't result in a marked improvement in SIS (i.e. speech perception).

Though there was no significant difference found between the two compression types (syllabic and dual), there are studies showing significant benefit of compression over linear amplification systems (Moore et al, 1991; Stone, Moore, Alcantara, & Glasberg, 1999).The study done by Geetha (2005) also yielded similar results reporting there was no significant difference between syllabic and dual compression in individuals with sensorineural hearing loss.

Conclusions

The results of this study are similar to the previous studies by Bentler and Nelson (1997), Geetha (2005). Hence, opting syllabic and dual compression alone won't possibly help in improving speech perception as the former act on the rapidly varying cues within a speech signal as it has short attack and release times but unfortunately rapid increase in gain during the pauses in speech will cause greater gain to be applied to background noise than to speech; whereas the latter adopts the time constant depending on the input signal, so release time is short for brief intense sounds, but becomes longer as the duration of the intense sound increases. Thus long intense sounds (or a succession of several intense sounds, such as syllables in high level speech) will cause the release time to lengthen. This slow release means that the gain will not significantly increase amplification which is evident from the results showing no significant difference between the two types of compression.

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