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Research Article

Comparison of Envelope Perception between Syllabic and Dual Compression Hearing Aid Processed Kannada Chimeric Sentences

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Abstract

Introduction: Temporal envelope cues and temporal fine structure cues are essential for perception of speech. However, tonal language employ more of TFS cues and non-tonal language employ envelope cues for perception. The native speakers of Kannada use envelope cues for speech perception. Perception might vary depending on the compression characteristics and the number of processing channels in hearing aid users. So, it is important to understand the effect of compression system and processing channels on perception of envelope cues.

Objective: To compare the perception of envelope cues: across different frequency bands; between syllabic and dual compression, between an eight channel and sixteen channel hearing aids, using hearing aid processed Kannada chimeric sentences.

Methods and Materials: Sentence identification task was carried out in thirty native adult Kannada speakers with normal hearing acuity. Stimuli used was hearing aid processed Kannada chimeric sentences prepared with standardised sentence identification test in the Kannada language through Hilbert transformation and processed using 2 hearing aids of eight and sixteen processing channels in syllabic and dual compression programs.

Results: Perception of envelope cues were not significantly different using chimeric sentences processed using syllabic and dual compression system, where as it was significantly different while using chimeric sentence processed using 8 and 16 channel hearing aids.

Conclusions: Dynamic characteristics of compression system such as fast and slow acting have no effect on perception of envelope cues in native Kannada speakers, whereas number of signal processing channels need to be considered while evaluating the perception of envelope cues.

Keywords: Fine Structure; Bands; Hearing Aid Signal Processing; Channels; Chimeras; Compression

Abbreviations

TFS: Temporal Fine Structure; ENV: Envelope Cues

Introduction

The human auditory system perceives any speech sound through the inherent temporal cues i.e., the temporal fine structure (TFS) and envelope (ENV) cues which has its own predominance for perception across languages. Envelope cues are the slowly varying amplitude of a speech signal, however, the temporal fine structure are the rapid oscillation which is concurrent to time variation matching the centre frequency of the band [1]. Perception of English and Mandarin Chinese language showed the difference between these cues with tonal language employ more of TFS cues and non-tonal language employ ENV cues for perception [2]. Temporal envelope cues are essential for perception of speech in quiet, but neural envelope coding studies employing psychophysical measures have proven that envelope coding of speech are not only important for speech perception in quiet but also has significant contribution in noisy situations [3]. Studies were done on south Indian languages such as in Malayalam and Kannada using chimeric words and sentences. 'Auditory chimaeras' are synthesized stimuli which has the envelope of one sound and the fine structure of another, helps for the perception of the stimuli [2]. In Malayalam, the speech stimuli with the lower bands were identified with TFS cues whereas speech stimulus with the higher bands used E cues [4]. However, when Kannada chimeric words and sentences were used, the results revealed that envelope cues were employed majorly than fine structure cues [5].

Syllabic compression is fast acting compression system where as dual compression is a slow acting compression system. The syllabic compression and dual compression are reported to have an effect on speech identification scores (SIS) for both quiet and in noisy conditions but the hearing aid user preferred to use dual compression [6]. Similar findings were also obtained for evaluations across different degrees of hearing loss [7]. Speech discrimination improved as the number of channels increased up to 8 and then remained constant up to 16 [8]. Speech recognition scores in hearing impaired were better with an 8 channel than a 3 channel hearing aid in noisy situation [9]. While envelope cues are predominantly perceived across all frequency bands by non-tonal language speakers with normal hearing sensitivity and there can be influence by the type of compression system and number of signal processing channels on speech perception in hearing aid users. Hence, there is a need to study the effect of compression system and number of signal processing channels on perception of envelope cues by hearing aid users across different frequency bands for the Kannada Chimeric sentences. Aim of the present study was to compare the perception of envelope cues between different compression systems and number of signal processing channels using hearing aid processed Kannada chimeric sentence across different frequency bands. Objectives of the current study were to compare the perception of envelope cues across different frequency bands using hearing aid processed Kannada chimeric sentences, to compare the perception of envelope cues between syllabic and dual compression using hearing aid processed Kannada chimeric sentences across different frequency bands, and to compare the perception of envelope cues between 8 channel and 16 channel hearing aids using hearing aid processed Kannada chimeric sentences across different frequency bands.

Materials and Methods

Participants

Participants of the study included thirty normal hearing individuals, aged between 18 years to 30 years, (Mean = 24.9, SD = 3.15), with 15 males and 15 females. Those who are not native Kannada speaker and those with abnormal middle ear functioning, history of speech language disorders, neurological disorders, and cognitive deficits were not included in the study. Written consent was taken from the participants for their willingness to participate in the study. The study adhered to the 'Ethical guidelines for biobehavioural research involving human subjects' [10].

Materials

The sentences for preparing chimeric list were selected from "Sentence identification test in Kannada" [11]. The sentences were selected such that the total number of syllables in each sentence is limited to eight-nine syllables and each word in sentences was not have more than three syllables. Total of eighty pairs of sentences were taken to prepare speech – speech chimera across eight frequency bands which includes one, four, six, thirteen, sixteen twenty-four, thirty-two, and sixty-four.

Stimuli and procedure

Kannada chimeric sentences were constructed using Hilbert transform in MATLAB software (MATLAB 7.12.0 R2011a, Mathswork, USA) loaded on to a personal computer (HP pavilion with intel core i3 5th generation processor, California, USA). The selected eighty pairs of sentences were processed using Hilbert transform to extract the temporal cues such as envelope and fine structure. After obtaining envelope and fine structure for each sentence, these temporal cues were exchanged with each other in order to make speech-speech auditory chimeric sentences. Envelop of sentence one is combined with fine structure of sentences two to make one chimeric sentence. Likewise, cues were exchanged between all sentences and 320 chimeric sentences were prepared as the stimuli.

Two digital non-linear behind-the-ear hearing aids with 8 and 16 channels were chosen and programmed using NOAH 3.0 (HIMSA, Denmark) software for hypothetical flat sensorineural hearing loss with air conduction threshold of 40 dB HL at all audiometric frequencies. A flat hearing loss was used so that the compression characteristic, when tested, remained same across all the frequencies. The program 1 of the hearing aid was programmed for syllabic compression. The program 2 of the hearing aid was programmed for dual compression.

The prepared 320 Kannada chimeric sentences were played using Cubase software (version 2.0.2, Steinberg Media Technologies, Germany) loaded on to personal computer routed through an audiometer Inventis Piano (Inventis Limited, Italy). The stimuli were presented through speaker at an azimuth of 90 degree in front of KEMAR (GRAS Sound and Vibration, Denmark) fitted with non-linear hearing aids. The non-linear hearing aids were programmed for syllabic and dual compression as program 1 and 2 respectively. The output from the KEMAR was connected to the Bruel and Kjær (BZ-5503) sound level meter (Nærum, Copenhagen, Denmark) and the recordings were stored in it as .wav format. The final output was stored in personal computer individually for 8 and 16 channel hearing aids separately with syllabic and dual compressions. All chimeric stimuli having frequency bands of 1, 4, 6, 13, 16, 24, 32 and 64 were presented to the participants using Adobe Audition (version 3.0, Adobe Inc, California, USA) through the headphone TDH-39 (Telephonics Corp., New York, USA) at the most comfortable level 65dBHL. For each participant practice trial using three chimeric stimuli was given prior to testing. Each participant was provided with 320 chimeric sentences which were processed using two hearing aids with 8 and 16 channels in two programs respectively. Instruction provided includes ‘Listen carefully to each word and repeat back the sentences’. Speech identification scores were considered based on the percentage of number of correct key words identified from each auditory chimeric sentence. The responses were recorded. The recorded sentences were subjected to further analysis in the presence of a native Kannada speaker were speech identification scores were measured for each sentence. Based on the number of keywords repeated the score was given from 0 to 4 (0 being no words repeated and 4 being all the 4 words repeated correctly). After scoring these scores were converted to a percentage to estimate the speech identification scores.

Statistical analysis

Collected data were subjected to statistical analysis using IBM SPSS Statistics 21 software (produced by IBM Inc., New York, Unites States of America) loaded in lap top with intel core i3 5th generation processor (Manufactured by HP, California, USA). Kolmogorov-Smirnov and Shapiro-Wilk tests were used to analyse the normality of the data. Friedman test was used to compare more than three matched pairs of data and Wilcoxon signed rank test was used to compare the paired samples.

Results and Discussion

Descriptive statistics including mean, median and standard deviation of the percentage correct identification scores for TFS and ENV in all the four condition, including Kannada chimeric sentences processed using an 8 channel hearing aid programmed for syllabic and dual compression, and 16 channel hearing aid programmed for syllabic and dual compression, across different frequency bands such as 1, 4, 6, 13, 16, 24, 32 and 64 used for extraction of chimeric sentences. The data revealed that ENV were predominantly perceived across all frequency bands and conditions. So the scores of ENV were considered for further comparisons aimed in this current study. Figure 1 shows the median percentage scores of correct identification of temporal envelope cues across the frequency bands using 8 and 16 channel hearing aids with syllabic and dual compression.

Figure 1: Percentage of correct identification of envelope cues in sentences across frequency bands.

Figure 1 reveals that perception of ENV improves across frequency bands till 16 bands and then attains saturation of the scores in all the four conditions employed in the current study. Kolmogorov-Smirnov and Shapiro-Wilk test for normality indicated that the data was devoid of normal distribution. Hence, Friedman test was used which showed that there was a significant difference in identification scores for envelope cue perception across different frequency bands such as 1, 4, 6, 13, 16, 24, 32 and 64 ($\chi 2$= 207.357; $p < 0.05$). Wilcoxon signed ranked pairwise comparison showed that identification scores significantly improved up to 13 bands, after which it attained 100% in all four conditions. Such results show that 16 bands frequency resolution is sufficient to represent the temporal envelope of speech in Kannada using Hilbert transform logarithm.

In order to make comparison between the different compression systems that is dual and syllabic compression, Wilcoxon signed rank test was used. Table 1 shows Z values and asymptotic significance computed for medians percentage correct identification scores of ENV obtained with syllabic and dual compression system in an 8 channel hearing aid.

No. Of frequency bands	Z	Asymptotic significance($p < 0.05$)
1	-.57	.56
4	-2.79	.00
6	-1.89	.05
13	-3.59	.00
16	.00	1.00
24	.00	1.00
32	.00	1.00
64	.00	1.00

Table 1: Z values and asymptotic significance computed for medians percentage correct identification scores of ENV obtained with syllabic and dual compression system in an 8 channel hearing aid.

The results revealed that scores for perception of ENV didn't vary significantly across all frequency bands for Kannada chimeric sentences processed with dual and syllabic compression using an 8 channel hearing aid. Table 2 shows Z values and asymptotic significance computed for medians percentage correct identification scores of ENV obtained with syllabic and dual compression system in a 16 channel hearing aid.

No. Of frequency bands	Z	Asymptotic significance($p<0.05$)
1	-1.41	.15
4	-.98	.32
6	-.29	.77
13	-.77	.43
16	.00	1.00
24	.00	1.00
32	.00	1.00
64	.00	1.00

Table 2: Z values and asymptotic significance computed for medians percentage correct identification scores of ENV obtained with

The results revealed the same as that of obtained with 8 channel hearing aid. Further to compare the percentage correct identification scores of ENV between the different hearing aid processing channels with dual compression, Wilcoxon signed rank test was used. Table 3 and 4 shows Z values and asymptotic significance computed for medians percentage correct identification scores of ENV obtained with 8 and 16 channel hearing aid using dual compression and syllabic compression respectively.

No. Of frequency bands	Z	Asymptotic significance ($p < 0.05$)
1	-1.3	.19
4	-2.67	.00
6	-2.64	.00
13	-2.49	.01
16	-1.27	.20
24	-2.04	.04
32	-1.09	.27
64	-0.81	.41

Table 3: Z values and asymptotic significance computed for medians percentage correct identification scores of ENV obtained with 8 and 16 channel hearing aid using dual compression ($p < 0.05$).

No. Of frequency bands	Z	Asymptotic significance ($p < 0.05$)
1	-1.2	.16
4	-2.56	.00
6	-2.63	.00
13	-2.75	.01
16	-1.37	.30
24	-2.23	.04
32	-1.19	.28
64	-0.71	.42

Table 4: Z values and asymptotic significance computed for medians percentage correct identification scores of ENV obtained with 8 and 16 channel hearing aid using syllabic compression ($p < 0.05$).

The results revealed that there were significant difference found only across the frequency bands of 4, 6, 13 and 24 on both the compression types. However, the median value reveals that scores for perception of ENV on the16 channels hearing aid was better compared to the 8 channels hearing aid.

In a normal hearing individual the TFS cues were processed by the phase locking ability of a normal cochlea but the ability is restricted till 5 KHz and after which TFS cues become unusable [1]. E and TFS convey important but distinct phonetic cues between 1 and 2 kHz. Unlike TFS, E conveys information up to 6 kHz, consistent with the characteristics of neural phase locking to E and TFS [13]. Speech processed to contain only TFS leads to envelope recovery through cochlear filtering, which has been suggested to account for TFS-speech intelligibility for normal-hearing listeners [14].

The aim of the current study is to compare the perception of temporal envelope in 8 and 16 channels hearing aid programmed with dual and syllabic compression. The first objective was to study the effect of compression system on perception of temporal envelope of speech. The current study indicates that both the compression system invariably affects the perception of temporal envelope cues in speech processed through hearing aids with 8 and 16 channels because there was no significant difference in % correct identification of ENV using hearing aid processed Kannada chimeric sentences when tested using normal hearing listeners in both the conditions. The fast acting compression system will disturb the temporal characteristics of speech signal processed by a hearing aid, hence syllabic compression was expected to yield poor score than dual compression but the current study is not in agreement with this. Syllabic compression and dual compression had same effect on speech identification scores (SIS) for both quiet and in noisy conditions but the hearing aid user preferred to use dual compression [6,7]. This result provides evidence that both the syllabic and dual compression systems provide similar speech perception in the hearing aid users. So results of the current study also denote the same notion that dynamic characteristics of a hearing aid will not affect the temporal envelope of the speech it processes.

The second objective of the current study is to study the effect of hearing aid processing channels on perception of temporal envelope cue. It has been reported that the speech discrimination improved as the number of channels increased up to 8 and then remained constant up to 16 [9]. The current study reveals that there is a significant difference in scores for identification of ENV in the performance using 8 and 16 channel hearing aids. But these results were not evident in the entire frequency bands chosen to extract the chimeric sentences. The perception of ENV itself improves up to 13 bands hence minimum of 13 bands are required to construct the ENV in Hilbert transform using Kannada sentences. So, the differences in the frequency bands until 13 can be attributed to insufficient ENV in the constructed chimeric sentences. But when using 24 bands there was a significant difference in scores, so it can be assumed that there is an influence on ENV in the processed speech signal by the number of processing channels in the hearing aid. Still, it has to be verified whether there is a similar effect experienced by a hearing aid user, which will provide more insight knowledge about the effect of processing channels on perception of ENV cues from speech.

Conclusion

In conclusion, the study revealed a better processing of envelope cues which are important and predominant for understanding speech through hearing aid for Kannada sentences. Further study on a comparison between individuals with hearing impairment and the normal hearing individual will provide better understanding regarding the difficulties in perception due to problems in peripheral hearing mechanism.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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