EFFECT OF NUMBER OF CHANNELS AND COMPRESSION PARAMETER IN HEARING AIDS ON MUSIC PERCEPTION

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MANASAGANGOTHRI, MYSORE - 570 006

JUNE 2011

DEDICATED TO
AMMA
ANNU
RAMMU
POONI PACHI

‘Love you lots’

CERTIFICATE

This is to certify that this dissertation entitled **'Effect of Number of Channels and Compression Parameter in Hearing Aids on Music Perception'** is a bonafide work in part fulfillment for the degree of Master of Science (Audiology) of the student **Registration No.: 09AUD024**. This has been carried under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any diploma or degree.

Prof. S. R. Savithri

Director

Mysore — All India Institute of Speech & Hearing

June 2011 — Manasagangothri, Mysore-570 006

CERTIFICATE

This is to certify that this dissertation entitled **'Effect of Number of Channels and Compression Parameter in Hearing Aids on Music Perception'** has been prepared under my supervision & guidance. It is also certified that this dissertation has not been submitted earlier to any other university for the award of any diploma or degree.

Prof. P. Manjula

Guide

Professor in Audiology

All India Institute of Speech & Hearing

Mansagangothri, Mysore - 570 006

Mysore

June 2011

DECLARATION

This is to certify that this dissertation entitled '**Effect of Number of Channels and Compression Parameter in Hearing Aids on Music Perception'** is the result of my own study and has not been submitted earlier to any other university for the award of any degree or diploma.

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CHAPTER - 1

INTRODUCTION

Music is an art of arranging sounds in time so as to produce a continuous, unified, and evocative composition, as through melody, harmony, rhythm, and timbre (The American Heritage Dictionary, 2000). The common elements of music are pitch (which governs melody and harmony), rhythm (and its associated concepts tempo, meter, and articulation), dynamics, and the sonic qualities of timbre and texture.

To many people, in many cultures, music is an important part of their way of life. A sensorineural hearing loss affects perception of sound in many ways. Difficulty in perceptual analysis of complex sounds such as speech and music is one such aspect. In individuals with hearing loss, the existence of pitch anomalies, such as diplacusis and exaggerated pitch intensity effects, may affect the enjoyment of music. These are very disturbing especially when listening to live performance where the range of sound levels can be very large. Music intervals are also distorted in an ear with hearing impairment.

Hearing loss also affects timbre perception which depends on both spectral and temporal aspects of sounds. Changes in either long-term spectral shape of a sound or its temporal envelope may lead to change in perceived timbre. The aspects of timbre perception that are affected by spectral shape depend on frequency selectivity of the ear which is reduced in individuals with cochlear damage. Hence, the excitation pattern contains less information about the spectrum. This leads to reduced ability to distinguish sounds based on their spectral shape (Summers & Leek, 1994). Also the internal representation of spectral shape may be influenced by suppression which enhances the contrast between peaks and dips in the excitation pattern evoked by complex sound (Tyler & Lindblom, 1982; Moore & Glasberg, 1983). This makes it easier to pick spectral features like formants in vowel sounds. The loss of suppression associated with cochlear damage would lead to a greater difficulty in picking such features.

For many sounds such as different musical instruments, differences in spectral shape are so large that even poor frequency selectivity allows their discrimination. However, it may be more difficult for a person with reduced frequency selectivity to distinguish sounds that differ in spectrum in subtle ways.

For an individual with hearing loss who enjoys listening to music or is a professional instrumentalist or singer, the adverse effect of hearing impairment would prevent them from enjoying music. Studies on music perception in individuals with hearing impairment have shown that sensorineural hearing loss (SNHL) impairs the perception of musical elements. deLaat and Plomp (1985) found that participants with SNHL had greater difficulty recognizing a melody presented simultaneously with two other melodies than individuals with normal hearing. Santurette and Dau (2007) investigated melody recognition using different types of binaural pitches and found that listeners with hearing impairment performed poorly in melody recognition compared to listeners having normal hearing.

For individuals with hearing impairment, there are hearing aids which are devices designed to amplify the acoustic signals in such a way as to make them audible to the user. Hearing aids amplify sounds by using either analogue or digital signal processing. They can be optimized to provide specific gain at specific frequencies based on the hearing threshold at individual frequencies of its user.

The main focus of hearing aid research and development has so far been on improving the perception of speech through hearing aid. However, a hearing aid that performs well with speech signals need not necessarily perform well with music. This is because music signals are much more variable than speech, and our perception of music is more sensitive to distortion. A hearing aid that is optimally set for music can be optimally set for speech, even though the converse may not necessarily be true. (Chasin & Russo, 2004).

There are four primary physical differences between speech and music. These include the long-term spectrum, differing overall intensities, crest factors, and phonetic vs. phonemic perceptual requirements of different musicians. These serve as the basis for differing electro-acoustic settings of a hearing aid for inputs of speech and music.

Chasin and Russo (2004) defined a set of electro acoustic parameters in a hearing aid that are optimal for enjoying music. This includes 1) a sufficiently high-peak input-limiting level so that the more intense components of music are not distorted at the front-end of the hearing aid; 2) a single-channel or a multi-channel system with all channels set for similar compression ratios and knee-points; 3) an RMS detector of compression scheme with knee-point set to engage at inputs 5-8 dB higher than that for speech; and 4) disabled feedback and noise reduction circuits.

The prescriptive fitting formulae commonly used for fitting hearing aids are based on two principles, loudness normalization and loudness equalizations (Smeds & Leijon, 2001). Loudness normalization aims at amplifying the sounds in such a way that they sound as close as possible to the way in which an individual with normal hearing perceives the loudness of the same sound. Loudness equalization maximizes the speech intelligibility for every input level without exceeding the overall loudness above the overall normal loudness for speech. This is achieved by presenting all the speech bands at equal loudness. Dillon et al. (1998), and Keidser et al. (2003) found that NAL-NL1, being a fitting procedure based on loudness equalization, prescribes lesser low frequency gain than other fitting procedures based on loudness normalization such as DSL (i/o) and FIG 6. But for better appreciation of music, the lower frequencies are relatively more important. Music is generally more intense than speech, with larger peaks, greater crest factor and slightly more low-frequency and high-frequency energy content (Chasin & Russo, 2004). Hence, the present study uses the DSL (i/o) version5 prescriptive formula.

Studies have focussed on both perceptual and objective analysis of music samples in participants with normal hearing and hearing loss. These studies have included parameters such as number of channels, noise reduction and feedback cancellation circuits and compression parameters.

1.1 Need for the Study

Following the perception of speech, appreciation of music is next most commonly expressed requirement by the users of hearing aids. When individuals who enjoy listening to music acquire hearing impairment, it will have significant effect on music perception. Although there is improvement in speech perception through hearing aids, it is questionable whether a hearing aid could process music in a way so as to enable the user to hear and enjoy the music to the same extent as prior to acquiring hearing loss. The reason that persons with hearing impairment fail to perceive or appreciate the sound quality of music is because hearing loss has a differential effect on frequency selectivity, loudness perception, temporal resolution and suprathreshold performance (Chasin, 1996).

Killion (2009) concluded that hearing aids that sounded best and worst for the listeners with normal hearing were rated similarly by the listeners with hearing impairment. Previously, the use of analogue technology in hearing aids limited the options of manipulating the parameters of hearing aid to optimize it for speech or music. The advent of digital technology enables manipulation of various algorithms like noise reduction, adaptive directionality, adaptive feedback suppression and compression. It also allows for sound processing in different channels having different compression settings.

There have been studies in literature on varying different parameters of hearing aids and its effect on music perception. However, majority of these have been carried out in listeners with normal hearing by simulation of hearing loss. Also, most of the hearing aid users who enjoy music have hearing impairment with a sloping configuration. Therefore, music perception through hearing aids needs to be evaluated in individuals with hearing impairment. Further, this helps the audiologist to decide whether to choose the default music program stored in the hearing aid for listening to music (default setting for music) or to manually adjust certain parameters for better perception of music. Thus, by using a controlled study design, effect of manipulating the channel and compression parameters will be evaluated.

1.2 Aim of the Study

The present study attempts to evaluate the effect of varying the hearing aid parameters on perception of music, based on perceptual measures of music sample, in a group of participants with hearing impairment.

1.3 Objectives of the study

The specific objectives include -

a) Comparison of music perception through a hearing aid using the default setting for music vs. a high knee-point of compression, for a two channel hearing aid, in individuals with flat vs. sloping mild-moderate sensorineural hearing loss.

b) Comparison of music perception through a hearing aid using the default setting for music vs. a high knee-point of compression, for a eight channel hearing aid, in individuals with flat vs. sloping mild- moderate sensorineural hearing loss

CHAPTER - 2

REVIEW OF LITERATURE

Hearing loss impairs the perception of acoustic stimuli, be it speech or music. The primary goal of hearing aid design and fitting was optimization for speech inputs (Chasin & Russo, 2004). However, if the individual with hearing impairment is a musician or is an individual who likes to listen to music, then the impact of hearing loss on music perception needs to be given due consideration. The hearing aid fitting in such cases should incorporate optimization for both music and speech inputs (Chasin & Russo, 2004). The following section provides a brief review of literature regarding music perception by individuals with hearing loss. For easier conceptualization, the review has been divided into different headings. They include

2.1 Introduction to music

2.2 Music perception in individuals with hearing impairment

2.3 Hearing aids and music perception

2.4 Studies on music perception through hearing aids

2.1 Introduction to Music

As mentioned earlier, music is an art of arranging sounds in time so as to produce a continuous, unified, and evocative composition, as through melody, harmony, rhythm, and timbre (The American Heritage Dictionary, 2000). Music perception can be studied better by understanding the unique characteristics of music.

The physical characteristics of music:

Olson (1967) defined musical sound waves in terms of six physical variables, viz., frequency, intensity, waveform, duration, growth and decay, and vibrato.

Frequency is defined as the number of cycles occurring per unit time. The sound intensity in a specified direction is the amount of sound energy flowing through a unit area normal to that direction. The intensity, distribution and phase relations of the fundamental frequency and overtones of a complex sound wave constitute its waveform. Duration is the length of time for which a tone persists. Growth of a tone involves the time required for the tone to build up to some arbitrary fraction of its ultimate intensity whereas the time required for a tone to fall in intensity to some arbitrary fraction of the reference intensity is called the decay time. The frequency modulation of the musical tone is referred to as vibrato, which is accompanied by an amplitude modulation called the tremolo.

Psychological Characteristics of music:

Olson (1967) classified the psychological characteristics of music as tonal, dynamic, temporal and qualitative. The tonal characteristics involve pitch, timbre, melody, harmony and all forms of pitch variants. The dynamic characteristics depend upon the loudness. The temporal characteristics include time, duration, tempo, and rhythm. The qualitative characteristics include timbre or the harmonic constitution of the tone.

Russo (2006) describes the perceptual dimensions contributing to music experience. These include the relative pitch, melodic pitch relations, timbre, harmonic pitch relations, hierarchical pitch structure, intensity variations, tonality, and harmonicity.

Similarities and differences between speech and music:

Wolfe (2002) pointed out several differences between speech and music in terms of fundamental frequency, formant structure, temporal structure, silence and transient spectral details. He concluded that, in both music and speech, the perception of different sub-sets of acoustical features is categorical. However, the way in which these features are used to encode different elements of the signals in music and speech is quite different and in some ways complementary.

Fundamental frequency contributes to the pitch component of melody in music and prosody in speech. Unlike speech, fundamental frequency is categorized and precise in music. In languages without lexical tones, the fundamental frequency carries almost no information in the written text (Wolfe, 2002).

In music, frequencies remain stable for the duration of a note whereas in speech, the pitch usually changes continuously. The spectrum of music changes less and in a more regular way when compared to the speech spectrum. In music, the pitch of individual notes is relatively stable whereas in speech the pitch varies continuously. Also, the formants in speech varies from one phoneme to the next while in music, there is no much variation (Wolfe, 2002).

The temporal regularities contribute to the rhythmic component of melody in music and that of prosody in speech. Unlike speech, the rhythm is categorized and precise in music. With the exception of few vowels distinguished by being long and short, timing information or rhythm conveys little information in speech (Wolfe, 2002).

Chasin and Russo (2004) highlighted the differences between the spectral requirements for speech and music. They opined that everyday speech has a well-controlled spectrum with well-established intensity range and predictable perceptual characteristics. In speech there is usually a single sound source, i.e., the speaker. On the other hand, the spectra of music are highly variable and the perceptual requirements vary based on the musician, the type of music, and the instrument being played. Music usually requires the simultaneous processing of multiple input sources. Another difference is the differing intensity levels for speech and music. The typical levels for normal conversational speech can range from 53 to 77 dB SPL, and shouted speech can reach 83 dB SPL at the listener's ear (Chasin & Russo, 2004). For music, intensities can range from very soft sounds of 20 to 30 dB SPL to sounds exceeding 120 dB SPL. In effect, the dynamic range for music as an input to a hearing aid can be close to 100 dB, compared to 30-35 dB for speech (Chasin, 2006). The frequencies important for music perception and enjoyment encompass a much greater range than those required for speech. The ranges of fundamental frequencies are often higher for music than for speech. Speech frequencies fall within 500 to 4000 Hz, whereas the fundamental frequency can be lower than 20 Hz for a low piano tone and the upper partials of violin tones can exceed 20,000 Hz (Russo, 2006).

2.2 Music perception in individuals with hearing impairment

Franks (1982) compared the performance of listeners with normal hearing and those with mild to moderate hearing loss in judging the hearing aid processed music under conditions of extended and reduced high and low frequency ranges. He concluded that individuals with hearing impairment are unable to detect or appreciate the high frequency components of music that was processed through the hearing aids.

deLaat and Plomp (1985) studied melody recognition threshold of a short melody presented simultaneously with other two melodies, lower and higher in frequency. The threshold was defined as the frequency distance required for recognizing the test melody. The mean threshold was five semitones for individuals with normal hearing and 27 semitones for listeners with hearing impairment. They concluded that individuals with sensori-neural hearing loss had greater difficulty recognizing melodies presented simultaneously with two other melodies than did the individuals with normal hearing.

Pitch perception along with identification and segregation of melodic lines are important in music listening. Deficits in these areas may hamper the perception of music by these listeners with hearing impairment. Further, the existence of pitch anomalies such as diplacusis and impairment of temporal resolution may affect the enjoyment of music (Moore, 1995).

Santurette and Dau (2007) investigated the effects of hearing impairment on the perception of binaural pitch stimuli. The subjects included listeners with normal-hearing and those with hearing impairment. The tests administered included detection and discrimination of binaural pitch, and melody recognition using different types of binaural pitches. For the listeners with normal hearing, all types of binaural pitches could be perceived immediately and sounded musical. The listeners with hearing impairment were divided into three groups based on their results: (a) some perceived all types of binaural pitches, but with decreased musicality compared to listeners with normal hearing; (b) some could perceive only the strongest pitch types; (c) some were unable to perceive any binaural pitch at all. The performance of the listeners with hearing impairment could not be correlated with audibility. So they concluded that reduced frequency discrimination led to poorer melody recognition skills.

2.3 Hearing aids and music perception

Hearing aids are devices designed to amplify the acoustic signals in such a way as to make them audible to the user. They amplify sounds either by using an analogue or digital technology. Based on the user's hearing thresholds at individual frequencies, hearing aids can be designed to provide specific gain at specific frequencies.

Prescribing hearing aid:

There are mainly two approaches for hearing aid selection namely the prescriptive approach and the evaluative approach. A prescriptive approach to hearing aid fitting is one in which the required amplification characteristics are calculated from subject's threshold of hearing or loudness data, whereas in the evaluative approach, a number of hearing aids or response shapes are selected randomly, and then each is tested on the person with hearing impairment to find out the one that suits best (Dillon, 2001).

Most fitting strategies are based on two major objectives which are loudness normalization and loudness equalization (Smeds & Leijon, 2001). Loudness normalization aims at amplifying the sounds in such a way that they sound as close as possible to how the listener with normal hearing perceives the loudness of the same sound. This goal is achieved by comparing the loudness data of participants with hearing impairment with that of listeners with normal hearing. The aim of loudness equalization is to maximize the speech intelligibility for every input level without exceeding the overall loudness above the overall normal loudness for speech. This is achieved by presenting all the speech bands at equal loudness (Keidser & Grant, 2003).

The prescriptive procedures are based either on threshold measures or the suprathreshold measures, such as MCL. The procedures that are based on threshold measures include National Acoustic Laboratories (NAL; Byrne & Tonisson, 1976), Prescription Of Gain and Output (POGO; McCandless & Lyregaard, 1983), National Acoustic Laboratories - Revised (NAL-R; Byrne & Dillon, 1986), Prescription Of Gain and Output - II (POGO-II; Schwartz, Lyregaard, & Lundh, 1988), National Acoustic Laboratories -Revised, Profound (NAL-RP; Byrne, Parkinson, & Newell, 1991), FIG6 (Killion & Fikret-Pasa,1993), National Acoustic Laboratories Non-Linear 1 (NAL-NL1; Dillon,1999) etc. The prescriptive procedures based on supra-threshold loudness measures include, Shapiro’s method (Shapiro, 1976), Central Institute for the Deaf procedure (CID; Pascoe,1978), Loudness growth in octave bands (LGOB; Allen, Hall, & Jeng, 1990), Independent hearing aid fitting forum(IHAFF; Cox,1995; Valente & Van Vliet, 1997), Scal-Adapt (Keissling, Schubert, & Archut, 1996) etc. Desired Sensation Level input/output [DSL (i/o); Cornelisse, Seewald, & Jamieson, 1995] gives the option of basing the gain on threshold alone or on a combination of threshold and uncomfortable listening levels. Of these procedures, NAL-NL1, DSL (i/o) and FIG6 are the most commonly preferred threshold-based prescriptive procedures for non-linear hearing aids.

NAL-NL1 (Byrne & Tonisson, 1976)

NAL-NL1 is based on the rationale of loudness equalization. For deriving the gain and frequency response, NAL-NL1 uses two models. The first is a modification of Speech Intelligibility Index method to reduce the adverse effects of listening at high levels and it also considers the hearing loss desensitization which may occur in cases of dead region in the cochlea or when the degree of hearing loss is severe to profound. In these situations, NAL-NL1 prescribes lesser gain. The second model involves calculating loudness using the hearing threshold data. Here, the software calculates gain for each and every input so as to maximize speech intelligibility without exceeding the loudness more than the loudness perceived by listeners with normal hearing (Dillon, 2001).

DSL [i/o] (Cornelisse, Seewald, & Jamieson, 1995)

DSL [i/o] is based on the rationale of loudness normalization. The goal is for the listeners with hearing impairment to hear soft sounds as soft, medium sounds as comfortable and loud sounds as loud, but not uncomfortable. The method aims to fit the long-term average speech spectrum into the dynamic range of the individual with hearing impairment. The formula also incorporates the sound field-to-eardrum transfer function so that the acoustic features that are lost by placing a hearing aid in the ear are still available to the user with hearing impairment. This contributes to speech sounding more "normal" to the listener with hearing impairment. The audiologist can also enter the patient's real ear to coupler difference (RECD) or loudness discomfort levels (LDL). This is done to ensure that the hearing aid will not amplify sounds so that they are uncomfortable for the user (Cornelisse, Seewald, & Jameison, 1995). Venema (2002) did a study by programming a digital hearing aid to compare the targets of NAL-NL1 and DSL. It was found that for a flat hearing loss of 60 dB, NAL-NL1 prescribed approximately 10 dB less output than DSL for frequencies below 1000 Hz and above 4000 Hz. On the other hand, their output targets for the same hearing loss were very similar between 1000 and 4000 Hz. For sloping hearing loss, again, DSL prescribed more low-frequency output than NAL-NL1. DSL v5.0 is the most recent version of the Desired Sensation Level (DSL) method. This algorithm is referred to as DSL *m* [i/o] or the DSL multistage input-output algorithm (Scollie et al., 2005). The additional features include different targets for children and adults, correction for conductive hearing loss, channel matching to the specific instrument, support for severe/profound hearing loss, corrections for conductive loss and it supports binaural fittings.

FIG 6 (Killion & Fikret-Pasa, 1993)

FIG 6 is based on loudness normalization. In this procedure, loudness data averaged across a large number of people with similar degrees of threshold loss is used. Gain is directly prescribed for each of the input levels 40, 65 and 95 dB SPL, and is inferred for other levels by interpolation (Dillon, 2001). For low level (40 dB SPL) input signal, gain is based on the threshold of hearing. Gain is not prescribed, if the hearing threshold is 20 dB or below. If hearing loss is within 20 to 60 dB, for every one dB hearing loss, an additional one dB gain is given. For hearing loss greater than 60 dB, the gain prescribed is based on half gain rule to avoid feedback. For comfortable level (65 dB SPL) input signals, the amount of gain for any degree of loss is equal to the difference between the MCL for normal listeners and that of listeners with hearing impairment at that frequency. For high levels (95 dB SPL) of the input, gain is equal to the extra signal level needed to make the sounds equally loud as that for an individual with normal hearing (Dillon, 2001).

Proprietary fitting methods:

Proprietary fitting methods are device specific fitting algorithms to prescribe appropriate gain, frequency response and compression characteristics of hearing aids (Smeds & Leijon, 2001). Kuk and Ludvigsen (1999) reported that use of generic fitting procedures are affected by variables such as the number of channels, bandwidth of each channel, characteristics of the detector used and the time constants of the hearing aid. This problem can be overcome by developing manufacture prescribed formula based on unique characteristics of the particular hearing aid (Kuk & Ludvigsen, 1999).

Byrne (2001) examined the prescriptions of four different generic procedures including NAL-NL1 and DSL (i/o) for five different audiograms. Comparisons were made using 13 audiograms with varying degrees and configurations of hearing loss. For standardization purposes all hearing losses were considered to be sensorineural. For the flat audiograms, DSL (i/o) prescribed more low frequency gain than NAL-NL1. For the reverse sloping audiograms the NAL-NL1 prescribed more gain for the higher frequencies, while both prescribed similar gain for the mid frequencies, and DSL (i/o) prescribed more gain for the low frequencies. For the moderately sloping high frequency hearing loss, DSL (i/o) prescribed more gain at the highest frequencies (above 4000 Hz) and at the low frequencies with the mid frequencies were given approximately the same amount of gain. For the steeply sloping high frequency hearing loss DSL (i/o) prescribed more gain at the low and highest frequencies than NAL-NL1 with similar prescriptions for the mid frequencies. The NAL-NL1 assumes that prescribing gain for hearing loss exceeding 73 dB SPL will not have a positive effect on speech intelligibility and therefore, the amount of gain for those frequencies in which the hearing loss is severe or profound is reduced. The DSL (i/o) aims to normalize loudness and extend the dynamic range. Thus, it prescribes more gain for low frequencies and for high frequencies when there is a more severe hearing loss.

Thus, it can be seen that different prescriptive formulae are based on different rationales and are used to meet the needs of different type/degree of hearing loss. The present study therefore used the DSL (i/o) formula to assess the perception of music in individuals with flat and sloping hearing loss.

2.4 Studies on music perception through hearing aids:

Punch (1978) measured different frequency responses in hearing aids for 10 participants with normal hearing and 10 participants with high frequency sensorineural hearing loss, while listening to music. Preference by the individuals with hearing impairment was similar to those with normal hearing. He concluded that both the groups preferred frequency responses that had strong representation of low frequencies. This is consistent with Franks (1982), who also found preference for low frequencies in both individuals with hearing impairment and listeners with normal hearing.

Franks (1982) conducted paired comparison perception and preference judgments of hearing aid processed music in 20 participants with a mild to moderate hearing loss and 20 control subjects with normal hearing. The subjects listened to music in various conditions which included extended and reduced, high and low frequency ranges. Listeners with normal hearing reported a preference towards extended ranges for both conditions i.e., both high and low frequencies, whereas in those with a hearing loss, some indicated a preference for high-frequency ranges, while the majority demonstrated accurate perception and preference for extended lower-frequency adjustments.

According to Chasin and Russo (2004), a hearing aid optimally set for music can be optimally set for speech, even though the converse is not necessarily true. It is important to understand the programming and internal algorithm changes necessary for optimal listening to music with hearing aids. This requires the knowledge of the differences between speech and music.

Chasin (2003, 2006) has reported that speech and music differs in terms of four major factors, they are (1) the long-term spectrum of music versus speech, (2) differing overall intensities, (3) crest factors, and (4) phonetic vs. phonemic perceptual requirements of different musicians.

1) *Long-term spectrum of music vs. the long-term spectrum of speech:*

The long-term spectrum of speech is well defined and is typically language independent. In contrast, music can be derived from many sources such as the vocal tract and/or different musical instruments. Depending on the source, the music spectrum may be high- or low- frequency in emphasis. Unlike speech, music is highly variable and a 'long-term music spectrum' is ill defined.

2) Differing Overall Intensities:

At one meter, speech averages at 65 dB SPL (RMS) and comprises of peaks and valleys with a magnitude of 12-15 dB. In contrast, depending on the type of music played or listened to, various musical instruments can generate a range from very soft sounds (20-30 dB SPL) to loud sounds (in excess of 120 dB SPL). The dynamic range of music, as an input to a hearing aid, is therefore of the order of 100 dB, whereas for speech it is only 30-35 dB.

3) Crest Factors:

The crest factor is the difference in decibels between the highest peak of a waveform and its average or root mean square (RMS). The RMS value corresponds with an individual's perception of loudness. For speech, the RMS value is about 65 dB with peaks extending about 12 dB beyond the RMS level. The crest factor for speech is therefore of the order of about 12 dB. This information is used by the compression circuitry and the hearing aid test systems. Crest factor for music is of the order of about 18-20 dB. Therefore, music may cause compression systems to enter the non-linear phase at a lower intensity than would be appropriate for that individual.

4) *Phonetic verses phonemic differences:*

For speech, the long-term speech spectrum contains most of its energy in the lower frequency region and less in the higher frequency region. The clarity is derived from high- and mid- frequency regions. In contrast to speech, some of the musicians need to hear the lower-frequency sounds more than the others, regardless of the output of the instrument. For example, the clarinet and the violin both have similar energy spectra (phonetics) but dramatically differing uses of the sound (phonemics), i.e., the clarinet needs low frequency part of the spectrum and the violin requires high frequency part of the spectrum for the music perception.

Chasin and Russo (2004) defined a set of optimal electro acoustic parameters for enjoying music which included the following:

1. Having a sufficiently high peak input limiting level so that the more intense components of music are not distorted at the front end of the hearing aid.

2. Use of either a single-channel or a multi-channel hearing aid in which all channels are set for similar compression ratios and knee-points.

3. If a hearing aid uses a peak compression detector, then use an RMS detector compression scheme (similar to the speech-based compression system) with a knee-point set to engage at inputs 5-8 dB higher.

4. Disabling the feedback reduction system

5. Disabling the noise reduction circuit, although because of long attack times and a short release times, this circuitry may rarely be activated for many forms of music.

The 16 bit A/D converter used in modern digital hearing aids limits the dynamic range to about 96 dB at best. The front end of the hearing aid will be overloaded resulting in distortion of the input signal (Chasin, Lawrence, & Rewitt, 2009). This problem can be solved by the use of a microphone that is less sensitive to low frequencies. Low frequency signals would not be amplified and transduced to the ear. Intense low frequency music would not enter the hearing aid, thereby minimizing audio signals that can potentially overload the front end A/D converter. Ross (2009) suggested that in order for someone to fully hear and appreciate all the components in a musical selection, the hearing aid must be designed to deal with a dynamic range of inputs in the order of 100 dB, from about 20 to 120 dB. Moreover, unlike hearing aids designed to maximize speech perception by emphasizing the higher frequencies, in music it is the lower frequencies that are more important. Also, the hearing aid must be able to amplify the lower frequencies without exceeding the capacity of the analog-to-digital (A/D) converter found in all digital hearing aids. These studies illustrate that the requirement of a hearing aid user is different while listening to speech as compared to that while listening to music.

2.4.1 Perceptual Studies on music perception with hearing aids

Looi, McDermott, McKay, and Hickson (2008) conducted a study comparing the quality ratings by cochlear implant and hearing aid users in response to musical sounds. Single instruments, solo instruments with background accompaniment and ensembles were used as the musical stimuli. The participants were asked to provide a rating out of ten, according to how pleasant each extract sounded, with 10 being very pleasant and zero being very unpleasant. Neither device enabled highly satisfactory music appreciation, though the users with cochlear implant judged the music to be more pleasant than the users with hearing aid. Also, music that involved multiple instruments was judged as less pleasant than that involving single instrument by both the subject groups.

Russo (2006) provided a selective overview of the perceptual dimensions contributing to music experience that may have implications for management of hearing loss. He postulated that music listeners having high frequency hearing loss may experience some benefit by transposing recorded music into lower registers. Spectral enhancement may reduce the effects of reduced frequency selectivity. With recorded music, presentation by headphone will preserve phase relationships, which can contribute to relative pitch perception. With live music, FM systems may also be of some benefit. An optimally placed microphone can compensate for numerous problems including sensitivity to noise, high-frequency losses, as well as reduced frequency selectivity.

On perceptual analysis of music samples (classical and hard rock), in participants with normal hearing, Mishra, Kunnathur, and Rajalakshmi (2004) reported significantly low scores for music processed through hearing aids for both music samples across all hearing aids. Further, in another study by them in 2005, they recommended the use of multichannel hearing aid programmed as single or double channel for better music perception. They also advocated switching-off of the noise reduction and feedback cancellation.

Mishra and Manjula (2007) compared the perception of music processed by a hearing aid with fifteen channels with that of six channels, with and without the noise reduction and feedback management. The music processed by hearing aid was recorded and played to listeners with normal hearing. The listeners were asked to rate the quality of music on a five-point rating scale. The results showed that music processed by a fifteen channel hearing aid was rated to be better than that of a six channel hearing aid. It was also found that the music processed by hearing aids was rated to be better when the feedback management and noise reduction were turned-off. This was due to the fact that if the feedback management and noise reduction system were switched-on, then the hearing aid would interpret the low frequency/feedback related sounds as noise / feedback and reduce it.

Killion (2009) examined the relationship between speech perception and quality of music, for both individuals with normal hearing and those with hearing loss, as heard through hearing aids. The results indicated that fidelity ratings varied considerably for seven different aids, with the highest scores obtained in the "open-ear" condition (no aid) and with the Digi-K (hearing aid circuit developed by the author). He also concluded that both the groups rated the fidelity of all the aids to be similar; i.e., hearing aids that sounded best and worst for individuals with normal hearing were rated similarly by the subjects with hearing impairment. In his opinion, the key factor was the quality of the reproduction through the hearing aid, and not whether it was a person with hearing impairment or an individual with normal hearing. In another component of the same study, he compared the speech perception scores in noise obtained by 26 participants with hearing impairment with these seven different digital aids to the fidelity ratings that individuals with normal hearing gave to the aids. He found an orderly relationship between the fidelity ratings given to the various hearing aids by the individuals with normal hearing and the ability of the users of hearing aid to understand speech in noise. The aids judged to reproduce music with the highest fidelity were also the ones with which hearing aid users understood speech the best.

2.4.2 Effect of prescriptive formulae on music perception:

In a study done by Chowdhury (2008), the music perception through digital hearing aids was studied by comparing the subjective preference for two non-linear hearing aid gain prescriptive formulae. A digital hearing aid was programmed with NAL-NL1 and DSL (i/o) curvilinear gain prescription formulae. The music processed by hearing aid was recorded on to a computer and played to 15 Carnatic musicians with normal hearing and five listeners with hearing loss. There was a discrepancy for the normal group in the preference for a particular hearing aid gain formula, though higher scores were obtained for NAL-NL1. All the subjects with hearing loss preferred the hearing aid programmed with DSL (i/o) formula for listening to music.

The effect of different prescriptive fitting formulae (NAL-NL1, DSL (i/o) and FIG 6) on music perception in adult hearing aid users with moderate to moderately-severe sensorineural hearing loss was investigated by Fathima and Basavaraj (2010). They obtained both perceptual and objective measures in four listening conditions. They found that in the aided condition, FIG6 and DSL (i/o) prescriptive formulae to be better than NAL-NL1 for the rating of clarity, melody, rhythm and naturalness of vocal music and clarity, rhythm and naturalness of violin music. Based on these studies, the present study uses the DSL (i/o) prescriptive formula.

To summarize the review, speech and music have similarities as well as differences in their physical and perceptual characteristics. This, in turn, leads to the differences in the ways in which a hearing aid processes speech and music. The ideal hearing aid settings for speech may not always give good results with music. Therefore, music perception through hearing aids needs to be evaluated in individuals with hearing impairment. Further, this helps the audiologist to decide whether to choose the default music program stored in the hearing aid or manually adjust certain parameters to perceive the music better. Thus, by using a controlled experimental study design, the effect of manipulating the channel and compression parameter is being evaluated in the present study.

CHAPTER - 3

METHOD

The main aim of the study was comparison of music perception through two and eight channel digital hearing aids. This was done using the default compression knee-point setting for music and a high knee-point of compression in individuals with mild to moderate flat and sloping sensorineural hearing loss.

3.1 Participants

A total of 24 participants were a part of this study. The age of the participants ranged from 39 to 59 years (Mean = 48.3, SD = 6.38). They were divided into two groups. Group I consisted of twelve participants who were non-musicians. They had mild to moderate flat sensorineural hearing loss in the test ear which was the better ear. Flat configuration of hearing loss being operationally defined as the difference between the least and the highest air-conduction threshold of the test ear being less than 20 dB from 250 to 8000Hz (Pittman & Stelmachowicz, 2003). Group II consisted of twelve participants who were non-musicians with sloping sensorineural hearing loss in the test ear which was the better ear. Sloping configuration of hearing loss being operationally defined as the air-conduction thresholds occurring at successively higher levels from 250 to 8000Hz and air-conduction threshold at 250 and 8000 Hz differing by 20 dB or more. (Pittman & Stelmachowicz, 2003). All the participants had post-lingually acquired hearing loss. History of otologic, cognitive or neurological problems was ruled out. All the participants had speech identification scores (SIS) of at least 80% on phonemically balanced bi-syllabic word list in Kannada (Yathiraj & Vijayalakshmi, 2005).

3.2 Instrumentation

The following instruments were used to collect the data:

a) A calibrated two-channel clinical audiometer Madsen OB-922 (version 2), with TDH-39 headphones housed in Mx-41/AR ear cushions, was used for obtaining behavioural air-conduction thresholds, for speech audiometry and for delivering the test stimulus during the unaided and aided testing. Radio ear B-71 bone vibrator of the audiometer was used for obtaining the bone-conduction thresholds during unaided testing. A loudspeaker (Martin Audio, C115) placed at 45 degree azimuth and at one meter distance from the participants aided ear was used for presenting the music perception test battery during the aided testing.

b) A calibrated middle ear analyzer, Grason-Stadler TympStar (version-2) was used to assess the middle ear functioning of the participants and to rule out retrocochlear pathology.

c) Two digital behind the ear (BTE) hearing aids were used. These hearing aids differed in terms of the number of channels, two and eight, but incorporated similar signal processing strategy. These hearing aids had the option of switching 'off' of noise cancellation and feedback management systems. They incorporated wide dynamic range compression.

d) A personal computer with NOAH software, connected to HiPro was used to program the hearing aid.

3.3 Test Environment - All the tests were carried out in an air–conditioned, sound treated double room suite. The ambient noise levels were within permissible limits.

3.4 Test Stimuli

Stimuli from the Music Perception Test Battery (MPTB) (Das & Manjula, 2010) were used to evaluate the efficacy of hearing aid for processing the music. The CD form of the Music Perception Test Battery (MPTB) included the following tests –

a) Pitch discrimination: Pairs of musical notes recorded from the harmonium was used for the pitch discrimination task. There were four pairs of ‘sa’ notes, each note having either high or low pitch. Within each pair, there was a silence interval of two seconds. The following table (Table 3.1) is the response sheet for this task.

Table 3.1

Response Sheet for Pitch Discrimination Task

Items	*Same*	*Different*
Practice 1		
Practice 2		
Test1		
Test2		
Test 3		
Test 4		
Test 5		
Test 6		
Test 7		
Test 8		
Test 9		
Test 10		

b) Pitch ranking: Pair of recorded musical notes was used for the pitch ranking task. The notes consisted of sustained phonation of the vowel /a/ by a trained female and male singer at different notes. The duration of each note was three seconds and the gap between the pair was five seconds. This test was further divided into three sub-tests. Each sub-test had two practice items and six test items. In sub-test A, the two notes were separated by an interval of one octave; in sub-test B, the two notes were separated by an interval of half-octave, and in sub-test C, the two notes were separated by an interval of quarter octave. Table 3.2 shows the response sheet used for this task.

Table 3.2

Response Sheet for Pitch Ranking Task

A			*B*			*C*		
Items	*First note is high*	*Second note is high*	*Items*	*First note is high*	*Second note is high*	*Items*	*First note is high*	*Second note is high*
Practice 1			Practice 1			Practice 1		
Practice 2			Practice 2			Practice 2		
Test1			Test 1			Test 1		
Test 2			Test 2			Test 2		
Test 3			Test 3			Test 3		
Test 4			Test 4			Test 4		
Test 5			Test 5			Test 5		
Test 6			Test 6			Test 6		

c) Melody recognition: A list of five recorded melodies played on the violin was presented to the participants; one melody played at a time. There were 12 items, two practice items and ten test items. The melodies included were ‘Saare jahaan se achha’, ‘Vande maataram’, ‘Hum honge kaamyab’, Raghupati raaghav rajaram ’ and ‘Ae maalik tere bande hum’. Table 3.3 shows the response sheet that was used in this task.

Table 3.3

Response Sheet for Melody Recognition Task

Melody names	*Practice items*		*Test items*									
	1	2	1	2	3	4	5	6	7	8	9	10
Saare jahaan se achha												
Vande maataram’												
Hum honge kaamyab’												
Raghupati raaghav rajaram												
Ae maalik tere bande hum’												

d) Rhythm discrimination: A recorded pair of rhythm excerpts composed on a tabla served as the stimuli for this task. There were five different rhythms of 15 seconds duration each. Between the two rhythm excerpts, there was a gap of five seconds. Table 3.4 shows the response sheet used for the task.

Table 3.4

Response Sheet for Rhythm Discrimination Task

Item	*Same*	*Different*
Practice 1		
Practice 2		
Test 1		
Test 2		
Test 3		
Test 4		
Test 5		
Test 6		
Test 7		
Test 8		
Test 9		
Test 10		

e) Instrument identification: This test had two sub-tests. The first sub-test was single instrument identification task which consisted of identification of ten musical instruments. There were 12 items, two practice items and ten test items. Table 3.5 shows the response sheet used for this sub-test.

Table 3.5

Response Sheet for Single Instrument Task

Item	Flute 	Violin 	Tabla 	Jaltarang 	Harmonium 	Nadaswara 	Dhol 	Veena 	Mridangam 	Sitar 
Practice 1										
Practice 2										
Test 1										
Test 2										
Test 3										
Test 4										
Test 5										
Test 6										
Test 7										
Test 8										
Test 9										
Test 10										

The other sub-test was music ensemble identification task, which consisted of identification of ten music instrumental duets. There were 12 items, two practice items and ten test items. Table 3.6 shows the response sheet used for this sub-test.

Table 3.6

Response Sheet for Music Ensemble Identification Task

Item	Flute 	Violin 	Tabla 	Jaltarang 	Harmonium 	Nadaswara 	Dhol 	Veena 	Mridangam 	Sitar 
Practice 1										
Practice 2										
Test 1										
Test 2										
Test 3										
Test 4										
Test 5										
Test 6										
Test 7										
Test 8										
Test 9										
Test 10										

3.5 Procedure

Testing involved two phases. In Phase I, tests were carried out in order to select the participants for the study. Phase II involved collection of data for the purpose of verifying the objectives of the study.

Phase I: The following audiological tests were carried out for participant selection.

1.1 *Case history:* A detailed case history was taken to confirm if the participants met the inclusion criteria. Music training and experience questionnaire (adapted from Looi, 2008) (Given in Appendix A) was administered to evaluate the competency of the participant in music. Only the participants who had knowledge of the instruments and melodies used in MPTB but without professional music training were considered for the study. The music training and experience questionnaire consisted of six questions. The first four questions were intended to seek information regarding areas in which musical training has been taken, i.e., formal training in vocal and / or instrument/instruments. The fifth question probed regarding the duration of listening to music on an everyday basis. The sixth question probed proficiency in five skills related to music using a five-point rating scale. A cut-off criterion of 15 out of the maximum score of 25 was followed in order to consider a participant as 'experienced' in music (Looi, 2008). For the purpose of this study, a participant was considered as being 'inexperienced' in music if he/she obtained a cut-off score of less than 15 out of the maximum score of 25.

1.2 *Pure tone audiometry:* Pure tone audiometry was done at octave frequencies from 250 Hz to 8 kHz for air-conduction stimuli and from 250 Hz to 4 kHz for bone-conduction stimuli. The testing was done using a calibrated dual channel audiometer. Air-conduction stimuli were presented through a calibrated head phone and bone-conduction stimuli were presented through a calibrated bone vibrator. The testing was done using the modified Hughson-Westlake procedure (Carhart & Jerger, 1959) with + 5 and – 10 dB step-size.

1.3 *Speech audiometry:* Speech Identification Score (SIS) was established by presenting the speech identification test material (Yathiraj & Vijayalaksmi, 2005) at a level of 40 dB SL (re: SRT). The participant was instructed to repeat the words heard. The total number of correctly identified words was noted down to represent the SIS. Maximum SIS was 100% (25/25) as the PB list consisted of 25 words.

1.4 *Uncomfortable loudness level:* The speech stimulus was presented through head phones at a comfortable loudness level. The intensity of the stimulus was increased gradually. The participant was asked to indicate when the experience of loudness became uncomfortable. This test was repeated once to check for reliability. The level at which the participant reported that the loudness of speech became uncomfortably loud was taken as the uncomfortable loudness level (UCL) for that participant.

1.5 *Immittance evaluation:* Tympanometry was done with a probe tone frequency of 226 Hz (Brooks, 1968; Holte, Margolis, & Cavanaugh, 1991) at 85 dB SPL. Reflexometry was done at 500 Hz, 1 kHz, 2 kHz and 4 kHz, with ipsilateral as well as contralateral modes of stimulation. This was done to rule out middle ear and retrocochlear pathology in the participants.

Phase II: In this phase, two digital behind the ear hearing aids were programmed for each participant. Then, the Music Perception Test Battery was administered.

2.1 Programming of the hearing aid

The participants were fitted with the two/eight channel digital behind the ear hearing aid. The hearing aid was connected to HiPro which in turn was connected to a PC with NOAH and the hearing aid software for programming. The hearing thresholds were entered and the hearing aid was programmed using DSL (i/o) v.5 prescriptive formula with acclimatization level of 2. This prescriptive formula was used as it provides slightly higher gain in the low frequencies when compared to other formulae as it aims to normalize loudness and extend the dynamic range (Byrne, 2001). This improves the perception of music in terms of quality. Also, in an unpublished study done by Chowdhury (2008), participants with hearing loss preferred the hearing aid programmed with DSL (i/o) curvilinear formula for listening to music than NAL-NL1. DSL (i/o) formula was also ranked higher by adult hearing aid users with moderate to moderately-severe sensorineural hearing loss than FIG6 and NAL-NL1 for clarity, melody, and naturalness of the music sample (Fathima & Basavaraj, 2010). Only the knee-point of compression was manipulated and all other parameters were kept constant between the two settings (default vs. high knee-point).

The Music Perception Test Battery was administered in the following settings.

- Two channel digital hearing aid programmed for two settings/programs
    - with default settings for music
    - with high compression knee-point as was permissible

- Eight channel digital hearing aid programmed for two settings/programs:
    - with default settings for music
    - with high compression knee-point as was permissible

2.2 Presentation of the music

A laptop was used to play the music of the MPTB which was recorded on the CD. This was routed to the loudspeaker through the auxilliary input of the audiometer. The loudspeaker was located at 45 degree azimuth and at one meter distance from the aided ear of the participant. The presentation level of the music was set to 45 dBHL for all participants. The music sample was presented to the participant fitted with the two hearing aids programmed for two settings (default vs. high knee-point). The hearing aids and the settings were randomly selected so that the participant was not aware of the number of channels in hearing aid or the settings within a particular hearing aid. The stimuli from the music perception test battery were also randomized to prevent practice effect.

Before administrating the music perception test battery, a response sheet was given to each of the participant. Each of the above tests was administered on all the participants. Scoring was done separately for each hearing aid by adding the scores from each sub-test.

2.3 Instructions for Administration of Music Perception Test Battery

a) Pitch discrimination: A pair of musical notes, i.e., /sa/ note at low pitch and /sa/ note at high pitch, was played. The task was to indicate whether the given stimuli had “same” or “different” notes or pitches. There were 12 pairs of notes, two practice items and ten test items. For each of the two conditions (default knee-point of compression vs. high knee-point of compression) five test items were presented randomly.

b) Pitch ranking: In this test, the participant was presented with a pair of musical (vocal) notes in differing pitches. The task of the participant was to identify the higher note of each stimuli pair. There were three sub-tests; Subtest-A, which consisted of stimuli pairs having a difference of one octave between the two notes in a given pair. Likewise, Subtests-B and C consisted of stimuli pairs with half octave and quarter octave intervals between the two notes in a given stimulus pair respectively. Three items were presented randomly for each sub-test for each of the two heaing aid settings.

c) Rhythm discrimination test: In this test, the participant was presented with a pair of rhythm excerpts. The task of the participant was to discriminate whether the pair of excerpts was "same" or "different". There were 12 pairs of notes, two practice items and ten test items. For each of the two settings (default knee-point of compression vs. high knee-point of compression), five test items were presented randomly.

d) Melody recognition test: In this test, the participant was presented with a melody played on a violin, one at a time. The task of the participant was to identify (name or hum) the melody perceived following presentation of each test stimuli. There were 12 melodies which included two practice items and ten test items. For each of the two hearing aid settings (default knee-point of compression vs. high knee-point of compression), five melodies were presented randomly.

e) Instrument identification test: In this test, the participant was presented with a musical piece of an instrument/s at a time. The task of the participant was to identify the instrument or instruments, present in a given test stimulus. This test comprised of two sub-tests**,** single instrument identification sub-test and music ensemble sub-test. In each of the two sub-tests, five items were presented in each of the two settings.

2.4 Scoring for music perception test battery

a) Pitch discrimination task: For each item, a score of ‘1’ was given for every correct discrimination and a score of ‘0’ for every incorrect or no response. Maximum score for this test was five for each of the two aided settings with each hearing aid.

b) Pitch ranking task: In each item of the sub-test, a score of ‘1’ was given for every correct ranking and a score of ‘0’ for every incorrect or no response. Maximum score for this test was nine (3 sub-tests * 3).for each of the two aided settings with each of the two hearing aids

c) Rhythm discrimination task: For each item, a score of ‘1’ was given for every correct discrimination and a score of ‘0’ for every incorrect or no response. Maximum score for this test was five for each of the two aided settings with each hearing aid.

d) Melody recognition task: For each item, a score of ‘1’ was given for every correct recognition of melody and a score of ‘0’ for every incorrect or no response. Maximum score for this test was five for each of the two aided settings with each hearing aid.

e) Instrument identification task: In each sub-test, for each item, a score of ‘1’ was given for every correct instrument identification and a score of ‘0’ for every incorrect or no response. Maximum score for this test was five for each of the two aided settings with each hearing aid.

The MPTB was administered for each participant from Groups I and II.

In addition to the administration of the MPTB, in the two aided settings, with each of the two hearing aids, subjective analysis was done using a five-point perceptual rating scale for quality which is a modification of the scale given by Gabrielsson et al. (1979) and used by Chasin and Russo (2004). The participant was asked to rate from 1 (poorest) to 5 (best) on five perceptual parameters. A perfect perceptual reproduction of music through the hearing aid would get a maximum score of 25 points i.e., a maximum rating of 5*5 parameters.

The participants were given the following definitions of the five perceptual parameters:

1. *Loudness:* the music is sufficiently loud, in contrast to soft or faint
2. *Fullness:* the music is full, in contrast to thin
3. *Clearness:* the music is clear and distinct, in contrast to blurred, and diffuse
4. *Naturalness:* the music seems to be as if there is no hearing aid, and the music sounds as “I remember it”
5. *Overall Fidelity:* the reproduction of sound with little distortion, giving a result very similar to the original.

2.5 Determining subjective preference

After listening and rating the music sample, the participant was asked to rate each of the aided condition in terms of their overall preference in listening to music. The participant had to choose between a two vs. eight channel hearing aid. Later, with the best hearing aid they had to choose between the default vs. high knee-point setting. This procedure was followed for each of the participant in Groups I and II.

2.6 Statistical Analysis

At the end of data collection, appropriate statistical procedures were used to obtain different statistical measures for the data from the participants. The mean and standard deviation of the scores on the MPTB and the perceptual quality rating of loudness, fullness, clearness, naturalness and overall fidelity of music were obtained. This was done for two channel vs. eight channel, as well as the two conditions of default vs. high compression knee-point. The scores obtained using the MPTB and perceptual quality rating for the two hearing aids programmed for the two settings were also compared for significance of difference, if any.

Chapter - 4

RESULTS AND DISCUSSION

The objectives of the present study were to compare the music perception through a two vs. an eight channel hearing aid using the 'default setting for music' vs. a 'high knee-point of compression'. This was done in individuals with flat vs. sloping mild-moderate sensorineural hearing loss. The evaluation was carried out using the music perception test battery (MPTB) and a perceptual rating scale.

The statistical analysis was done using Statistical Package for Social Sciences (SPSS, version 18). There were three independent variables i.e., two groups of participants (flat vs. sloping hearing loss); two hearing aids with different number of channels (two vs. eight) and two settings within each of the two hearing aids (default vs. high knee-point of compression setting). The dependent variables were the performance of the participants on MPTB and the rating given by the participants on the five-point perceptual rating scale.

The following statistical analyses were carried out:

a) *Descriptive analysis for all the parameters:* Mean and standard deviation values for the scores on the music perception test battery and for the parameters on the perceptual rating scale, for the participants in both the groups.

b) *Analysis of variance:*

   - Mixed Analysis of Variance, two-way repeated measures ANOVA to find out the overall interaction with settings (default vs. high knee-point) and hearing aids (two vs. eight channels) as the within subject factors and groups (flat vs. sloping) as the between subject factor.

- Multivariate analysis of variance (MANOVA) was carried out to compare between the two groups (flat vs. sloping).
- Paired t-test was carried out to compare between the hearing aid settings (default vs. high knee-point) and the hearing aid channels (two vs. eight).

c) *Non-parametric analysis:* Mann-Whitney U test was carried out to compare between the two groups of participants on the five-point perceptual rating scale. This was done due to the ordinal nature of the data. This was also preferred for the pitch ranking sub-test of the music perception battery. Wilcoxon Signed-Rank test was done for pair-wise comparison for the settings and channels.

The results will be discussed based on the performance on the Music Perception Test Battery (MPTB) for each sub-test as well as the rating on the five-point perceptual rating scale.

4.1 Performance on the Music Perception Test Battery

The results of various parameters on MPTB are given below. The relevant discussion of the results is done at the end of this chapter.

4.1.1 Pitch Discrimination Test

The mean and standard deviation (SD) of the pitch discrimination scores (Maximum score = 5), for each setting of the two hearing aids, for the two groups (flat vs. sloping) of participants is given in Table 4.1.1. Figure 4.1.1 depicts the performance of the two groups on the pitch discrimination task for the two hearing aids and the two settings within each hearing aid.

Table 4.1.1.
Mean and Standard deviation (SD) values of the pitch discrimination scores in the two groups of participants

Groups	*Hearing aids*	*Settings*	*Pitch discrimination scores*	
			Mean (Max=5)	*SD*
Flat configuration (N=12)	2 channel	Default setting	4.42	0.90
		High knee-point of compression	4.92	0.29
	8 channel	Default setting	4.50	0.79
		High knee-point of compression	5.00	0.00
Sloping configuration (N=12)	2 channel	Default setting	4.92	0.29
		High knee-point of compression	5.00	0.00
	8 channel	Default setting	4.92	0.29
		High knee-point of compression	5.00	0.00

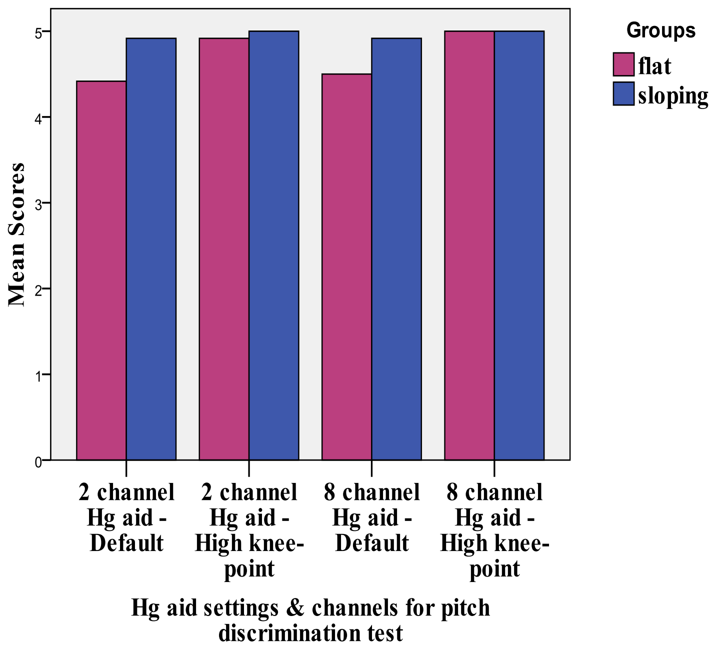

Figure 4.1.1: Performance of the two groups on the pitch discrimination task for the two hearing aids and the two settings within each hearing aid.

From Table 4.1.1 and Figure 4.1.1, it can be seen that the mean score was good on pitch discrimination task for the two groups, two hearing aids and two settings, except for slight differences. To see if these differences were significant, two-way repeated measures analysis of variance (ANOVA) was performed. This test did not reveal interaction effect between hearing aid and groups [$F(1,22)=1, p>0.05$)]; settings and groups [$F(1,22)=3.31$, $p>0.05$] ; hearing aid and settings [$F(1,22)=1$, $p>0.05$]; and hearing aids, settings and groups [$F(1,22)=0, p>0.05$].

Further, the two-way repeated measures ANOVA showed no significant difference between the participants with flat and sloping configuration of audiograms [$F(1, 22) = 3.35$, $p>0.05$] and also between the two channel and eight channel hearing aids [$F(1, 22) = 1$, $p>0.05$]. However, there was a significant difference between the hearing aid at default setting and the setting with high knee-point of compression [$F(1, 22) = 6.49$, $p<0.05$], with the performance being better when the knee-point of compression was high.

Paired samples t-test revealed significant differences between the default and the high knee-point of compression, for both the two and the eight channel hearing aid ($p<0.05$), with the performance being better in the high knee-point of compression setting.

4.1.2 Rhythm discrimination test

The mean and standard deviation (SD) of the rhythm discrimination scores (Maximum score = 5) for each setting of the hearing aid among the two groups (flat vs. sloping) of participants is given in Table 4.1.2. Figure 4.1.2 depicts the performance of the two groups on the rhythm discrimination task for the two hearing aids at two settings within each hearing aid.

Table 4.1.2
Mean and standard (SD) values of the rhythm discrimination scores in the two groups of participants

Groups	*Hearing aids*	*Settings*	*Rhythm discrimination scores*	
			Mean (Max=5)	*SD*
Flat configuration (N=12)	2 channel	Default setting	2.42	0.90
		High knee-point of compression	3.92	1.08
	8 channel	Default setting	3.08	0.90
		High knee-point of compression	4.25	1.21
Sloping configuration (N=12)	2 channel	Default setting	3.50	1.11
		High knee-point of compression	3.83	1.11
	8 channel	Default setting	3.83	1.11
		High knee-point of compression	4.00	1.04

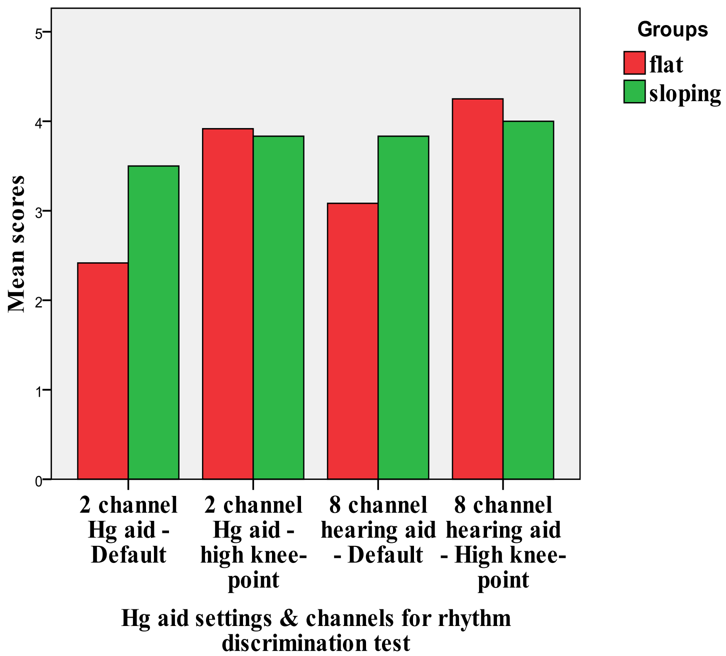

Figure 4.1.2: Performance of the two groups on the rhythm discrimination task for the two hearing aids and the two settings within each hearing aid.

From Table 4.1.2 and Figure 4.1.2, it can be seen that the mean scores were better for high knee-point of compression setting on rhythm discrimination task for the two groups and two hearing aids. Both the groups (flat and sloping) achieved better mean scores with the eight channel hearing aid for this task. To see if these differences were significant, two-way repeated measures analysis of variance (ANOVA) was performed.

On two-way repeated measures ANOVA, it was found that there was no significant interaction between the hearing aids and groups [$F(1, 22) = 0.6$, $p>0.05$]; between settings and hearing aids [$F(1, 22) = 1.02$, $p>0.05$]; and between hearing aids, settings and groups [$F(1, 22) = 0.11$, $p>0.05$]. However, significant interaction was observed between the settings and groups [$F(1, 22) = 16.45$, $p<0.05$]

Further, the two-way repeated measures ANOVA showed no significant difference between the participants with flat and sloping configuration of audiograms [$F(1, 22) = 1.06$, $p>0.05$]. There was a significant difference between the hearing aid settings (default vs. high knee-point) [$F(1, 22) = 35.14$, $p<0.05$]; between the two channel and eight channel hearing aids [$F(1, 22) = 5.4$, $p<0.05$].

Further, analysis using MANOVA was carried out to see if there was any significant difference between the two groups. The results showed significant difference ($p<0.05$) between the two groups for the default condition on this task. As there was a significant difference between the two groups, paired t-test was done separately for both the groups.

The paired t-test for participants with flat configuration of hearing loss revealed significant differences ($p<0.05$) between the hearing aid settings (default vs. high knee-point of compression) for both the hearing aids (two vs. eight channels); with the performance being better when the knee-point of compression was high. No significant difference was seen between the channels. For participants with sloping configuration of hearing loss, paired t-test revealed no significant differences ($p>0.05$) between the hearing aid settings (default vs. high knee-point of compression) for both the hearing aids (two vs. eight channels).

4.1.3 Melody recognition test

The mean and standard deviation (SD) of the melody recognition scores (Maximum score = 5) for each setting of the hearing aid for the two groups (flat vs. sloping) of participants is given in Table 4.1.3. Figure 4.1.3 depicts the performance of the two groups on the melody recognition task for the two hearing aids and the two settings within each hearing aid.

Table 4.1.3
Mean and standard deviation (SD) values of the melody recognition scores in the two groups of participants

Groups	*Hearing aids*	*Settings*	*Melody recognition scores*	
			Mean (Max=5)	*SD*
Flat configuration (N=12)	2 channel	Default setting	2.67	1.43
		High knee-point of compression	3.50	1.44
	8 channel	Default setting	2.50	1.56
		High knee-point of compression	3.50	1.31
Sloping configuration (N=12)	2 channel	Default setting	2.75	1.54
		High knee-point of compression	3.67	1.30
	8 channel	Default setting	3.08	0.99
		High knee-point of compression	3.67	1.23

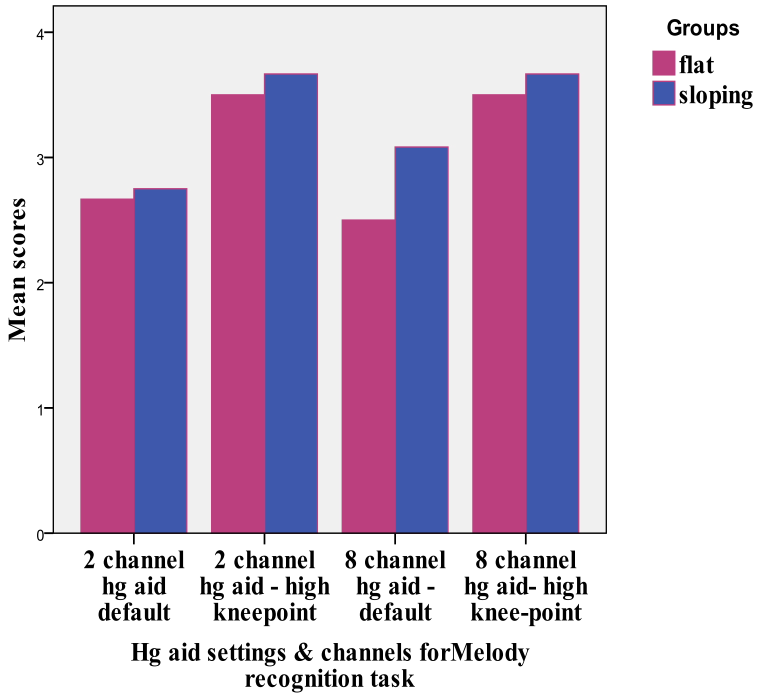

Figure 4.1.3: Performance of the two groups on the melody recognition task for the two hearing aids and the two settings within each hearing aid.

From Table 4.1.3 and Figure 4.1.3, it can be seen that the mean scores were better for high knee-point of compression setting on melody recognition task for the two groups and two hearing aids. Participants with flat configuration of hearing loss achieved better mean scores with the two channel hearing aid for the default setting whereas, participants with sloping configuration of hearing loss achieved better mean scores with the eight channel hearing aid for the default setting. Participants with flat and sloping configuration of hearing loss achieved equal mean scores with the two and eight channel hearing aid for the high knee-point of compression setting. To see if these differences were significant, two-way repeated measures analysis of variance (ANOVA) was performed.

Two-way repeated measures ANOVA showed no interaction between the hearing aids and groups [$F (1, 22) = 0.52, p>0.05$]; between settings and groups [$F (1, 22) = 0.44, p>0.05$]; between hearing aids and settings [$F (1, 22) = 0.12, p>0.05$] and between hearing aids, settings and groups [$F(1, 22) = 1.08$, $p>0.05$]. Further, there was no significant difference between the two groups (flat vs. sloping) [$F(1, 22) = 0.24$, $p>0.05$]; and between the two channel and eight channel hearing aids [$F(1, 22) = 0.05$, $p>0.05$]. However, a significant difference existed between the hearing aid settings (default vs. high knee-point) [$F(1, 22) = 44.89$, $p<0.05$], with performance being better with high compression knee-point.

Paired samples t-test revealed significant differences between the default and the high knee-point of compression, for both the two and the eight channel hearing aid ($p<0.05$), with the performance being better in the high knee-point of compression setting.

4.1.4 Instrument identification test

The results of the two sub-tests for instrument identification test are given below.

4.1.4.1 Single instrument identification sub-test

The mean and standard deviation (SD) of the single instrument identification test scores (Maximum score = 5) for each setting on the hearing aid for the two groups (flat vs. sloping) of participants are given in Table 4.1.4.1. Figure 4.1.4 depicts the mean scores of the two groups in the single instrument identification task for the two hearing aids and the two settings within each hearing aid.

Table 4.1.4.1.
Mean and standard deviation (SD) values of the single instrument identification scores in the two groups of participants

Groups	*Hearing aids*	*Settings*	*Single instrument identification scores*	
			Mean (Max=5)	*SD*
Flat configuration (N=12)	2 channel	Default setting	2.00	0.95
		High knee-point of compression	2.92	0.79
	8 channel	Default setting	1.58	1.08
		High knee-point of compression	2.33	1.30
Sloping configuration (N=12)	2 channel	Default setting	1.58	0.99
		High knee-point of compression	2.58	0.90
	8 channel	Default setting	1.67	1.43
		High knee-point of compression	2.50	1.31

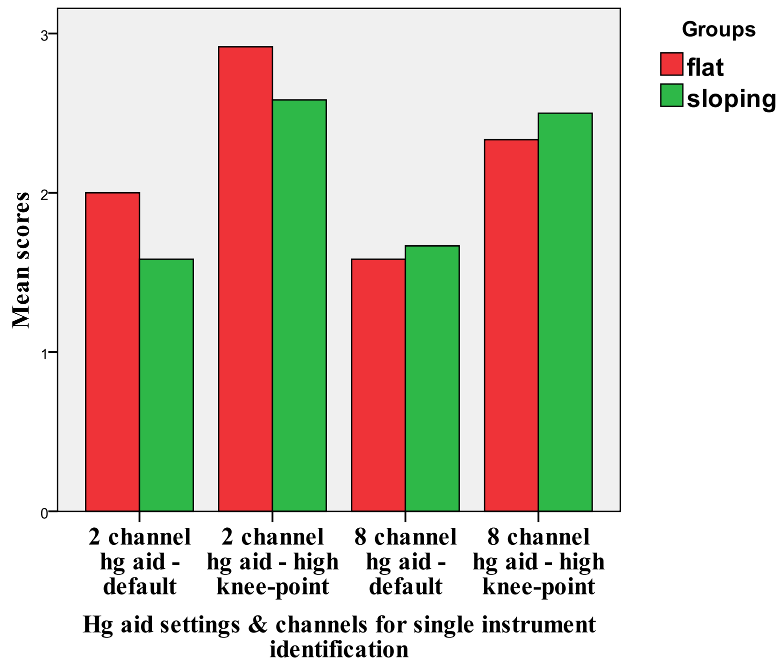

Figure 4.1.4.1: Performance of the two groups on the single instrument identification task for the two hearing aids and the two settings within each hearing aid

From Table 4.1.4.1 and Figure 4.1.4.1, it can be seen that the mean scores were better for high knee-point of compression setting on single instrument identification task for the two groups and two hearing aids. Participants with flat configuration of hearing loss achieved better mean scores with the two channel hearing aid for both the default and the high knee-point of compression settings whereas, participants with sloping configuration of hearing loss achieved better mean scores with the eight channel hearing aid (default setting), with the two channel hearing aid (high knee-point setting). To see if these differences were significant, two-way repeated measures analysis of variance (ANOVA) was performed.

Two-way repeated measures ANOVA showed no interaction between the hearing aids and groups [$F(1, 22) = 2.64$, $p>0.05$]; between settings and groups [$F(1, 22) = 0.07$, $p>0.05$]; between hearing aids and settings [$F(1, 22) = 0.44$, $p>0.05$] and between hearing aids, settings and groups [$F(1, 22) = 0$, $p>0.05$]. Further, there was no significant difference between the two groups with flat and sloping configuration of audiogram [$F(1, 22) = 0.10$, $p>0.05$]; and between the hearing aids (two vs. eight channel) [$F(1, 22) = 2.6$, $p>0.05$]. However, there was a significant difference observed between the hearing aid settings (default vs. high knee-point) [$F(1, 22) = 33.45$, $p<0.05$], with scores from hearing aid at high knee-point settings being better than the default settings.

Paired samples t-test revealed significant differences between the default and the high knee-point of compression, for both the two and the eight channel hearing aid ($p<0.05$), with the performance being better in the high knee-point of compression setting.

4.1.4.2 Music ensemble identification sub-test

The mean and SD of the music ensemble identification test scores (Maximum score = 5) for each setting of the hearing aid for the two groups (flat vs. sloping) of participants are given in Table 4.1.4.2. Figure 4.1.4.2 shows the mean scores for the two groups on music ensemble identification sub-test.

Table 4.1.4.2.

Mean and standard deviation (SD) values of the music ensemble identification scores in the two groups of participants

Groups	*Hearing aids*	*Settings*	*Music ensemble identification scores*	
			Mean (Max=5)	*SD*
Flat configuration (N=12)	2 channel	Default setting	0.67	0.65
		High knee-point of compression	2.17	1.11
	8 channel	Default setting	1.00	0.95
		High knee-point of compression	1.33	1.07
Sloping configuration (N=12)	2 channel	Default setting	0.58	1.16
		High knee-point of compression	1.33	1.15
	8 channel	Default setting	0.25	0.45
		High knee-point of compression	1.33	0.89

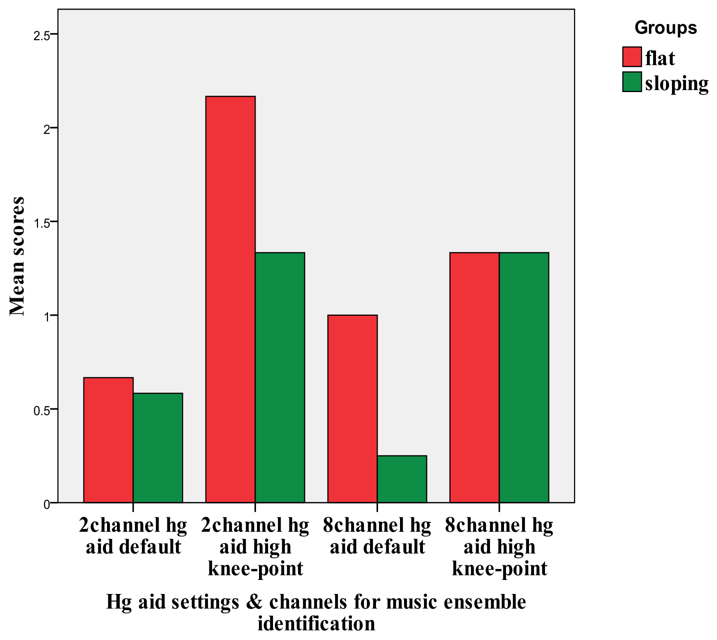

Figure 4.1.4.2: Performance of the two groups on the music ensemble identification task for the two hearing aids and the two settings within each hearing aid

From Table 4.1.4.2 and Figure 4.1.4.2, it can be seen that the mean scores were better for high knee-point of compression setting on music ensemble identification task for the two groups and two hearing aids. Participants with flat configuration of hearing loss achieved better mean scores with the eight channel hearing aid for the default setting and with the two channel hearing aid for the high knee-point of compression settings whereas, participants with sloping configuration of hearing loss achieved better mean scores with the two channel hearing aid (default setting), with no difference seen between the hearing aids for the (high knee-point setting. To see if these differences were significant, two-way repeated measures analysis of variance (ANOVA) was performed.

A significant interaction was seen between the hearing aids, conditions and groups [F (1, 22) = 12.20, $p<0.05$] on two-way repeated measures ANOVA. No interaction was seen between the hearing aids and groups [F (1, 22) = 0.04, $p>0.05$];

between settings and groups [F (1, 22) = 0.0, p>0.05]; and between hearing aids and settings [F (1, 22) = 3.76, p>0.05]. The two-way repeated measures ANOVA showed no significant difference between the two groups (flat vs. sloping) [F (1, 22) = 2.14, p>0.05]; and between the hearing aids (two vs. eight channel) [F (1, 22) = 1.12, p>0.05]. However, a significant difference was seen for the hearing aid settings (default vs. high knee-point) [F (1, 22) = 35.97, p<0.05], with scores being better in the high knee-point of compression setting, for duet instrument identification.

Further, analysis using MANOVA revealed a significant difference between the two groups for the eight channel hearing aid in the default condition. As there was a significant difference between the two groups, paired t-test was done separately for each of the two groups. For participants with flat hearing loss, the paired t-test revealed a significant difference (p<0.05) between the hearing aid settings (default vs. high knee-point of compression) for two channel hearing aid, but not for the eight channel hearing aid; with the performance being better when the knee-point of compression was high. A significant difference was noticed between the two vs. eight channel hearing aid, with the two channel hearing aid in the high knee-point condition showing better performance.

Paired t-test for participants with sloping hearing loss revealed significant differences (p<0.05) between the two hearing aid settings (default vs. high knee-point of compression) for the eight channel hearing aid; with the performance being better when the knee-point of compression was high. This was not true for the two channel hearing aid.

4.1.5 Pitch ranking test

For the pitch ranking test, non-parametric Mann-Whitney U test was carried out to compare the groups, due to the nature of the test. Wilcoxon Signed-rank test was done for pair-wise comparison. The mean and SD of the scores of the participants with flat and sloping hearing loss are represented in Table 4.1.5. Figure 4.1.5 represents performance of the two groups on pitch ranking task, sub-test A, B and C

Table 4.1.5.
Mean and standard deviation (SD) values for the three sub-tests A, B and C of pitch ranking scores in the two groups of participants.

Pitch ranking subtests	*Hearing Aid*	*Settings*	*Flat group*		*Sloping group*	
			Mean	*SD*	*Mean*	*SD*
A	2 channel	Default	1.33	0.65	1.42	1.16
		High knee-point	2.33	0.89	1.58	0.67
	8 channel	Default	1.08	0.51	1.50	0.90
		High knee-point	1.92	0.79	1.92	0.67
B	2 channel	Default	1.25	0.75	0.67	0.65
		High knee-point	2.17	0.83	1.25	0.87
	8 channel	Default	0.75	0.62	0.67	0.49
		High knee-point	1.50	0.90	1.42	0.67
C	2 channel	Default	1.42	0.51	1.42	1.31
		High knee-point	2.08	0.67	1.25	0.97
	8 channel	Default	1.08	0.51	1.08	0.79
		High knee-point	1.67	0.49	1.17	0.72

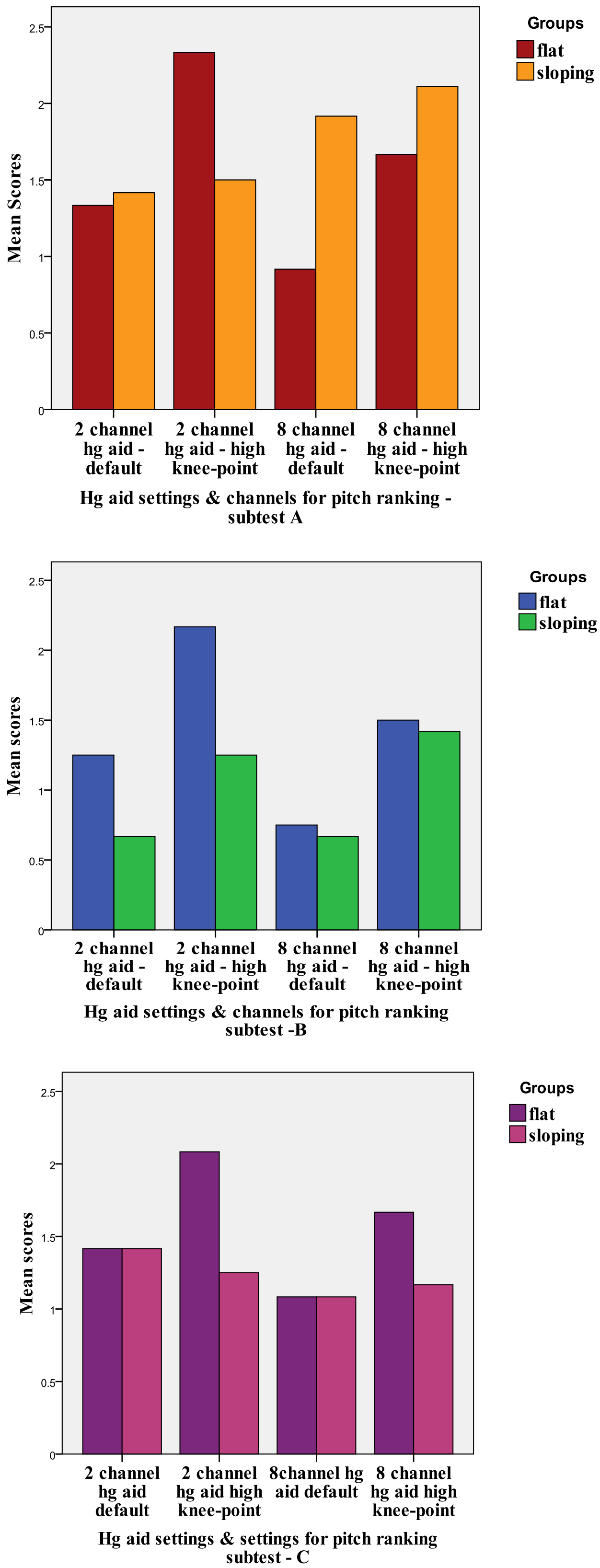

Figure 4.1.5: Performance of the two groups on the pitch ranking task subtest A(brown & orange), B(blue & green) and C(purple & pink) for the two hearing aids and the two settings within each hearing aid.

From Table 4.1.5 and Figure 4.1.5, it can be seen that the mean scores for all the three sub-tests of the pitch ranking task were better for high knee-point of compression setting, for the two groups and two hearing aids. Participants with flat configuration of hearing loss achieved better mean scores with the two channel hearing aid for both the default and the high knee-point of compression settings for sub-tests A and B, whereas, participants with sloping configuration of hearing loss achieved better mean scores with the eight channel hearing aid for the same task. For sub-test C, participants with both flat and sloping configuration of hearing loss achieved better mean scores with the two channel hearing aid for both the default and the high knee-point of compression settings. To see if these differences were significant, non parametric tests were applied.

For sub-tests A, B and C, Mann-Whitney U test showed a significant difference ($Z= -2.41$, -2.33 and -2.18 for sub-tests A, B and C respectively) ($p<0.05$) for the high knee-point of compression setting, for the two channel hearing aid, for both the groups. This was not true for the eight channel hearing aid.

For participants with flat configuration of hearing loss, Wilcoxon Signed-Rank test showed significant difference between the default and the high knee-point of compression for both two and eight channel hearing aid ($p<0.05$), with the performance being better in the high knee-point of compression condition. This was seen for sub-tests A and B. For sub-test C, significant difference between the two settings was seen only for the eight channel hearing aid. Significant difference was also seen between the default conditions of the two and eight channel hearing aids for sub-tests B and C.

Wilcoxon Signed-Rank test for participants with sloping configuration of hearing loss showed no significant difference between the default and the high knee-point of compression for both two and eight channel hearing aids. This was seen for sub-tests A and C. For sub-test B, significant difference between the two settings was seen for both two and eight channel hearing aids.

4.1.6 Overall performance on the Music Perception Test Battery

The overall performance on various sub-tests of the MPTB was analyzed. Table 4.1.6 below shows the mean scores and SD of the two groups (flat vs. sloping) for overall performance on the MPTB (Maximum score = 34). Figure 4.1.6 represents performance of the two groups on the MPTB (Total scores) for the two hearing aids and the two settings within each hearing aid.

Table 4.1.6
Mean of the total scores and standard deviation (SD) values on the various tasks of MPTB in the two groups of participants

Groups	*Hearing aids*	*Settings*	*Total scores on MPTB*	
			Mean (Max=34)	*SD*
Flat configuration (N=12)	2 channel	Default setting	16.17	3.46
		High knee-point of compression	24.00	5.20
	8 channel	Default setting	15.58	3.45
		High knee-point of compression	21.50	4.25
Sloping configuration (N=12)	2 channel	Default setting	16.83	3.29
		High knee-point of compression	20.67	3.49
	8 channel	Default setting	16.92	3.80
		High knee-point of compression	21.00	3.33

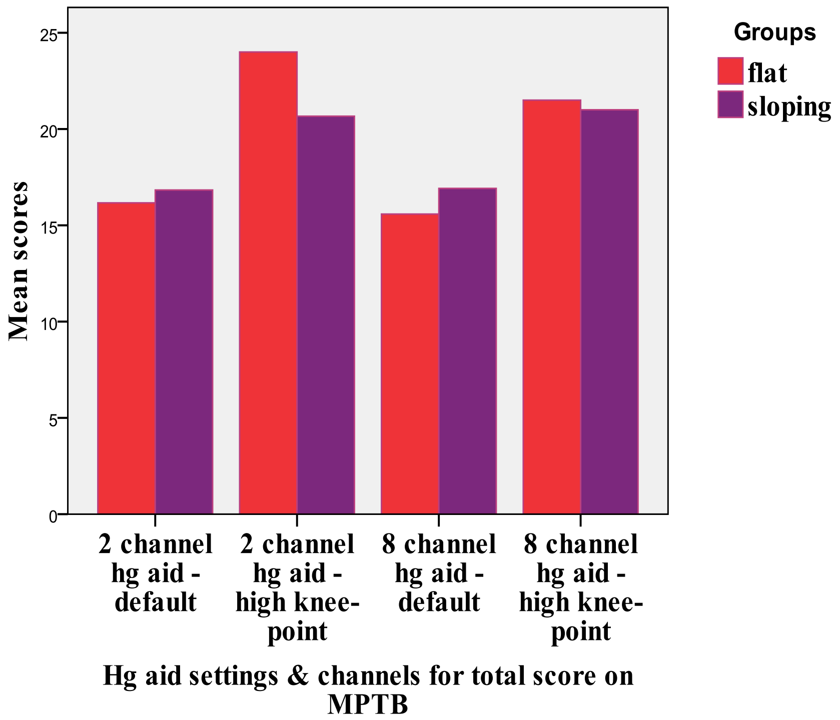

Figure 4.1.6 Total mean scores of the two groups on the MPTB for the two hearing aids and the two settings within each hearing aid.

From Table 4.1.6, it can be noted that for the participants with flat hearing loss, the overall mean scores on MPTB, for two channel hearing aid are higher compared to eight channel hearing aid. For the participants with sloping hearing loss, the overall mean scores on MPTB, for the eight channel hearing aid are slightly higher compared to two channel hearing aid.

Further, it can also be observed that the overall mean scores were higher for the high knee-point of compression compared to the default setting in both the groups with both the hearing aids. In order to find out if these differences were significant, two-way repeated measures ANOVA was performed.

Two-way repeated measures ANOVA showed significant interaction between the hearing aid setting and groups [$F(1,22) = 4.71$, $p<0.05$]; but no overall no interaction was present between the hearing aids and groups [F (1, 22) = 2.72, p>0.05]; between hearing aids and settings [F(1, 22) = 1.62, p>0.05] and between hearing aids, settings and groups [F(1,22) = 2.75, p>0.05]. There was no significant difference between the two groups (flat vs. sloping) [F(1, 22) = 0.13, p>0.05]; and between the hearing aids (two vs. eight channel) [F(1,22) = 1.58, p>0.05]. However, a significant difference was seen between the hearing aid settings (default vs. high knee-point) [F (1, 22) = 65.01, p<0.05].

Paired samples t-test revealed significant differences between the default and the high knee-point of compression, for both the two and the eight channel hearing aid (p<0.05), with the performance being better in the high knee-point of compression setting.

4.2 Performance on the perceptual rating scale

The results of the five perceptual parameters, namely, loudness, fullnesss, clearness, naturalness and overall fidelity are given below. The relevant discussion of the results is done at the end of this chapter.

4.2.1 Perception of 'Loudness' of music

Loudness of music through hearing aids was rated on a five-point rating scale (1 to 5). Mean and SD of the ratings of the participants on the loudness scale is given in Table 4.2.1. Figure 4.2.1 represents performance of the two groups for rating of the parameter 'loudness' for the two hearing aids and the two settings within each hearing aid.

Table 4.2.1- Mean scores and standard deviation (SD) values of perceptual rating for the parameter of loudness from the two groups of participants.

Groups	*Hearing aids*	*Settings*	*Parameter – Loudness*	
			Mean (Max=5)	*SD*
Flat configuration (N=12)	2 channel	Default setting	2.75	0.62
		High knee-point of compression	3.67	0.49
	8 channel	Default setting	2.00	0.95
		High knee-point of compression	2.50	0.52
Sloping configuration (N=12)	2 channel	Default setting	2.17	0.94
		High knee-point of compression	2.50	1.09
	8 channel	Default setting	1.92	1.08
		High knee-point of compression	2.83	0.94

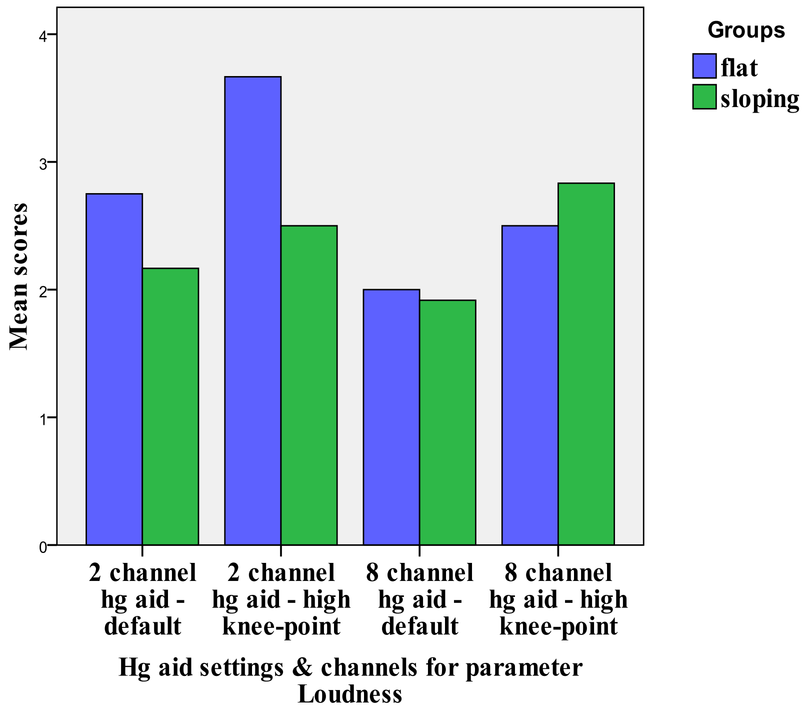

Figure 4.2.1: Performance of the two groups in the rating of the parameter 'loudness' for the two hearing aids and the two settings within each hearing aid

From Table 4.2.1 and Figure 4.2.1, it can be seen that the mean scores for the rating of 'loudness' were better for high knee-point of compression setting for the two groups and two hearing aids. Participants with flat configuration of hearing loss achieved better mean scores with the two channel hearing aid for both the default and high knee-point of compression settings, whereas, participants with sloping configuration of hearing loss achieved better mean scores with the eight channel hearing aid for high knee-point setting and with the two channel hearing aid for default setting. To see if these differences were significant, Mann-Whitney U test and Wilcoxon Signed-Rank tests were applied.

Mann-Whitney U test showed significant difference ($Z= -2.70$; $p<0.05$) for the high knee-point of compression setting for the two channel hearing aid for both the groups, but not for the eight channel hearing aid. Wilcoxon Signed-Rank test, for participants with flat as well as sloping hearing loss, showed significant difference between the default and the high knee-point of compression, for both the two and the eight channel hearing aids ($p>0.05$), with the performance being better in the high knee-point of compression condition.

4.2.2 Rating for the parameter 'Fullness' on the scale

Fullness of music through hearing aids was rated on a five-point rating scale. Mean scores and SD of the groups with flat and sloping hearing loss for 'Fullness' (Maximum score = 5) is represented in table 4.2.2. Figure 4.2.2 depicts the performance of the two groups for the rating of the parameter 'fullness' for the two hearing aids and the two settings within each hearing aid.

Table 4.2.2: Mean scores and standard deviation (SD) values of perceptual rating for the parameter of fullness from the two groups of participants.

Groups	*Hearing aids*	*Settings*	*Parameter - Fullness*	
			Mean (Max=5)	*SD*
Flat configuration (N=12)	2 channel	Default setting	2.67	0.49
		High knee-point of compression	3.83	0.72
	8 channel	Default setting	2.17	0.72
		High knee-point of compression	2.42	0.90
Sloping configuration (N=12)	2 channel	Default setting	2.33	0.65
		High knee-point of compression	2.67	0.98
	8 channel	Default setting	1.83	1.19
		High knee-point of compression	2.42	1.16

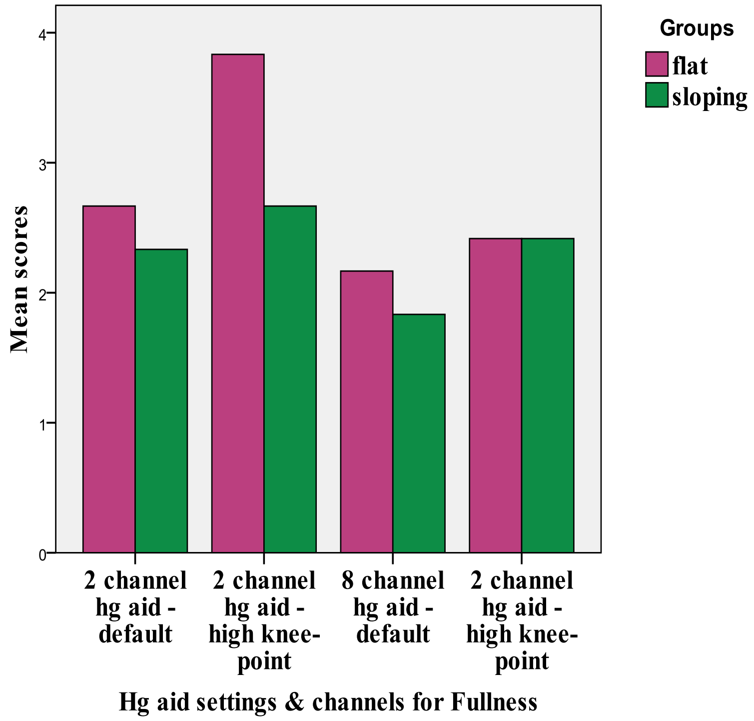

Figure 4.2.2: Performance of the two groups in the rating of the parameter 'fullness' for the two hearing aids and the two settings within each hearing aid.

From Table 4.2.2 and Figure 4.2.2, it can be seen that the mean scores for the rating of 'fullness' were better for high knee-point of compression setting for the two groups and two hearing aids. Participants with both flat and sloping configuration of hearing loss achieved better mean scores with the two channel hearing aid for both the default and high knee-point of compression settings. To see if these differences were significant, Mann-Whitney U test and Wilcoxon Signed-Rank test were applied.

Mann-Whitney U test showed significant difference (Z= -2.7, $p<0.05$) for both the groups, favouring the high knee-point of compression setting for the two channel hearing aid but not for the eight channel hearing aid. test for participants with flat hearing loss showed a significant difference between the default and the high knee-point of compression for the two channel hearing aid ($p>0.05$), with the performance being better in the high knee-point of compression condition. Wilcoxon Signed-Rank test for participants with sloping hearing loss showed significant difference between the default and the high knee-point of compression for both two and eight channel hearing aids.

4.2.3 Rating for the parameter 'Clearness' on the scale

The participants rated the parameters of clearness on a five-point rating scale. Table 4.2.3 below shows the mean and SD of the group with flat and sloping hearing loss for rating of the parameter 'Clearness', maximum score being 5. Figure 4.2.3 depicts the performance of the two groups for the rating of the parameter 'clearness' for the two hearing aids and the two settings within each hearing aid.

Table 4.2.3: Mean scores and standard deviation (SD) values of perceptual rating for the parameter of clearness from the two groups of participants.

Groups	*Hearing aids*	*Settings*	*Parameter - Clearness*	
			Mean (Max=5)	*SD*
Flat configuration (N=12)	2 channel	Default setting	2.83	0.39
		High knee-point of compression	3.75	0.75
	8 channel	Default setting	2.08	0.67
		High knee-point of compression	2.58	0.67
Sloping configuration (N=12)	2 channel	Default setting	2.00	0.60
		High knee-point of compression	2.25	0.75
	8 channel	Default setting	1.83	1.19
		High knee-point of compression	2.42	1.16

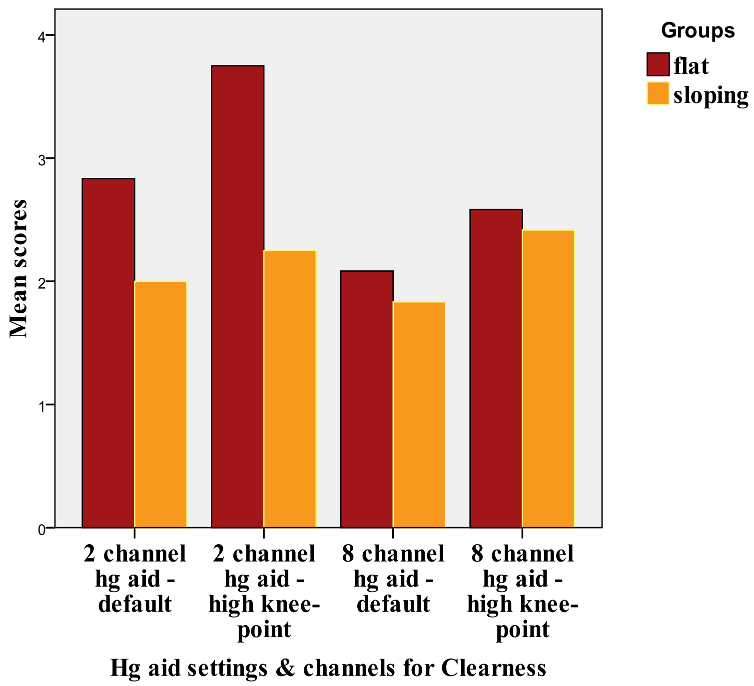

Figure 4.2.3: Performance of the two groups in the rating of the parameter 'clearness' for the two hearing aids and the two settings within each hearing aid.

From Table 4.2.3 and Figure 4.2.3, it can be seen that the mean scores for the rating of 'clearness' were better for high knee-point of compression setting for the two groups and two hearing aids. Participants with flat configuration of hearing loss achieved better mean scores with the two channel hearing aid for both the default and high knee-point of compression settings, whereas, participants with sloping configuration of hearing loss achieved better mean scores with the eight channel hearing aid. To see if these differences were significant, Mann-Whitney U test and Wilcoxon Signed-Rank test were applied.

Mann-Whitney U test showed significant difference for the default and high knee-point of compression setting for the two channel hearing aid for both the groups ($Z= -3.2$ and $Z= -3.6$ respectively; $p<0.05$) but not for the eight channel hearing aid. Wilcoxon Signed-Rank test for participants with flat hearing loss showed a significant difference between the default and the high knee-point of compression, for the two and eight channel hearing aid ($p<0.05$), with the performance being better in the high knee-point of compression condition. Wilcoxon Signed-Rank test for participants with sloping hearing loss showed a significant difference between the default and the high knee-point of compression, for both the two and the eight channel hearing aids.

4.2.4 Rating for the parameter 'Naturalness' on the scale

The naturalness was rated on a five-point rating scale, Table 4.2.4 shows the mean and standard deviation (SD) of the group with flat and sloping hearing loss for the parameter of 'Naturalness' (Maximum score = 5). Figure 4.2.4 depicts the performance of the two groups on 'naturalness' for music perception, for the two hearing aids and the two settings within each hearing aid

Table 4.2.4: Mean scores and standard deviation (SD) values of perceptual rating for the parameter of naturalness from the two groups of participants.

Groups	*Hearing aids*	*Settings*	*Parameter - Naturalness*	
			Mean (Max=5)	*SD*
Flat configuration (N=12)	2 channel	Default setting	3.25	0.62
		High knee-point of compression	4.00	1.04
	8 channel	Default setting	2.17	0.72
		High knee-point of compression	2.50	0.52
Sloping configuration (N=12)	2 channel	Default setting	2.50	0.67
		High knee-point of compression	2.92	1.00
	8 channel	Default setting	2.33	1.44
		High knee-point of compression	3.00	1.48

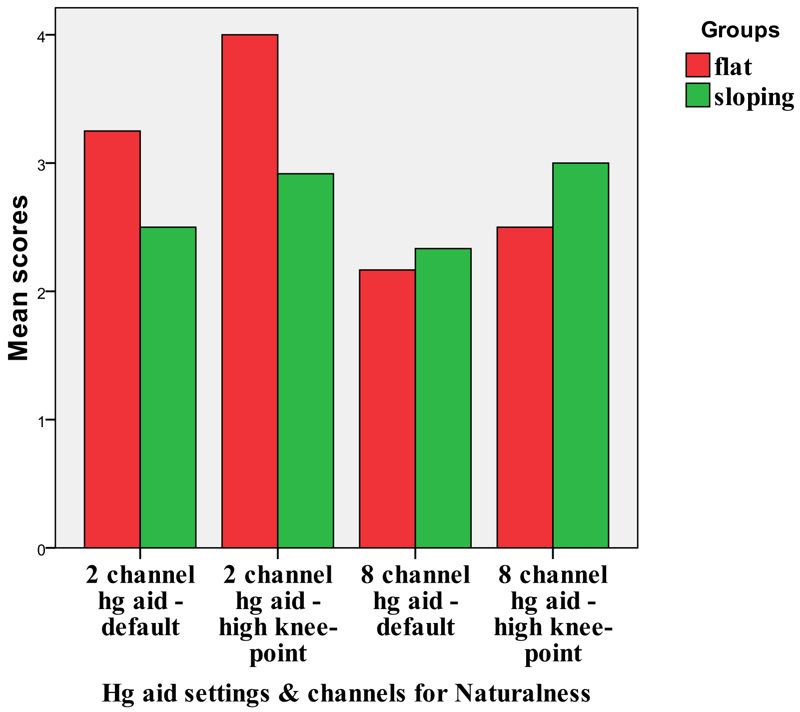

Figure 4.2.4: Performance of the two groups in the rating of the parameter 'naturalness' for the two hearing aids and the two settings within each hearing aid.

From Table 4.2.4 and Figure 4.2.4, it can be seen that the mean scores for the rating of ‘naturalness’ were better for high knee-point of compression setting for the two groups and two hearing aids. Participants with flat configuration of hearing loss achieved better mean scores with the two channel hearing aid for both the default and high knee-point of compression settings, whereas, participants with sloping configuration of hearing loss achieved better mean scores with the eight channel hearing aid for high knee-point setting and with the two channel hearing aid for default setting. To see if these differences were significant, Mann-Whitney U test and Wilcoxon Signed-Rank test were applied.

For participants with flat and sloping hearing loss, Mann-Whitney U test showed significant difference for the default and high knee-point of compression setting for the two channel hearing aid ($Z = -2.5$ and $Z = -2.7$ respectively; $p<0.05$) but not for the eight channel hearing aid. Wilcoxon Signed-Rank test for participants with sloping hearing loss showed significant difference between the default and the high knee-point of compression for both the two and the eight channel hearing aid.

4.2.5 Rating for the parameter ‘Overall fidelity’ on the scale

The overall fidelity was measured by using a five-point rating. Table 4.2.4 below shows the mean and SD of the group with flat and sloping hearing loss for the parameter ‘Overall fidelity’ (Maximum score = 5). Figure 4.2.5 depicts the performance of the two groups for rating of the parameter ‘overall fidelity’ for the two hearing aids and the two settings within each hearing aid.

Table 4.2.4: Mean scores and standard deviation (SD) values of perceptual rating for the parameter of overall fidelity from the two groups of participants.

Groups	*Hearing aids*	*Settings*	*Parameter – Overall fidelity*	
			Mean (Max=5)	*SD*
Flat configuration (N=12)	2 channel	Default setting	3.33	0.49
		High knee-point of compression	4.00	1.04
	8 channel	Default setting	2.42	0.67
		High knee-point of compression	2.92	0.51
Sloping configuration (N=12)	2 channel	Default setting	2.50	0.67
		High knee-point of compression	3.00	0.95
	8 channel	Default setting	2.33	1.23
		High knee-point of compression	3.17	1.27

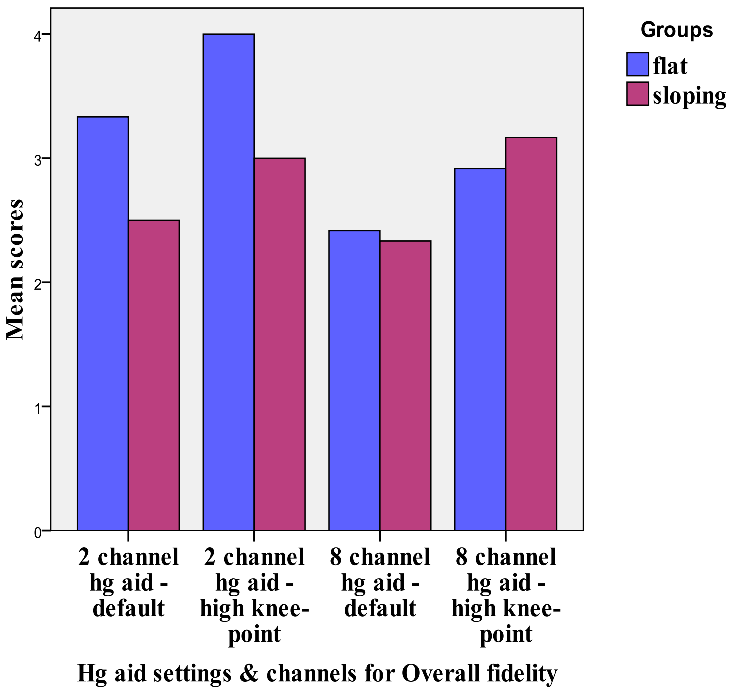

Figure 4.2.5: Performance of the two groups in the rating of the parameter 'overall fidelity' for the two hearing aids and the two settings within each hearing aid.

From Table 4.2.5 and Figure 4.2.5, it can be seen that the mean scores for the rating of 'overall fidelity' were better for high knee-point of compression setting for the two groups and two hearing aids. Participants with flat configuration of hearing loss achieved better mean scores with the two channel hearing aid for both the default and high knee-point of compression settings, whereas, participants with sloping configuration of hearing loss achieved better mean scores with the eight channel hearing aid for high knee-point setting and with the two channel hearing aid for default setting. To see if these differences were significant, Mann-Whitney U test and Wilcoxon Signed-Rank test were applied.

Mann Whitney 'U' test showed significant difference for the default and high knee-point of compression setting for the two channel hearing aid for both the groups ($Z = -2.8$ and $Z = -2.5$ respectively; $p<0.05$) but not for the eight channel hearing aid. Wilcoxon Signed rank test for participants with 'flat' hearing loss showed significant difference between the default and the high knee-point of compression setting for the eight channel hearing aid, but, not the two channel hearing aid. Wilcoxon Signed rank test for participants with 'sloping' hearing loss showed significant difference between the default and the high knee-point of compression for both the two and the eight channel hearing aid.

4.2.6 Overall rating on the five-point perceptual rating scale

The overall performance was computed. Table 4.2.6 below shows the mean and SD of the group with flat and sloping hearing loss for the perceptual rating scale (Maximum score – 25). Figure 4.2.6 depicts the performance of the two groups for overall ratings on the perceptual rating scale for the two hearing aids and the two settings within each hearing aid.

Table 4.2.6 Mean scores and standard deviation (SD) values for the total scores on quality rating from the two groups of participants.

Groups	*Hearing aids*	*Settings*	*Perceptual rating scale - Total*	
			Mean (Max=25)	*SD*
Flat configuration (N=12)	2 channel	Default setting	14.83	3.46
		High knee-point of compression	19.92	5.20
	8 channel	Default setting	10.83	3.45
		High knee-point of compression	12.92	4.25
Sloping configuration (N=12)	2 channel	Default setting	11.50	3.29
		High knee-point of compression	13.42	3.49
	8 channel	Default setting	10.25	3.80
		High knee-point of compression	13.92	3.33

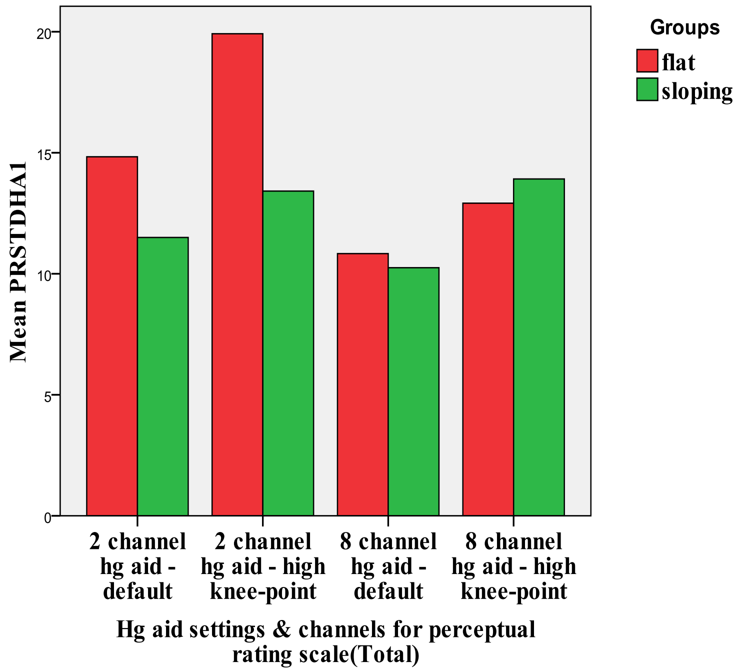

Figure 4.2.6: Mean of total scores of the two groups on the perceptual rating scale for the two hearing aids and the two settings within each hearing aid

From Table 4.2.6 and Figure 4.2.6, it can be seen that the mean scores for overall rating on the perceptual rating scale were better for high knee-point of compression setting for the two groups and two hearing aids. Participants with flat configuration of hearing loss achieved better mean scores with the two channel hearing aid for both the default and high knee-point of compression settings, whereas, participants with sloping configuration of hearing loss achieved better mean scores with the eight channel hearing aid for high knee-point setting and with the two channel hearing aid for default setting. To see if these differences were significant, two-way repeated measures ANOVA was applied.

Two-way repeated measures ANOVA showed significant difference between the two groups (flat vs. sloping) [$F(1, 22) = 5.76$, $p<0.05$]; between the hearing aids (two vs. eight channel) [$F(1, 22) = 6.34$, $p<0.05$], between the hearing aid settings (default vs. high knee-point) [$F(1, 22) = 121.51$, $p<0.05$]; significant interaction was seen between the hearing aids, conditions and groups [$F(1,22) = 40.11$, $p<0.05$; $p<0.05$]; interaction was also seen between the hearing aids and groups [$F(1, 22) = 4.82$, $p<0.05$]; between settings and groups [$F(1, 22) = 1.87$, $p>0.05$]; and between hearing aids and settings [$F(1, 22) = 2.77$, $p>0.05$]. Table 4.1.4.2.1 represents the mean and SD of the two groups. MANOVA showed significant difference between the two groups in both the default and the high knee-point of compression setting for the two channel hearing but not for the eight channel hearing aid.

For the participants with flat hearing loss, paired sample t-test revealed significant differences between the default and the high knee-point of compression for both the two and the eight channel hearing aid ($p<0.05$) with the performance being better in the high knee-point of compression setting; significant difference was also seen between the default conditions for two vs. the eight channel hearing aid and the high knee-point of compression setting for two vs the eight channel hearing aid ($p<0.05$).

For the participants with sloping hearing loss, paired sample t-test revealed significant difference between the default and the high knee-point of compression for the eight channel hearing aid ($p>0.05$), with the performance being better in the high knee-point of compression condition.

Although no significant difference was seen between the two groups in terms of their preference for a particular hearing aid, participants with flat hearing loss preferred the two channel hearing aid in the high knee-point of compression setting for listening to music samples. Whereas among participants with sloping hearing loss, a few of the subjects (seven out of twelve) preferred the two channel hearing aid in the high knee-point of compression setting, remaining five preferred the eight channel hearing aid in the high knee-point of compression setting for listening to music samples.

Tables 4.3 and 4.4 show the summary of the findings of the performance of the participants on different tests of the Music perception test battery and the ratings given by the participants on the five point perceptual rating scale respectively.

Table 4.3
Summary of the scores on tests of MPTB from participants in the two groups

Music Perception Test Battery (MPTB)	*Flat hearing loss (Mean scores)*	*Sloping hearing loss (Mean scores)*
1. Pitch discrimination task	• 8 channel > 2 channel (both default and high knee-point condition) • High knee-point setting > default *	• 8 channel = 2 channel (both default and high knee-point condition) • High knee-point setting > default *
2. Rhythm discrimination task	• 8 channel > 2 channel (both default and high knee-point condition) • High knee-point setting > default *	• 8 channel = 2 channel (default) 8 channel > 2 channel (high knee-point) • High knee-point setting > default *
3. Melody recognition test	• 2 channel > 8 channel (default) 2 channel = 8 channel (high knee-point) • High knee-point setting > default *	• 8 channel > 2 channel (default) 2 channel = 8 channel (high knee-point) • High knee-point setting > default *
4. Instrument identification		
a) Single instrument identification test	• 2 channel > 8 channel (default & high knee-point) • High knee-point setting > default *	• 8 channel > 2 channel (default) 2 channel > 8 channel (high knee-point) • High knee-point setting > default *
b) Music ensemble	• 8 channel > 2 channel	• 2 channel > 8 channel

identification test	(default) 2 channel > 8 channel (high knee-point *) • High knee-point setting > default *	(default) 8 channel = 2 channel (high knee-point) • High knee-point setting > default *
5. Pitch ranking test a) Sub-test A	• 2 channel > 8 channel (default & high knee-point) • High knee-point setting > default *	• 8 channel > 2 channel (default & high knee-point) • High knee-point setting > default *
b) Sub-test B	• 2 channel > 8 channel (default * & high knee-point) • High knee-point setting > default *	• 8 channel > 2 channel (default & high knee-point) • High knee-point setting > default *
c) Sub-test C	• 2 channel > 8 channel (default * & high knee-point) • High knee-point setting > default *	• 2 channel > 8 channel (default & high knee-point) • High knee-point setting < default (2 channel) High knee-point setting > default (8 channel) *
Overall performance on the MPTB	• 2 channel > 8 channel (default & high knee-point) • High knee-point setting > default *	• 8 channel > 2 channel (default & high knee-point) • High knee-point setting > default *

Note: * = scores significantly different ($p<0.05$)

Table 4.4

Summary of the ratings given by participants on quality perception on a five point rating scale by the two groups.

Perceptual rating scale - Parameters	*Flat hearing loss (Mean scores)*	*Sloping hearing loss (Mean scores)*
1. Loudness	• 2 channel > 8 channel (both default and high knee-point condition *) • High knee-point setting > default *	• 2 channel > 8 channel (default) 8 channel > 2 channel (high knee-point condition) • High knee-point setting > default *
2. Fullness	• 2 channel > 8 channel (both default and high knee-point condition *) • High knee-point setting > default *	• 2 channel > 8 channel (both default and high knee-point condition) • High knee-point setting > default *
3. Clearness	• 2 channel > 8 channel (both default * and high knee-point condition *) • High knee-point setting > default *	• 8 channel > 2 channel (both default and high knee-point condition) • High knee-point setting > default *
4. Naturalness	• 2 channel > 8 channel (both default and high knee-point condition) • High knee-point setting > default *	• 2 channel > 8 channel (default) 8 channel > 2 channel (high knee-point condition) • High knee-point setting > default *

5. Overall fidelity	• 2 channel > 8 channel (both default and high knee-point condition) • High knee-point setting > default *	• 2 channel > 8 channel (default) 8 channel > 2 channel (high knee-point condition) • High knee-point setting > default *
Overall performance on the perceptual rating Scale	• 2 channel > 8 channel (both default * and high knee-point condition *) • High knee-point setting > default *	• 2 channel > 8 channel (default) 8 channel > 2 channel (high knee-point condition) • High knee-point setting > default *

Note: * = scores significantly different ($p<0.05$)

To summarize the results, it can be inferred from the study that the participants, with flat audiogram configuration, preferred and performed better with the two channel hearing aid compared to eight channel hearing aid. Further, they performed better and preferred the high knee-point of compression compared to the default settings. This trend was reflected even for participants with sloping configuration of audiogram, where majority of the participants (seven out of 12) preferred the eight channel hearing aid with high knee-point of compression setting; the remaining five participants preferred the two channel hearing aid in the high knee-point of compression setting.

DISCUSSION

The results will be discussed separately for the Music Perception Test Battery (MPTB) and the five point perceptual rating scale.

1) Results of the Music Perception Test Battery

From the results of the MPTB and the quality rating on the perceptual rating scale, the following inferences were drawn:

a) There was no significant effect of configuration of the audiogram of the participants on music perception.

b) For music perception, the scores were better for the two channel hearing aid compared to the eight channel hearing aid for the majority of the tasks on the MPTB and for quality rating. However, this difference was not significant.

c) For the perception of music, high knee-point of compression setting was favoured over the default setting by participants with hearing loss in both the groups.

The discussion will be divided under the following headings for the results of MPTB and perceptual rating scale

a) Configuration of the audiogram

b) Number of channels

c) Hearing aid settings

1) Music perception test battery

a) Configuration of the audiogram (Flat vs. Sloping)

For majority of the tasks on the MPTB, there was no significant effect of configuration of the audiogram of the participants (flat vs. sloping). The possible reasons for this could be that the tasks of pitch discrimination, melody recognition, and single instrument identification were relatively easy when compared to the other tasks. For e.g. – in the pitch discrimination task, there was wider difference between the stimuli pairs being used which made the task easier. Further, Olson (1967) reported that the pitch discrimination is least affected by hearing loss. Studies have also reported that individuals with hearing impairment, including both cochlear implant and users of hearing aid, perceive musical rhythm almost as well as those with normal hearing (Darrow, 1979; Gfeller et al., 1997). In addition, the degree of hearing loss considered in this study was of mild - moderate degree. This degree of hearing loss relatively preserves most of the spectral and temporal cues which become more distorted as the degree of hearing loss increases.

b) Number of channels (two vs. eight channels)

The scores were better for the two channel hearing aid compared to the eight channel hearing aid for the majority of the tasks on the MPTB. However, this difference was not significant. This could be because, use of either a single-channel or a multi-channel hearing aid (all channels set for similar compression ratios and knee-points) is optimal for music perception as it helps to maintain a balance between the lower and higher harmonics (Chasin & Russo, 2004). In the present study, there were a few exceptions where there was a significant effect of number of channels. This included the music ensemble identification task wherein the participants with sloping configuration of audiogram performed better with the eight channel hearing aid, whereas those with flat configuration performed better with two channel hearing aid. This can be attributed to the difficult task of music ensemble identification which may require increase in the number of channels for better timbre perception in participants with sloping configuration.

c) Hearing aid settings (default vs. high knee-point)

High knee-point of compression setting in the hearing aid was favoured over the default music program setting by participants with hearing loss, in both the groups, for all the tasks on the MPTB. As described by Chassin and Russo (2004), this could be attributed to the crest factor for musical instruments which is 18 to 20 dB, whereas it is 12 dB for speech. Therefore, higher knee-point of compression prevents the music from forcing the hearing aid to operate in its non-linear mode prematurely. Chasin and Russo (2004) recommended that the compression knee-point for music be set at 5 to 8 dB higher than for equivalent intensities of speech.

2) Five-point perceptual rating scale

a) Configuration of the audiogram (Flat vs. Sloping)

For majority of the parameters on the quality rating, there was no significant effect of configuration of the audiogram of the participants (flat vs. sloping). This could be because only participants with lesser degree of hearing loss were considered.

b) Number of channels (two vs. eight)

Participants with flat configuration rated the two channel hearing aid higher when compared to the eight channel hearing aid; whereas those with sloping configuration of audiogram rated the eight channel hearing aid higher for the majority of the parameters. However, this difference was not significant. This could be because a single channel hearing aid maintains the optimal balance between the lower and higher harmonics which a multi-channel hearing aid with different compression thresholds and knee-points may distort the information in participants with flat configuration (Chasin & Russo, 2004). For participants with sloping configuration, an eight channel hearing aid was more suitable as gain could be adjusted for in different channels according to their needs.

c) Hearing aid settings (default vs. high knee-point)

High knee-point of compression setting was given a higher rating over the default setting by the participants with hearing loss in both the groups on the perceptual rating scale. Higher knee-point of compression prevents the music from forcing the hearing aid to operate in its non-linear mode prematurely. This is because the crest factor for musical instruments is 18 to 20 dB, whereas that for speech is 12 dB. Due to these differences, Chasin and Russo (2004) have recommend that compression knee-point for music be set at 5 to 8 dB higher than for equivalent intensities of speech.

Thus, it can be inferred from the results of the present study that, two channel hearing aid set with high knee-point of compression provides better perception of music.

CHAPTER - 5

SUMMARY AND CONCLUSION

A sensorineural hearing loss leads to difficulty in perceptual analysis of complex sounds such as speech and music. Presence of hearing impairment may affect the enjoyment of music.

Hearing devices, such as hearing aids and cochlear implant, have been primarily developed with the main purpose of optimizing speech. However, increasingly other type of inputs such as music is now being widely researched (Chasin & Russo, 2004). A hearing aid that is optimally set for music can be optimally set for speech, though the converse may not necessarily be true (Chasin & Russo, 2004). This is due to differences in the physical requirements for speech and music such as differences in the long-term spectrum, differing overall intensities, crest factors, and phonetic vs. phonemic perceptual requirements of different musicians.

There have been studies in literature on varying different parameters of hearing aids and its effect on music perception. However, majority of these have been carried out in listeners with normal hearing. Also, most of the hearing aid users who enjoy music may have hearing impairment with a sloping configuration. Therefore, music perception through hearing aids needs to be evaluated in individuals with hearing impairment. Further, evaluation is required to find out if the default program for music stored in the hearing aid (default) or to manually adjusting the compression parameter (knee-point) is better for the perception of music.

The present study therefore compared music perception through a hearing aid using the default setting for music vs. a high knee-point of compression, for a two vs. eight channel hearing aid. This was done in individuals with flat vs. sloping mild-moderate sensorineural hearing loss. A total of 24 participants in the age range of 39 to 59 years participated in this study. They were divided into two groups; Group I and II, consisting of 12 participants each. They were non-musicians. Group I had mild to moderate flat hearing loss and Group II had gradually sloping sensorineural hearing loss in the test ear, which was the better ear. Music perception in these individuals was assessed using the Music Perception Test Battery (MPTB) which included tests like pitch discrimination test, pitch ranking test, rhythm discrimination test, melody recognition test and instrument identification test. These tests assessed the pitch, rhythm, melody and timber parameters of music perception. The participants also rated five parameters (loudness, fullness, clearness, naturalness and overall fidelity) using a five-point perceptual rating scale.

Statistical analyses was carried out using descriptive statistics, two-way repeated measures ANOVA and paired t-test to compare the MPTB scores between the hearing aid settings (default vs. high knee-point) and the hearing aid channels (two vs. eight). Mann-Whitney U test was carried out for perceptual ratings on a five-point rating scale and for the pitch ranking sub-test of the music perception battery. Wilcoxon Signed- Rank test was done for pair-wise comparison.

The results indicated that, for most of the parameters, there was no significant difference between the two groups (flat vs. sloping) or the channels (two vs. eight). However significant difference was observed between the hearing aid settings (default vs. high knee-point of compression) for both the hearing aids (two vs. eight channels); with the performance on most of the parameters tested being better when the knee-point of compression was high. This was seen for both the MPTB and for the five point perceptual rating scale. The above result is in agreement with that reported by Chasin and Russo (2004) which stated that the compression knee-point for music should be set 5 to 8 dB higher than for equivalent intensities of speech as the crest factor for musical instruments are 18-20 dB. This prevents the music from forcing the hearing aid to operate in its non-linear mode prematurely.

Although no significant difference was seen between the two groups in terms of their preference for a particular hearing aid, participants with flat hearing loss preferred the two channel hearing aid set at high knee-point of compression for listening to music samples; whereas among the participants with sloping hearing loss, seven out of 12 participants preferred the two channel hearing aid set at high knee-point of compression, whereas others preferred the eight channel hearing aid set at high knee-point of compression for listening to music samples.

5.1 Clinical implications

The present study impresses upon the need to make special changes in the hearing aid parameters for individuals with hearing loss who like listening to music or are musicians. The parameters for optimal music perception must be manipulated based on individual requirements of the client with hearing loss.

5.2 Future directions for research

Though the findings of the present supports the findings reported by Russo and Chasin, 2004), there are many areas which require to be investigated. They include -

a) Studies can be done on music perception by manipulating other hearing aid parameters such as compression ratio, different types of compression etc.

b) Use of objective methods for validating the effect of manipulation of the hearing aid parameters can be studied.

c) Electroacoustic measurements / real ear measurements of the hearing aids set at different programs would actually throw more light on the actual amount of change required for better perception of music.

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Appendix A

Music training and Experience Questionnaire
(Looi, 2008)

Name----------------------------------   Age------------------------------
Gender--------------------------------   Education-----------------------

1) A: Have you ever had instrumental (Theory or practical) music lessons (i.e. specifically for a music instrument or vocal/singing)?

(a) Instrumental: Theory (Yes/No) --------,   If yes, please give detail:

Instruments   Numbers of years of lessons   Age at which received lesson

(b) Instrumental: Practical (Yes/No) --------, If yes, please give detail:

Instruments   Numbers of years of lessons   Age at which received lesson

(c) Vocal: Theory (yes/No) --------,   If yes, please give detail:--------------------------

(d) Vocal: practical(yes/No) --------, If yes, please give detail:--------------------------

B: Did you complete formal music exams in the above instrument(s) or Vocal?

-----------Yes   ----------------No   If yes, please give detail:

Instrument/vocal   Grade level achieved

________________   ______________________
________________   ______________________

2) Did you ever do music, as subject, at school, university or any other post-school learning institution?

-----------Yes   ----------------No   If yes, please give detail:

Place   Number of years   Age at which involved in class(es)

3) Have you ever been involved in a music group or ensemble?

-----------Yes ----------------No If yes, please give detail:

Group	Number of years	Age at which involved
-------------------	------------------------	---------------------------------

4) Have you ever been involved in any other formal or informal music classes, experiences, activities etc., not covered above?

--------Yes ----------------No If yes, please give detail:

Type	Number of years	Age at which involved

5) Do you listen music every day?

Yes/No------------------------ If Yes, for how many hours per day-------------------------

6) On a scale of 1-5, please rate the following:

(1=None or Not able; 2= Limited; 3= Average; 4= Above average; 5= Extensive or Very able)

a) Knowledge of music history:	1	2	3	4	5
b) Knowledge of music theory:	1	2	3	4	5
c) Ability to read music:	1	2	3	4	5
d) Ability to play an instrument or sing	1	2	3	4	5
e) Overall music ability:	1	2	3	4	5