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Impact of Different Hearing Aid Amplification Strategies on Speech Recognition in Hearing-Impaired Urdu-Speaking Children: A Comparative Study

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Author`s Contribution

[1 4] Substantial contributions to the conception or design of the work for the acquisition, analysis or interpretation of data for the work, [2 3] Drafting the work or reviewing it critically for important intellectual content, [4] Final approval of the version to be published, [5 6] Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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A B S T R A C T

Background: Hearing aids are most commonly used for effective amplification in the hearing impaired. Hearing aid technology has rapidly progressed from analogue to digital sound processing devices. However, controversy still exists in connection with the compression strategy most appropriate for better word and speech recognition especially for the Urdu language.

Objectives: To compare the three amplification strategies, including peak clipping, compression limiting and wide dynamic range compression, to suggest the most appropriate strategy in hearing aids for moderate and severe hearing loss, for the development of better word recognition in the Urdu language.

Methodology: This Quasi-experimental, recruited N=50 children with moderate and severe hearing loss, from Salamat Hospital, Gujranwala from Sept. 2017 to August 2018. The sample of N=50 children included both genders aged 7-15 years, bilaterally fitted with digital programmable, multichannel compression aids, integrating one of three amplification strategies including peak clipping, compression limiting and wide dynamic range compression for at least 1 month in a compensated order across children. After using a specific amplification strategy for at least one week, word recognition score was measured through monosyllabic words in Urdu language. SPSS Ver-20 was used for data analysis.

Results: Results revealed significant differences (p=0.000) among word recognition score means of 64.40±5.01, 69.00±5.80 & 94.20±5.75 for peak clipping, compression limiting and wide dynamic range compression hearing aid amplification strategies respectively with maximum increase noted for wide dynamic range compression amplification strategy.

Conclusion: Wide-dynamic-range compression (WDRC) fitting strategy is better for word recognition in Urdu speaking population than linear amplification, and output compression for moderate and severe hearing loss in children

Key Words: Amplification strategies, Compression limiting, Hearing impaired, Hearing aid, Peak Clipping, Wide dynamic Range compression, Word recognition score.

Introduction

Early identification of hearing loss (HL) and intervention play a key role in the speech and language development of child [1], which acts as the basic tool for the development of communication. Hence, the severity of the problems resulting from HL can be catered to with the use of well-fitted hearing aids (HA) which provide appropriate amplification for

improvement of speech and language.[2] Despite substantial improvement in cochlear implantation technology, hearing aids still remain the most commonly used and cost-effective treatment for hearing impaired.[3] Therefore amplification using suitable HA still remains the most commonly used treatment of sensory neural hearing loss (SNHL), so much so that the projected figure for HA's required in developing countries alone amounts to 35 million with two-thirds of cases of severe to profound HL living in developing countries [4]. According to the World Health Organization (WHO), there is demand for high quality, affordable, robust, low maintenance, and energy-efficient HA's with inbuilt noise reduction features in Lower Middle Income Countries (LMICs).[4] For benefit from HAs, candidacy for HA should be based on severity and configuration of HL, range of communication disorder, patient needs and motivation, and attitude toward the use of HA amplification.[5]

Even with slight hearing difficulties that trigger communicational issues, patients get motivated toward hearing amplification. Traditionally analogue HA's are prescribed being easily available as well as cheap, however with the increasing availability of programmable digital HA's, which provide better performance, patients are shifting to programmable digital HA's with higher chances of improved quality of life (QoL) since they decrease the psychological and emotional impact of SNHL [6], hence now being preferred choice for amplification.

According to Stach & Ramachandran [5], HA technology has shown rapid progress from conventional analogue to digital HA's with digital hearing aids now having digital sound processing (DSP) to reproduce sound with minimum or no distortion, adaptive directionality, feedback control with reduced noise, battery trench and are freely programmable and have different advanced amplification strategies to reduce distortion and provide ease of listening experience. Amplification can be provided through a HA in a linear or non-linear manner as.[5]

The Linear Amplification strategy is in use since the early years of HA's and is still used for some mild hearing losses. It cannot cater to the non-linearity of loudness progress usually seen with SNHL. While the non-linear Amplification strategy involves the amplification of low-intensity sounds more compared to high-intensity sounds. Hence, it deals with the reduction in dynamic range and loudness growth which is seen with SNHL. The dynamic range of hearing varies from 0 to 100 decibels (dB) for a normal person and is decreased with SNHL. HA's compression circuitry enhances the gain of sounds of low intensity, making them listenable, as well as limiting the gain of sounds of high intensity so they don't cause discomfort or pain.

A number of non-linear amplification plans can handle the dynamic range of HA's. Some provide compression over a percentage of a range called "Partial dynamic-range compression" with some compression at a specific level of input and the other strategy provides compression over a broader area called "wide dynamic-range compression (WDRC)". This improves the amplification of noiseless sounds & reduces the amplification of loud sounds, hence it matches speech into a listener's residual dynamic range which can be altered for different frequencies. Another typical method to limit output is peak clipping which does not permit the signal crests to rise beyond a definite level. However, this causes the high-intensity signals to distort. Compression limiting is the up-to-date standard method of output limiting, which allows the amplifier to become nonlinear as input signals reach a programmed level so that the amount of gain is lessened meaningfully near the maximum output level.[5]

Controversy still exists in connection with the impact of linear or nonlinear amplification on speech perception with some studies reporting no significant difference [7]. Hillock-Dunn A et al. in their study reported that nonlinear frequency compression (NLFC) was neither harmful nor beneficial at moderate strength in laboratory setting, while HA's fitted with higher compression with NLFC indicate the need for further research to assess the effect of NLFC processing on speech perception with wide range of speech perception settings.[8]

Therefore, it is necessary to determine which compression (Amplification) strategy is most appropriate for better word or speech recognition by applying different strategies and collecting results through word recognition score (WRS) by using monosyllabic words. With Urdu language commonly understood by most of the population, the same is necessary to be conducted using Urdu monosyllabic word list to cater to the language barrier and get reliable results. WRS requires a single syllable words list presented at 30 dBHL above the threshold.

Hence, this study was conducted to compare the three amplification strategies, including peak clipping (PC), compression limiting (CL), and wide dynamic range compression (WDRC), to suggest the most appropriate amplification strategy in hearing aids for a moderate and severe degree of hearing loss, for development of better word recognition in the Urdu language with the alternate hypothesis of "Wide-dynamic-range compression (WDRC) fitting strategy is better for word recognition in Urdu speaking population than linear amplification, and output compression for moderate and severe hearing loss".

The main advantage of this study is that it is conducted in the Urdu language which has the greater edge as individuals can fully understand the nature and aspect of monosyllabic words used in speech audiometry and respond to it properly

without any language barrier, resulting in reliability. The study is of significant importance since it can prove to be of significant benefit for the Audiologists for HA fitting and also serve as baseline data for future studies.

Methodology

This Quasi experimental study was conducted at the Audiology Department of Salamat Hospital Gujranwala over a period of 12 months from 1st Sept. 2017 to 31st August, 2018.

This study utilized non-probability convenient sampling to recruit a sample of N=50 children with following selection criteria:

Children of both genders, aged 7-15 years with moderate and severe HL and fitted bilaterally with digital programmable, multichannel compression HAs by the researcher incorporating one of three different amplification strategies: linear with peak clipping, linear with compression limiting, or WDRC on counterbalanced order across children, following pure tone audiometry (PTA) & Speech Audiometry including word recognition score.

Pre-lingual deaf children, and children in which pure tone and/or speech audiometry was not possible, children using hearing aid for less than 1 month, and non-Urdu speaking children were excluded from the study.

Sample of N=53 was calculated from the following Statistical formula [9] and N=50 who consented for inclusion were included in the study:

With 90% level of significance α=0.1, Z α/2 = 1.645, margin of error 'E' = 1, calculated population standard deviation CJ =4.43. n= [(1.645) (4.43)/1]2 = 53. Hence a sample size of n=53 was calculated. Study was conducted after obtaining ethical approval of the research from Institutional Research Board of Isra Institute of Rehabilitation Sciences, Isra University vide reference No. 1509-M.Phil-HS-001 and informed consent of patient and / or parent.

For data collection, WRS was measured for each child before using hearing aid. After that the children wore hearing aids programmed with any of the amplification strategies ie., Peak clipping, compression limiting and wide dynamic range compression, one by one, for minimum 1 week, in a compensated order across children. After using a specific amplification strategy for at least one week, WRS were measured through monosyllabic words in Urdu language [10], presented at 30dBHL above threshold (figure 1).

Data analysis and interpreted was conducted using SPSS-V20.0. Descriptive statistics were utilized. Age and threshold of hearing was presented in frequency and percentage, while WRS were presented with mean and standard deviation. Repeated measure Anova statistics was utilized to see any statistically significant difference in results of the three amplification strategies and improvement in WRS by using different amplification strategies shown by line graph.

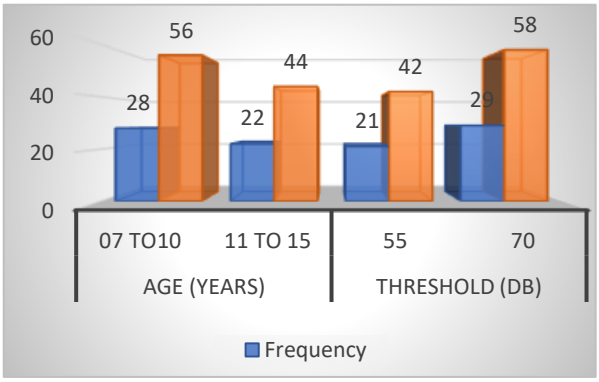

Figure 2: Age and Hearing threshold characteristics (N=50)

Table I: Descriptive Statistics of Word Recognition Score for Different Amplification Strategies. (N=50)

Amplification Strategy	Word Recognition Score	
	Mean±SD	Range
No Amplification	48.60±7.83	40-60
Peak Clipping	64.40±5.01	60-70
Compression Limiting	69.00±5.80	60-80
Wide Dynamic Range Compression	94.20±5.75	80-100

Results

Current study with a sample of N=50 HI children with an equal gender distribution comprised of 28(56%) 7-10 years and 22(44%) 11-15 years old children (figure 2). Their hearing thresholds in the moderate HI category comprised of 21(42%) children with mean hearing threshold of 55dB and 29(58%) were in the severe HI category having a mean threshold of 70dB.

Table I reveal a baseline mean WRS of 48.6±7.83 dB with a range of 40 to 60 and a maximum mean WRS of WDRC 94.20±5.75.

The mean and SD of WRS seem to increase with the type of amplification used with maximum increase noted with WDRC. However, to see significance Repeated Measure Anova test was applied. The assumption of sphericity is met as Mauchly's test of sphericity has a p-value of greater than 0.05. (table II)

Since sphericity is assumed with p=0.089 (Mauchly's test of sphericity), we found a statistically significant difference between means for different amplification strategies (p= <0.001)

Table II: Comparison of Word Recognition Scores: Repeated Measure Anova Statistics with Mauchly's test of Sphericity.							
Source	**Test**	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**		**Sig.**
Amplification Strategy	Sphericity Assumed	53617.5	3	17872.5	535.356		0.000
	Greenhouse-Geisser	53617.5	2.659	20162.716	535.356		0.000
	Huynh-Feldt	53617.5	2.826	18972.494	535.356		0.000
	Lower-bound	53617.5	1	53617.5	535.356		0.000
Error	Sphericity Assumed	4907.5	147	33.384			
	Greenhouse-Geisser	4907.5	130.303	37.662			
	Huynh-Feldt	4907.5	138.477	35.439			
	Lower-bound	4907.5	49	100.153			
	Mauchly's W	**Approx. Chi-Square**	**Df**	**Sig.**		**Epsilon**	
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Strategy	0.818	9.56	5	0.089	0.886	0.942	0.333

on RM Anova statistics test with a maximum increase in WRS with WDRC.

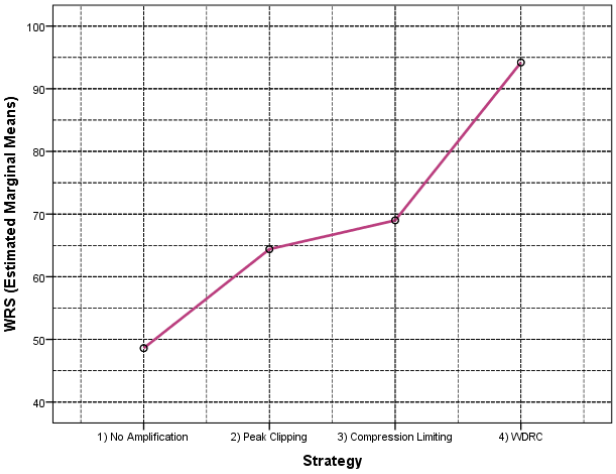

Figure 3. Line graph for comparison between Word recognition scores with three amplification strategies showing estimated marginal means

Following the application of three amplification strategies including PC, CL, and WDRC for the same period of one week with the same hearing aid model and patient one by one and WRS recorded one by one for each amplification strategy then these WRS of three amplification strategies were compared which revealed significant difference (p=0.000) among WRS means of 64.40±5.01, 69.00±5.80 & 94.20±5.75 respectively, which supports the alternate hypothesis which states that Wide-dynamic-range compression (WDRC) fitting strategy is better for word recognition in Urdu speaking population than linear amplification, and output compression for moderate and severe hearing loss.

Discussion

The current study focused on the use of amplification strategies by using digital programmable HA's, since these are considered superior to conventional non programmable HA's.[11] In a local comparative study by Majid compared speech articulation using digital and analogue HA and found significantly better intelligibility in digital HA users.[12] Also Kam & Wong reported that compared to LA, WDRC has better results as regards intelligibility of speech in quite environment compared to noise, where there was no difference.[13] Similarly in current study in which WRS were obtained by speech audiometry by applying three amplification strategies including PC, CL, and WDRC, then the WRS of three amplification strategies were compared which revealed statistically significant differences with the means of 64.40±5.01, 69.00±5.80 & 94.20±5.75 respectively, which supports the alternate hypothesis which states that Wide-dynamic-range compression (WDRC) fitting strategy is better for word recognition in Urdu speaking population than linear amplification, and output compression for moderate and severe hearing loss. These findings are also in line with a study by Stach & Ramachandran.[5].However, our study has the significance of having been conducted using Urdu monosyllabic words, hence more applicable to the regional perspective, this is even more important since information delivery associated with high frequency is of utmost importance in learning articulation and embedded grammatical rules. [14] The results are also supported by a study by Boike & Souza, which reported that compression ratios chosen depending on the quality of speech did not negatively impact recognition of speech.[15] Also, since most hearing impaired who require amplification have SNHL, the accompanied issue of significantly lowered dynamic range of hearing needs to be catered to.[16] WDRC as seen in this study is a suitable option.

In another study, the WDRC amplification strategy has been reported to be much better than linear amplification with peak clipping for moderately severe SNHL.[17] A study by Yund EW et al. [18], involving acclimatization in hearing-impaired (HI) patients with no previous amplification experience and fitted with either wide dynamic range multichannel compression

(WDRMCC) or LA HA strategies, at 8 weeks revealed more (4.6%) improvement in syllable recognition in users of WDRMCC compared to lesser (2.2%) in LA users along with improved consonant identification in WDRMCC, while LA users primarily changed their response biases. Also, WDRMCC use resulted in more improvement for aided than unaided stimuli, while LA users did not, indicating acclimatization with WDRMCC HAs but not with LA HAs and a switch in amplification type at 32 weeks did not produce significant change, indicating that acclimatization depended on the type of amplification. Also, Marriage JE et al. also reported the WDRC amplification strategy to be superior to PC and CL in children with severe and profound HL [19], in compliance with current study. However, for a good fitting good assessment of HL, characteristics of the patient, controlling output function of HA by making necessary and suitable adjustments, real-ear measurements to confirm the fitting, good counselling skills and necessary rehabilitation should ultimately result in acceptance of amplification.[20]

Conclusion

Wide-dynamic-range compression (WDRC) fitting strategy is better for Speech recognition in Urdu speaking population than linear amplification, and output compression for moderate and severe hearing loss in children.

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