EFFECT OF SYLLABIC AND DUAL COMPRESSION ON LINEAR AND NON LINEAR HEARING AID PROCESSED MUSIC

Merin Mathews

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MAY, 2014

Dedicated to

Pappa, Mamma

Minna, Achu

Teachers

&

Chithrechy

CERTIFICATE

This is to certify that this masters dissertation entitled '*Effect of Syllabic and Dual Compression on Linear and Non Linear Hearing Aid Processed Music*' is a bonafied work in part fulfilment for the master of sciences (Audiology) of the student with registration number 12AUD018. This has been carried out under the guidance of the faculty of this institute and has not been submitted earlier to any other university for the award of any other diploma or degree.

Mysore

May, 2014

Dr. S. R. Savithri

Director

All India Institute of Speech and Hearing

Manasagangothri,

Mysore - 570006

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Mysore

May, 2014

Mrs. N Devi

Guide

Lecturer in Audiology

Department of Audiology

All India Institute of Speech and Hearing

Manasagangothri,

Mysore - 570006

DECLARATION

This is to certify that this master's dissertation entitled '*Effect of Syllabic and Dual Compression on Linear and Non Linear Hearing Aid Processed Music*' is the result of my own study and has not been submitted earlier to any other university for the award of any diploma or degree.

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CHAPTER 1

INTRODUCTION

Music has its own characteristics. It not only provides soothing effect for the listeners, but also heals from pain, reduces stress and indeed promotes a feeling of well being. Music becomes necessity to enhance quality of life as well as feelings of well-being (Menon & Levitin, 2005; Zatorre, 2005; Levitin, 2012). Majority of the population enjoys listening to music as a main entertainment even though they are not trained.

When the individuals who enjoy listening to music acquire hearing impairment significant effect can be expected of music perception and the pleasure derived from it. However individuals do not lose their affection to music once they acquire hearing loss.

The reason that individuals with hearing impairment fail to perceive or appreciate the sound quality of music is because the hearing loss has differential effects on frequency selectivity, temporal resolution, loudness perception/intensity discrimination and supra-threshold performance. These add on to the difficulty of the individuals with hearing impairment to perceive or appreciate music (Chasin, 1996).

The sound appears to fluctuate more in impaired ears than normal ears. When listening to music, forte passages may be perceived at normal loudness but piano passage may be perceived as inaudible. This distorts the smoother perception of music melodies (Moore, 1998). Several studies suggest the pitch discrimination was affected in individuals with hearing impairment (Hoekstra & Ritsma, 1977; Moore & Glassberg, 1988; Moore & Peters, 1992).

Although there may be some restoration of hearing through the use of hearing aids, it is questionable whether most hearing aids process music in such a way to ensure the user to hear and enjoy music to the same degree as prior to acquiring hearing loss. Even though the digital technology is providing different algorithm in improving speech perception, the perception of music through hearing aids is still unclear. Chasin and Russo (2004) suggested that an optimal music program should use the following: (a) a comparatively high knee-point threshold if the compression circuitry incorporates a peak level detector so intense components of music are not distorted, (b) a single-channel compression system or a multichannel system in which all channels have similar compression ratios and knee-points, and use higher knee-points than for speech, (c) feedback reduction disabled (or where this is not possible, use of a feedback reduction technique that treats all frequencies equally), (d) and a disabled noise reduction system.

Prajna & Manjula (2011) suggested high knee point of compression to be better for music perception. A 15 channel hearing aid with higher compression knee point, feedback management and noise reduction cancellation system turned off is better when compared to a 6 channel hearing aid with similar setting (Sushmith & Manjula, 2007).

Most modern hearing aids incorporate some form of multichannel compression to compensate for the effects of loudness recruitment that are experienced by people with cochlear hearing loss (Moore, 2007). Since the music has got higher dynamic range (120 dB) compression strategies need to be implemented to prevent it reaching the loudness discomfort level of the person.

Dreschler (1988) found that for 16 teenagers with hearing loss, a compression aid was superior to a linear aid with peak clipping for phoneme perception in quiet. Presumably, different compression systems may alter the acoustic characteristics of the speech signal, which in turn may result in changes in phoneme perception.

There is only tentative support for the use of syllabic compression which is fast acting compression system for those with hearing loss (Dreschler 1989). Commercial single-channel aids were no better for speech intelligibility than linear aids (Dreschler, Eberhardt, & Melk, 1984).

Automatic volume control (AVC), can theoretically benefit people with hearing loss who do not have a severely reduced dynamic range but who have an optimum level for speech discrimination above which their performance starts to decline (King & Martin, 1984). They also assert that AVC allows the listener to accept a wider range of input levels, without continually adjusting the gain, than would be possible with a linear aid.

Dual compression is a combination of both syllabic and AVC. It exploits the advantage of both syllabic compression and AVC (Moore & Glassberg 1991). 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 (Geetha & Manjula 2005).

For a high-input level (80 dB SPL) of music, slow compression was preferred over fast compression (Moore, 2012).

CHAPTER 2

REVIEW OF LITERATURE

Characteristics of Music:

Music is an art form consisting of sequences of sounds in time, especially tones of definite pitch organized melodically, harmonically; rhythmically and according to tone colour and it characterize particular people, culture, or tradition (Collins English Dictionary, 2003). Main components of music include pitch, rhythm, melody and timbre.

Pitch is used to describe a particular tone as how much low or high is it in music. Fundamental frequency is the physical correlate of pitch. Looi, (2008); Drennan & Rubinstein, (2008) have suggested that musical pitch can be referred to as spatial (frequency) and temporal (time) mechanism. Other factors like loudness and timbre can also change pitch (Donnelly & Limb, 2008).

Rhythm generally describes the temporal features of music that typically occur on the order of milliseconds, which are crucial in the perception of pitch and timbre. Rhythm gives a dynamic effect to music. It is crucial to the recognition of a familiar song and, at times, can be of greater importance than pitch cues alone (Kong, Cruz, et al. 2004, Gfeller, Turner, et al., 2007). Both hearing impaired and normal hearing individual have difficulty in identifying the melody when rhythm cues are removed (Kong, Cruz, Jones & Zeng., 2004).

Melody is created when a series of pitches are sequentially and temporally organized into patterns of varying musical contour and interval (Donnell & Limb., 2008). Discrimination of changes in pitch, in terms of both direction of change (up or down) and degree of change (interval size) is very crucial in the perception of melody.

Timbre is the qualitative characteristics of music (Olsen 1967). It enables one to judge the difference between the same musical note played on different musical instrument (Plomp, 1970, Donnelly & Limb., 2008).

Menon & Levitin, (2005); Zatorre, (2005); Levitin, (2012) suggested that music provides a healing effect from pain, soothing effect, reduces stress and promotes a feeling of well being. Music represents a dynamic form of emotion, and the conveying of emotion is considered to be the essence of music and the reason that most people report spending large amounts of time listening to music.

Characteristics of Speech:

Speech consists of consonants and vowels which are phonemically and phonetically different in different languages of the world. The phonemic differences are more when compared to the phonetic differences across different languages in the world (Byrne et al. 1994., Chasin, 2011).

The phonetic similarity is because of the similarity in the dimensions of the vocal tract, nasal cavity, oral cavity, tongue and the mechanical and neurological systems of speaker belonging to any language of the world. The long term spectrum of the different languages is sufficiently similar across languages. Low-frequency sonorants (vowels, nasals, and liquids) and high-frequency obstruents (stops, affricates, and fricatives) are present in all the languages. Modern hearing aids have microphones, receivers, and amplifiers that can handle all phonetic elements of speech within their operating characteristic. Low frequency sonorants are typically more intense than the high frequency obstruents because of the nature of the mechanism of the human vocal tract and the air supply from lungs (Chasin, 2012).

Speech Vs Music:

Music fundamentally differs from speech; music does share several similarities to spoken language. In both speech and music, sounds of varying frequency, duration, and timbre unfold over time to communicate a message, whether concrete (speech) or abstract (music). Both convey prosodic information that significantly affects their respective interpretations, such as inflection and phrasing. Perception of timbre is involved in both the recognition of a familiar voice or the identification of a musical instrument. Like language, music communicates, by conveying important affective and expressive messages. However, unlike spoken language, music is ultimately abstract and its interpretation is highly subjective, depending on factors such as musical training, music listening habits, and cultural background (Donnell & Limb., 2008).

According to Wolfe (2002), music and speech are perceived separately because the subsets of acoustic features of both music and speech are coded differently. In both speech and music the subsets of acoustic features are perceived categorically. Fundamental frequency contributes to pitch in music while it contributes to prosody in speech. In music fundamental frequency is categorized and more precise, but this is not true in case of speech. Steady formants in music give information about components of instrumental timbre in music and components of sustained phonemes in speech. Varying formants are not of much important in music because they are relatively invariant, but it gives information about the plosive phonemes in speech. Spectrum of speech contains more modulations which are more rapid and irregular when compared to music. Temporal regularities account for rhythmic components of melody in music and prosody in speech. These temporal regularities are perceived categorically in music unlike in speech.

As discussed above according to Chasin (2003) five primaries, physical differences between speech and music are the long-term spectrum of music versus speech, differing overall intensities, crest factors, phonetic vs. phonemic perceptual requirements of different musicians and difference in loudness summation and loudness intensities.

a) The long term speech spectrum is well defined and typically language independent because it is produced by the tongue causing constrictions in a vocal tract of length 17cm. In contrast, music can be derived from many sources such as the vocal tract, a percussive instrument a woodwind, brass instrument etc. So long term spectrum of music is poorly defined and the relationship between the loudness and intensity is also highly variable (Fabiani & Friberg, 2011).
b) The differing overall intensity for speech is less when compared to music, approximately 30-35dB. In contrast, depending on the music played or listened to, different instrument used in the music can generate loud (120dB SPL) and soft sounds (20-30dB SPL). So when music becomes input for the hearing aid the dynamic range of intensity becomes approximately 100dB.
c) The crest factor is the difference in decibels between the highest peak of a waveform and its average or root mean square (RMS). For speech, the RMS is about 65 dB with peaks extending about 12 dB beyond the RMS level. The crest factor for speech is therefore on the order of about 12 dB. Crest factors of 18-20 dB are not uncommon for many musical instruments. Compression systems and

detectors based on peak sound pressure levels may have different operating characteristics for music as input to a hearing aid than for speech. That is, music may cause compression systems to enter the non-linear phase at a lower intensity than would be appropriate for that individual.

d) Phonetic vs. phonemic perceptual requirements refers to the difference between what is actually heard: the physical vibrations in the air (phonetic) as opposed to the perceptual needs or requirements of the individual or group of individuals (phonemic). For speech, the long-term speech spectrum includes most of its energy in the higher frequency area and less in the lower frequency area (its phonetic manifestation). Depending on the language, the clarity, measured by word discrimination scores or the articulation index, depends on the mid- and high-frequency regions. In contrast to speech, many musicians prefer to hear the lower-frequency information more than other frequencies, irrespective of the output (phonetics) of the instrument.

e) Difference in loudness summation and loudness intensities depends on number of harmonics falling outside a critical bandwidth. In speech the harmonics are equally spaced with a minimum of 100 Hz, which means that no two harmonics fall within one critical bandwidth. Therefore in speech the loudness summation occurs. In some musical instruments which are mainly quarter wave generators produce harmonics which fall within one critical bandwidth. Therefore in music the loudness summation rarely occurs. A stringed instrument musician depends on the relationship between the lower frequency fundamentals and higher harmonic

Hearing Impairment and Music Perception:

Sensorineural hearing loss have a large impact in the perception of speech as well as music. The hearing loss has differential effects on frequency selectivity, temporal resolution, loudness perception/intensity discrimination and supra-threshold performance. These add on to the difficulty of the individuals with hearing impairment to perceive or appreciate music (Chasin, 1996). While listening to music our ears are sensitive to fine distortions in music. These subtle distortions are not processed in an impaired ear. Moore (1996) suggested that auditory filters in persons with hearing loss greater than 50 dB HL are twice wider than the normal hearing individuals. These wider auditory filters will lead to poor frequency resolution which in turn is responsible for the poor pitch melody and timbre perception (Looi, 2008). Hearing impaired people gain improvement in speech comprehension in quiet when using hearing aids (Cullington & Zeng, 2011; Kong, 2005; Looi, 2008; Looi, 2010). Music perception and enjoyment remains a challenge for many hearing impaired people (Kong, 2005; Looi, 2008; Looi, 2010).

Timbre is a variable which is not only dependent on pitch, but it is based on an amalgam of physical changes, including changes to the frequency spectrum, phase spectrum, and the intensity of a sound. People are depending on timbre when trying to identify a sound source or when trying to stream apart the independent constituents of a polyphonic piece (Bregman, 1990). The disruptions in the perception of timbre can lead to poor identification and streaming of an instrument. Research has shown that, if a rising pitch contour involves a transition from a dull tone to a bright tone, the perceived pitch distance will be expanded; if it involves a transition from a bright to dull tone, the perceived pitch distance will be contracted (Russo, 2005). The converse is true for falling pitch contours. The listeners with selective hearing loss will experience these kind of relative pitch distortions when listening to melody even though there is no actual change in timbre occurred. These relative pitch distortions may have aesthetic consequences (Russo, 2006).

Music Perception through Hearing Aids:

Van Buuren, Festen, Houtgast (1996) studied the effects of irregularities in frequency response for people with impaired hearing in 26 participants with slopping SNHL. Artificially imposed peaks in the frequency response of a sound reproduction system via digital filtering prior to delivery via headphones. The peaks were centered at 1.3, 2.8, or 5.5 KHz and had heights of 10, 20 or 30 dB. The peaks were presented singly or all three together. A reference without any peak was also included. Several music signals were used including (a) flute, piano & voice; (b) trumpet & orchestra; (c) drum, synthesizer and voice and piano. Participants were asked to rate the pleasantness of the sound. Results reveal that the quality of music perceived by hearing impaired people is reduced by frequency response irregularities when the peak to valley ratio response is 10dB or more.

Conventional hearing aids are optimized for perceiving speech audibility and intelligibility. Perceiving music is not but taken care of, to a great extent. Modern digital hearing aids are designed for processing speech of all languages. Hearing aid that is optimally set for music can be optimally set for speech; even though its converse may not be necessarily true (Chasin & Russo, 2004). Hearing aid optimally set for speech is optimum for folk music also which is mostly singing along with some slightly less intense instrumental noise. Such hearing aid are not optimum for rock music which has peak maxima at around 110 – 115dB SPL because the hearing aids have a limitations at this level (Chasin, 2004).

Chasin, (2004) suggested some tips while programming the hearing aid for music as input.

- Choose a hearing aid which does not alter the fidelity of intense sounds.
- Set the peak input limiter more than 100dB SPL and high knee point for the front end compressor.
- Choose a wide dynamic range compression with fast attack and release time along with low compression ratio and this is converse as in for cochlear hearing loss.
- Choose a hearing aid with compressors working with a principle of RMS characteristics rather than peak detector type since the music have a larger crest value when compared to speech.
- Set the compression ratio to be 5 to 8 dB higher for music than for speech if it is a compressor working under the principle of peak detector type.
- One – two channel hearing aids are recommended than a multichannel hearing aid because a multichannel hearing aid might alter the relationship between the intensity of fundamental frequency to the intensity of harmonics.
- Set all the WDRC parameters the same for all the channels in the program for music, if using a multichannel hearing aid.

- Feedback manager and the noise reduction algorithm should be turned off since music can be considered as noise and also the music needs only lesser gain requirement.
- Omnidirectional mode should be used for music in order to reduce the low frequency information getting lost because of directionality.

Mishra, Kunnathur & Rajalakshmi (2004) compared the perceptual rating obtained from 15 normal hearing subjects for classical and rock music processed by commercially available 4 different digital hearing aids. Both the hearing aid processed music samples were rated lower by all the subjects. The authors suggested that through the microphone noise would have entered with the desired sound making it difficult to process or manipulate further. This might be the reason for poor rating for the hearing aid processed music even for the most advanced digital hearing aid.

A similar study by Mishra & Rajalakshmi (2005) used a ten point rating scale to compare the hearing aid processed 3 musical samples (2 classical and 1 hard rock music samples). The results were similar as their previous study and suggested ways to improve music perception through hearing aids based on the rating obtained for 4 commercially available digital hearing aids. They suggested using single channel hearing aids or multichannel hearing aids programmed to work like a single channel hearing for music. Hearing aid algorithms are inclined to consider music as noise or feedback; hence it is wise to turn off the noise reduction algorithm and feedback manager. Omni directional mode is better for music perception since music itself has got good signal to noise ratio. They further highlight that music programs in the commercially available hearing aids cannot provide good quality for music because the hearing aids are still optimized for speech. Hence it is better to select a hearing aid with multiple programs which permits individual programs for music and speech.

Mishra & Abraham (2007) compared the music processed through analog body level hearing aid, analog BTE and digital BTE hearing aid. The music samples used were of piano, guitar, flute and violin. The results of subjective rating and the graphs suggested superior music quality for analogue BTE hearing aid processed music. The piano sample was found to be better represented by all the hearing aids, which may be because of piano has got harmonics falling in different critical bandwidth like speech. All the hearing aids taken for the study suppressed the low frequency information which affected the music perception.

Gfeller et al. (2007) studied musical pitch perception in 101 CI users, 13 CI + HA users and 21 normal hearing subjects. The test stimuli were ranging from frequencies 131 to 1048 Hz in which each pitch pair intervals was separated by 1 to 4 semitones. Both normal hearing and bimodal group performed better for different interval size at low frequencies than CI users.

Looi et al. (2008) compared the 4 main parameters of music perception in 15 CI users, 15 HA users and 10 normal hearing subjects. The four main parameters used in the study were rhythm discrimination, pitch ranking, instrument recognition and melody recognition. The results showed that HA users performed highly better than CI users at pitch and melody perception. The rhythm discrimination and instrument recognition scores were also higher for hearing aid users but were not statistically different from CI users. However, they could still not achieve as good as normal hearing subjects in all the 4 parameters of music perception.

Uys (2011) studied rhythm perception in four normal hearing people and 20 hearing aid users. Subject's task was to identify, discriminate, rhythm melody identification musical melody identification. HA users gained relatively high scores, but they still were poorer than normal hearing subjects

Prajna & Manjula (2011) studied the effect of number of channel and compression knee point in hearing aid processed music. Subjects included were with flat and sloping mild – moderate sensorineural hearing loss. The hearing aid processed music was subjectively rated and subject's music perception was assessed using the Music Perception Test Battery (MPTB). Significantly no effect was seen between the number of channels and the configuration of hearing loss but higher was the rating for the music processed with a higher set compression knee point than the default compression ratio offered by the hearing aid. Even though there was no significant difference majority of the subjects from both the groups preferred 2 - channel hearing aid with high compression knee point than 8 channel hearing aid with high compression knee point.

Moore (2012) studied the effect of bandwidth, compression speed and gain at high frequencies on preference for amplified music in sloping sensorineural hearing loss individuals. The preferred higher cut off frequency varies with participants. The preference for higher upper cutoff frequency was associated with a shallow high frequency slope of the audiogram. For high quality of reproduction of music lower cutoff frequency of a hearing should be between 50Hz to 200Hz and ripples in the frequency should be less than ±5 dB. For better sound quality of percussion instrument (xylophone) a system should be there to reduce the overshoot effects of compression. Slow acting compression was more preferred for a high input level (80 dB SPL) over fast acting compression. The participants preferred to have higher gain at higher frequencies while listening to music.

The effect of prescriptive formula in hearing aid processed music through subjective preference was probed by Chowdhury (2008). A commercially available digital hearing aid was programmed with 2 nonlinear prescriptive formulae (NAL-NL1 and DSL i/o curvilinear prescriptive formulae). Hearing aid processed music samples were played to 15 carnatic musicians with normal hearing and 5 listeners with hearing loss. The higher ratings were obtained for NAL–NL1 even though there was a discrepancy between the normal hearing subjects. All the subjects with hearing loss preferred listening music through the hearing aid programmed with DSL (i/o) formula.

Fathima & Basavaraj (2010) studied the influence of different prescriptive formulae in music processed by hearing aids in moderate to moderately severe sensorineural hearing loss subjects. The hearing aid was programmed for FIG 6, NAL-NL1 and DSL (i/o). Both perceptual and objective measurements were done. FIG 6 and DSL (i/o) prescriptive formulae were superiorly rated for clarity, melody, rhythm, and naturalness than NAL-NL1 prescriptive formula.

Moore & Sek (2013) in 15 participants with mild to moderate SN HL, compared the relative preferences of sound quality of hearing aid fittings based on CAM2 and on NAL-NL2 using the simulated 5 channel compression hearing aid. Both fast acting and slow acting compressions were used. The music stimuli were jazz, classical and vocal male stimuli. For all 4 music stimuli, the input levels were 50, 65 & 80dBSPL. Within a pair of sound presentation (one trial), the only difference was in fitting methods (NAL-NL2 & CAM2). Results revealed a higher preference for CAM2 than NAL-NL2. CAM2 and NAL-NL2 methods differ mainly in the gain applied for frequencies above 4KHz. (CAM2 more gain than NAL-NL2). This shows that extending upper cut off frequency is more beneficial in music perception through hearing aids.

The sensorineural hearing loss will alter the sound processing in different aspects; in which reduced dynamic range, recruitment and softness imperceptions are some of them. The recruitment and softness imperceptions phenomena in cochlear hearing loss patients are resolved through implementing different types of amplitude compressions.

There are majorly 2 types of compression based on the speed of time constants in compression. They are as follows:

- Fast acting compression or syllabic compression or dynamic compression
- Slow acting compression or automatic volume control or dual compression

Fast compression might be better for dealing with sudden changes in sound levels, as it can occur in the transition from a forte passage to piano passage, or vice versa (Moore, 1997). On the other hand fast compression can introduce cross modulation effects between the signals from different sound sources (Stone & Moore, 2003, 2004, 2008) & this might make it more difficult to hear different instruments or group of instruments in an ensemble performance.

Periodic variations in intensity create a temporal framework (rhythm) that supports representations of relative pitch in music (Jones & Boltz, 1989). Generally speaking, when variations in intensity are weak or non-existent (isochronous), we are left with a relatively shapeless piece of music, without any clear hierarchical structure. The use of compression in hearing aids is particularly important for the music signal given its inherently wide dynamic range. However, the overuse of compression may have the effect of minimizing intensity differences, leaving important pitch relationships less apparent. It would be interesting to test sensitivity to hierarchical structure in music in the presence of varying levels of compression (Russo, 2006).

Syllabic Compression / Fast Acting Compression:

Fast acting compression amplifies with relatively shorter attack and release time resulting in a variation in gain during a syllable or word (Walker, Byrne & Dillion, 1984). The time constants of the compression are set shorter than typical syllable duration which is approximately 200 to 300ms (Hickson, 1994). The frequency -gain shape characteristics also changes rapidly based on the short term speech spectrum of incoming signal (Moore, Peters & Stone, 1999). Fast acting compression helps in increasing the audibility of low level sounds along with upward spread of masking of low level sounds (Dillion, 2001). Fast acting compression provides improvement in speech perception in noise because it helps in perceiving speech from spectral and temporal dips of noise though it does not replace normal performance (Moore, Peters & Stone, 1999).

There are contradictory opinions to syllabic compression. Johnson (1993) state that since syllabic compression reduces the peak to valley ratio of the ongoing speech noise enters the remaining dips present in the processed speech. Reduction in the peak and valleys in speech because of syllabic compression can result in distortions (Kuk, 1999).

Dual Compression/ Slow Acting Compression:

Slow acting compression has longer attack and release time for compression. The time constants are usually longer than a typical syllable or a word. Usually release time can vary from 150ms to several seconds which means that system adjust the gain by considering the long term spectrum of the incoming signal (Hickson, 1994).

Several studies have evaluated the effect of slow acting compression in speech identification. The studies are showing varied results in speech identification. Effect of release time in compression hearing aids were evaluated by Neuman, Bakke, Mackersie, Hellman and Levitt (1995). They found that longer release time (200ms and 1000ms) were more preferred by the subjects with hearing loss in high level noisy situations like cafeteria noise. But this longer release time will result in loss of information in a situation where the level of the incoming signal changes rapidly. Unfortunately this represents the real life situation. Rapid increment in the level of the incoming signal occurs when the hearing aid wearer is also included in the conversation since his/her mouth is closer to the microphone of the hearing aid than the other speakers (Dillon 2001).

Geetha & Manjula (2005) studied the effect of syllabic and dual compression on speech perception in quiet and in noise. A non linear hearing aid programmed with syllabic and dual compression. Speech Identification Scores were obtained in sound field at two different presentation levels (45 dB HL and 70 dB HL), in quiet and in the presence of noise (SNR + 10 dB). Results showed that even though there was no difference between both compressions in any of the situations, subjects showed a preference to dual compression.

Moore (2008) suggested following conclusions regarding the choice of compressions speed in hearing aids:

- The benefit from compression is greatest among individuals, who experience a wide range of sound levels within short periods of time,
- Slow compression generally leads to higher listening comfort than fast compression,
- The benefit from fast compression varies across individuals, and those with high cognitive ability are able to benefit from fast compression to take advantage of temporal dips in a background sound. It is argued that listening in the dips depends on the ability to process the temporal fine structure of sounds. It is proposed that a test of the ability to process temporal fine structure might be useful for selecting compression speed for an individual.

Moore (2011) studied relative preference for music using 3 compressor speeds (fast, medium & slow) in subjects with mild to moderate hearing loss. Medium acting compression had an attack time of 20msec and release time of 300msec in all channels. The stimulus bandwidth was 10 KHz in all cases. The stimuli used were the jazz and classical music. The effect of different compression at input levels of 50, 65 & 80 dB SPL was checked. Results suggested that at input level of 50 dB SPL, compression speed nearly had any effect on both stimuli. For 65dB SPL, subjects' preference was for slow acting compression when listening to classical music stimuli. But jazz music stimulus was not affected of compression. Effect of compression speed for pleasantness and clarity were greater for high than low input level and that, for the 80dBSPL input level, slow compression was generally preferred over fast and medium compression.

Moore et al., (2011) assessed the effect of alignment decay for the slow and fast compression system in music quality. For slow systems, alignment delays of 0, 5, 10 & 15msec were used. For fast system alignment delay was 0, 2.5, 5 & 7.5msec. Test stimuli used was percussion instrument (xylophone). Since the abrupt onset of each note played by this instrument elicit strong overshoot effects. Overall input level was 65dBSPL. Results showed that there was a trend for increased pleasantness with increasing alignment delay in fast acting compression. The preference score was almost equal for both fast and slow acting compression as alignment delay increases. But for lesser alignment delay, slow acting compression was more preferred.

Higgins, Searchfield & Coada, (2012) studied effect of fast and slow acting WDRC and adaptive dynamic range optimization (ADRO) in music perception and speech in noise perception. Two receiver-in-the-ear hearing aids were compared: one using 32-channel adaptive dynamic range optimization (ADRO) and the other wide dynamic range compression (WDRC) with dual fast (4 channel) and slow (15 channel) processing. The manufacturer's first-fit settings based on subject's audiograms were used in both cases. Results were obtained from 18 participants on a quick speech-in noise (QuickSIN) task and for 3 music listening conditions (classical, jazz, and rock). ADRO processing improved music quality and speech recognition in noise compared to the multichannel WDRC processing. The suggested reason for the better performance of the ADRO hearing aids was lesser fluctuation in output when there is a change in sound dynamics.

The influence of non-linear frequency compression on the perception of timbre and melody by adults with a moderate to severe hearing loss was studied by Uys, Pottas

& DijK (2013). Perception of timbre and melody was evaluated using Music Perception Test (MPT). 40 subjects with moderate to severe hearing loss were given digital hearing aids with and without nonlinear frequency compression. The results of the study showed a significant improvement in timbre and melody perception when subjects used digital hearing aids with nonlinear frequency compression.

Need of the Study

The primary concern in hearing aid design and fitting is the optimization for speech (Chasin & Russo 2004). The musicians using hearing aid often complain about the poor sound quality offered by the hearing aid processed music while they are playing or listening to music (Chasin 2003). Most of the strategies and technologies that are for speech in hearing aids are inadequate in handling the higher sound level inputs of music within their operating range. Advancing digital hearing aids are presently offering default music program settings. The music is having a large dynamic range and long term spectra which is poorly defined. So music stimuli reaching the hearing aid has to be compressed to avoid stimulating the wearer's loudness discomfort level. The efficiency of the default music program and the type of compression to be set while fine tuning music program need to be evaluated.

Aim of the Study

The aim of the study is to assess the effect of syllabic compression and dual compression on linear and non linear hearing aid processed music.

The objectives of the study:

- To find the perception of processed music through a hearing aid using default music program
- To find the perception of processed music stimuli using syllabic compression and dual compression
- To compare the perception of unprocessed and processed music across default music program and different compressions
- To subjectively analyze the perception of unprocessed and processed music stimuli

The current study hypothesized that there was no effect of compression on music perception.

CHAPTER 2

METHOD

To address the aim of the study, the experiment was carried out in four phases. Phase I included recording of the music stimuli. The Phase II included programming of the hearing aid. Phase III consisted recording of the hearing aid processed music samples. Phase IV included identification of processed music through a hearing aid which was programmed:

- to use default music program
- to use syllabic compression
- to use dual compression

Participants:

Fifteen normal hearing musicians in the age range of 18- 40 years was included in the study. The inclusion criteria for the musicians were as follows-

- Pure tone average of ≤ 15dBHL, that was confirmed using pure tone audiometry
- Normal middle ear function, as indicated by an 'A' type tympanogram and present acoustic reflexes, on immittance evaluation.
- No history of speech and language disorder, neurologic disorder or any cognitive deficits.
- Should have attended Indian Carnatic musical training for at least 3years/ passed junior grade of music training.

Prior written consent was taken from the participants for their willingness to participate in the study.

Instruments Used

Hearing Aids

A digital BTE hearing aid was selected with default music program setting as program 1, syllabic compression setting as program 2 and dual compression setting as program 3. The hearing aid had an option of switching of the feedback manager and noise cancellation system.

Computers, laptops and Hi-Pro: A personal computer installed with NOAH was used for programming the hearing aids. The music stimuli were recorded using omnidirectional microphone to a laptop installed with Praat Software. The recorded audio files were transferred to audio compact disc. The music was then played to the listeners through headphones from a laptop installed with Adobe Audition (Version 3).

Coupler: A 2cc coupler was used to couple with the microphone while recording the hearing aid processed music samples.

Microphone: An omnidirectional microphone will be connected to the laptop computer. This microphone was in turn attached to the coupler using 'fun tak' to record the output from the hearing aid on the Praat Software and these recordings were saved in wave format.

Music Sample: Indian Carnatic music sample was recorded on an audio compact disc. Two vocal (male & female) and instrumental music samples were used as the stimuli for recording the processed music. The music samples were based on basic ragas Shankarabarana, Hamsadhwani, Kalyani, Mohana of carnatic music. Four set of music samples were taken. Each set consisted of one aalapana from each raga to reduce the subject's familiarity with the samples. 90 second duration of the sample were selected for the purpose of evaluation.

Room Settings: Sound treated air conditioned room was selected with noise level within permissible limits according to ANSI S3.1.1991.

Procedure: For the purpose of the study, the study was divided into 4 stages:

Phase I: Recording of the music stimuli

Phase II: Programming of the hearing aid

Phase III: Recording of the hearing aid processed and unprocessed music samples

Phase IV: Identification of processed and unprocessed music samples and its subjective analysis.

Phase I: Recording of the Music Stimuli

Two professional singers and one violinist were selected to sing and play the 4 aalapanas based on the 4 basic ragas of Indian carnatic music. This was recorded using the microphone of CSL 4500 model (Kay Pentax, New Jers, USA) and these recordings were saved in .wav format. Goodness test was done to select the best music sample. The music sample was normalized using Adobe audition (version 3).

Phase II: Programming of the Hearing Aid

The hearing aids was programmed for a hypothetical flat sensorineural hearing loss with air conduction threshold being 40 dB HL at all the audiometric frequencies. A flat hearing loss was used so that the compression characteristic, when tested, remained same across all the frequencies. For programming, the digital hearing aid was connected through a Hi-Pro to the personal computer (PC) with software. After entering the hearing thresholds into the software (NOAH 3.0) the digital hearing aids was programmed based on the NAL-NL1 prescriptive procedure in the hearing aid programming software. An acclimatization level of 2 was used while programming. The program 1 of the hearing aid was programmed for the default music program offered by the company. The program 2 of the hearing aid was set for syllabic compression and program 3 for dual compression.

Phase III: Recording of Hearing Aid Processed and Unprocessed Music

The program 2 and 3 of the hearing aid were used for the comparison of the effect of syllabic compression and dual compression on processed music. The music samples were recorded with noise cancellation and feedback management systems off.

Music samples were recorded from the program 1 of the hearing aid, which has got a default music program. Music samples from each raga were recorded from the program 2 of the hearing aid, which was set for syllabic compression and program 3 set for dual compression. 1 set of music sample was recorded from the program 3 of the hearing aid. The normalized music sample was played to the programmed hearing aids from a laptop routed through an audiometer.

The original music samples were also recorded through hearing aid connected to the coupler with compression turned off. Thus, the recording of the music sample without and with compression turned on in the hearing aid was done. These four recorded set of music samples were later used for the subjective ratings and the identification of ragas used in the samples. The music samples were played using Adobe audition (version 3) software from a laptop routed through an audiometer.

The hearing aid was placed at equivalent distance of 1 m from the speaker and at 0^0 azimuths. The digital hearing aid was then connected with a HA-2 (2 cc) coupler which in turn was connected to the recording microphone of the SLM. The SLM was placed on a tripod. The recording microphone was connected to a laptop installed with Praat software for recording the hearing aid processed music sample and these recordings were saved in wave format.

In order to make the entire music samples equivalent, the original music samples were played in the same condition and were recorded through the hearing aid connected to the coupler with compression turned off to make the unprocessed music sample equivalent to the music sample processed through the hearing aids. The samples were then transferred to an audio compact disc.

Phase IV: Identification of Processed and Unprocessed Music Samples and Its Subjective Analysis

Measures of quality judgment of the music samples were obtained using five-point perceptual rating scales which is relevant to music. This is a modification of the work of Gabrielsion and Sjogren (1979) that has been used extensively in the hearing aid industry (Chasin & Russo, 2004). The participants were asked to rate the music samples on the perceptual parameters of loudness, fullness, clearness, naturalness and overall fidelity. Participants were given the following definitions of the five perceptual parameters (Chasin & Russo, 2004).

Specifically, the participants were asked to rate from 1 (poorest) to 5 (best) on the following perceptual scales: loudness, fullness, clearness, naturalness and overall fidelity. Thus, a perfect perceptual reproduction score was 25 considering all the five parameters on the scale.

The scales for rating on the five parameters will be as follows:

1. For loudness: 1 (faint)……………….5 (sufficiently loud)

2. For fullness: 1 (thin)………………….5 (full)

3. For clearness: 1 (blurred)………………5 (distinct and clear)

4. For naturalness: 1 (unnatural)……………...5 (natural)

5. For overall Fidelity: 1 (restricted)………………5 (wide and not constrained)

The recorded processed music samples were played through a headphone from a laptop installed with Adobe Audition 3.0 software.

The participants were allowed to adjust the volume to their comfortable level. The participants were asked to identify the ragas of each music samples. All the participants were made to listen to the music samples in similar conditions. A relatively quiet room away from traffic noise and other noises were selected. Each participant was made to listen to the four different set of music samples mentioned above. Each participant was provided with a response sheet (Appendix II, III, IV) to mark their response after listening to each music sample.

CHAPTER 4

RESULTS AND DISCUSSION

The study hypothesized that there was no effect of compression on music perception. To check this hypothesis the study was conducted on 15 musicians for the following:

A. Identification of hearing aid processed basic ragas of music

B. Subjective rating analysis for three different types of hearing aid processed music stimuli (vocal male, vocal female and instrumental)

C. Effect of compression on hearing aid processed music perception

A. Identification of Hearing Aid Processed Basic Ragas of Music:

Three different music stimuli were sung and played based on 4 basic ragas of Indian carnatic music (Sankarabharana, Mohana, Kalyani, and Hamsadhwani). The recorded stimuli were processed through the hearing aids with different compression setting like dual, syllabic, default music and no compression which was re-recorded. The participants were instructed to identify the ragas in each music sample. The order of presentation of the music stimuli in each type of compression was randomized in order to reduce the order effect. Different portions of the stimuli were presented at each repeated presentation of the stimuli to reduce the practice effect. The identification score of different ragas in different compression settings across the total participants are depicted in figure 1.

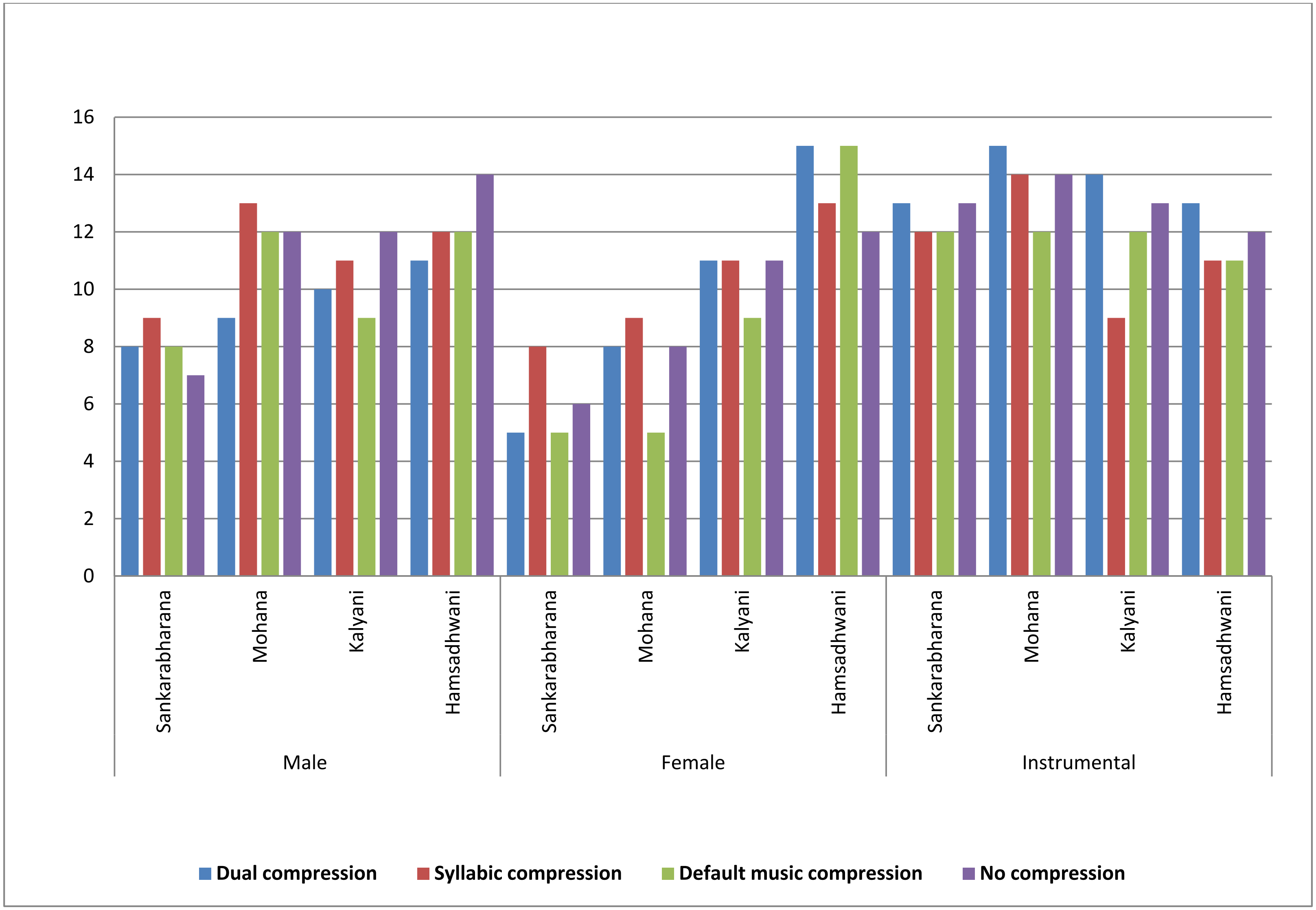

Figure 1: Identification score of different ragas for different type of stimuli in various compressions across participants

Summarizing figure 1, the highest identification of ragas was obtained for instrumental stimuli which was then followed in vocal male stimuli and least for vocal male stimuli. The instrumental stimuli were played based on a low musical scale which leads to have more low frequency content in the spectrum. The vocal male stimuli had more spectral energy towards low frequency when compared to vocal female stimuli. The possible reason for the better raga identification score for instrumental stimuli and vocal male stimuli may be because of the higher low frequency content present in them. The high frequency content of the vocal female stimuli might be out of the spectral bandwidth of the hearing aid which led to the poor raga identification scores when compared to the other two stimuli.

The statistical analysis was carried out using the R statistical software (version 2.9.1) instead of SPSS as the analysis values were binomially distributed. The effect of different compression on identification of ragas of different music stimuli was analyzed using McNemar non parametric test which is a paired version of Chi-square test.

I. Vocal Male Stimuli: All the three compression (dual, default music, syllabic compression) had no effect on four ragas of vocal male stimuli.

   a. Dual Compression: The identification of ragas was not significantly different for the dual compression in vocal male stimuli at $p>0.05$.

   b. Syllabic Compression: Results of McNemar test shows that syllabic compression has no significant effect ($p>0.05$) on identification of ragas of vocal male stimuli.

   c. Default Music Compression: The identification of ragas was not significantly different for default music compression in vocal male stimuli at $p>0.05$.

d. No Compression: The no compression had a significant effect of identification of Sankarabharana raga and Hamsadhwani raga with $\Psi^2(1) = 5.14$, $p<0.05$ in vocal male stimuli.

II. Vocal Female Stimuli: All the compression except syllabic compression had an effect on four ragas of vocal female stimuli.

a. Dual Compression: Significant effect was there on identification of Sankarabharana and Kalyani raga with $\Psi^2(1) = 4.20$, $p<0.05$; Sankarabharana and Hamsadhwani raga with $\Psi^2(1) = 8.1$, $p<0.01$; Mohana and Hamsadhwani raga with $\Psi^2(1) = 5.14$, $p<0.05$ in vocal female stimuli.

b. Syllabic Compression: There was no significant effect ($p>0.05$) on identification of ragas of vocal female stimuli.

c. Default Music Compression: There was a significant effect on identification of Sankarabharana and Hamsadhwani raga with $\Psi^2(1) = 8.1$, $p<0.01$; Mohana and Hamsadhwani raga with $\Psi^2(1)=8.1$, $p<0.01$; Kalyani and Hamsadhwani raga with $\Psi^2(1) = 4.17$, $p<0.05$ in vocal female stimuli.

d. No Compression: The identification of Sankarabharana and Hamsadhwani raga were significant with $\Psi^2(1) = 4.17$, $p< 0.05$ in vocal female stimuli.

III. Instrumental Sample: There was no significant effect of compression on identification of ragas in instrumental stimuli at significance of 0.05 levels.

The four basic ragas consist of different swaras/notes. These 7 notes represent different pitch. These frequencies of the notes may or may not fall in the frequency bandwidth of a hearing aid. Sankarabharana raga and Kalyani raga contains of all the 7 notes of classical music. The difference of Sankarabharana raga and Kalyani raga is the difference in just one swara. Sankarabharana raga contains a higher frequency swara (Ma) when compared to the same swara of Kalyani raga. Hamsadhwani (Sa Ri Ga Pa Ni) and Mohana raga contains only 5 notes (Sa Ri Ga Pa Dha) of classical music. Hamsadhwani raga contains higher pitch swara when compared to Mohana raga. This may be the possible reason for identification of Sankarabharana and Hamsadhwani raga is affected in all the type of compression.

B. Subjective Rating Analysis of Three Different Types of Hearing Aid Processed Music Stimuli (Vocal Male, Vocal Female and Instrumental)

For subjective analysis of the quality rating of the music stimuli, the three different types of music stimuli were given for 15 musicians for rating on a 5 point rating scale. The participants were asked to listen to the stimuli and rate the quality of the stimuli in terms of five parameters (loudness, fullness, clearness, naturalness, overall fidelity). The statistical analysis was carried out using the Statistical package for the Social Sciences, (SPSS version 19). Non parametric tests were used for the statistical analysis. The data in terms of five parameters were analyzed using Friedman test to check the comparison between 3 different compressions and 3 types of music stimuli. To see the pair wise comparison Wilcoxon signed rank test was used. Later the three music stimuli recorded with linear compression setting was also compared with other type of compression using Wilcoxon signed rank test.

I. <u>Comparison of Parameter of Loudness Rating Between the Different Compressions and Music Stimuli:</u>

The descriptive statistics for the loudness parameter in quality judgment in a 5 point rating scale for different compression setting in the hearing aid were obtained. The median, range and standard deviation of parameter of loudness for vocal male stimulus is depicted in the table 1.

Table 1

Median, Minimum and Maximum across stimuli for loudness parameter

Type of compression	**Vocal male**			**Vocal female**			**Instrumental**		
	Median	Min	Max	Median	Min	Max	Median	Min	Max
Dual	4	2	5	4	3	5	3	2	5
Syllabic	3	2	5	3	2	5	3	1	4
Default music	3	2	5	4	2	5	3	2	5
No compression	3	1	5	4	2	5	4	2	5

Note: Min- minimum rating, Max- maximum rating

From table 1 the following can be inferred:

i. <u>Vocal Male Stimuli</u>: From the median values for loudness parameter rating of vocal male stimulus, it was observed that the dual compression had a greater rating score. The median of loudness for syllabic compression, default music compression and the no compression settings were ranked equally.

ii. <u>Vocal Female Stimuli</u>: The median values of loudness parameter rating, the dual, default music and no compression had an equally greater rating score. The median of loudness for syllabic compression setting was ranked as the least.

iii. Instrumental Stimuli: No compression was observed to have highest rating in terms of loudness parameter for instrumental stimuli. The other three compressions provided equal median for loudness parameter.

Summarizing table 1 dual compression, default music compression and no compression provides better rating for loudness parameter in vocal female stimuli. The loudness parameter was rated least when syllabic compression was used.

II. Comparison of Parameter of Fullness Rating Between the Different Compressions and Music Stimuli:

The median, range and standard deviation of parameter of fullness for vocal male stimulus is depicted in the table 2.

Table 2

Median, Minimum and Maximum across stimuli for fullness parameter

Type of compression	**Vocal male**			**Vocal female**			**Instrumental**		
	Median	Min	Max	Median	Min	Max	Median	Min	Max
Dual	4	1	5	4	3	5	4	3	5
Syllabic	3	2	5	4	1	5	3	2	5
Default music	3	2	5	4	2	5	3	2	5
No compression	3	1	5	4	2	5	4	2	5

Note: Min- minimum rating, Max- maximum rating

From table 2 the following can be inferred:

i. Vocal Male Stimuli: From the median values for fullness parameter rating of vocal male stimulus, it was observed that the dual compression had a greater rating score. The median of fullness for syllabic compression, default music compression and the no compression settings were ranked equally.

ii. Vocal Female Stimuli: All the four compression had an equal rating score.

iii. Instrumental Stimuli: The dual compression and no compression had equally greater rating score. The median of fullness for syllabic compression, default music compression settings were ranked second equally.

Summarizing table 2 depicts that dual compression provides better rating for fullness parameter in all the three type of stimuli. The second highest rating for fullness parameter was shown by no compression followed by syllabic compression and default compression.

III. Comparison of Parameter of Clearness Rating Between the Different Compressions and Music Stimuli:

The median, range and standard deviation of parameter of clearness for vocal male stimulus is depicted in the table 3

Table 3

Median, Minimum and Maximum across stimuli for clearness parameter

Type of compression	**Vocal male**			**Vocal female**			**Instrumental**		
	Median	Min	Max	Median	Min	Max	Median	Min	Max
Dual	3	1	5	4	2	5	3	2	4
Syllabic	3	2	5	4	3	5	3	2	4
Default music	3	2	4	4	2	5	3	2	5
No compression	3	1	4	4	2	5	4	2	5

Note: Min- minimum rating, Max- maximum rating

From table 3 the following can be inferred:

i. Vocal Male Stimuli: All the four types of compression had an equally greater rating score.

ii. Vocal Female Stimuli: All the four types of compression had an equally greater rating score but the scores were greater than the clearness parameter of the vocal male stimuli.

iii. Instrumental Stimuli: The no compression had a greater rating score. The clearness parameter of instrumental stimulus for dual compression, syllabic compression and default music compression settings were ranked second equally.

Summarizing table 3 depicts that no compression provides better rating for clearness parameter in all the three type of stimuli. Three other compressions provide equal lesser rating for clearness parameter in all three types of stimuli.

IV. Comparison of Parameter of Naturalness Rating Between the Different Compressions and Music Stimuli:

The descriptive statistics for the naturalness parameter in quality judgment in a 5 point rating scale for different compression setting in the hearing aid were obtained.

Table 4

Median, Minimum and Maximum across stimuli for naturalness parameter

Type of compression	**Vocal male**			**Vocal female**			**Instrumental**		
	Median	Min	Max	Median	Min	Max	Median	Min	Max
Dual	4	2	4	4	2	5	4	3	5
Syllabic	3	1	4	3	2	5	3	2	5
Default music	3	1	5	4	2	5	4	2	5
No compression	4	1	5	4	2	5	4	2	5

Note: Min- minimum rating, Max- maximum rating

From table 4 the following can be inferred:

i. Vocal Male Stimuli: From the median values for naturalness parameter rating, it was observed that the dual compression and no compression had equally greater rating score. The naturalness parameter of vocal male stimuli for syllabic compression, default music compression settings were ranked second equally.

ii. Vocal Female Stimuli: The dual compression, default compression and no compression had equally greater rating score. The median of naturalness for syllabic compression settings was ranked least.

iii. Instrumental Stimuli: The dual compression, default compression and no compression had equally greater rating score. The median of naturalness parameter for syllabic compression settings was ranked least.

Summarizing table 4, dual compression and no compression provide better rating for naturalness parameter in all the three type of stimuli.

V. Comparison of Parameter of Overall Fidelity Rating Between the Different Compressions and Music Stimuli:

The descriptive statistics for the overall fidelity parameter in quality judgment in a 5 point rating scale for different compression setting in the hearing aid were obtained.

Table 5

Median, Minimum and Maximum across stimuli for overall fidelity parameter

Type of compression	Vocal male			Vocal female			Instrumental		
	Median	Min	Max	Median	Min	Max	Median	Min	Max
Dual	4	2	5	4	3	4	4	3	5
Syllabic	3	2	5	4	1	5	3	3	5
Default music	4	2	4	4	2	5	4	3	5
No compression	4	2	5	4	2	5	4	3	5

Note: Min- minimum rating, Max- maximum rating

From table 5 the following can be inferred:

i. Vocal Male Stimuli: The dual compression, default compression and no compression had equally greater rating score. The median of overall fidelity parameter for syllabic compression settings was ranked least.

ii. Vocal Female Stimuli: The median values for overall fidelity parameter of vocal female stimulus were similar to fullness and clearness parameter of vocal female stimulus. All the type of compressions was rated equally.

iii. Instrumental Stimuli: The median values for overall fidelity parameter of instrumental stimulus were similar to overall fidelity of vocal male stimulus. From the median values for overall fidelity parameter rating of instrumental stimulus, it was observed that the dual compression, default compression and no compression had equally greater rating score. The median of overall fidelity parameter for syllabic compression settings was ranked least.

Summarizing table 5, the rating for overall fidelity parameters of quality judgment were equally better for dual compression, default compression and no compression. Preference for syllabic compression was the least.

C. Effect of Compression on Hearing Aid Processed Music Perception

In order to compare the effect of compression on each stimulus parameter on quality judgment Friedman test had been administered. There was a significant effect seen for the compression on loudness, irrespective of the type of stimuli; for vocal male stimulus loudness Ψ^2 (3) =11.54, $p<0.01$; for vocal female stimuli loudness Ψ^2 (3) = 15.57, $p=0.001$; for instrumental stimuli loudness Ψ^2 (3) = 9.81, $p<0.05$.

The assigned ranks for each compression are depicted in the table 6.

Table 6

Friedman Test Results of Compression on Loudness Parameter of Different Type of Stimuli

Type of compression	Mean Rank		
	Vocal Male	Vocal Female	Instrumental
Dual compression	3.33	2.97	2.73
Syllabic compression	2.00	1.57	1.77
Music compression	2.33	2.63	2.57
No compression	2.33	2.83	2.93

Summarizing table 6, for vocal male and female stimuli loudness was highest for dual compression and it was followed by no compression, music compression and least for syllabic compression. In case of instrumental stimuli loudness the mean assigned rank was highest for no compression and least for syllabic compression.

Since there was a significant effect of compression on different type of stimuli loudness Wilcoxon signed ranks test had been administered.

i. Loudness Parameter:

a) Vocal male stimuli: There was a significant difference seen between syllabic and dual compression with $Z=2.27$, $p<0.05$ and also between dual and default music compression with $Z=1.99$, $p=0.05$.

b) Vocal Female Stimuli: There was a significant difference found between no compression and syllabic compression $Z=2.25$, $p=0.01$; syllabic compression and dual compression $Z= 3.20$, $p=0.001$; default music compression and syllabic compression $Z=2.49$, $p=0.01$ for vocal female stimuli loudness.

c) <u>Instrumental stimuli</u>: This was similar to that of loudness parameter of vocal female loudness. Wilcoxon signed ranks test showed significant difference between no compression and syllabic compression $Z=2.65$, $p<0.01$; syllabic compression and dual compression $Z=2.23$, $p<0.05$; default music compression and syllabic compression $Z=2.07$, $p<0.05$.

ii. <u>Other Parameters of Quality Judgment:</u> There was no significant effect seen for compression on other parameters of quality judgment like fullness, clearness, naturalness and overall fidelity of different type of stimuli at $p=0.05$.

Table 7 depicts the overall summary of the statistical analysis of the current study.

Table 7

Result of Statistical Analysis of Effect of Compression on Music Perception

Parameter	**Type of stimuli**	**Dual compression**	**Syllabic compression**	**Default music compression**	**No compression**
Loudness	Vocal Male	SD	SD	SD	SD
	Vocal Female	SD	SD	SD	SD
	Instrumental	SD	SD	SD	SD
Clearness	Vocal Male	NSD	NSD	NSD	NSD
	Vocal Female	NSD	NSD	NSD	NSD
	Instrumental	NSD	NSD	NSD	NSD
Naturalness	Vocal Male	NSD	NSD	NSD	NSD
	Vocal Female	NSD	NSD	NSD	NSD
	Instrumental	NSD	NSD	NSD	NSD
Overall Fidelity	Vocal Male	NSD	NSD	NSD	NSD
	Vocal Female	NSD	NSD	NSD	NSD
	Instrumental	NSD	NSD	NSD	NSD

Note: SD- Significantly different; NSD- Not significantly different

In the present study the compression had significant effect on loudness parameter of the music only. All the compressions had a significant effect on loudness. Loudness parameter of vocal male and female stimuli was better reproduced by dual compression and it was then equally followed by no compression and music compression. The subjective rating for loudness parameter in vocal male and female stimuli was least for syllabic compression.

Study done by Moore (2011) to check the relative preference for music using 3 compressor speeds (fast, medium & slow) in subjects with mild to moderate hearing loss also had similar results to the current study. The stimuli used were classical music. The effect of different compression was checked at input levels of 50, 65 & 80 dB SPL. For 65dB SPL, slow acting compression was more preferred for classical music stimuli.

Effect of compression speed for pleasantness and clarity were greater for high than low input level and that, for the 80dBSPL input level, slow compression was generally preferred over fast and medium compression.

Moore & Sek (2012) studied the effect of compression speed on music perception set using CAM2 and NAL NL2 fitting formula. The results of their study also are similar to that of the present study. There was a higher subject preference for slow acting compression for classical music, male speaker and female speaker. Even though the preferences varied with the level of input signal general trend was more preference seen for slow acting compression over fast and medium acting compression.

Moore et al., (2011) studies the effect of alignment decay for the slow and fast compression system in music quality. The results of their study were similar to the present study. For slow systems, alignment delays of 0, 5, 10 & 15msec were used. For fast system alignment delay was 0, 2.5, 5 & 7.5msec. Stimuli: Percussion instrument (xylophone). Since the abrupt onset of each note played by this instrument elicit strong overshoot effects. Overall input level was 65dBSPL. Results showed that there was a trend for increased pleasantness with increasing alignment delay in fast acting compression. The preference score was almost equal for both fast and slow acting compression as alignment delay increases. But for lesser alignment delay, slow acting compression was more preferred.

In case of instrumental stimuli loudness the mean assigned rank was highest for no compression. The subjective preference of other three compressions was in the order of dual, default music compression and least for syllabic compression.

The effect of different compressions is different between the vocal stimuli and the instrumental stimuli. This may be because of differences in instrumental stimuli over the other 2 vocal music stimuli. The sound production in the instrumental music sample will be from a resonance created in an entirely different hollow cavity which may have different dimensions when compared to a human vocal tract. Hence the resonance created will be in different frequencies.

The vocal music stimuli will be similar to speech in terms of long term spectrum, crest factor, differing overall intensity because this is produced by the same vocal tract which is used to produce speech. So the effect of compression on vocal music stimuli can be almost similar to its effect on speech stimuli.

CHAPTER 5

SUMMARY AND CONCLUSION

Most of the people enjoys music and consider it a very essential to enhance the quality of their life. This interest in music will not fade once they acquire hearing loss due to any of etiology. Mostly sensorineural hearing affects the different aspects of interpreting a complex tone which includes both speech and music. Hearing aid being the majorly used alternative or solution for hearing loss is optimized for speech. A hearing aid which is optimized for speech will not provide good quality for music. There are many researchers who focus on optimizing hearing aid for music also. The hearing aids which are optimized for music are automatically suitable for providing fairly good quality speech even though vice versa is not true (Chasin & Russo, 2004). This is because of the differences in the characteristics of speech and music, which includes long term spectrum, crest factor, differing overall intensities, phonetic vs. phonemic perceptual requirements of different musicians, differences in loudness summation (Chasin, 2006).

There are several literatures focusing on effect of different settings of hearing aid for music perception. Music being a stimulus with large crest factor when compared to speech there is a need to compress the music amplitude to fit into the reduced dynamic range of an individual with sensorineural hearing loss. There are hearing aid manufactures that had taken into consideration of music perception and provide a default music program in the hearing aid. However, the usefulness and the fine tuning of the compression which is set for default music program need to be studied. There is dearth in literature on hearing aid processed music sample in Indian context. Majority of studies are focused on hearing aid processed western music majorly in jazz music. The spectral content of the Indian music and the western music is different. The western music consists more of dissonance than consonance when compared to Indian music.

Therefore the present study is focused on the effect of linear and nonlinear compression in music perception and the efficacy of the default music program in music perception. This study was done in 15 normal hearing musicians. Three different type of music samples (vocal male, vocal female and instrumental stimuli) based on four basic ragas of Indian Carnatic music were recorded initially. These recorded music samples were then processed and re-recorded through a digital hearing aid with default music program setting as program, syllabic compression as program 2 and dual compression setting as program 3. The recorded music samples were also processed and re-recorded through linear compression setting by disabling the compression setting in the hearing aid. The noise cancellation and feedback manager system were disabled in order to reduce the quality reduction in music which might occur due to these systems considering music as noise. These hearing aid processed music samples were then played to the participants of the study. The participants were instructed to identify the ragas in which each of the samples are based on and to rate the quality of the music sample in terms of 5 parameter (loudness, fullness, clearness, naturalness and overall fidelity) on a five point rating scale. The participants were provided with response sheets (Appendix II, III, IV) to note down the responses.

The statistical analyses were done to compare the identification of ragas of hearing aid processed music. This was done using McNemar non parametric test. The subjective rating of quality of music processed through different programs of the hearing aid was analyzed using descriptive statistics, Friedman test. Pair wise comparison was done using Wilcoxon signed rank test.

The results of identification of raga task showed syllabic compression do not affect the identification of ragas irrespective of the type of stimuli. Dual compression and default music compression has no effect on identification of ragas of vocal male stimuli. No compression affects the identification of Sankarabharana and Hamsadhwani raga in vocal male stimuli. Except syllabic compression, other three compressions have an effect on identification on ragas in vocal female stimuli. Dual compression and music compression have greater effect than no compression on the identification of ragas of vocal female stimuli. None of the compression had an effect on identification of ragas in instrumental stimuli.

Results of subjective rating task loudness parameter of all three types of stimuli were affected by different compression. For vocal male and female stimuli loudness, highest effect was for dual compression and it was followed by no compression, music compression and least for syllabic compression. In case of instrumental stimuli loudness the mean assigned rank was highest for no compression and least for syllabic compression. None of the other parameter of quality judgment was affected by compression.

The present study is done by simulating mild to moderate SNHL. In order to generalize the results of the present study further research has to be done on other types and degrees of hearing loss since the music perception is also dependent on the type and degrees of hearing loss.

Clinical Implications:

The current study revealed the importance of need to fine tune the default music program to offer better music perception for individuals who are interested in listening to music and musicians. The parameters in the hearing aid need to be set based on individual's requirement.

Future Directions:

- The study can be conducted by changing the other parameter in hearing aid to get an optimum music perception like compression ratio, other types of compressions and prescriptive formulas.
- Objective measures can be included to check the validity of the changes made in the hearing aid to provide optimum music perception.
- Insertion gain and electro-acoustic measurements and spectral analysis can also be done to check whether the actual gain changes occurred because of different program settings assigned for music perception.
- Perception of hearing aid processed music by the non-musicians also needs to be studied.
- Effect of compression on hearing aid processed music based on other types of ragas in classical music can be studied.
- Effect of compression on other types of music like Hindustani music, Gazal music etc need to be checked.

REFERENCE:

Bregman, A. S. (1990). *Auditory Scene Analysis.* Cambridge, MA: MIT Press.

Chasin, M. (1996). *Musicians and the prevention of hearing loss*. San Diego: Singular Publishing Group.

Chasin, M. (2003). Music and hearing aids. *The Hearing Journal,* 56(7), 36-41.

Chasin, M. (2006). Hearing aids for musicians. *The Hearing Review,* 59(3), 7-11.

Chasin, M., & Russo, F. A. (2004). Hearing aids and music. *Trends in Amplification,* 8(4), 35-47.

Chowdury, S. (2008). Music perception through digital hearing aids: A comparison between gain prescription formulae. *Unpublished paper presented at International Symposium Frontiers of Research on Speech and Music.*

Cullington, H. E., & Zeng, F. G. (2011). Comparison of bimodal and bilateral cochlear implant users on speech recognition with competing talker, music perception, affective prosody discrimination and talker identification. *Ear and Hearing,* 32, 16 – 30.

Dillon, H. (2001). Hearing aids. *Sydney:* Boomerang Press.

Donnelly, P. J., & Limb, C. J. (2008). Music perception in cochlear implant users. *Peabody Conservatory of Music* (Unpublished Thesis)

Drennan, W. R., & Rubinstein, J. R. (2008). Music perception in cochlear implant users and its relationship with psychophysical capabilities. *Journal of Rehabilitation Research and Development,* 45, 779 – 89.

Dreschler, W. A. (1988). Speech intelligibility in noise with fast compression hearing aids. *Journal of Audiology, 37(3),* 127-150.

Dreschler, W. A. (1989). The effect of specific compression settings on phoneme identification in hearing impaired subjects. *Scandinavian Audiology,* 17, 35-43.

Dreschler, W. A., Eberhardt, D., & Melk, P. W. (1984). The use of single channel compression for speech intelligibility. *Scandinavian Audiology, 13*(4), 231-236.

Fabiani, M., & Friberg, A. (2011). Influence of pitch, loudness, and timbre on the perception of instrument dynamics. *Journal of the Acoustical Society of America,* 130, 193-199.

Fathima, H., & Basavaraj, V. (2010). Effect of prescriptive formulae on the perception of music in hearing aid users. Unpublished dissertation.

Franks, J. R. (1982). Judgments of hearing aid processed music. *Ear and Hearing,* 3(1), 18–23.

Franks, J. R., & Hall, T. C. (1985). Hearing aid wearers and music. *The Hearing Journal,* 38(5), 14-16.

Gabrielsson, A., & Sjogren, H. (1979). Perceived sound quality of hearing aids. *Scandinavian Audiology, 8*, 159-169.

Geetha, C., & Manjula, P. (2005). 'Effect of syllabic and dual compression on speech identification scores'. Unpublished, Department of Audiology, AIISH, Mysore.

Gennaro, S. D., & Braida, L. (1986). Multichannel syllabic compression for severely impaired listeners. *Journal of Rehabilitation Research and Development*, *23*(1), 17-24.

Gfeller, K., Turner, C., Mehr, M., Woodworth, G., Fearn R., & Knutson J. F, et al (2002). Recognition of familiar melodies by adult cochlear implant recipients and normal hearing adults. *Cochlear Implants International*. *3*, 29 – 53.

Gfeller, K., Turner, C., Oleson, J., Zhang, X., Gantz, B., Froman, R., & Olszewski, C. (2007). Accuracy of cochlear implant recipients on pitch perception, melody recognition, and speech reception in noise. *Ear and Hearing*, *28*, 412-423.

Gfeller, K., Witt, S., Adamek, M., Mehr, M., Rogers, J., Stordahl, J., et al. (2002). Effects of training on timbre recognition and appraisal by post-lingually deafened cochlear implant recipients. *Journal of American Academy of Audiology,* 13, 132 – 45.

Hickson, L. M. H. (1994). Compression amplification in hearing aids. *American Journal of Audiology, 3*, 51-63.

Higgins, P., Searchfield, G., & Coad, G. (2012). A comparison between the first-fit settings of two multichannel digital signal-processing strategies: music quality ratings and speech-in-noise scores. *American Journal of Audiology*, *21*(1), 13-21.

Hoekstra, A., Ritsma, R. J. (1977). Perceptive hearing loss and frequency selectivity. *In* E. F. Evans., J. P. Wilson (ed.), *Psychophysics and Physiology of Hearing.* London: Academic.

Johnson, W. A. (1993). Beyond AGC-O and AGC-I: Thoughts on a new default standard amplifier. *The Hearing Journa*l, 46(11), 37-42.

Jones, M. R., & Boltz, M. (1989). Dynamic attending and responses to time. *Psychological Review,* 96, 459-491.

King, A. B., & Martin, M. C. (1984). Is AGC beneficial in hearing aids? British Journal of Audiology, *18*(1), 31-38.

Kong, Y. Y., Cruz, R., Jones, J. A., & Zeng, F. G. (2004). Music perception with temporal cues in acoustic and electric hearing. *Ear and Hearing, 25,* 173–185.

Kong, Y. Y., Stickney, G. S., & Zeng, F.G., (2005). Speech and melody recognition in binaurally combined acoustic and electric hearing. *Journal of Acoustical Society of America, 117,* 1351 – 61.

Kuk, F. K. (1999). Hearing aid design considerations for optimally fitting the youngest patients. *The Hearing Journal, 52* (4), 48-55.

Levitin, D. J. (2012). What does it mean to be musical? *Neuron, 73*, 633-637.

Looi, V., McDermott, H., McKay, C., & Hickson, L. (2008). Music perception of cochlear implant users compared with that of hearing aid users. *Ear and Hearing,* 29, 421– 34.

Looi, V., & She, J. (2010). Music perception of cochlear implant users: a questionnaire, and its implications for a music training program. *International Journal Audiolology, 49*, 116 – 28.

Menon, V., & Levitin, D. J. (2005). The reward of music listening: response and physiological connectivity of the mesolimbic system. *Neuroimage, 28*, 175-184.

Mishra, S, K., Kunnathur, A., & Rajalaksmi, K. (2004). Why hearing aid and music seem to mix like oil and water ? *National Symposium on Acoustics,* Mysore.

Mishra, S. K., Kunnathur, A., & Rajalakshmi, K. (2005). Hearing aids and music: Do they mix? *Indian Speech and Hearing Association Conference,* Indore.

Mishra, S., & Abraham, A, K. (2007). Processing of music by hearing aids. *Frontiers of Research in Speech and Music,* Mysore.

Moore B. C. J. (1997). A compact disc containing simulations of hearing impairment. *British Journal of Audiology, 31*, 353-357.

Moore, B. C. J., Füllgrabe, C., & Stone, M. A. (2011). Determination of preferred parameters for multi-channel compression using individually fitted simulated hearing aids and paired comparisons. *Ear & Hearing, 32*, 556-568.

Moore, B. C. (1996). Perceptual consequences of cochlear hearing loss and their implications for the design of hearing aids. *Ear and Hearing, 17*, 133 – 61.

Moore, B. C. J. (1998). *Cochlear Hearing Loss*. London: Whurr Publishers.

Moore, B. C. J. (2008). The choice of compression speed in hearing aids: theoretical and practical considerations and the role of individual differences. *Trends in Hearing Spring, 20*, (12), 103-112.

Moore, B. C. J. (2012). Effects of bandwidth, compression speed, and gain at high frequencies on preferences for amplified music. *Trends in Amplification, 16*(3), 159- 172.

Moore, B. C. J., & Glassberg, B. R. (1988). Pitch perception and phase sensitivity for subjects with unilateral and bilateral cochlear hearing impairments. In A. Quaranta (ed.), *Clinical Audiology*, Bari, Italy: Laterza.

Moore, B. C. J., & Glassberg, B. R. (1991). Optimization of slow acting automatic gain control system for use in hearing aids. *British Journal of Audiology, 25*(3), 171 182.

Moore, B. C. J., & Peters, R. W. (1992). Pitch discrimination and phase sensitivity in young and elderly subjects and its relationship to frequency selectivity. *Journal of Acoustic Society of America, 91,* 2881-2893.

Moore, B. C. J., Peters, R. W., & Stone, M. A. (1999). Benefits of linear amplification and multichannel compression for speech comprehension in backgrounds with spectral and temporal dips. *Journal of the acoustical society of America, 105* (1), 400-411.

Moore. B. C. J., & Sek, A. (2013). Comparison of CAM2 & NAL-NL2 hearing aid fitting methods. *Ear & Hearing, 34,* (1), 83–95.

Neuman, A., Bakke, M., Mackesie, C., Hellman, S., & Levitt, H. (1995). Effect of release time in compression hearing aids: Paired-comparison judgement of quality. *Journal of the Acoustical Society of America, 98*, 3182-3187.

Plomp, R. (1970). Timbre as a multidimensional attribute of a complex tone. In: Plomp, R., Smoorenburg, G, F,eds. Frequency Analysis and Periodicity Detection in Hearing. Leiden:Sijtthoff, 397-414.

Prajna, N., & Manjula, P. (2011). '*Effect of number of channels and compression parameters in hearing aids on music perception'.* Unpublished, Department of Audiology, AIISH, Mysore.

Russo F. A., & Thompson, W. F. (2005). An interval-size illusion: The influence of timbre on the perceived size of melodic intervals. *Perception & Psychophysics. 67*, 559 568.

Russo, F. A. (2006). Perceptual Considerations in Designing and Fitting Hearing Aids for Music. *Psychology Publications and Research.* Paper 16.

Stone, M. A., & Moore, B. C. J. (2003). Effect of the speed of a single-channel dynamic range compressor on intelligibility in a competing speech task. *Journal of the Acoustical Society of America, 114*, 1023-1034.

Stone, M. A., & Moore B. C. J. (2004). Side effects of fast-acting dynamic range compression that affect intelligibility in a competing speech task. *Journal of the Acoustical Society of America, 116*, 2311-2323.

Stone, M. A., & Moore B. C. J. (2008). Effects of spectro-temporal modulation changes produced by multi-channel compression on intelligibility in a competing-speech task. *Journal of the Acoustical Society of America, 123*, 1063-1076.

Sushmith, M., & Manjula, P. (2007). '*Music processed by hearing aids*'. Unpublished, Department of Audiology, AIISH, Mysore.

Uys, M. (2011). Development of a music perception test for adult hearing-aid users. *South African Journal of Communication Disorders, 58,* 19 – 47.

Uys, M., Pottas, L., Dijk, C. V., & Vinck, B. (2013). The influence of non-linear frequency compression on the perception of timbre and melody by adults with a moderate to severe hearing loss. *Journal of Communication Disorders, Deaf Studies & Hearing Aids, 1,* 104.

van Buuren, R. A., Festen J., & Houtgast. (1996). Peaks in the frequency response of hearingaids: evaluation of the effects on speech intelligibility and sound quality. *Journal of Speech and Hearing Research, 39,* 239-250.

Walker, G., Byrne, D., & Dillon, H. (1984). The effect of multichannel compression/ expansion amplification on the intelligibility of non-sense syllables in noise. *Journal of the Acoustical Society of America, 76*(3), 746-759.

Zatorre, R. J. (2005). Music, the food of neuroscience? *Nature, 434*, 312-315.

APPENDIX I

Track No:	Description
1	Instrumental Hamsadhwani Raga
2	Instrumental Kalyani Raga
3	Instrumental Mohana Raga
4	Instrumental Sankarabharana Raga
5	Vocal Female Hamsadhwani Raga
6	Vocal Female Kalyani Raga
7	Vocal Female Mohana Raga
8	Vocal Female Sankarabharana Raga
9	Vocal Male Hamsadhwani Raga
10	Vocal Male Kalyani Raga
11	Vocal Male Mohana Raga
12	Vocal Male Sankarabharana Raga

APPENDIX II

Demographic Data:

1. Name: Phone number:
2. Age/Sex:
3. Age when you started learning music:
4. No: of years of experience:
5. Duration of training per day:
6. Duration of practice per day:
7. Have you learnt music continuously or intermittently:
8. Are you still learning music? If not, are you still in contact with music/dance?
9. What type of music did you learn? What is the duration of training for each of them?
    a)
    b)
10. Have you ever been exposed to music before training?
11. Have anyone of your family member learnt music? Who?
12. Do you learn any other performing art along with singing training?

APPENDIX III

Response Sheet II

<u>Raga Identification Task:</u>

Instructions: Music samples which are instrumental and vocal, sung by male and female will be played to you. Your task is to identify the ragas in which each sample is played and write the sample number in the appropriate column.

Ragas	Dual compression			Syllabic compression			Default Music			No compression		
	VM	VF	INST	VM	VF	INST	VM	VF	INST	VM	VF	INST
Shankarabharana												
Mohana												
Kalyani												
Hamsadhwani												

Note: VM- vocal male stimuli, VF- vocal female stimuli, INST- instrumental stimuli

APPENDIX IV

Response Sheet II:

<u>Quality Rating Task - Music:</u>

Instructions for quality rating task: Music sample will be played to you. Your task is to rate each sample in terms of loudness, fullness, clearness, naturalness, overall fidelity.

The scales for rating on the five parameters will be as follows:IV

1. For loudness: 1 (faint)……………….5 (sufficiently loud)

2. For fullness: 1 (thin)………………….5 (full)

3. For clearness: 1 (blurred)………………5 (distinct and clear)

4. For naturalness: 1 (unnatural)……………...5 (natural)

5. For overall Fidelity: 1 (restricted)………………5 (wide and not constrained)

Sample No:	Loudness			Fullness			Clearness			Naturalness			Overall Fidelity		
	M	F	INST	M	F	INST	M	F	INST	M	F	INST	M	F	INST
Practise															
Sample 1															
Sample 2															
Sample 3															
Sample 4															

Note: M- vocal male stimuli, F- vocal female stimuli, INST- instrumental stimuli, Sample 1- dual compression, Sample 2- syllabic compression, Sample 3- Default music compression, Sample 4- No compression.