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Original Research Article

Effect of Compression Parameters on the Gain for Kannada Sentence, ISTS and Non-Speech Signals in Hearing Aids

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ABSTRACT

International Speech Test Signal (ISTS) is relatively a new stimulus developed for the real ear measurement. The present study aimed to evaluate the differences in a gain of a hearing aid when measured with ISTS and a sentence in Kannada language. The ANSI- weighted digi-speech signal and ICRA- weighted digi-speech signal, ISTS and a Kannada sentence were routed through a calibrated audiometer and presented at a level of 45, 55, 65 and 85 dB SPL. The SPL in the ear canal of an adult individual was recorded using FONIX 8000 real-ear measurement system with the hearing aid on. The SPL was recorded for these stimuli in the ear canal with different compression ratios (2:1 and 3:1), attack time (2 ms, 5 ms and 10 ms), and release time (40 ms, 654 ms and 1280 ms) settings of the hearing aid. The difference in gain was calculated between the non-speech/ISTS and the Kannada sentence. Multi-linear regression analysis was done. The results showed that there are differences in the gain of a compression hearing aid when different stimuli are used. The present study also highlights the need for standardizing these differences, for different settings of compression hearing aid, so that, these can be applied while conducting real ear measures with the newer stimuli.

Key words: WDRC, DNR, Directionality, EDI, LLR

INTRODUCTION

The importance of using speech-like stimuli for hearing aid assessment has been emphasized by many investigators. [1-3] Henning and Bentler [4] have studied the effect of release time, compression ratio and the number of channels using different non-speech signals (tone and composite signals) in addition to a speech signal (English sentences). They measured gain of the hearing aid with those stimuli and calculated the gain difference between the non-speech signals and the speech signal at different signal levels. They reported that the effect of hearing aid settings on the gain difference was level-dependent. Increase in the compression ratio and release time resulted in increased gain difference in majority of the conditions at a moderate level of presentation. At a higher level, the effect was reversed when the compression ratio increased. Change in the release time and number of channels did not have an effect at higher stimulus level. They also suggested that a speech stimulus or a speech-like stimulus be used for measurement of hearing aid gain and output.

Recently, a standardized speech stimulus called International Speech Test Signal (ISTS) has been developed. This signal includes natural sentences of six languages spoken by a female. The ISTS was developed by the ISMADHA (An International Standard for Measuring Advanced Digital Hearing Aids) working group within EHIMA (European Hearing Instrument Manufacturers Association).This is more speech-like than the other existing test stimuli. [5]

The effect of compression ratio and release time on the gain of these newer stimuli is yet to be investigated. It is imperative to evaluate the difference in the gain between this and the real speech while interpreting the performance the hearing aid in real situation so as to see if the results obtained by ISTS is similar to that of actual speech.

In addition, it is also essential to compare the results of ISTS and the other non-speech signal with the native languages. Kannada is the native language of Karnataka, which is located in southern part of India. All India Institute of Speech and Hearing (AIISH), Mysore is located in Karnataka. This government institute provides services to individuals with communication disorders. Many of these individuals are from Karnataka. Hence, usage of Kannada material for evaluation is inevitable.

Sairam [6] has reported that the long-term average speech spectrum (LTASS) in Kannada has differences when compared to that reported for western languages. Kannada language has been found to have more energy, especially at low frequencies and the intensity drop is more across frequencies when compared to other languages. Hence, the purpose of the study was to evaluate the differences in gain of a hearing aid that exists, if any, between digital speech, ISTS and Kannada speech material. Further, evaluation of the effect of compression ratio and release time on the difference in gain was also intended.

MATERIALS AND METHODS

Stimuli

The non-speech stimuli used were digital speech ANSI-weighted and digital speech ICRA-weighted. The speech stimuli were ISTS and a Kannada sentence. Figure 1 shows the LTASS of these four stimuli. These stimuli were recorded from real ear measurement systems using Larsen-Davis sound level meter at the distance as specified by the manufacturer. These stimuli were then normalised to give similar RMS value.

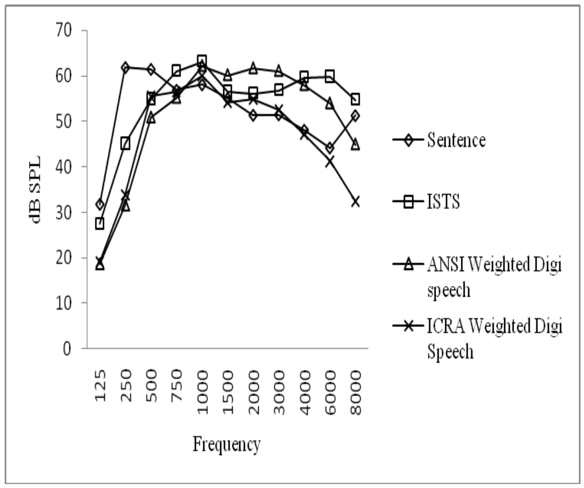


Figure 1: LTASS of a Kannada sentence, ISTS, ANSI Weighted digi-speech and ICRA weighted digi-speech.

Instruments and Test Environment

A calibrated two-channel diagnostic audiometer was used to present the stimulus routed through TDH-39 earphones housed in MX-41/AR ear cushions and audio cups, Radio ear B71 bone vibrator and Martin Audio CI 15 sound field speakers (with a power amplifier). The loud speaker was located at a distance of 1 metre at 45 degree azimuth angle from the test ear of the person. A computer with NOAH software and a HiPro with programming cables (for connecting the hearing aid with the HiPro which in turn was connected to computer) were used to program the hearing aid.

A non-linear two-channel digital behind-the-ear hearing aid with a fitting range of mild to severe hearing losses was used. This hearing aid had the option to vary the compression ratio, Attack time (AT) and Release time (RT). Programming the hearing aid to the test ear of the participant as well as evaluating the performance of the hearing aid was carried out in an air-conditioned sound treated room. This was a double room set-up.

Programming the hearing aid

The participants fulfilling the stated criteria were included in the study. Pure tone thresholds (from 250 Hz to 8000Hz for air-conduction and from 250 Hz to 4000Hz for bone-conduction) and UCLs for NBNs of the test ear were fed into the NOAH software. NAL non-linear 1 (NAL-NL1) prescriptive formula was used to calculate the target gain while programming the hearing aid. Acclimatization level of two was selected. The hearing aid was programmed with "first fit" programming feature. For fitting the hearing aid to the participant, National Acoustical Laboratory Non-linear 1 prescriptive formula was used. In order to see whether sufficient amplification is provided to the participant, verification of gain was done through insertion gain (IG) measurements. Changes in the settings of the hearing aid were done till the gain curve matched the target curve displayed on the IG system. Identification of Ling's six sounds was also ensured at 40 dB HL. Depending on the response, gain settings of the hearing aid were modified, if required. This was done to optimize the hearing aid and to ensure audibility of speech frequencies.

Measurement procedure:

Fonix 7000 system was used to measure the gain in the ear canal using real ear measurement module. The participant was located at one meter distance, and 45 degree Azimuth from the loud speaker of a calibrated dual channel audiometer. The stimuli were routed through the audiometer. An otoscopic examination was done to rule out any outer ear abnormalities. Immittance evaluation was carried out to rule out middle ear pathology. A custom made soft shell mould was made for the participant. After otoscopic examination, the probe tube was placed in the ear canal. The depth of insertion was equal to 5 mm more than the length of the ear mould. [7] The unaided and aided measurements were done with the above mentioned stimuli being presented at 45, 55, 65 and 85 dB SPLs. The aided conditions were as follows:

1) For a compression ratio of 2:1

i. With the short time constants of AT of 2 ms and RT of 40 ms

ii. With long time constants of AT of 5 ms and RT of 654 ms

iii. With longer time constants of AT of 10 ms and RT of 1280 ms

2) For a compression ratio of 3:1

i. With the short time constants of AT of 2 ms and RT of 40 ms

ii. With long time constants of AT of 5 ms and RT of 654 ms

iii. With longer time constants of AT of 10 ms and RT of 1280 ms

RESULTS

The gain difference was calculated by subtracting the gain for the sentence from the gain for a non-speech signal/ISTS. [4] For example, the gain for sentence was 30 dB and the gain for ISTS was 35 dB, the gin difference was 5 dB. The results showed that the gain difference ranged from -21.3 to 17.4 dB. The negative gain difference between the non-speech/ISTS and the sentence indicates that non-speech/ISTS resulted in higher gain and a positive value indicates that the sentence resulted in higher gain. Most of the conditions led to negative gain difference.

Gain difference between ISTS and Kannada sentence: Effect of release time

For this, the gain difference was calculated by subtracting the gain using sentence from the gain obtained using ISTS. Multi-linear regression analysis was carried out to analyze the gain difference. The results of this are given in the Table 1.The results showed that the gain difference was level dependent. The Kannada sentence resulted in higher gain resulting in a negative gain difference. At lower levels of input, that is, at 45 and 55 dB SPL, there were no significant predictors, except for 55 dB SPL at 500 Hz. Figure 2 reveals that the gain difference at 500 Hz decreased as the release time increased.

At 65 dB, there was a significant difference at 250 Hz. Figure 2 shows that, at this frequency, as the release time increased the gain difference also increased in the negative direction, that is, the Kannada sentence resulted in a higher gain.

At a presentation level of 85 dB SPL, the gain difference across release time was significantly different at 4000 Hz. Figure 2 shows that the 640 ms resulted in higher gain difference than the other release times. At this level too, the Kannada sentence resulted in a higher gain.

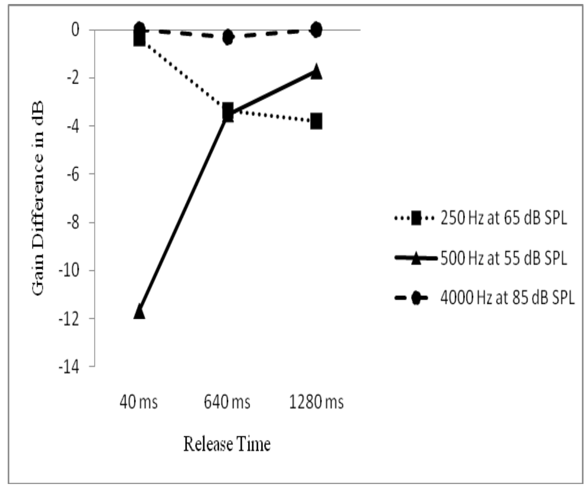
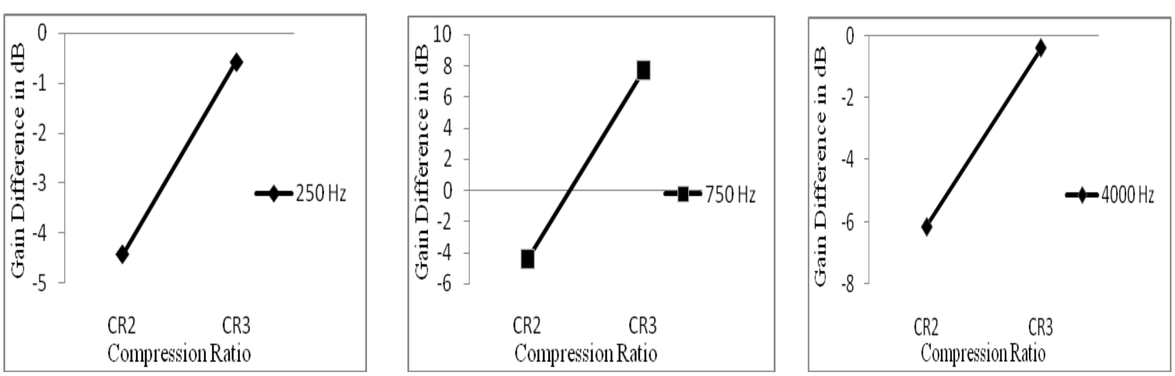


Figure 2: Effect of release time on the gain difference at 250 Hz at 65 dB SPL, 500 Hz at 55 dB SPL and at 4000 Hz at 85 dB SPL

Gain difference between ISTS and Kannada sentence: Effect of Compression ratio

At 45 and 55 dB SPL levels of input, compression ratio was not a significant predictor. At a presentation level of 65 dB, the compression ratio was significantly different at 250 Hz, at 0.01 level of significance. In this condition, the lower compression ratio resulted in higher gain difference at 250 Hz and the Kannada sentence resulted in a higher gain. This is evident in Figure 3



(a) (b) (c)

Figure 3: Effect of compression ratio on gain difference between ISTS and Kannada sentence (a) at 250 Hz at 65 dB SPL; (b) 750 Hz at 85 dB SPL; (c) 4000 Hz at 85 dB SPL.

Table 1: Results of regression analysis for the gain difference between ISTS and Kannada sentence at 45, 55, 65 and 85 dB SPL

	Level (dB SPL)	*Frequency (Hz)*								
		250	*500*	*750*	*1k*	*1.5k*	*2k*	*3k*	*4k*	*6k*
R	45	0.871	0.842	0.679	0.895	0.441	0.218	0.331	0.669	0.508
	55	0.866	0.953	0.498	0.899	0.774	0.480	0.527	0.827	0.664
	65	0.985	0.626	0.242	0.318	0.797	0.430	0.384	0.044	0.792
	85	0.635	0.763	0.967	0.660	0.203	0.895	0.824	0.970	0.482
R2	45	0.759	0.709	0.461	0.800	0.195	0.047	0.109	0.448	0.258
	55	0.749	0.908	0.248	0.808	0.599	0.230	0.278	0.684	0.441
	65	0.971	0.392	0.059	0.101	0.636	0.185	0.147	0.002	0.627
	85	0.404	0.630	0.934	0.436	0.041	0.800	0.679	0.941	0.232
Constant	45	1.907	7.363	-1.776	10.484	-5.829	-1.528	-1.776	-2.610	-2.811
	55	-17.752	-22.926*	-8.929	-10.673	3.230	-15.731	-10.311	-4.356	-6.579
	65	-10.096**	-9.045	9.266	11.649	10.240	9.636	-4.353	0.259	0.885
	85	-30.741	-37.439	-27.988*	-13.434	-4.380	-17.360	-32.438*	-14.199*	-1.634
RT	45	-0.006	-0.007	-0.004	-0.009	-7.510	4.0915	-4.301	0.000	0.000
	55	0.001	0.011*	0.006	0.008	0.010	0.001	0.004	0.002	0.003
	65	-0.004**	-0.004	0.000	0.002	0.006	0.000	0.002	-4.506	0.001
	85	0.003	0.008	-0.001	-0.002	-0.002	-0.003	6.759	-0.006*	0.000
CR	45	0.100	-1.800	2.333	-0.967	1.967	1.200	0.600	1.033	0.933
	55	5.167	4.533	2.100	2.600	-3.700	4.867	1.900	0.600	1.667
	65	3.867**	3.414	-1.733	-2.767	-5.400	-3.533	-0.533	-0.133	-0.900
	85	7.767	9.433	12.100**	7.533	2.033	7.267	8.800	5.800*	0.500

Note: *p<0.05; **p<0.01

At 85 dB SPL level of presentation, the release time was significantly different at 750 Hz (p<0.01) and at 4000 Hz (p<0.05). Figures 3(b) and 3(c) show that the results were similar to that which was obtained at 65 dB SPL.

Gain difference between ANSI weighted digi-speech and Kannada sentence: Effect of release time

Table 2 shows the results of effect of release time and compression ratio on the gain difference (GD) between ANSI weighted digi-speech and Kannada sentence. The results showed that at 45 dB SPL, the GD across release time was significantly different at 250 Hz (p<0.05). As it can be seen in Figure 6, at 40 ms release time, digi-speech resulted in more gain. The gain measured by Kannada sentence increased as the release time increased. At 55 and 65 dB SPL, release time was not a significant predictor.

At 85 dB SPL, the GD was significantly (p<0.05) different across release time at 1 kHz. The GD became more negative as the release tome increased. This is because, at 40 ms, ANSI weighted digi-speech resulted in higher gain, at 640 ms, there was not much of difference in gain between the stimuli and at 1280 ms, Kannada sentence resulted in higher gain. This is evident in Figure 4.

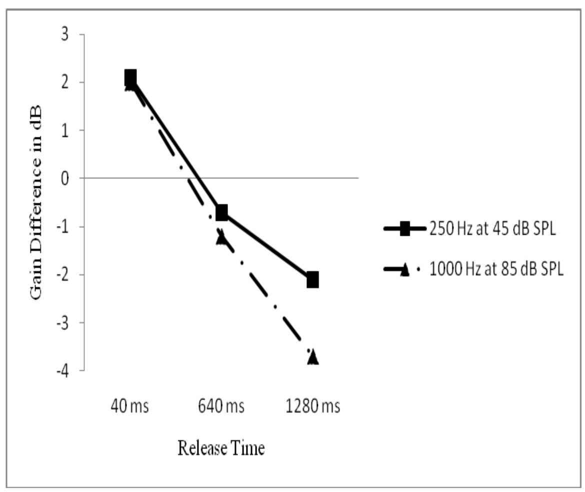
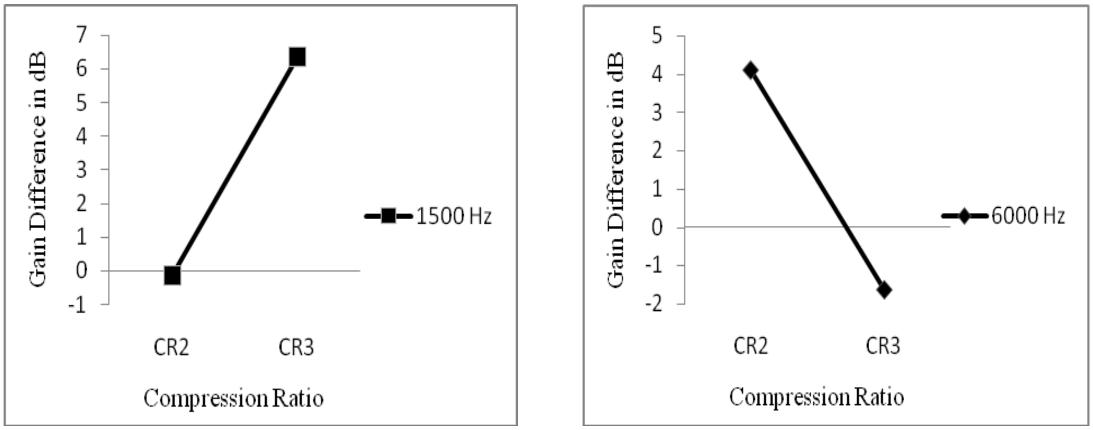


Figure 4: Effect of release time on the gain difference at 250 Hz at 45 dB SPL and at 1000 Hz at 85 dB SPL

Gain difference between ANSI weighted digi-speech and Kannada sentence: Effect of Compression ratio

At 45 and 55 dB SPL levels of input, compression ratio was not a significant predictor. At 65 dB level of presentation, the gain differences across two compression ratios were significantly different at 1500 Hz, at a 0.01 level of significance. Figure 5(a) shows that the lower compression ratio resulted in higher and positive GD, indicating that the non-speech signal resulted in a higher gain.



(a) (b)

Figure 5: Effect of compression ratio on gain difference between ANSI weighted Digi-speech and Kannada sentence (a) at 1500 Hz at 65 dB SPL; (b) 6000 Hz at 85 dB SPL

Table 2: Results of regression analysis for the gain difference between digi-speech ANSI and Kannada sentence at 45, 55, 65 and 85 dB SPL

	Level (dB SPL)	*Frequency (Hz)* 250	500	750	1k	1.5k	2k	3k	4k	6k
R	45	0.947	0.715	0.488	0.340	0.256	0.460	0.103	0.818	0.522
	55	0.871	0.738	0.058	0.623	0.690	0.691	0.643	0.701	0.844
	65	0.473	0.430	0.531	0.440	0.965	0.480	0.579	0.650	0.747
	85	0.284	0.224	0.855	0.915	0.877	0.780	0.394	0.845	0.948
R2	45	0.896	0.511	0.238	0.115	0.066	0.211	0.011	0.669	0.272
	55	0.758	0.544	0.003	0.389	0.476	0.478	0.413	0.492	0.713
	65	0.223	0.185	0.282	0.194	0.932	0.230	0.335	0.422	0.559
	85	0.080	0.050	0.730	0.837	0.769	0.609	0.155	0.715	0.898
Constant	45	5.881	9.758	.-4.121	5.498	1.529	-0.610	4.951	3.156	1.719
	55	-13.091*	-8.696	3.807	15.466	16.751	1.812	-1.270	2.540	-6.473
	65	-0.026	-11.962	-18.459	-19.207	-41.564*	-12.690	-0.851	-1.786	-18.751
	85	-19.349	-18.962	-7.468	10.640	25.040	8.511	-8.761	7.367	17.727*
RT	45	-.004*	-0.004	0.001	0.000	0.002	0.001	0.000	0.001	-0.002
	55	0.002	0.009	0.001	0.004	0.006	0.004	0.008	0.002	0.000
	65	-0.003	0.001	0.004	7.168	0.004	-0.002	-0.012	-0.006	0.007
	85	0.005	0.001	-.011	-.014*	-0.011	-0.013	-0.004	-0.011	-0.004
CR	45	-1.467	-3.433	1.933	-1.033	-0.467	1.200	-0.600	-0.733	-0.433
	55	3.833	1.133	-.167	-5.133	-5.600	0.733	1.167	0.033	2.867
	65	-0.352	3.000	3.933	5.067	18.367**	5.567	3.867	2.567	7.300
	85	2.700	2.933	4.367	-1.000	-6.700	0.333	3.000	-0.567	-5.733*

Note: *p<0.05; **p<0.01

Gain difference between ICRA weighted digi-speech and Kannada sentence: Effect of release time

Multi-linear regression analysis was carried out to see if there was any significant difference in the gain difference across the release time. The results of this are given in the Table 3. The results showed that the release time was a significant predictor, at 250 Hz, 6000 Hz and 1000 Hz at 45, 55 and 65 dB SPL respectively. At lower levels, as the release time increased, the gain difference became negative, that is, the non-speech signal resulted in higher gain. At 85 dB SPL, the effect was reverse. This is shown in Figure 6.

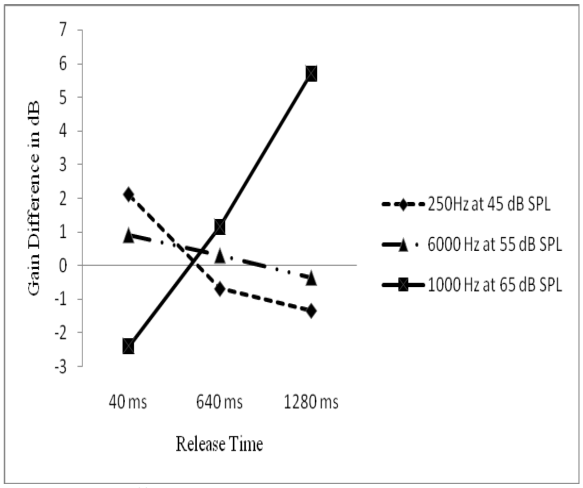


Figure 6: Effect of release time on the gain difference at 250 Hz at 45 dB SL, 6000 Hz at 55 dB SPL and 1000 Hz at 65 dB SPL

Table 3: Results of regression analysis for the gain difference between digi-speech ICRA and Sentence at 45, 55, 65 and 85 dB SPL

	Level (dB SPL)	*Frequency (Hz)*								
		250	*500*	*750*	*1k*	*1.5k*	*2k*	*3k*	*4k*	*6k*
R	45	.961	.688	.516	.354	.227	.268	.057	.752	.570
	55	.864	.853	.486	.723	.732	.484	.458	.456	.987
	65	.732	.889	.738	.970	.881	.664	.869	.919	.682
	85	.730	.940	.931	.766	.580	.718	.732	.755	.257
R2	45	.923	.473	.266	.126	.052	.072	.003	4000	6000
	55	.747	.727	.236	.522	.536	.234	.210	.208	.973
	65	.536	.790	.545	.941	.777	.441	.756	.845	.465
	85	.534	.883	.867	.587	.336	.516	.536	.570	.066
Constant	45	4.487*	8.456	.249	5.591	2.458	2.458	4.300	4.178	2.370
	55	-12.998*	-11.206	-1.120	11.190	14.334	4.229	2.077	6.723	-3.591**
	65	-17.284	-26.120*	-17.214	-19.830*	-14.682	-13.561	-25.379	-10.080	-2.668
	85	-14.669*	-32.783**	-38.517*	-19.751	-12.978	-8.309	-24.474	-11.358	-1.598
RT	45	-.004*	-.003	-.002	.000	.002	.000	-5.939	.000	-.002
	55	.002	.010	.003	.006	.007	.003	.006	.000	-.001*
	65	-.003	.000	.007	.008*	.001	.003	.001	-.002	.001
	85	.000	.003	-.004	-.002	.005	-.009	.003	-.002	.001
CR	45	-.967	-2.967	.367	-1.067	-.800	.100	-.367	-1.100	-.667
	55	3.800	2.033	1.600	-3.600	-4.733	-.133	-.033	-1.467	1.833**
	65	5.967	8.333*	5.300	6.700*	7.000	5.800	10.567	5.500*	.967
	85	1.733	7.900*	14.967*	8.033	4.300	5.733	5.833	3.967	.600

Note: *p<0.05; **p<0.01

Gain difference between ICRA weighted digi-speech and Kannada sentence: Effect of compression ratio

At 45 dB SPL, the compression ratio was not a predictor. The compression ratio was a predictor at 6000 Hz at 55 dB SPL, 500 Hz at 65 dB SPL, 1000 Hz at 65 dB SPL, 4000 Hz at 65 dB SPL, 500 Hz at 85 dB SPL and at 750 Hz at 85 dB SPL. At all these frequencies, the non-speech signal resulted in higher gain at lower compression ratio and speech signal resulted in higher gain at higher compression ratio.

The test-retest reliability was evaluated by comparing the gain difference between two trials. Alpha model was used to analyse this. The results showed good reliability of the results, Cronbach's Alpha being 0.7.

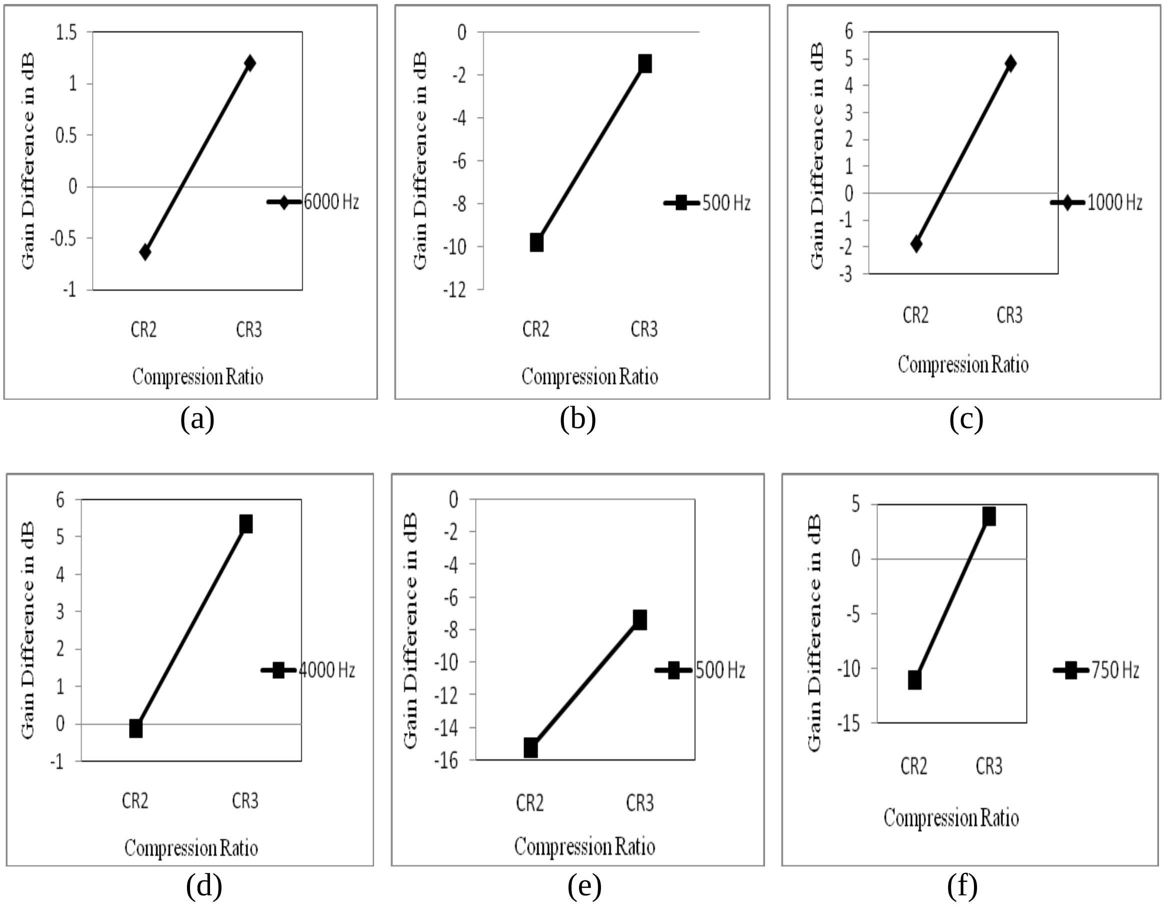


Figure 7: Effect of compression ratio on gain difference between ICRA weighted Digi-speech and Kannada sentence (a) at 6000 Hz at 55 dB SPL; (b) 500 Hz at 65 dB SPL, (C) 1000 Hz at 65 dB SPL, (d) 4000 Hz at 65 dB SPL (e) 500 Hz at 85 dB SPL (f) 750 Hz at 85 dB SPL.

DISCUSSION

The study compared the gain difference between non-speech/ISTS and sentence in Kannada Language. The results showed that there were no significant gain differences at mid- frequencies and at lower levels. These results could be because of the fact that the LTASS of Kannada language differed from ISTS and other stimuli majorly at low frequencies and at higher frequencies. Further, at lower presentation levels, the compression circuit is inactive most of the time, hence, did not bring about much variance in the gain across the stimuli. Further, the results revealed that the ISTS and ANSI-Weighted digi-speech resulted in lesser significant differences when compared to ICRA-weighted digi-speech. The reason for this could not be explained as the spectrum of ANSI-weighted and ICRA-Weighted digi-speech is similar, except at high frequencies. ICRA-Weighted digi-speech has lower energy at higher frequencies than ANSI-weighted digi-speech, and most of the significant differences were seen at lower frequencies.

Effect of release time on the gain difference

In general, the release time was not a significant factor at most of the frequencies. However, the Kannada sentence resulted in higher gain at the release time of 40 ms, the same gain as non-speech signal at 640 ms and the non-speech signal resulted in higher gain at 1280 ms, at some frequencies. The results showed that the gain difference was level dependent. At lower levels of input, the gain difference was lesser and did not vary much across the release time. As the level increased, the gain difference decreased with the increase in the RT. However, Henning and Bentler's study reported that, at 65 dB SPL, gain difference increased as the release time increased and at 85 dB SPL, release time was not significantly different. Even though, in the present study, there were significant differences, most of the frequencies resulted in similar gain differences across the release time.

Effect of Compression ratio on the Gain difference

The effect of compression ratio depended on the level and frequency. The lower intensity levels did not significantly bring about changes in the gain difference across compression ratio. At mid- and high-intensity levels, the gain difference decreased as the compression increased at lower frequencies. At mid- and high-frequencies, the gain difference increased in a positive direction as the compression ratio increased. The reason for this could be that the gain given at lower frequencies was lesser. This is in consensus with the results of Henning and Bentler. [4]

CONCLUSIONS

The present study reveals that there were differences in the gain of compression hearing aids when different stimuli are used. The present study highlights the need for standardizing these differences, so that, these can be applied while conducting real ear measures with the newer stimuli. Though the results can be considered reliable due to the high re-test reliability, similar studies are required for different kind of stimuli within the language and across languages, for different models of compression hearing aids.

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