Chapter 2

MUSIC PERCEPTION

Chapter aim: This chapter serves as a theoretical basis for the empirical research and provides a critical evaluation as well as interpretation of the relevant literature. The focus is placed on music perception tests described in the literature and the development of the music perception test used as data collection material in this study.

2.1 INTRODUCTION

With recent improvements in speech recognition through hearing aids and cochlear implants, other aspects of auditory performance, including the appreciation of music, are becoming increasingly important (Spitzer, Mancuso & Cheng, 2008:57). This escalation of interest in the accuracy of music perception and the enjoyment of music is also reflected in publications of a variety of investigative experimental studies that assessed performance on musical tasks. As advanced hearing aid technology is introduced clinically, its impact on musical performance has become an assessment area of interest.

There is no standard test of music perception, and to compound the problem, different musical styles thrive in strikingly different acoustical environments (Wessel *et al.*, 2007:1). A further limitation to the choice of currently available measures for the assessment of music skills is that most music tests are advanced and specifically designed to examine the skills of individuals undergoing formal music training (Don *et al.*, 1999:158). Previous studies on assessment of music perception in cochlear implant recipients (Gfeller, Olszewski, Rychener, Sena, Knutson, Witt & Macpherson, 2005; Gfeller, Witt, Adamek, Mehr, Rogers, Stordahl & Ringgenberg, 2002; Gfeller, Turner, Mehr, Woodworth, Fearn, Knutson, Witt & Stordahl, 2002; Gfeller, Witt, Woodworth, Mehr & Knutson, 2002; Gfeller, Woodworth, Robin, Witt & Knutson, 1997; Gfeller & Lansing, 1991) confirmed the difficulty of assessing the perception of music and highlighted the need for a clinically relevant/appropriate measure of music recognition and performance (Spitzer *et al.*, 2008:57).

2.2 THE PERCEPTION OF MUSIC

Music is a very complex and wide-ranging phenomenon (Leal, Shin, Laborde, Calmels, Verges, Lugardon, Andrieu, Deguine & Fraysse, 2003:826) and its definition differs among various cultures and social milieus. Cross (2006:80) suggests that music can be best explored in terms of a tripartite model that embraces music as *sound* (what might conventionally be thought of as constituting music from Western perspective), as *behaviour* (which embraces the musical and 'non-musical' acts of musicians (the activities in which the production of music is embedded), and as *concept* (how people think about music in terms of its powers and its relations to other domains of human life).

A basic observation of music psychology is that listening to music may give rise to a large variety of experiences that are based on highly interrelated emotional and cognitive processes in the brain (Kreutz, Schubert & Mitchell, 2008:57; Iakovides, Iliadou, Bizeli, Kaprinis, Fountoulakis & Kaprinis, 2004:2). For example, one individual’s deepest appreciation of music may be based on the structural features of a musical work, whereas for another individual the emotional content of a piece of music may elicit strong experiences. Thus the possibility arises that music processing depends on cognitive styles that vary between individuals as well as numerous participative factors that influence enjoyment, including personal preferences for musical genres and the situational context such as the listening environment and the listener’s mood (Kreutz *et al.*, 2008:57; Nimmons, Kang, Drennan, Longnion, Ruffin, Worman, Yueh & Rubinstein, 2008:149). The effect of temporal context in music – what was played before and what is about to be played – continuously influences a listener’s experience. An identical physical stimulus may be perceived differently, depending on the context; therefore, music perception is a dynamic, time-dependent process. Changes in loudness of musical performance are but one example of temporal dynamics of music in the greater sense. Other examples include fluctuations in tempo, changes in pitch, and adjustments in timbre (Vines, Nuzzo & Levitin, 2005:137).

These participative factors mentioned above may all greatly affect music perception and thereby render it difficult to measure. Thus, many studies focus on the objective characteristics of sound, which can be described in terms of physical parameters of the acoustic signals (Nimmons *et al.*, 2008:149). Several structural features of music that have been examined with regard to music perception include pitch, melody, rhythm, timbre and intensity (Deutsch, 2007:4473; Iakovides *et al.*, 2004:4). Musical perception primarily involves pattern perception, be it variations in rhythm, pitch, loudness or timbre. Whereas the sequencing of patterns of pitch forms the musical correlates of melody and harmony, the sequencing of patterns of duration or tempo forms the foundation of rhythm. However, although these attributes are separate entities, the combinations of, and interactions between the different attributes largely contribute to music as we commonly know it (Looi, McDermott, McKay & Hickson, 2008a:258).

One of the fundamental components of music is **pitch**, which can be operationally defined as the attribute of sound that carries melodic information (McDermott & McKay, 1997:1622). Pitch perception is an important underlying component of music perception, as melody recognition strongly depends on perceiving exact pitch intervals between successive notes (Galvin, Fu & Nogaki, 2007:303; McDermott & McKay, 1997:1622), therefore variations in pitch are central to our experience of melody, harmony and key (Chasin & Russo, 2004:39). The discrimination of the pitch of complex sounds by persons with a hearing loss has been studied relatively little, despite the fact that it is of both practical and theoretical interest (Moore & Peters, 1992:2881). One example of practical interest stems from the relevance of pitch discrimination for speech perception. The pitch patterns of speech indicate the most important words in an utterance, in many languages they distinguish between a question and a statement and they indicate the structure of sentences in terms of phrases (Moore & Peters, 1992:2881). When the pitch of complex signals, particularly musical sounds, is perceived to change the underlying physical parameter that has changed is the fundamental frequency (McDermott, 2005:70). Changes in the fundamental frequency result in corresponding changes in the frequency of all the harmonics (multiples of the fundamental) contained in the spectrum. An increase in the fundamental frequency, perceived as a pitch increase, corresponds to an increase in the spacing between the harmonic components of the signal (McDermott, 2005:70).

In normal hearing, the pitch of a sound is thought to be extracted from the place of stimulation in the cochlea (place code), by resolving frequency components in the neural firing pattern (temporal code), or possibly by analyzing phase components across the signal spectrum at different cochlear locations (Galvin *et al.*, 2007:303).

A difficulty faced by researchers in assessing pitch is that relatively few people have sufficient knowledge of musical terminology, or sufficient experience in judging musical pitch relationships (McDermott & McKay, 1997:1622). One solution to this problem is to make use of portions of familiar melodies as exemplars of pitch intervals. However, this imposes several constraints on a researcher. Firstly, only a few different intervals occur in the most easily recognized tunes; secondly, it is difficult to isolate the perceived pitch or a specific interval from confounding effects such as the rhythm or the overall pitch contour of the melody; thirdly, it is difficult to identify enough suitable tunes with which most persons with a hearing loss are familiar. Moreover, it is reasonable to doubt the accuracy of a person's memory for pitch intervals, even in the context of well-known melodies, particularly if he or she has endured a long period of auditory deprivation before receiving amplification (McDermott & McKay, 1997:1622).

Melodic perception, which develops from infancy, relies on a sensitivity to change over time, as does the perception of harmonic chord progressions and rhythmic relations (Vines *et al.*, 2005:137). Familiar melody recognition is the most common task used to measure music perception in persons with cochlear implants (Cooper *et al.*, 2008:618). However, the use of familiar melody recognition tasks in music perception research also presents some challenges. Firstly, the reliance of these tasks on a person's memory presents a problem, particularly for persons with a severe hearing loss who were deaf for a long duration before being fitted with hearing aids or having received a cochlear implant, because it is difficult to ascertain the level of familiarity a person has had with a given melody. Secondly, a person's ability to recognize a familiar melody provides little information about the individual mechanisms that underlie the melody recognition process. Accordingly, when people with a hearing loss perform poorly on familiar melody recognition tasks, as is often the case, little is learned about why their level of performance is low. Thirdly, these tasks are of little to no use in measuring music perception by pre-lingually deaf persons because familiar melody recognition tasks rely on the memory of a familiar melody, memories that were never formed by congenitally deaf individuals (Cooper *et al.*, 2008:618).

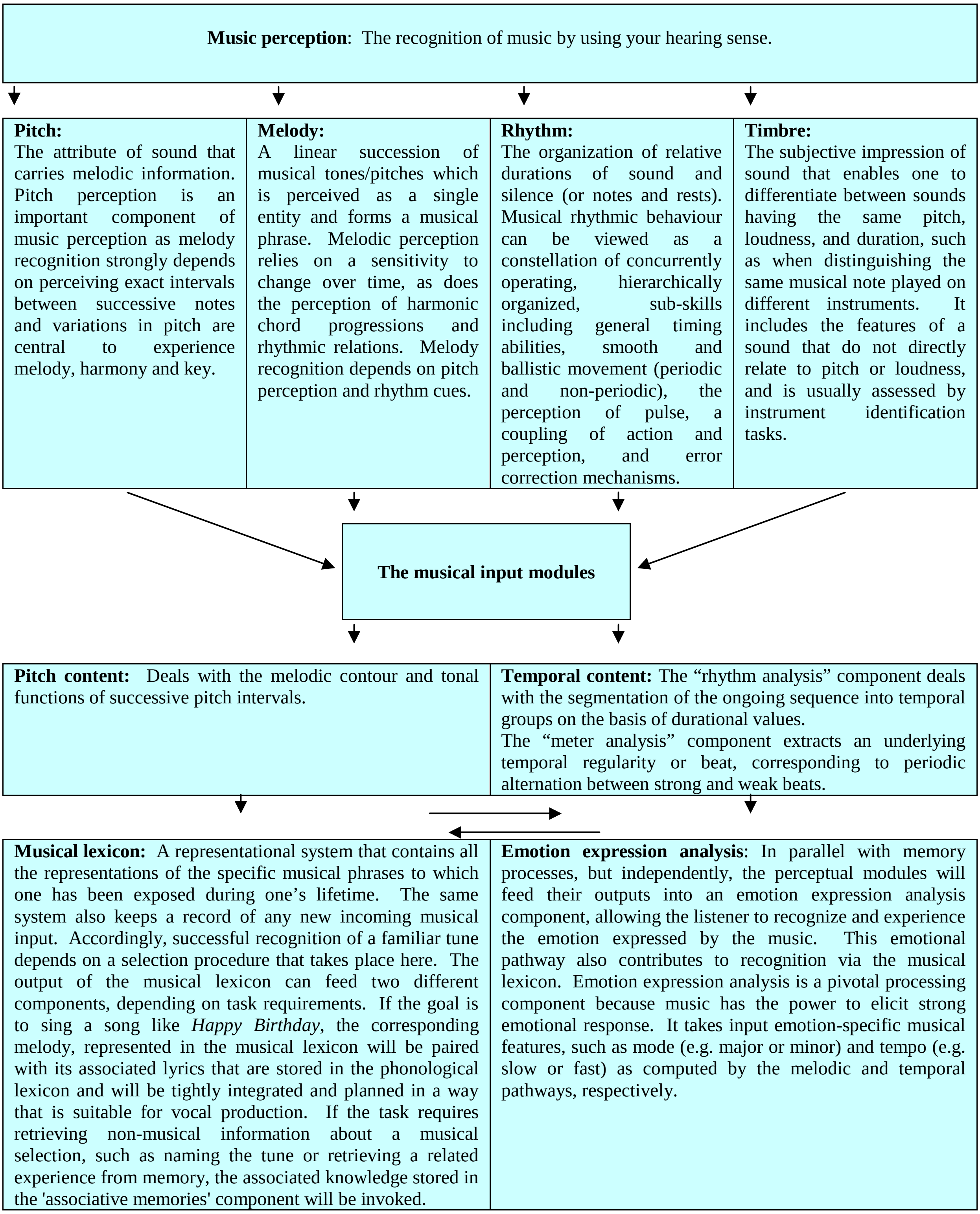
Melody recognition depends greatly on cues provided by rhythm (Galvin *et al.*, 2007:313) but also requires a degree of accurate pitch perception (Looi *et al.*, 2008b:429). Although melodies are inherently rooted in time and have their own temporal structure and phrasing, it is the pitch relationship of one note to the next which is the signature of a particular melody

(Limb, 2006:441). Both the intervals between individual notes and the overall contour of the sequence are incorporated into the processing of melody. The proper perception of melodies (and chords of notes presented simultaneously) rests on the accurate processing and cognitive perception of individual pitches (Limb, 2006:442). Perceiving the pitch of a complex sound primarily involves the listener having to extract information about the fundamental frequency form the complex acoustic signal. A range of environmental, physiological, and pathological phenomena could affect an individual's ability to perceive pitch. Examples of these variables include their memory for melodic pitches, music knowledge and/or training, the amount of residual hearing, pathological processes and central processing factors (Looi *et al.*, 2008b:429). It may however be hypothesized that many common tunes can be recognized when only rhythm is perceived while any pitch cues are absent (McDermott, 2005:68).

The creation of rhythmic patterns is arguably the most basic of all musical impulses, common even to primitive societies and children (Limb, 2006:442). **Rhythm** is defined as the organization of relative durations of sound and silence (or notes and rests), and differs from meter, which is the division of rhythmic patterns according to equal periods (or measures marked by an underlying tempo) (Limb, 2006:442). Musical rhythmic behaviour can be viewed as a constellation of concurrently operating, hierarchically organized, sub-skills including general timing abilities, smooth and ballistic movement (periodic and non-periodic), the perception of pulse, a coupling of action and perception, and error correction mechanisms (Bispham, 2006:125). Of all components of music perception, rhythm is the most fundamentally linked to the movement of time and therefore perception of rhythmic patterns necessarily implicates brain regions involved in temporal processing.

Timbre is the subjective impression of sound that enables one to differentiate between sounds having the same pitch, loudness, and duration, such as when distinguishing the same musical note played on different instruments (Nimmons *et al.*, 2008:149). It includes the features of a sound that do not directly relate to pitch or loudness, and is usually assessed by instrument identification tasks (Looi *et al.*, 2008a:258). The physical variables that contribute to our experience of timbre include the spectrum, temporal envelope, and transient components of a tone (Chasin & Russo, 2004:39). Changes in timbre can often be described in terms such as "lower" or "higher" and therefore are sometimes confused with changes in pitch, especially by non-musicians (McDermott, 2005:70).

Music perception consists of various components that work together to give each individual a unique perception of music. These components are visually presented in Figure 2-1 below:



Music perception: The recognition of music by using your hearing sense.

Pitch: The attribute of sound that carries melodic information. Pitch perception is an important component of music perception as melody recognition strongly depends on perceiving exact intervals between successive notes and variations in pitch are central to experience melody, harmony and key.

Melody: A linear succession of musical tones/pitches which is perceived as a single entity and forms a musical phrase. Melodic perception relies on a sensitivity to change over time, as does the perception of harmonic chord progressions and rhythmic relations. Melody recognition depends on pitch perception and rhythm cues.

Rhythm: The organization of relative durations of sound and silence (or notes and rests). Musical rhythmic behaviour can be viewed as a constellation of concurrently operating, hierarchically organized, sub-skills including general timing abilities, smooth and ballistic movement (periodic and non-periodic), the perception of pulse, a coupling of action and perception, and error correction mechanisms.

Timbre: The subjective impression of sound that enables one to differentiate between sounds having the same pitch, loudness, and duration, such as when distinguishing the same musical note played on different instruments. It includes the features of a sound that do not directly relate to pitch or loudness, and is usually assessed by instrument identification tasks.

The musical input modules

Pitch content: Deals with the melodic contour and tonal functions of successive pitch intervals.

Temporal content: The "rhythm analysis" component deals with the segmentation of the ongoing sequence into temporal groups on the basis of durational values.
The "meter analysis" component extracts an underlying temporal regularity or beat, corresponding to periodic alternation between strong and weak beats.

Musical lexicon: A representational system that contains all the representations of the specific musical phrases to which one has been exposed during one's lifetime. The same system also keeps a record of any new incoming musical input. Accordingly, successful recognition of a familiar tune depends on a selection procedure that takes place here. The output of the musical lexicon can feed two different components, depending on task requirements. If the goal is to sing a song like *Happy Birthday*, the corresponding melody, represented in the musical lexicon will be paired with its associated lyrics that are stored in the phonological lexicon and will be tightly integrated and planned in a way that is suitable for vocal production. If the task requires retrieving non-musical information about a musical selection, such as naming the tune or retrieving a related experience from memory, the associated knowledge stored in the 'associative memories' component will be invoked.

Emotion expression analysis: In parallel with memory processes, but independently, the perceptual modules will feed their outputs into an emotion expression analysis component, allowing the listener to recognize and experience the emotion expressed by the music. This emotional pathway also contributes to recognition via the musical lexicon. Emotion expression analysis is a pivotal processing component because music has the power to elicit strong emotional response. It takes input emotion-specific musical features, such as mode (e.g. major or minor) and tempo (e.g. slow or fast) as computed by the melodic and temporal pathways, respectively.

Figure 2-1: Components of music perception

Considering the diagram above, music perception can be summarized as follows:

Central to pitch organization is the perception of pitch along musical scales (Peretz & Coltheart, 2003:689). A musical scale refers to the use of a small subset of pitches (usually seven) in a given musical piece. Scale tones are not equivalent and are organized around a central tone, called the tonic. Usually, a musical piece starts and ends on the tonic. The other scale tones are arranged in a hierarchy of importance or stability, with the fifth scale tone and the third scale tone being most closely related to the tonic. The remaining scale tones are less related to the tonic, and the non-scale tones are the least related; the latter often sounding like 'foreign' tones. This tonal hierarchical organization of pitch facilitates perception, memory and performance of music by creating expectancies (Peretz & Coltheart, 2003:689).

There is substantial empirical evidence that listeners use this tonal knowledge in music perception automatically (Peretz & Coltheart, 2003:689). Tonal organization of pitch applies to most types of music, but it does not occur in processing other sound patterns, such as speech. Although the commonly used scales differ somewhat from culture to culture, most musical scales use pitches and afford the building of pitch hierarchies (Peretz & Coltheart, 2003:689).

The musical input modules are organized in two parallel and largely independent sub-systems of which the functions are to specify, respectively, the **pitch content** (the melodic contour and the tonal functions of the successive pitch intervals) and the **temporal content**, by representing the metric organization as well as the rhythmic structure of the successive durations (Peretz & Coltheart, 2003:689). The 'rhythm analysis' component deals with the segmentation of the ongoing sequence into temporal groups on the basis of durational values without regard to periodicity, whilst the 'meter analysis' component extracts an underlying temporal regularity or beat, corresponding to periodic alternation between strong and weak beats. The strong beats generally correspond to the spontaneous tapping of the foot. Both the melodic and temporal pathways send their respective outputs to either the 'musical lexicon' or the 'emotion expression' analysis component (Peretz & Coltheart, 2003:690). The **musical lexicon** is a representational system that contains all the representations of the specific musical phrases to which one has been exposed during one’s lifetime. The same system also keeps a record of any new incoming musical input. Accordingly, successful recognition of a familiar tune depends on a selection procedure that takes place in the musical lexicon. The output of the musical lexicon can feed two different components, depending on task requirements. If the goal is to sing a song like *Happy Birthday*, the corresponding melody, represented in the musical lexicon, will be paired with its associated lyrics that are stored in the phonological lexicon and will be tightly integrated and planned in a way that is suitable for vocal production. If the task requires retrieving non-musical information about a musical selection, such as naming the tune or retrieving a related experience from memory, the associated knowledge stored in the 'associative memories' component will be invoked (Peretz & Coltheart, 2003:690).

In parallel with memory processes, but independently, the perceptual modules will feed their outputs into an 'emotion expression' analysis component, allowing the listener to recognize and experience the emotion expressed by the music (Peretz & Coltheart, 2003:690). This emotional pathway also contributes to recognition via the musical lexicon. **Emotion expression analysis** is a pivotal processing component because music has the power to elicit strong emotional response. It takes input emotion-specific musical features, such as mode (e.g. major or minor) and tempo (e.g. slow or fast) as computed by the melodic and temporal pathways respectively (Peretz & Coltheart, 2003:690).

Musical skills are not typically associated with a specific brain hemisphere and neuropsychological investigations of musical abilities are often contradictory, this is a likely consequence of the complex nature of music (Don *et al.*, 1999:155). Nevertheless, research based on listening tasks, infant development, and lesion analysis reveals clues to the neurobiology and neuro-anatomy of music processing and concluded that music is processed in both hemispheres of the brain within the primary and secondary auditory cortices (Don *et al.*, 1999:155; Kuk & Peeters, 2008: par. 7). While the right hemisphere is responsible for the processing of timbre, pitch, and melody, the left hemisphere process rhythmic information (Andrade & Bhattacharya, 2003:285; Tervaniemi & Hugdahl, 2003:241; Don *et al.*, 1999:155).

All sound processing begins with the peripheral auditory apparatus, in which sound vibrations are transmitted to the cochlear inner hair cells (via the ear canal, tympanic membrane, and ossicular chain) (Limb, 2006:436). The early process of acoustic deconstruction takes place within the cochlea, which responds to acoustic vibrations in a frequency dependent fashion and triggers afferent potentials that travel down the cochlear nerve to the brainstem. Through a chain of sub-cortical processing structures (cochlear nuclei, olivary pathways, lateral lemnisci, inferior colliculi, and medial geniculate nuclei of the thalamus), neural impulses representing sound information eventually reach the auditory cortical structures (Limb, 2006:436). As the musical signal enters the primary auditory cortex it relays sound to the appropriate processing centres for further analyses, including the planum temporale, perisylvian language centres, motor areas, the frontal lobe and so forth (Kuk & Peeters, 2008: par. 7). The end result of this process is that of auditory percept (Limb, 2006:436). The processing of timing features of music begins as early as the cochlear nucleus with the brainstem. Processing of music is conducted in the Heschl's gyrus of the auditory cortex and the limbic system (Kuk & Peeters, 2008: par. 6). All auditory processing, whether environmental, linguistic, or musical in nature, relies on the integrity of this ascending auditory pathway (Limb, 2006:437). It is important to take note that the auditory cortex shows plasticity[11] throughout life (Tremblay, 2006:10) and in the case of a hearing loss, this is beneficial as it allows adaptation to behaviorally important sound and adapts easily to changes induced by a hearing loss and subsequent application of hearing aids or cochlear implants (Eggermont 2008:819).

The preceding information underlines the complexity of musical perception assessment and it is clear that many dimensions, such as pitch, timbre, rhythmic perception, melody recognition, and listening satisfaction may be evaluated to formulate a better understanding of music perception (Spitzer *et al.*, 2008:57).

2.3 PHYSIOLOGICAL EFFECT OF MUSIC

Music plays a central role in all human cultures, and for humans the experience of music is an important contribution to quality of life (Luis, Castro, Bastarrica, Perez-Mora, Madero, De Sarria & Gavilan, 2007:686). Both people with a hearing loss and normal hearing persons are continuously exposed to musical sounds in daily life. The idea that music conveys emotions seems an intuitive one; one only has to think of the central role played by music in social functions ranging from celebration (e.g. weddings) to grieving (e.g. funerals). One could

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[11] Refers to the brain's capacity to change as a function of experience, reorganizing throughout the lifespan according to the auditory input that is available to the individual

easily posit that the pervasive nature of music in the world is largely due to its ability to evoke emotion (Limb, 2006:439).

The limbic system is associated with emotions and is highly involved in music processing (Kuk & Peeters, 2008: par. 8). Parts of the limbic system that have shown activity to music stimulation include the amygdale, hypothalamus, prefrontal cortex, and the ventral tegmental area. It has been seen in animal studies that exposure to slow instrumental music alters the level of certain neuro-trophins in the hypothalamus. These changes in the concentration of neuro-trophins could also lead to a reduced stress response, which is regulated by the hypothalamus. Happy musical pieces have been associated with activation of specific portions of the limbic system including the ventral striatum (bilaterally) and left hemisphere structures like the dorsal striatum, para-hippocampal gyrus and the anterior cingulated cortex. Sad musical pieces activate the right medial temporal structures, including the hippocampus and amygdale (Kuk & Peeters, 2008: par. 10).

Changes in a person’s mood and emotions while listening to music have been linked to physiological changes in heart rate and respiration rate (Kuk & Peeters, 2008: par. 11). This may be mediated by changes in the release of arousal hormones, including epinephrine (adrenaline) and cortisl from the adrenal glands. The musical characteristics that may be responsible for influencing changes in heart rate of listeners include changes in tempo and aesthetics, intensity, rhythm, and texture (having to do with the number of voices or instruments) of music. Specifically, researchers found that participants’ heart rates and respiration rates decreased over time when listening to a soothing piece of music. Music selected for the purpose of relaxation shares some common characteristics. These include providing a tempo at or below resting heart rate (60 to 72 beats per minute), predictable dynamics (soft or moderately loud), few changes in tempo, volume or instrumentation, fluid melodic movement, pleasing harmonics, regular rhythm without sudden changes, and tonal qualities that include flute, strings or piano. Sounds of the voice, organ and acoustical wind instruments are also recommended. In addition it is suggested including a greater number of lower pitches to promote relaxation (Kuk & Peeters, 2008: par. 11). However, heart rates remained the same and respiration rates increased over time in response to an exciting piece of music. The features reported as disruptive to relaxation included depressing music, loud volume, and high-pitched instruments (Kuk & Peeters, 2008: par. 15).

Recently, the effect of music in quality of life has been explored. The benefits of music and music therapy in physiological, psychological, and social-emotional aspects of a patient's life have been stressed. Music therapy has been proved to be useful for post-operative pain, as well as for anxiety, mood, comfort, and relaxation. Moreover, a significant difference has been reported in quality of life of patients with a terminal illness receiving music therapy (Luis *et al.*, 2007:686).

2.4 MUSIC PERCEPTION TESTS DESCRIBED IN THE LITERATURE

Because of the importance of music, some tests of music perception have been developed. Almost all of these tests focus on music perception in persons with cochlear implants. Gfeller and colleagues (2005, 1997 & 1991) began by adapting the *Primary Measures of Music Audition* test and also developed *the Musical Excerpt Recognition* test. Many other groups have also assembled in-house tests to evaluate cochlear implant strategies and designs developed by their laboratories (Kong, Stickney & Zeng, 2005:1355). The instruments used in these studies were designed to address specific research questions regarding perception of different structural features of music. The methods used were often similar, but they were not intended to be standardized tests and it is therefore not possible to directly compare results across laboratories (Nimmons *et al.*, 2008:150). Furthermore, most of these tests were developed to examine the music perception skills of cochlear implantees and was therefore not applicable to the evaluation of persons using hearing aids. Other motivations for not using existing music perception tests included the facts that test constructs were not pertinent to this study; tests were too lengthy for the time available, they required formal musical knowledge such as notation or technical vocabulary and test items might have been too difficult for the test population (Gfeller & Lansing, 1992:26). A detailed description of the existing music perception tests follow in Table 2-1:

Table 2-1: Existing music perception tests described in the literature

Purpose	Tasks	Procedure	Reasons for exclusion from this study
Appreciation of Music in Cochlear Implantees (AMICI)			
The test was developed to assess the ability of persons with cochlear implants to interpret musical signals (Spitzer *et al.*, 2008:56).	**Discrimination of music vs. noise:** The participant had to indicate whether the stimulus was noise or music (Spitzer *et al.*, 2008:60). **Timbre identification:** The participant held a list of instruments (trumpet, piano, flute, drum, tuba, guitar, violin, female and male vocal) and had to identify the musical instrument playing (Spitzer *et al.*, 2008:60). **Identification of musical styles:** The participant was presented with a musical piece from different musical styles (classical, Latin, country and western, jazz and rock and roll) and had to identify the musical style represented by each stimulus (Spitzer *et al.*, 2008:60). **Melody recognition:** The participant had to identify musical pieces, either popular or classical excerpts. Acceptable responses included naming the song, its composer, context in which it was used, singing or humming the melody (Spitzer *et al.*, 2008:60).	The test was administered in sound field in a sound attenuating booth, with stimuli presented through external speakers at 65 dB HL. The participant held a set of written instructions for each test section (Spitzer *et al.*, 2008:59).	♬ Was developed to interpret musical signals in cochlear implantees and not hearing aid users (Spitzer *et al.*, 2008:56). ♬ It addresses melody identification (part of pitch identification) and timbre identification but does not address rhythm. ♬ The melody identification task includes melodies familiar to American countries and the American culture which are not all familiar in South Africa (Spitzer *et al.*, 2008:63).
Clinical Assessment of Music Perception (CAMP)			
To develop a test to quantify music perception by cochlear implant (CI) listeners in a clinically practical manner that could be standardized for administration at any cochlear implant centre (Nimmons *et al.*, 2008:149).	**Melody identification:** Assessed recognition of common melodies from a closed set (Nimmons *et al.*, 2008:149). The listener was permitted to listen to all the test melodies during the practice session, after which each melody was presented three times in random order for identification. **Pitch direction discrimination**: Used a two alternative forced-choice adaptive procedure to determine a threshold interval for discrimination of complex pitch direction change (Nimmons *et al.*, 2008:149). On each presentation, a tone at the reference frequency and a higher pitched tone determined by the adaptive interval size were played in random order. The users were asked to identify which note was higher in pitch. The frequencies were distributed within the octave surrounding middle C (262 Hz) (Nimmons *et al.*, 2008:151). **Timbre identification:** Assessed recognition of eight commonly recognisable musical instruments from a closed set (Nimmons *et al.*, 2008:149). The instruments were recorded playing an identical melodic sequence composed specifically for this test. Listeners were permitted to listen to all the instruments during the practice session. Each instrument was presented three times in random order for identification.	The test was presented on a computerized interface developed on *Matlab 7* and run on an *Apple Powerbook*. The graphical interface consisted of large buttons that the listeners navigated using a mouse. The test was administered in sound field in a sound attenuating booth, with stimuli presented through external speakers at 65 dB HL. Listeners were allowed to adjust their cochlear implant volume to the most comfortable level of loudness (Nimmons *et al.*, 2008:152).	♬ This is a computerized test (Nimmons *et al.*, 2008:149). Service delivery in South Africa is characterised by limited resources and facilities (Johnsen, 1998:217) and the need for extra equipment to conduct the test will reduce the usage of such a test in South Africa. ♬ Was developed to quantify music perception in persons with cochlear implants and not hearing aid users (Nimmons *et al.*, 2008:149). ♬ It addresses pitch and timbre identification but does not address rhythm (Nimmons *et al.*, 2008:150). ♬ The melody identification task includes melodies familiar to European and Asian countries that are not all relevant to the South African context (Nimmons *et al.*, 2008:152).

Purpose	Tasks	Procedure	Reasons for exclusion from this study
Medel Medical Electronics Mu.S.I.C. Perception Test			
To develop a test battery to quantify musical perception in cochlear implant users and to use as measurement tool to determine the effectiveness of cochlear rehabilitation (Medel Medical Electronics, 2006:1).	**Melody:** Determines a participant's ability to detect melodic differences between two short phrases. After a pair of melodies were played the participant had to decide if they were the same or different (Medel Medical Electronics, 2006:21). **Pitch:** Determines the participant's pitch difference limen by using a staircase algorithm. Pairs of descending and ascending sounds are played and the participant must select whether the second note is higher or lower in pitch by clicking the appropriate button (Medel Medical Electronics, 2006:18). **Distinguish chords:** Participant must distinguish between pairs of two piano chords and indicate whether they are the same or different (Medel Medical Electronics, 2006:22). **Rhythm:** Determines the participant's ability to distinguish temporal rhythms. Participant will hear pairs of rhythms and must decide if they were the same or different (Medel Medical Electronics, 2006:20). **What instrument:** Participants must identify what instrument they heard playing. To avoid the need for the participant to know the name of the instrument, responses are given by clicking on a picture of the instrument (Medel Medical Electronics, 2006:23). **Number of instruments:** Determines how many different instruments participants can distinguish in a piece of music (Medel Medical Electronics, 2006:24). **Emotional:** The participant needs to position a short piece of music on a happy-to-sad scale. Responses are given by indicating the appropriate number from one to ten (Medel Medical Electronics, 2006:25). **Dissonance:** This test asks participants to grade a piano chord on a consonance/dissonance scale, where one is the harshest possible sound and ten is the most melodious, smoothest sound (Medel Medical Electronics, 2006:26).	The test is delivered on DVD and first needs installation to a computer (Medel Medical Electronics 2006:3). The test was administered through the computer on a level comfortable to the participant (Medel Medical Electronics, 2006:9). The participant responded to each test by pressing the appropriate buttons on the computer screen (Medel Medical Electronics, 2006:9).	♬ Was developed to assess music perception in cochlear implantees and not hearing aid users. ♬ This is a computerized test (Medel Medical Electronics, 2006:3). Service delivery in South Africa is characterised by limited resources and facilities (Johnsen, 1998:217) and the need for extra equipment to conduct the test might reduce the usage of such a test in South Africa.
Musical Excerpt Recognition Test (MERT):			
This test was designed to evaluate recognition of 'real-world' musical excerpts by cochlear implant users (Gfeller *et al.*, 2005:241).	The excerpts in the test represented the frequency range of orchestral music and the grand piano and consisted of complex multi-dimensional combinations of melodies and harmonies, timbres, rhythmic patterns and sometimes sung lyrics (Gfeller *et al.*, 2005:241). The excerpt selection was limited to pop, country and classical genres, the musical styles most commonly heard by the target populations of post-lingually deafened cochlear implant recipients and normal hearing adults. This test includes fifty musical excerpts representing a primary musical theme. To promote greater reliance on perception of the musical features (as opposed to lyrics), excerpts that included the title of the selection in the lyrics were excluded. The first five excerpts were practice items, the remaining 45 items consisted of 36 target items (8 familiar and 4 obscure for each genre), and 9 familiar target items (three from each genre) repeated to obtain indices of participant reliability (Gfeller *et al.*, 2005:242).	The sound level was averaged at 70 dB SPL, however implant recipients were permitted to adjust their processor for maximum comfort and normal hearing adults could adjust the volume on the speakers (Gfeller *et al.*, 2005:243). Test administration began with instructions on the computer screen and the five practice items. The participant listening to the items had to indicate whether or not the item sounded familiar.	♬ Was developed to assess recognition of musical excerpts in cochlear implantees and not hearing aid users (Gfeller *et al.*, 2005:241). ♬ This is a lengthy test of open-set recognition and music appraisal, which can take many hours and require trained musical personnel to code the responses (Nimmons, *et al.*, 2008:150).

Purpose	Tasks	Procedure	Reasons for exclusion from this study
Montreal Battery for Evaluation of Amusia (MBEA)			
The MBEA was used to measure six different aspects of music perception along a melodic and temporal dimension (Cooper *et al.*, 2008:619). This test does not rely on the memory of familiar melodies, it is a measure based on cognitive theories and neuro-psychological evidence (Cooper *et al.*, 2008:619).	**Contour:** This test measures the ability to detect changes in the contour of the melody. It alters the contour of a melody by changing one note of the melody in such a way that its pitch height, respective to its neighbouring notes, is reversed (Cooper *et al.*, 2008:620). **Interval:** This test measures the perception of pitch step size information. The contour of the original melody is preserved but the pitch distance between the changed note and its neighbouring notes are altered (Cooper *et al.*, 2008:620). **Scale:** It measures the perception of musical scale information or tonality. The altered notes in the scale test are in the same pitch range as the altered notes used in the rules of the contour and interval tests. In contrast to these two measures, the altered note in the scale test is not in the correct (same) key and therefore sounds out of tune (Cooper *et al.*, 2008:621). **Rhythm:** It measures the perception of temporal aspects of music. It uses the same melodies as the previous tests but it is the duration of two adjacent notes that are altered rather than the pitch of the notes (Cooper *et al.*, 2008:621). **Meter:** Participants are required to indicate whether the melodic patterns were in either duple or triple meter, using the terms 'march' or 'waltz' respectively (Cooper *et al.*, 2008:621). **Melodic memory:** It consisted of 15 melodies from the previous tests and 15 unheard melodies. Participants are required to indicate whether the melody was presented in the earlier tests (Cooper *et al.*, 2008:621).	With the exception of the Meter and Melodic memory sub-tests in each task, participants listened to two melodies and indicated whether they were the same or different. For the meter tests, participants indicated whether the melodies were either a march or a waltz. On the sub-test for incidental memory, participants indicated whether the melody was presented in an earlier test (yes/no). In all conditions, participants indicated their response to each trial by marking with 'x' on a provided answer sheet (Cooper *et al.*, 2008:620).	♬ It was specifically designed for the evaluation of Amusia (Cooper *et al.*, 2008:618). ♬ The test was only evaluated as a possible test for using with cochlear implantees and not for persons with hearing aids (Cooper *et al.*, 2008:625). ♬ The pitch test appears to be too difficult for cochlear implantees and therefore is limited in its use. No information on persons with hearing aids is available (Cooper *et al.*, 2008:625). ♬ The melodic stimuli consist of a relatively low frequency range and are therefore not relevant for this specific study where the focus is placed on high frequency stimuli. The fundamental frequencies of the stimuli range from 247 to 988 Hz (Cooper *et al.*, 2008:625). ♬ This test addresses two aspects of music perception, namely rhythm and pitch but does not address timbre (Cooper *et al.*, 2008:625). ♬ It is a lengthy test and takes more than an hour to complete (Cooper *et al.*, 2008:619).
Music Test Battery			
A music test battery was designed for evaluation of music perception in persons with cochlear implants (Looi *et al.*, 2008b:423).	**Rhythm:** Stimuli for this test were derived from the PMMA rhythm sub-test. The verbal prompts used in the original recording were eliminated for this study because of previously identified difficulties (Looi *et al.*, 2008b:423). **Pitch:** This test comprised three sub-tests, each identical in format but using differing interval sizes. The first sub-test consisted of pairs of one octave (12 semitones) apart, the second sub-test presented half-octave (6 semitones) intervals, and the third sub-test quarter-octave (3 semi-tones) intervals. Recordings of the vowels /i/ and /a/ were obtained from trained singers with the two notes of the same vowel, and sung	As testing was conducted at two different sites, the signals were not presented to participants in the sound field to avoid the effects of variable loudspeaker frequency response and room acoustics. Sound-isolation booths were used for all of the	♬ The melody test includes melodies familiar to the Australian population (Looi *et al.*, 2008b:425) which may not be recognized by South African people. ♬ It is a very lengthy test (about 4 hours) and therefore participants have to complete it in two or three sessions (Looi *et al.*, 2008b:426).

	by the same singer at the designated interval size. For half of the presentations, the first note was higher than the second (descending), while the other half was ascending. Participants were required to select the higher note for each stimulus pair (Looi *et al.*, 2008b:424). **Instrument:** This test consisted of three sub-tests, each with the same procedure but different stimuli. The first sub-test consisted of single instrument sounds, the second of solo instruments with background accompaniment, and the third involved music ensembles. For each sub-test, participants were presented with a list of the instruments or ensembles. They were instructed to name the instrument or ensemble that they though were playing (Looi *et al.*, 2008b:425). **Melody:** The first 15 seconds of well-known melodies were recorded, preserving the original rhythms. After each melody had been presented, participants were asked to name the melody from a list of melody titles (Looi *et al.*, 2008b:425).	testing. All stimuli were presented from a computer, connected to an external sound box and presented via earphones. Participant’s responses were entered directly into the computer. For all the tests, participants selected their preferred listening settings on their device, and presentation levels were individually verified to be of a comfortable loudness (Looi *et al.*, 2008b:425).	
Primary Measures of Music Audiation (PMMA)			
This test was developed by Gordon in 1979 and assesses discrimination of short tonal and rhythm patterns (Gfeller & Lansing, 1991:917). It was used in musical perception experiments by Gfeller *et al.*, 1997, Gfeller & Lansing (1992) and Gfeller & Lansing (1991).	**Melodic (tonal):** Each melodic pattern contains from two to five notes ranging in pitch. The items have identical temporal patterns, but those item pairs that are different vary on one or more notes in frequency (Gfeller & Lansing, 1991:917). Respondents are asked to indicate if the item pair is the same or different. **Rhythm:** All stimuli are presented at the same frequency and differences are in duration or intensity of notes. Respondents are again asked to indicate whether the item pair is the same or different (Gfeller & Lansing, 1991:917).	Each participant was tested individually in a small room. Participants were asked to complete a questionnaire. The tests were played over a portable cassette tape recorder in sound field at most comfortable level of loudness (range of 65-84 dBA SPL) (Gfeller & Lansing, 1992:25).	♬ This test is normed on young children (up to grade three) (Gfeller & Lansing, 1991:917). ♬ One difficulty with the recorded format of the PMMA was the verbal prompt prior to each item pair: Each rhythmic pair or tonal pair is preceded by the name of an object (e.g. apple or leaf) and prompts of 'first' and 'second'. For some listeners these auditory stimuli might be perceived as a part of the signal for the discrimination task. Rather, a visual prompt is recommended before each item pair begins (Gfeller & Lansing, 1992:27). ♬ This is a lengthy test of open-recognition and music appraisal (Nimmons, *et al.*, 2008:150). ♬ The test requires trained musical personnel to code the responses (Nimmons, *et al.*, 2008:150).

Note that all the tests mentioned above were developed or used for cochlear implant users and no test for music perception for hearing aid users is available at present.

Additionally to the music perception tests described above, some academics did research regarding different aspects of music perception. No formal test was used in the research and they used material for the purposes of their particular studies only. Such research studies included:

- ♬ *Temporal stability of music perception and appraisal scores in adult cochlear implant recipients (Gfeller, Jiang, Oleson, Driscoll & Knutson, 2010).*

  This study included the analysis of six measures of music perception or appraisal collected twice, approximately one year apart. The measures were:

  - familiar melody recognition, which involved open-set recognition of 12 familiar melodies without lyrics (synthesized piano tones),
  - timbre recognition, which involved closed set recognition of eight different musical instruments (recordings of solo instrumentalists playing a standardized melody),
  - recognition of excerpts of real-world instrumental music (no lyrics),
  - recognition of excerpts of real-world music with lyrics,
  - appraisal of excerpts of real-world instrumental music (no lyrics), and
  - appraisal of excerpts of real-world music with lyrics. The recordings of the real-world music tests were comprised of excerpts representative of three musical styles including classical, pop and country (Gfeller *et al.*, 2010:30).

- ♬ *Effects of training on recognition of musical instruments presented through cochlear implant simulations (Driscoll, Oleson, Jiang & Gfeller, 2009).*

  Sixty-six adults with normal hearing completed three training sessions per week, over a five-week time period, in which they listened to the cochlear implant simulations of eight different musical instruments. Results indicated that different types of training are differently effective with regard to improving recognition of musical instruments presented through a degraded signal, with direct instruction being the most effective (Driscoll *et al.*, 2009:71).

- *The ability of cochlear implantees to recognise melodies as a function of melody frequency range, harmonicity and number of electrodes (Singh, Kong & Zeng, 2009).*

  In this study, 12 well-known melodies were used in low, mid and high frequency ranges to identify from a closed-set. The melodies were presented via direct connection from the speech processor of the cochlear implant to the computer with the volume adjusted to a comfortable level as judged by each participant. Each melody was played three times in random order, producing a block of 36 melodies (Singh *et al.*, 2009:162).

- *Multivariate predictors of music perception and appraisal by adult cochlear implant users (Gfeller, Oleson, Knutson, Breheny, Driscoll & Olszewski, 2008).*

  Cochlear implant recipients participated in a pitch ranking task, melody recognition task, the Musical Excerpt Recognition Test (MERT), timbre recognition, an excerpt appraisal task and several cognitive and speech measures to determine whether performance by cochlear implant users could be predicted from technological, demographic and life experience variables, as well as speech recognition scores (Gfeller *et al.*, 2008:124).

- *Melodic contour identification by cochlear implant listeners (Galvin et al., 2007).*

  Cochlear implantees were asked to identify one of nine five-note melodic contours. The interval between successive notes in each contour was systematically varied to test musical pitch resolution provided by the cochlear implant device (Galvin *et al.*, 2007:304). The 'root note' (i.e. the lowest note in the contour) was also varied to test whether there was optimal sensitivity to musical pitch in different frequency ranges. Three-harmonic complexes were used to represent the musical notes to test cochlear implant user performance in a multi-channel context. For comparison purposes, familiar melody recognition was also evaluated with two sets of 12 familiar melodies, in which the rhythm cues were either preserved or removed (Galvin *et al.*, 2007:304). Cochlear implant users were tested in free field in a sound-treated booth and stimuli were delivered via a single loudspeaker (Galvin *et al.*, 2007:306).

- *Temporal information processing in musicians and non-musicians (Rammsayer & Altenmuller, 2006).*

  This study included the following tasks:

Temporal discrimination task: Filled intervals were white noise bursts presented binaurally through headphones and empty intervals were marked by onset and offset clicks 3 ms in duration (Rammsayer & Altenmuller, 2006:39). Because interval timing may be influenced by the type of interval (filled vs. empty) and base duration, this task consisted of one block of filled and one block of empty intervals with a base duration of 50 ms each, as well as one block of filled intervals with a base duration of 1000 ms. The order of blocks was counterbalanced across participants. Each block consisted of 64 trials, and each trial consisted of one standard interval and one comparison interval. The duration of the comparison interval varied according to an adaptive rule to estimate x.25 and x.75 of the individual psychometric function, that is, the two comparison intervals at which the response 'longer' was given with a probability of .25 and .75, respectively. In each experimental block, one series of 32 trials converging to x.75 and one series of 32 trials converging to x.25 were presented. Within each series, the order of presentation for the standard interval and the comparison interval was randomized and balanced, with each interval being presented first in 50% of the trials. The participant’s task was to decide which of the two intervals was longer and to indicate his decision by pressing one of two designated response keys. After each response, visual feedback was displayed on the computer screen (Rammsayer & Altenmuller, 2006:39).

Temporal generalization task: The stimuli were sine wave tones presented through headphones. The standard duration of the long intervals was 1000 ms and the non-standard durations were 700, 800, 900, 1100, 1200 and 1300 ms (Rammsayer & Altenmuller, 2006:39). The standard duration of the short intervals was 75 ms and the non-standard durations were 42, 53, 64, 86, 97 and 108 ms. Performance on temporal generalization was assessed separately for intervals in the range of milliseconds and seconds. Participants were required to identify the standard stimulus among the six non-standard stimuli. In the first part of the experiment, participants were instructed to memorize the standard stimulus duration. For this purpose, the standard interval was presented five times accompanied by the display 'standard duration' (Rammsayer & Altenmuller, 2006:39). Then participants were asked to start the test. The test consisted of eight blocks. Within each block, the standard duration was presented twice, while each of the six non-standard intervals was presented once. On each test trial, one duration stimulus was presented. Participants were instructed to decide whether or not the presented stimulus was of the same duration as the standard stimulus stored in the memory (Rammsayer & Altenmuller, 2006:40).

Rhythm perception task: The stimuli consisted of 3 ms clicks presented binaurally through headphones (Rammsayer & Altenmuller, 2006:40). Participants were presented with auditory rhythmic patterns, each consisting of a sequence of six 3ms clicks marking five beat-to-beat intervals. Four of these intervals were of a constant duration of 150 ms, while one interval was variable (150 ms + x). The value of x changed from trial to trial depending on the participant's previous response according to the weighted up-down procedure. Correct responding resulted in a decrease of x and incorrect responses made the task easier by increasing the value of x. The participant's task was to decide whether the presented rhythmic pattern was perceived as regular (all beat-to-beat intervals appeared to be the same in duration) or irregular (one beat-to-beat interval was perceived as deviant) (Rammsayer & Altenmuller, 2006:40).

Auditory flutter fusion task: The stimuli consisted of 25 ms noise bursts presented binaurally through headphones (Rammsayer & Altenmuller, 2006:40). Auditory flutter fusion threshold estimation consisted of 12 trials, and each trial consisted of two noise bursts separated by a variable period of silence ranging from 1 to 40 ms. After each trial, the participant's task was to indicate by pressing one of two designated keys whether he/she perceived the two successive noise bursts as one sound or two separate sounds. To enhance reliability of measurement, two auditory flutter fusion threshold estimates were obtained for each participant (Rammsayer & Altenmuller, 2006:40).

- *Speech and melody recognition in binaurally combined acoustic and electric hearing (Kong et al., 2005).*

For the melody recognition experiment, three sets of 12 familiar melodies, consisting of single notes, were generated using a software synthesizer. For each melody, rhythmic information was removed by using notes of the same duration. Therefore, pitch was the only available cue for melody recognition (Kong *et al.*, 2005:1356) Three sets of the 12 melodies were generated in low-, mid-, and high frequency ranges. All participants were tested with cochlear implant, hearing aid and both in three melody conditions (low, mid and high) for a total of nine conditions. For either the hearing aid or the cochlear implant stimuli were presented at the participant's most comfortable level with the hearing aid or cochlear implant at its usual settings. The titles of the 12 melodies were displayed on a computer screen and the participant was asked to choose the melody that was presented. A practice session with feedback was given before the actual test. Repetition of the stimulus was not allowed and visual feedback regarding the correct response was given immediately after the participant's response (Kong *et al.*, 2005:1356).

♬ *Music perception with temporal cues in acoustic and electric hearing (Kong, Cruz, Auckland & Zeng, 2004).*

This study included tasks of tempo discrimination, rhythmic pattern identification and melody identification which are discussed below:

Tempo discrimination: Musical tempos were generated with a drum machine and it was measured with four standard tempos at 60, 80, 100 and 120 beats per minute. For each standard tempo, 21 or more tempos were used to pair with the standard tempo. Participants listened to these tempo pairs and were asked to identify the faster tempo in a two-interval, forced choice paradigm (Kong *et al.*, 2004:176).

Rhythmic pattern identification: All musical patterns were played on and recorded by a drum machine. It was measured at four standard tempos: 60, 90, 120 and 150 beats per minute. Each participant listened to two bars of drumbeats. The first bar was always a standard rhythmic pattern. The second bar contained one of the seven patterns displayed in a graphical representation. Participants were asked to choose the musical notation corresponding to the rhythmic pattern they heard. All participants were trained to read basic musical notation before the study (Kong *et al.*, 2004:177).

Melody identification: Two sets of 12 familiar songs, rendered in single notes, were generated using a software synthesizer. One set contained both rhythmic and melodic information (rhythm condition), whereas the other set contained only melodic information (no rhythm condition). In the no-rhythm condition, all melodies were played using notes of the same duration; therefore, pitch was the only available cue for melody recognition (Kong *et al.*, 2004:178). Both normal hearing and cochlear implant users were first tested with the original, unprocessed stimuli. In addition, normal hearing listeners were tested with all the rhythmic and no-rhythm processed stimuli (simulation). Cochlear implantees however, were only tested using 1-band with rhythm processed stimuli. The condition of

1-band without rhythm was not performed in the cochlear implantees because their performance was already near the chance level when presented with the original stimuli. The titles of the 12 melodies were displayed on a computer screen and the participants were asked to identify the melody from a closed set. All melodies were presented three times in random order for each experimental condition (Kong *et al.*, 2004:178).

- *Music perception in adult cochlear implant recipients (Leal et al., 2003).*
  The following sub-tests were included in this study:

Timbre: In order to obtain evaluative responses of perceptions of various timbres, the participants listened to short solo melodies produced by three commonly heard musical instruments representing different instrumental families and frequency ranges. These included wind (trombone), percussion (piano) and string families (violin). The participants were asked to identify each instrument. To reduce the structural variability of the phrases between instruments, all instruments were played using the same pitch scale. The instrumental recordings played the same French nursery melody (single note) (Leal *et al.*, 2003:827).

Pitch: Twelve pairs of items with identical temporal patterns but differences in frequency were used. The pairs of items were sometimes similar and pitch was changed in an increasingly difficult manner. In the pitch discrimination test the respondents were asked to indicate whether the pair of items was the same or different and in the pitch identification test they were asked whether the pitch became higher or lower and where this change occurred (beginning, middle or end) (Leal *et al.*, 2003:827).

Rhythm: This test was similar to the pitch test. They evaluated changes in duration or intensity of the notes by presenting ten pairs of musical pieces separated by five seconds of silence. All stimuli were presented at the same frequency. In the first part of the test (discrimination), respondents were asked to discriminate whether the pair of items was the same or different. In the second part (identification) they were asked to determine the point of change (Leal *et al.*, 2003:827).

Song recognition: For this task, they showed participants a list of 16 songs and asked which ones they were familiar with. Eight songs were selected that the participant was familiar with and these songs (closed set) were presented at random. The songs were presented first by an orchestra without verbal cues, then played on piano (single note) and finally by an orchestra with verbal cues. Participants were asked to identify the songs by name or by singing a part of the song (Leal *et al.*, 2003:827).

- *Effects of frequency, instrumental family and cochlear implant type on timbre recognition and appraisal (Gfeller* et al.*, 2002).*

  These researchers used timbre stimuli from eight different commonly known musical instruments (Gfeller *et al.*, 2002:350). These timbre stimuli were used in three different tasks, including timbre recognition (identification of the instrument being played by sound alone) and timbre appraisal which included the overall pleasantness of the sound and qualitative ratings for different timbre dimensions (Gfeller *et al.*, 2002:351). For the timbre recognition test, stimuli based on each instrument were presented three times in random order. After each melody was played the individual selected the instrument that he/she believed produced the sound just heard. In the general appraisal test participants were asked to appraise the overall pleasantness of items by touching a point along a 100 mm visual analogue scale (0 represents dislike very much and 100 represents like very much). Lastly participants were asked to rate the sound quality (Gfeller *et al.*, 2002:351).

- *Effects of training on timbre recognition and appraisal by post-lingually deafened cochlear implant recipients (Gfeller* et al.*, 2002).*

  This study used the same timbre stimuli and procedures as in the previous study described by Gfeller *et al.* (2002), but with only evaluating participants before and after a training period.

- *Recognition of familiar melodies by adult cochlear implant recipients and normal hearing adults (Gfeller* et al.*, 2002).*

  To conduct this study, the researchers included a familiar melody recognition task as well as a complex-tone discrimination task. Both of these are discussed below.

  Familiar melody recognition task: To identify items likely to be familiar to non-musicians, collections of songs commonly known to the general public in the United States were reviewed and a pool of song titles was submitted to a panel of university experts in music education, who verified that these were well-known melodies (Gfeller, *et* *al.*, 2002:34). Adult volunteers were tested individually in open-set recognition of 35 selected songs, played on piano and recorded on cassette tape (Gfeller, *et al.*, 2002:35). From the most familiar items, a subset of 12 was chosen. As prior research indicates that normal hearing adults and adults with cochlear implants rely on rhythmic features for melodic recognition, melodies were selected that could be grouped into two categories based on rhythmic features: items with distinctive rhythmic features within the melody line (e.g. dotted eight notes, triplet figures, etc.) and items made of quarter notes (no distinctive rhythm) with a half note at the closure of the musical phrase Gfeller, *et al.*, 2002:35). In addition to the 12 familiar melody items, the test included 12 foils, one for each of the familiar melodies. These newly composed items were created by using the durational values and the pitches of the familiar melodies, but in a new sequential order. Each familiar melody and its foil were presented in melody only, and melody plus harmony (no lyrics). All melody lines were presented in the same fundamental frequency range; melody-only versions included a fundamental frequency range of 194-659 Hz. Harmony versions consisted of the melody (figure) against background harmony (ground) (Gfeller, *et al.*, 2002:35). The harmony versions included a fundamental frequency range of 87 to 659 Hz. The melodies were presented in C major, and at the same tempo (Gfeller, *et al.*, 2002:36). The test was delivered via a computer with touch screen and external speakers in free field. The stimuli were transmitted through the speech processor and the sound level was set at 70 dB. First, the participant read standardized instructions for the test on the computer screen and practiced on two sample items. A total of 45 items (familiar and foils) were then presented in random order. Each familiar item was presented twice: melody-only and melody-plus-harmony format. Six item foils were presented in melody-only format and six in harmony format. A sub-group of nine items was repeated a second time during the test to determine internal consistency of participant responses (Gfeller, *et al.*, 2002:36).

Complex-tone discrimination task: The tone stimulus was a standard synthesized acoustic grand piano. A range of 36 semitones (three octaves) was used which has fundamental frequencies ranging from E (73 Hz) to C (553 Hz) (Gfeller, *et al.*, 2002:38). The task was a two alternate forced choice interval test. Two tones separated by silence were presented to the participant, who had to make a decision on whether the second tone was higher or lower in pitch than the first tone (Gfeller, *et al.*, 2002:38). The direction of the interval was also randomized for each presentation. This method was used to gather an overall and relatively quick assessment of discrimination across a wide frequency range. The used algorithm, which has a memory of the last three interval levels the user has achieved, adapts to the participant's response. Generally, if a participant responds correctly to the item, the interval size is reduced, based on previous interval levels tested. Likewise, when the participant responds incorrectly, the interval size is increased. The algorithm continues until it finds an interval size judged significantly correct. The minimum resolution of the test is one semitone, which is the smallest interval size on standard pianos and in the scale for traditional western music (Gfeller, *et al.*, 2002:39).

- *The ability of Nucleus Cochlear implantees to recognize music (Fujita & Ito, 1999).* These researchers tested the ability of persons with cochlear implants to recognize music (Fujita & Ito, 1999:634). They used 20 well-known nursery songs that were obtained from commercial cassette audiotapes and presented the stimuli at 65 to 75 dB SPL to the participants. Each participant was asked to recognize nursery songs (both open and closed set), distinguish among nursery songs with the same rhythm and pitch range, distinguish musical intervals played on the keyboard and distinguish which musical instrument (piano, banjo, violin, harp or trumpet) was being played on the keyboard. These tasks required about 1.5 hours to complete (Fujita & Ito, 1999:635).

- *Perception of rhythmic and sequential pitch patterns by normally hearing adults and adult cochlear implant users (Gfeller et al., 1997).*
  For this study the tonal and rhythmic sub-tests of the PMMA were used (Gfeller *et al.*, 1997: par. 19). The researchers also conducted a 6-pulse task. Stimuli for this rhythmic pattern task were computer generated square waves presented at 71 dB SPL. The frequency of each pulse was 440 Hz, and the duration of all pulses was equal. A given pattern consisted of six pulses separated by either of two inter-pulse intervals. Four of the inter-pulse intervals were equal in duration and called the long inter-pulse intervals. One of the intervals was 10% of the long inter-pulse interval and termed the short inter-pulse interval. Four different patterns were used, each differentiated by the position of the short inter-pulse interval (i.e. interval 1, 2, 3 or 4) (Gfeller *et al.*, 1997: par. 19). Participants were asked to listen and determine where in the entire pattern the short inter-pulse interval was perceived, either more toward the beginning or more toward the end of the pattern. To register their response, they were given a key pad with two buttons and instructed to push the button marked 'B' (for beginning) to indicate that the two closest pulses occurred

toward the beginning of the pattern or marked 'E' (end) to indicate the two closest pulses occurred toward the end of the pattern (Gfeller *et al.*, 1997: par. 20). Each participant was instructed through visual cues on the computer screen to listen to each stimulus item. Responses were automatically recorded by a computer for later data analysis (Gfeller *et al.*, 1997: par. 24).

♬ *Psychometric features and motivational benefits of Computerized-Adaptive and Self-Adapted Music-Listening tests (Vispoel & Coffman, 1994).*

A study was done with computerized-adaptive tests (CAT) and self-adapted tests (SAT) to demonstrate the features and benefits of both. Both tests measured tonal memory (the ability to remember tonal sequence) (Vispoel & Coffman, 1994:29). Two forms of the CAT and two forms of the SAT were constructed from non-overlapping item pools. One CAT form and one SAT form used Pool A whereas the other CAT and SAT form used Pool B. Items were selected for the pools in such a way that their information curves were essentially identical. Each test consisted of a series of short melodies played twice. Examinees indicated whether the melodies were the same or different; if different, they indicated the number of the single altered tone (Vispoel & Coffman, 1994:30). Each CAT and SAT was administered on a computer and terminated at 30 items. The CAT began with an item of medium difficulty. Examinees chose items from six difficulty levels when taking the SAT. If examinees responded to all items at a given level, they were asked to choose another level (Vispoel & Coffman, 1994:30).

♬ *Pitch discrimination and phase sensitivity in young and elderly participants and its relationship to frequency selectivity (Moore & Peters, 1992).*

All stimuli were digitally generated (Moore & Peters, 1992:2884). The complex tones were harmonic complexes composed of equal-amplitude harmonics with fundamental frequencies of 50, 100, 200 and 400 Hz (the range of voice pitch). The tones contained harmonics 1-12, 6-12, 4-12 and 1-5. For fundamental frequency of 400 Hz, the highest harmonic number was ten to insure that all harmonics were audible for all participants; absolute thresholds were typically increasingly elevated above 4 kHz for most of the participants with a hearing loss. The components of the harmonic complexes were added in one of two phase relationships, all cosine phase or alternating cosine and sine phase (Moore & Peters, 1992:2884). Frequency discrimination of pure tones was measured for frequencies of 50, 100, 200, 400, 800, 1000, 1200, 2000, and 4000 Hz. The level of the tones was 25 dB above the absolute threshold at the test frequency. Measurements were done using an adaptive three-interval, three-alternative forced-choice method. Each trial consisted of three observation intervals, marked by lights. In two of the intervals, the frequency of the stimulus was the same, while in the third, selected at random, the frequency was higher. The task of the participant was to select the observation interval containing the higher frequency. At least three threshold estimates were obtained for each condition (Moore & Peters, 1992:2884). Participants were given a small amount of training before data collection began. However, the three-interval task used in this study appears to be easier to learn than the two-interval task more commonly used and there was no evidence of participants improving during the course of the experiment. It seems likely that participants find it easier to pick the 'odd one out' than to decide whether a pitch ascended or descended (Moore & Peters, 1992:2885).

- ♫ *Melodic, rhythmic and timbral perceptions of adult cochlear implant users. (Gfeller & Lansing, 1991).*

  In order to obtain evaluative reports of perceived quality for varied timbres, participants listened to short taped excerpts of solo melodies produced on nine acoustic instruments (Gfeller & Lansing, 1991:918). These instruments were selected to represent a variety of harmonic spectra and frequency ranges. The instrumental recordings included familiar folk and semi-classical melodies. Following each example, participants completed a musical instrument quality rating form where they selected descriptors from lists of bipolar adjectives, such as beautiful/ugly. The participants were also asked to identify the melody and name the musical instrument (Gfeller & Lansing, 1991:918).

As mentioned before, all of the above were developed to assess cochlear implantees' performances on different aspects of music perception. These tests however, contain important aspects that need to be included in the development of a music perception test for hearing aid users.

2.5 DEVELOPMENT OF A MUSIC PERCEPTION TEST FOR HEARING AID USERS

It is important to consider the very complex and wide-ranging nature of music and to realize that the tasks in several studies regarding music perception in cochlear implant users represent a specific and narrow aspect of music listening. Music generally constitutes a unified whole that cannot be naturally subdivided (e.g. it is difficult to listen to the notes of a melody while ignoring its rhythmic underpinning and vice versa) (Limb, 2006:436). As such, it is plausible that the division of music into smaller musical elements may not be the best method to approach the subject of music at large. When participants hear all the musical parameters together their perception is not as good as when they hear them separately (Leal *et al.*, 2003:834). Fujita and Ito (1999) found the same outcome – good ability to recognize songs that were sung with instrumental accompaniment but poor ability to recognize songs played on a keyboard without verbal cues, indicating that patients recognized songs by verbal cues rather than by musical qualities such as tones and melodic intervals. Yet, in order to establish basic concepts, this approach has been commonly taken and has even been used to outline a modular organization for music processing. The scientific study of music perception has used stimuli based on both discrete musical elements and intact, musically rich stimuli (Limb, 2006:436).

As none of the tests mentioned above were designed for hearing aid users, none of them were used in this study. Therefore the researcher has decided to compile a music perception instrument for this study to serve the purpose of data collection. Depending on the results of this study, the self-compiled music perception instrument might possibly be accessible in South Africa for future use by students, audiologists in the hearing instrument dispensing market and audiologists involved with persons with cochlear implants.

Rhythm, timbre, pitch and melody are structural features of music that have been previously examined with regard to music perception and are important aspects to assess in order to gain insight into a person’s perception of musical stimuli (Deutsch, 2007:4473; Iakovides *et al.*, 2004:4). These aspects are discussed below because they form an integral part of any music perception test and because they are also included in the music perception test compiled for this study.

♬ Rhythm

Rhythm is described as a regular movement or beat or a regular pattern of changes (Collins, 1989:683). The major focus of rhythm perception is on discriminating a series of temporal patterns (Rammsayer & Altenmuller, 2006:38). Commonly, in a rhythm perception task, a participant is presented with a click pattern, devoid of any pitch, timbre, or dynamic variations to avoid possible confounding influences on perceived rhythm. In the self-compiled music perception test rhythm identification, discrimination, recognition and rhythm perception tasks were included.

♬ Timbre

Timbre is defined as the characteristic feature of a sound or pitch (Brink, 1997:486). It is an attribute of auditory sensation in which a participant can judge that two sounds similarly presented and having the same loudness and pitch are dissimilar (Mueller & Hall, 1998: 965). This test evaluated timbre identification with single instruments and a combination of instruments playing together.

♬ Pitch

The participative impression of the highness or lowness of a sound is called the pitch and it is known to be the psychological correlate of frequency (Martin & Clark, 2000:66). Pitch perception is an important underlying component of music perception, as melody recognition strongly depends on perceiving exact intervals between successive notes (Galvin *et al.*, 2007:303). In normal hearing, the pitch of a sound is thought to be extracted from the place of stimulation in the cochlea, by resolving frequency components in the neural firing pattern, or possibly by analyzing phase components across the signal spectrum at different cochlear locations (Galvin *et al.*, 2007:303). Pitch sub-tests in this test included a pitch identification and pitch discrimination task.

♬ Melody

A melody, also tune, voice or line, is a linear succession of musical tones/pitches which is perceived as a single entity and forms a musical phrase (Limb, 2006:441). In its most literal sense, a melody is a sequence of pitches and durations, while, more figuratively, the term has occasionally been extended to include successions of other musical elements such as tone colour. Melodies often consist of one or more musical phrases and are usually repeated throughout a song in various forms. Melodies may also be described by their melodic motion or the pitches or the intervals between the pitches, pitch range, tension and release, continuity and coherence and shape (Brink, 1997:301). Melody is one of the absolute quintessential elements of music (Limb, 2006:441).

2.6 COMPUTERIZED-ADAPTIVE TESTS VS. SELF-ADAPTED TESTS

The use of computers for administering and scoring music listening tests has increased dramatically in recent years (Vispoel & Coffman, 1994:27).

When a person is subjected to a music listening test, a momentary lapse in attention can lead to an incorrect response because each item is played only once. This problem is less serious in visually administered tests because the items may be reread as many times as desired before responding (Vispoel & Coffman, 1994:27). The high degree of concentration required to perform well on listening tests is difficult to maintain over a long period of time and quickly tires the subject/s The repetitious nature of many music tests (e.g. indicating whether each of 30 consecutive pairs of tones is the same or different) frequently compounds fatigue problems with effects of apathy and boredom. To reduce these problems, music test developers usually limit administration time to one hour or less. This practice, however, sometimes reduces the reliability and validity of individual sub-tests in aptitude and achievement batteries to unacceptably low levels (Vispoel & Coffman, 1994:27). Computerized-adaptive test procedures have been greeted with enthusiasm by many music test developers because such procedures provide a vehicle for significantly enhancing the reliability and validity of music listening tests while maintaining or even reducing test length and administration time (Vispoel & Coffman, 1994:27).

The major advantage of computerized-adaptive music listening tests was found to be its efficiency (Vispoel & Coffman, 1994:43). When a fixed measurement precision termination and fixed length stopping criterion was used, the computerized-adaptive test required less than half the administration time that the self-adaptive test required. This gap in efficiency occurred because the self-adaptive test required both additional items to attain the precision criterion and additional time for examinees to choose the difficulty levels of items. These findings indicate that at fixed lengths the self-adaptive tests inefficiency resulted predominantly from the time subjects spent selecting item difficulty levels. At the fixed-reliability criterion, however, the self-adaptive tests' inefficiency was largely due to the time needed to administer additional items (Vispoel & Coffman, 1994:43).

What this pattern of correlations suggests is that self-adaptive tests may yield more construct valid scores than computerized-adaptive tests (Vispoel & Coffman, 1994:44). The reason for this is that self-adaptive tests might reduce the influence of debilitative motivational processes (excessive anxiety or arousal, self-preoccupying worry, self-doubts, etc.) and promote the influence of facilitative ones (attention to tasks, optimal arousal, positive self-regard, etc.). Under these circumstances, a self-adaptive test score would better reflect an individual's maximum performance level and thereby provide a more accurate or construct valid indicator of the ability of interest (Vispoel & Coffman, 1994:44).

If self-adaptive tests promote positive attitudes and reduce the influence of debilitative motivational factors on test performance, then the consequences of taking such tests may be more favourable than those resulting from other testing procedures (Vispoel & Coffman, 1994:46). Self-adaptive tests, for example, could make assessment experiences more pleasant for many subjects, and this in turn might motivate them to expend greater effort and persistence in accomplishing future tasks in the assessed content domain. If this is the case, then self-adaptive tests might be particularly beneficial for assessing music skills due to the motivational problems often associated with learning music related tasks (unfavourable attitudes, internal locus of control for failure, high performance anxiety, etc.). Therefore one may conclude that computerized-adaptive tests provide greater efficiency and self-adaptive tests provide greater potential motivational benefits (Vispoel & Coffman, 1994:46).

For the purpose of this study, the researcher did not make use of a computerized test as this would imply the need for extra equipment to present the test and as mentioned before, this may limit the future use of the test in the South African context as service delivery in South Africa is characterized by limited resources and facilities (Johnsen, 1998:217).

2.7 MUSIC PERCEPTION IN THE SOUTH AFRICAN CONTEXT

Music includes a considerable variety of structural elements presented in manifold combinations and styles occurring within a cultural context (Leal *et al.*, 2003:826). Some aspects of music are culturally based, and one might well expect to see differences due to this in results from participative assessments that test emotional responses (Medel Medical Electronics, 2006:1). Research by Chasin and Russo (2004:39) found that individuals of the same culture with normal or corrected-to-normal hearing tend to experience melody, harmony and key in a similar manner – that is, sensitivity to these constructs does not require formal training.

The South African music industry is founded upon a rich and resourceful cultural heritage which is borne by a conglomerate of cultures with strong elements of demographic diversity, cross-cultural influences, social development and emotionally deep-rooted musical development and therefore this multi-racial, multi-cultural demography creates a diverse, yet richly creative environment with unique musical products (De Villiers, 2006:1).

South Africa is very diverse, with many native African ethnic groups as well as European and Indian people (Barrett, 2007:11). In the South African context, cultural and musical identities are often intertwined with language, racial and even tribal identities (Joseph & Van Niekerk, 2007:488). The South African music scene includes both popular and folk forms. Early South African music was brought by Christian missions that provided the first organized musical training in the country. Since the pre-colonial period, traditional music was performed on social occasions such as communal work and during ritual ceremonies such as marriages or funeral rites. Many African ceremonies go hand in hand with music performance and music is used as a carriage that embodies relevant messages (Wanyama, 2006:1). African music is functional in that whenever it is performed there is a specific role it usually accomplishes. The content of music is dictated by the day-to-day occurrences in the respective societies. Technological development, growth of towns and industries has contributed to changes in ways of life in African communities and gave rise to new compositions with new themes together with new performance styles (Wanyama, 2006:2).

South African popular music began in 1912 with the first commercial recordings, but only began booming after 1930 when Gallo Record Company sent several South African musicians to London for recordings. Gallo Record Company remains the largest and most successful music label in South Africa. In the early twentieth century, the Zionist Christian churches spread across South Africa and incorporated African musical elements into their worship – hence the advent of South African gospel music (Stewart, 2001:2) and in 1936 the Stellenbosch University Choir, which is the oldest running choir in the country, was formed.

Afrikaans music was primarily influenced by Dutch folk music styles along with French and German influences in the early twentieth century. In this era string bands led by a concertina were popular as were elements of American country music. Afrikaans music is currently one of the most popular and best selling industries on the South African music scene (Senekal & Van den Berg, 2010:99)

In the 1950s the music industry became greatly diversified and included several major labels. The first major style of South African popular music to emerge was pennywhistle jive, also known as kwela. Jazz was also popular during this era. The late 1960s saw the rise of soul music from the United States, followed by the punk rock boom of the United Kingdom and the American disco of the late 1970s (De Villiers, 2006:17).

Since the 1970s, each ethnic group enjoyed its own traditional music. The Sotho traditional music was characterized by the concertina which was replaced in the 1970s with accordion and electric backing bands while the Zulu people adopted the guitar from the Portuguese in the sixteenth century that was central to their musical tradition (Wanyama, 2006:8). Tsonga traditional music showed a largely African style influenced by Latin rhythms whereas the traditional music of the Pedi group is principally based on the harp (Wanyama, 2006:9).

In 1994, South African media was liberalized and new musical styles arose. Kwaito, named after the Amakwaito (a group of 1950s gangsters in Sophiatown) is a style of music similar to hip hop, featuring vocals recited over an instrumental backing with strong bass lines (Oxford, 2010). There was also a dramatic growth in the popularity of Afrikaans music and numerous new young Afrikaans singers attracted large audiences to art festivals such as the *Klein Karoo Nasionale Kunstefees*, *Aardklop* and *Innibos* (Senekal & Van den Berg, 2010:106). Apart from dozens of new songs being introduced into the Afrikaans music market, it became popular for modern young artists to sing old Afrikaans songs on a stage or in a pub with crowds of admirers singing along. The first South African live techno bands also emerged – their music was mainly influenced by European artists but included a unique South African touch.

The 2000s were characterized by kwaito, Afrikaans music (different forms emerging like Afrikaans rock and alternative music) and metal that continued to grow rapidly (Senekal & Van den Berg, 2010:99). The South African music scene has continued to flourish in the 2000s with the music scene focused around four major areas including Johannesburg, Cape

Town, Durban and Bloemfontein where there is a strong sense for actively developing the local talent.

The introduction of the South African Music Awards (SAMA) intended to recognize accomplishments in the South African recording industry and has raised the awareness of local artists and bands. The awards are given in various categories, including album of the year, best newcomer, best male and female artists, etc. South Africa also has several annual music festivals including *Oppikoppi* and *Rocking the Daisies* that cater to different genres and styles of music (Allen, 2008:31).

As seen from the above, the story of South African music is one of dialogue with imported forms and varying degrees of hybridization over the years. From the earliest colonial days until the present time, South African music has created itself out of the mingling of local ideas and forms with those imported form outside the country, giving it all a special twist that carries the unmistakable flavour of the country. It is however, sad that South Africa does not have a functional archive of all its previous music. This is due to factors such as lack of care of master tapes, ineffective storage practices, and fire. Also, record companies did not keep a library of the recordings they released and there was no effective national copyright library that collected sound recordings published in South Africa (Allen, 2008:29).

2.8 CONCLUSION

Hard-of-hearing musicians have long complained about the poor sound quality they experience while playing their instruments or when listening to music through hearing aids. Indeed, many non-musicians also complain of the reduced sound quality of music heard through their personal amplification, to such an extent that hearing aid users often prefer to remove their hearing aids when listening to music (Wessel *et al.*, 2007:1; Chasin, 2003b:36).

The field of Audiology acknowledges the value of musical perception in quality of life (Spitzer *et al.*, 2008:57); the experience of music is complex and wide-ranging, and may be an important enhancer of quality of life for both normal hearing and hearing impaired participants. However, great differences in terms of musical background, listening habits, musical tastes and involvement reflect the diverse universe of listening experiences, which cannot be summarized by means of tests and questionnaires (Luis *et al.*, 2007:682).

The effects of hearing aid processing on musical signals and on the perception of music have received very little attention in research (Wessel *et al.*, 2007:1). Though listeners and musicians who have a hearing loss are no less interested in music than normal hearing listeners, there is evidence that the perception of fundamental aspects of Western musical signals, such as the relative consonance and dissonance of different musical intervals, is significantly altered by hearing impairment. Measuring instruments such as the *Articulation Index* and the *Speech Intelligibility Index* can be used to predict intelligibility from the audibility of speech cues across all frequencies and a variety of objective tests of speech comprehension are used to measure hearing aid efficiency. There is, however, no standard metric for a patient's perception of music (Wessel *et al.*, 2007:1). Moreover, persons with a hearing loss are less consistent in their judgments about what they hear than normal hearing listeners, and individual differences in performance among listeners having similar audiometric thresholds make it difficult to predict the perceptual effects of hearing aid processing on musical stimuli (Wessel *et al.*, 2007:1). These factors, combined with the differences in the acoustical environments in which different styles of music are most often presented, underline the importance of individual preferences in any study of the effects of hearing aid processing on the perception of music. Therefore, the researcher developed a test of music perception for persons with hearing aids comprising rhythm, timbre, pitch and melody recognition and it is hoped that this test will provide a method to measure music perception in hearing aid users that is efficient and will contribute to improved hearing aid fittings as well.

2.9 SUMMARY

In this chapter music perception is defined. The physiological effects of music are discussed and detailed descriptions of current music perception tests are provided. The researcher described the development of the music perception test compiled for this study and concluded with an overview of music perception within the South African context.