Chapter 4

METHOD

Chapter aim: The aim of this chapter is to provide an outline of the methodological approach implemented in the conduction of the empirical research component of this study.

4.1 INTRODUCTION

Research is the systematic process of collecting and logically analyzing data in order to answer specific questions or solve specific problems (McMillan & Schumacher, 2006:9). An important aspect of the research process is the method employed to conduct the research, since the researcher must ensure that the acquired information is reliable and valid (McMillan & Schumacher, 2006:9).

The professional knowledge underlying an occupation is mainly scientific information that consists in part of generalizations made from the everyday practices and observations in that occupation (De Vos, Schulze & Patel, 2005:24). Until such generalizations are systemized and found to be valid they can, however, not qualify as scientific knowledge. The main task of professionals in an occupation involving service delivery to people is therefore to transform these generalizations through the process of research to scientific proposals. According to De Vos *et al.*, (2005:25) professional research is a scientific phenomenon directed towards addressing problems that arise from service delivery to people. The assumption is therefore made that professional research within an occupation, like that of the audiologist, will not only lead to the expansion of knowledge within the field but will also result in better service delivery to persons with a hearing loss. It should be clear from the above that it is of critical importance to apply the correct procedures and methods in the research process in order to increase the reliability and validity of obtained results.

The research question underlying the current research project was already highlighted in Chapters 1, 2 and 3. Advances in modern digital hearing aid technology focus almost entirely on improving the intelligibility of speech in noisy environments. The effects of hearing aid processing on music signals and on the perception of music, however, received very little attention, despite reports that hearing impairments are the primary impediment to enjoyment of music in older listeners, and that hearing aid processing is frequently so damaging to music signals that hearing aid wearers often prefer to remove their hearing aids when listening to music (Wessel *et al.*, 2007:1).

These are early days for most forms of frequency lowering hearing aids, with non-linear frequency compression certainly no exception (Scollie *et al.*, 2008:7). As Ross (2000: par. 10) indicated, there is very little research evidence attesting the effectiveness of frequency compression, with the available research focuses mainly on speech perception. The results of the current study may therefore provide audiologists with valuable scientific information on the advantages and disadvantages of non-linear frequency compression with musical stimuli, thereby addressing an area of limited knowledge in the field of Audiology as it currently stands. Determining the influence of non-linear frequency compression on music perception may assist in more evidence-based hearing aid fittings to improve the quality of life for persons with a hearing loss; it may also assist in counselling these persons regarding their expectations of hearing aids. Evidence-based practice has been widely embraced in many health care fields as a way of maintaining currency of knowledge and state-of-the-art treatment recommendations in an age of abundant information and rapid scientific progress (Cox, 2005:419).

Despite evident advances in hearing aid technology, the percentage of people with hearing loss owning hearing aids (about 22%) has not changed since 1991 (Cox, 2005: 420). A question arises as to why better hearing aids have not produced a corresponding improvement in satisfaction with amplification. The answer lies, at least in part, in the fact that the scientific basis of hearing aid fitting has fallen far behind the technological development of amplification devices (Cox, 2004:10). This problem has two components: Firstly, there is relatively little high-quality research to provide effective guidelines for the fitting process. Secondly, practitioners are generally unprepared to critically evaluate the body of research that does exist (Cox, 2005:420).

As a result of these factors, professionals involved in providing hearing health care do not have an accurate appreciation of the value of technological developments in amplification or other newly proposed treatment strategies for hearing aid wearers (Cox, 2005: 420). Therefore, this study hopes to contribute to the provision of effective hearing health care to music loving hearing aid users and thereby to the attainment of a new level of success in the profession of Audiology.

Taking the above into account, the purpose of this chapter is to describe the research method that was used to determine the influence of non-linear frequency compression on the perception of music of adults with a moderate to severe hearing loss. The description of the research method will focus on the aims formulated for the study, the research design implemented, ethical considerations taken into account, participants included, material and apparatus used for data collection as well as procedures implemented for the collection, recording and analysis of data. The chapter will conclude with a general summary.

4.2 AIMS

The following aims have been formulated for this study:

4.2.1 Main aim

The purpose of this study was to determine, through the use of a music perception test compiled by the researcher, the influence of non-linear frequency compression on the perception of music by adults presenting with a moderate to severe hearing loss.

4.2.2 Sub-aims

The following sub-aims were formulated in order to attain the main aim of the study:

♫ To compile a test for music perception as part of the material for data collection;
♫ To determine the influence of non-linear frequency compression on the perception of:

- rhythm;

- timbre;
- pitch;
- melody;

♬ To determine the influence of non-linear frequency compression on participants' subjective impression of listening to music;

♬ To determine whether there is an objective and subjective benefit for listening to music with the extended use of non-linear frequency compression.

4.3 RESEARCH DESIGN

The purpose of a research design is to plan and structure the research project to provide results that are judged to be credible (McMillan & Schumacher, 2006:117). The purpose of social research may be three-fold, namely, that of *exploration*, *description* and *explanation* (Babbie, 2002:79). Due to the empirical nature of the study, research was conducted within a *quantitative* paradigm (with a combination of quasi-experimental and non-experimental research designs) and was distinguished from a qualitative approach by its purpose, process, data collection procedures, data analysis and reported findings (Leedy & Ormrod, 2005:102-103).

The purpose of the study was to *explore* the topic of the effect of non-linear frequency compression on the music perception abilities of adults in an attempt to provide a basic understanding of this phenomenon; a need exists for exploration in this field due to the dearth of reported research on non-linear frequency compression technology. This goal was met by *determining* and *describing* the music perception abilities in a number of participants and also by attempting to *explain* the causality between non-linear frequency compression and music perception. The field of quantitative research is more formalized, explicitly controlled and is more precisely defined (Neuman, 2006:253); such research designs maximize objectivity by using numbers, statistics, structure and control (McMillan & Schumacher, 2006:23). Procedures for data gathering and measurements are compiled prior to the study and are conducted in a standardized manner (Leedy & Ormrod, 2005:102). Data collection from a quantitative approach is specifically related to these variables, and is collected from a sample of a specific population. In the case of the current study, data collection took place in four phases. A schematic

representation of the research design used in each phase is presented in Figure 4-1 below, whilst a detailed schematic representation of the alternating assessment schedule used in Phase 2 and Phase 3 is contained in Table 4-11.

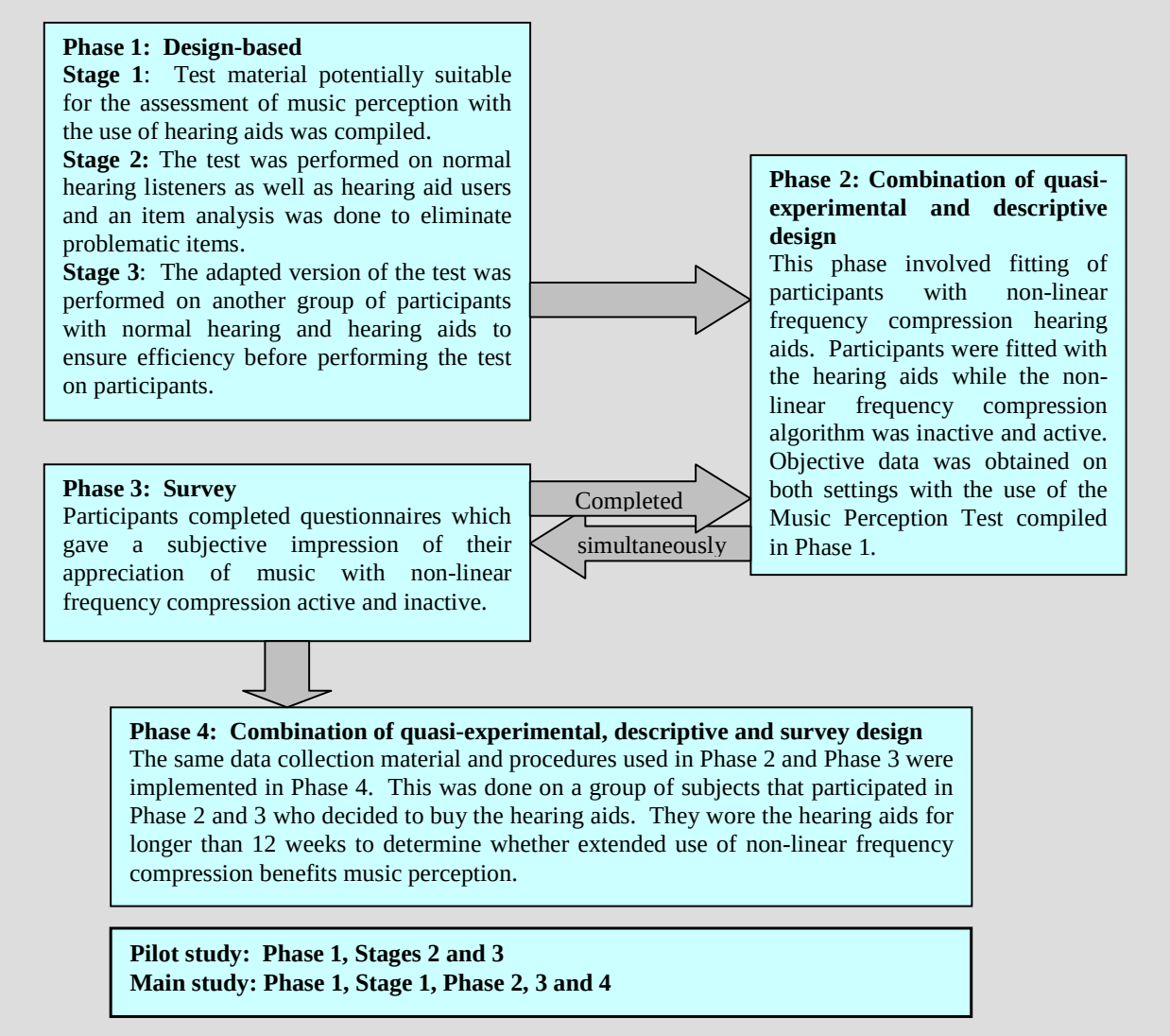

Figure 4-1: Schematic representation of the research phases of the current study

Phase 1 entailed the compilation of the Music Perception Test (MPT) and can be described as design-based. Although this paradigm is mostly applied to educational contexts (Barab & Squire, 2004:5), it provides a suitable framework for the first phase of this study, involving the design of

a test for the assessment of music perception in hearing aid users. In the conventional application of this method, theoretical expertise is used to design a particular learning environment or intervention, which is then applied in an educational setting (Barab & Squire, 2004:3). The principles of this approach was applied to the **first stage** of this phase of the current study by using theoretical knowledge and literature to compile test material that would be potentially suitable for the assessment of music perception with hearing aids within the South African context. **Stage 2** involved the presentation of the MPT to normal hearing listeners and hearing aid users. Based on the findings of Stage 2, an item analysis was performed to eliminate or change stimuli that resulted in high error rates. In **Stage 3** the adapted version of the test was performed on a different group of normal hearing listeners and hearing aid users. This stage in the research process served as the pilot study and was conducted to ensure the appropriateness and efficiency of the test material in order to render optimal validity and reliability of the results of the main study.

A quasi-experimental research design was selected to form the structure of the method employed in **Phase 2**. This phase involved the fitting of participants with non-linear frequency compression hearing aids. Objective data was obtained with the hearing aids on conventional settings (non-linear frequency compression algorithm inactive) and with the non-linear frequency compression algorithm activated. Advantages of experimentation included the control over the experiment and the opportunity to observe change over time (Babbie, 2002:219). A true experiment starts with a hypothesis, modifies a situation, and then compares the outcome with or without modification (Neuman, 2006:247) as was done in the current study where the hypothesis was made that non-linear frequency compression might influence music perception. This was verified with the activation and deactivation of the non-linear frequency compression algorithm to compare the possible music perception benefits received by hearing aid users. Random assignments of subjects are also necessary for creating similar groups in order to facilitate comparison (McMillan & Schumacher, 2006:47) and therefore a cross design was used in this phase. This implies that some participants were first fitted with the non-linear frequency compression algorithm active, while for others this algorithm were first inactive, as calculated with the use of statistical programming. Some deviations from the classical experimental design were made in order to materialize the aims of research due to the characteristics of this study. A

quasi-experimental design still allowed for testing of causal relationships in a variety of situations (Neuman, 2006:256), but accounted for the lack of randomness in the selection of participant group members in the current study, since only a limited number of adults fitted the selection criteria (Leedy & Ormrod, 2005:237). Furthermore, in this phase single blinding was used. This implies that only one party knows which group a subject was assigned to (Cox, 2005:428). During the course of the evaluation, the participant did not know whether the frequency compression algorithm was activated or not. This removed any potential participant bias that could influence the results (Bentler & Duve, 2000:636).

Within the framework of non-experimental research this study had a descriptive as well as a survey design. A descriptive design provides a summary of an existing phenomenon by using numbers to characterize individuals or a group (McMillan & Schumacher, 2006:24). It assesses the nature of existing conditions and is limited to characterizing something as it is (McMillan & Schumacher, 2006:24). In the current study, the manner in which participants perceived music with and without the use of non-linear frequency compression was described.

In the survey research design the investigator administered questionnaires in order to collect data and to describe attitudes, beliefs and opinions (McMillan & Schumacher, 2006:25). **Phase 3** of this study involved two short, structured questionnaires to be completed by the participants. The first questionnaire obtained background information from participants while the second questionnaire elicited a subjective impression of the participants' musical experiences with the hearing aids when the non-linear frequency compression algorithm was both active and inactive. After completion of the questionnaire participants' perception of music with non-linear frequency compression active and inactive were compared in order to determine possible advantages of this algorithm for listening to music.

In **Phase 4** the same music perception test was performed on a group of participants that used the non-linear frequency compression algorithm for at least twelve weeks. They were also asked to again complete the second questionnaire. This was done in order to explain the effect of extended use of non-linear frequency compression and acclimatization on music perception.

In most descriptive research and some survey research, there in only one variable of interest (McMillan & Schumacher, 2006:55) and specific variables are not necessarily isolated and manipulated. The variable that is manipulated by the researcher to investigate the effect is called the independent variable while the dependent variable is the one which is affected by the independent variable (McMillan & Schumacher, 2006:54). In this study the independent variable was non-linear frequency compression with music perception (of the participants) as the dependent variable. Control variables are defined as factors that can be controlled by the researcher to neutralize or eliminate any influence which they might have on the phenomenon being researched (Bless & Higson-Smith, 2000:69) and in the current study included the adult population as well as the degree of hearing loss.

As can be seen from the above, an extended research design was implemented to accommodate the different phases of the study. This included the design of data acquisition material as well as a combination of quasi-experimental, descriptive and surveys designs.

4.4 ETHICAL ASPECTS REGARDING RESEARCH

It is important that any research be conducted within the framework of research ethics. Therefore, ethical clearance for this study was obtained from the institutions involved. The underlying foundation of ethical research is to preserve and protect the human dignity and rights of all the participants participating in a research study (Jenkins, Price & Straker, 2003:46). The ethical principles of autonomy, beneficence and justice were incorporated in this study, and are discussed below:

- **Autonomy**

In research, autonomy means strictly voluntary participation in any research project (Leedy & Ormrod, 2005:107) and includes the following components:

Table 4-1: The components of autonomy relevant to this study

COMPONENT	DESCRIPTION
Informed consent	The participants involved in a study should have the legal capacity to give consent (Jenkins *et al*., 2003:47), by making an informed decision whether or not to take part in this study. Written informed consent was obtained from each participant through a letter (Appendix A) explaining the purpose of the study, the procedures to be followed and the possible advantages and disadvantages of taking part in the study (Struwig & Stead, 2001:68). It also stated that information will be kept strictly confidential. By signing the letter, participants acknowledged that they were informed about the purpose and procedures of the study and that participation is completely voluntary.
Withdrawal of participants	The norm for social research is that all participation in research should be voluntary (Babbie, 2002:521). The participant therefore reserves the right to withdraw at any time from the study, without being penalized or sacrificing any tangible benefits they might receive for participating in this study.
Privacy, confidentiality and anonymity	The participants' right to privacy was protected by viewing all information to be confidential and anonymous (Strydom, 2005:69).
Disclosure of information	Participants were informed that the information gained from the study might be used for academic purposes – either as an article or presentation. This will be done in an objective manner, keeping the principle of confidentiality and the language accurate, objective and unambiguous. All forms of bias and plagiarism were avoided during the report writing. Errors and limitations of the study were admitted and recommendations were made for future research (Strydom, 2005:57).
Ethical clearance	Ethical clearance for this study was requested from the Postgraduate Research and Ethics Committee of the Faculty Humanities, University of Pretoria (Appendix B). A letter requesting permission for conduction of the study at the audiological practice was sent to the directors of the practice (Appendix C) and permission was obtained from the audiological practice (Appendix D).

As can be seen from Table 4-1 all the principles of autonomy were observed in the current study.

- **Beneficence**

Beneficence refers to showing active kindness and to the conferral of benefits (Hyde, 2004:297). Participants should not be exposed to undue physical or psychological harm (Babbie, 2002:522). This was ensured by including the components discussed in Table 4-2:

Table 4-2: Beneficence as a relevant ethical principle for this study

COMPONENT	DESCRIPTION
Competency	The researcher is qualified to conduct research due to her qualifications and experience in the field of Audiology. Three research supervisors from the University of Pretoria supervised the study, and valuable input was also gained from leaders in the local and international field of Audiology. The researcher (STA 0026395) and the supervisors are registered with the Health Professions Council of South Africa (HPCSA).
Relevance	As all clinicians are urged to conduct evidence-based practice, this study is highly relevant and may yield valuable information regarding the prescription of technology to meet the needs of the population with a hearing loss.
Risks	Taking part in a research study may involve the disruption of regular, daily activities (Babbie, 2002:521). However, the risk of participating in this study did not unreasonably exceed the normal risk of day-to-day living. No medical risks were involved in this study. Normal procedures for any hearing aid fitting were followed. A date and time were arranged with each participant to suit him/her.
Discrimination	Participants were not discriminated against on grounds of gender, race or economic status.

By applying the principles of beneficence, as described in Table 4-2, the researcher ensured that no harm was done to any of the participants in the current study.

- **Justice**

Justice refers to honesty with professional colleagues (Leedy & Ormrod, 2005:108). The researcher had a responsibility towards other colleagues in the scientific community and therefore all co-workers were acknowledged. Behaviour throughout the research process was strictly professional and the collection of data took place in an honest and responsible manner. The researcher also has an ethical responsibility to convey the results of this study accurately. The true results obtained had at all times been indicated as the results of this study in order to avoid research misconduct (Maxwell & Satake, 2006:67; Ingham, 2003:325).

4.5 PARTICIPANTS

For this study adult clients of a private hearing aid practice were used. Data collection was conducted by means of real-ear measurements, performance in the MPT as well as hand-delivered, personal questionnaires on the premises. As Phase 1 of the study constitutes the pilot study, participants included in Phase 1 are described in detail in section 4.7.1.1. The main study involved Phase 2 and Phase 3, which included a total of 40 participants as described below.

4.5.1 Sampling techniques and sample size

Due to the quasi-experimental design of the study where random assignment of subjects was not possible, true quantitative sampling techniques were not used. Non-probability sampling techniques are usually associated with qualitative research designs, since the characteristics of each case determine whether it is selected or not (Neuman, 2006:220). The researcher used a non-probability sampling technique which does not include any type of random selection from a population, but rather participants who happen to be accessible or who may represent certain types of characteristics (McMillan & Schumacher, 2006:125). This method is justified on grounds of feasibility (Babbie, 2005:189). The specific type of non-probability sampling used was the purposive convenient sampling method. According to this method participants were chosen on the basis of accessibility and because they articulated with the researcher's aim of study (McMillan & Schumacher, 2006:125). This method seemed appropriate for the current study because participants' characteristics articulated with the aims of the study. Furthermore, participants were accessible as clients of the hearing aid practice selected, thereby addressing the logistic convenience of the researcher. This method was also time effective.

4.5.2 Selection criteria

The following selection criteria were developed for all participants with hearing aids:

Table 4-3: Selection criteria

CRITERIA	JUSTIFICATION
Geographical location Participants had to reside within the Gauteng province.	Data collection took place at a private practice in Pretoria as it was logistically convenient for the researcher. The practice is also within an hour's reach for most people staying in the Gauteng area. As the data collection took place in more than one phase, participants had to visit the practice more than once.
Language status Participants had to be proficient and literate in English.	This is a language in which the researcher is proficient and therefore the MPT, questionnaires, all instructions and explanations were provided in English. Furthermore, the 2001 South African Census indicate that English is the third most common primary language, the most common second language in Gauteng (Statistics South Africa, 2001) and the most commonly used language in South Africa (Napier & Napier, 2002:9).

CRITERIA	JUSTIFICATION
Age Participants had to be between the ages of 18 years 0 months and 64 years 11 months.	Persons of 18 years and older have matured central auditory systems since the maturation of the central auditory nerve system is completed at the age of approximately twelve years (Bellis, 1996:71). According to Katz and Wilde (1994:492) the performance on central auditory processing tests is consistent from the teenage years until the middle of adulthood and only starts to deteriorate from the age of 65 years and older due to physiological changes in the brain. This age group (18-65 years) is further legally independent and permission to participate in this study can be obtained directly from the participant. Older adults are described as persons 65 years and older (Weinstein, 2002:597).
Middle ear functioning Participants were required to present with normal middle ear functioning.	Middle ear pathology could result in adding a conductive component to the hearing loss (Rappaport & Provencal, 2002:19). People with a conductive or mixed hearing loss experience different amplification needs than people with sensory neural hearing loss (Dillon, 2000:256).
Onset of hearing loss All participants had to have an acquired hearing loss rather than a congenital hearing loss.	DSL v5.0 targets for adults were used as fitting formula during the fitting of the prototype hearing aids. Adult targets for DSL are on average 7 dB lower than those for children and will make a difference in the fitting because the amount of gain will differ with different targets (Scollie, Seewald, Cornelisse, Moodie, Bagatto, Laurnagaray, Beaulec & Pumford, 2005:166). If adults with a congenital hearing loss were included, they would probably (even though they are now adults) be using DSL child targets as this is what they were fitted with before and are used to.
Configuration and degree of hearing loss Participants had to have a bilateral, moderate to severe sensory neural hearing loss, with a pure tone average of 41-90 dB at the frequencies 500 Hz, 1kHz and 2kHz (Plante & Beeson, 1999:100; Mueller & Hall, 1998:951).	The hearing aid with the non-linear frequency compression algorithm was specifically designed for people with severe hearing losses (Glista & McDermott, 2008:5) and therefore this type of hearing loss will be a good indicator for a person to benefit from non-linear frequency compression.
Previous experience with hearing instruments Participants should not have had non-linear frequency compression hearing aids before. Participants' current hearing aids had to be digital hearing aids as opposed to analogue hearing aids.	Previous experience with non-linear frequency compression technology will possibly have influenced the participant's beliefs and attitudes towards frequency lowering technology and therefore can cause the participant not to be objective in the study whereas with current use of analogue hearing aids one might measure the switch from analogue to digital and not the effects of non-linear frequency compression (Flynn, Davis & Pogash, 2004:480). The hearing aids used in this study were digital hearing aids and if participants were already used to digital amplification, it might reduce adaptation problems and time to adjust to the new hearing aids.
Current hearing aid experience Participants had to have at least two years' experience with conventional amplification hearing aids utilizing serial or parallel processing set according to the amplification targets described by DSL v5.0 (Scollie, 2006:10).	The person's current hearing aids must be optimized to reflect current best practice (Flynn *et al.*, 2004:480) to enable accurate comparisons between different technologies. A minimum of two years' experience with conventional amplification hearing aids is required because previous hearing aid experience will also influence acclimatization to non-linear frequency compression hearing aids and a homogeneous acclimatization period will ease comparison of results between patients.
Voluntary informed participation Participants had to take an informed decision to participate voluntarily in this study.	Persons taking part in any research project should do so of their own choice, based on comprehensive information provided in advance (Struwig & Stead, 2001:67).

The clients of the selected hearing aid practice met the above-mentioned selection criteria.

4.5.3 Selection procedure

The following procedures were followed during the selection of participants:

- Written permission to conduct this research project was provided by the directors of the Audiology practice. Ethical clearance was granted by the Postgraduate Research and Ethics Committee, Faculty of Humanities, the University of Pretoria.
- The selection criteria for identification of possible candidates were submitted to the Audiology practice; subsequently the researcher consulted with an audiologist from the practice to compile a list of possible participants and to obtain their contact details.
- The researcher contacted all the candidates either telephonically or by e-mail. In this process the aim and the procedures of the study were explained. If a potential candidate agreed to take part in this research project an appointment was made for a date and time that suited both the candidate and the researcher.
- If the candidate declined the offer to take part in this research project, he/she was thanked for his/her time.
- These procedures were followed until the appropriate number of candidates for all the different phases of the study agreed to participate in the research project.

4.5.4 Description of participants

Table 4-4 presents the biographical information of the persons that participated in the main study (Phase 2 and Phase 3). The data in this table was obtained from the participants' files at the Audiology practice.

Table 4-4: Biographic information of participants with hearing aids included in Phase 2 and Phase 3 of the study.

Partici-pant	Age	Cause of hearing loss	Shape of hearing loss	Pure tone average (PTA)	Oto:acoustic emissions (OAE's)	Current hearing aids	Signal processing scheme	Time wearing hearing aids
1	62 years	Unknown	R: Sloping L : Sloping	R: 77 dB L: 85 dB	Absent for both ears.	R: Una SP AZ L: Una SP AZ	dWDRC	3 years
2	64 years	Unknown	R: Sloping L: Sloping	R: 60 dB L: 60 dB	Absent for both ears.	R: Extra 411 L: Extra 411	dSC	4 years
3	64 years	Unknown	R: Flat L: Flat	R: 75 dB L: 63 dB	Absent for both ears.	R: Extra 311 L: Extra 211	dSC	3 years
4	51 years	Unknown	R: Flat L: Flat	R: 72 dB L: 88 dB	Absent for both ears.	R: Eleva 33 L: Eleva 33	dSC	3 years
5	33 years	Unknown	R: Sloping L: Sloping	R: 78 dB L: 62 dB	Absent for both ears.	R: Supero 411 L: Supero 411	dWDRC	15 years
6	44 years	Unknown	R: Sloping L: Sloping	R: 60 dB L: 60 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Eleva 22 L: Eleva 22	dWDRC	5 years
7	42 years	Unknown	R: Flat L: Flat	R: 63 dB L: 62 dB	Absent for both ears.	R: Una M AZ L: Una M AZ	dWDRC	3 years
8	59 years	Presbycusis	R: Sloping L: Sloping	R: 60 dB L: 60 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Extra 33 L: Extra 33	dSC	3 years
9	31 years	Unknown	R: Sloping L: Sloping	R: 75 dB L: 68 dB	Absent for both ears.	R: Una SP L: Una SP	dWDRC	2 years
10	63 years	Presbycusis	R: Sloping L: Sloping	R: 58 dB L: 57 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Eleva 311 L: Eleva 311	dWDRC	17 years
11	60 years	Unknown	R: Sloping L: Sloping	R: 63 dB L: 67 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Eleva 411 L: Eleva 411	dWDRC	3 years
12	21 years	Unknown	R: Sloping L: Sloping	R: 75 dB L: 68 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Extra 411 L: Extra 411	dSC	4 years
13	18 years	Virus infection	R: Sloping L: Sloping	R: 88 dB L: 88 dB	Absent for both ears.	R: Maxx 411 L: Maxx 411	dWDRC	12 years
14	26 years	Unknown	R: Sloping L: Sloping	R: 60 dB L: 55 dB	Absent for both ears.	R: Extra 311 L: Extra 311	dWDRC	14 years
15	39 years	Unknown syndrome	R: Sloping L: Sloping	R: 72 dB L: 72 dB	Absent for both ears.	R: Solo prog L: Solo prog	dWDRC	19 years
16	58 years	Presbycusis	R: Sloping L: Sloping	R: 57 dB L: 63 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Extra 311 L: Extra 411	dSC	4 years

17	61 years	Unknown	R: Flat L: Flat	R: 80 dB L: 88 dB	Absent for both ears.	R: Novoforte E4 L: Novoforte E4	dWDRC	7 years
18	43 years	Unknown	R: Sloping L: Sloping	R: 50 dB L: 63 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Una M L: Una M	dWDRC	2 years
19	38 years	Trauma	R: Flat L: Flat	R:53 dB L:52 dB	Absent for both ears.	R: Solo prog L: Solo prog	dWDRC	7 years
20	64 years	Presbycusis	R: Sloping L: Sloping	R: 65 dB L: 78 dB	Absent for both ears.	R: Extra 311 L: Extra 311	dWDRC	3 years
21	60 years	Presbycusis	R: Sloping L: Sloping	R: 43 dB L: 52 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Una M AZ L: Una M AZ	dWDRC	7 years
22	42 years	Unknown	R: Sloping L: Sloping	R: 58 dB L: 45 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Una M AZ L: Una M AZ	dWDRC	2 years
23	61 years	Unknown	R: Flat L: Sloping	R: 85 dB L: 48 dB	Absent for both ears.	R: Astro L: Astro	dWDRC	15 years
24	58 years	Unknown	R: Flat L: Flat	R: 63 dB L: 62 dB	Absent for both ears.	R & L: Oticon digital (type unknown)	Unknown	8 years
25	64 years	Presbycusis	R: Sloping L: Sloping	R: 58 dB L: 57 dB	Absent for both ears.	R: Solo prog L: Solo prog	dWDRC	2 years
26	64 years	Presbycusis	R: Sloping L: Sloping	R: 55 dB L: 55 dB	Absent for both ears.	R: Eleva 211 L: Eleva 211	dWDRC	4 years
27	61 years	Unknown	R: Sloping L: Sloping	R: 57 dB L: 85 dB	Lowered at low frequencies and absent at high frequencies for right ear. Absent for left ear.	R: Eleva 311 L: Eleva 311	dSC	10 years
28	64 years	Unknown	R: Sloping L: Sloping	R: 60 dB L: 48 dB	Absent for right ear. Lowered at low frequencies and absent at high frequencies for left ear.	R: Extra 311 L: Extra 211	dWDRC	5 years
29	60 years	Unknown	R: Flat L: Flat	R: 57 dB L: 57 dB	Absent for both ears.	R: Extra 311 L: Extra 311	dWDRC	5 years
30	60 years	Presbycusis	R: Sloping L: Sloping	R: 73 dB L: 73 dB	Absent for both ears.	R: Eleva 411 L: Eleva 411	dSC	12 years
31	64 years	Unknown	R: Flat L: Sloping	R: 78 dB L: 60 dB	Absent for both ears.	R: Extra 411 L: Extra 411	dWDRC	8 years
32	22 years	Virus infection	R: Flat L: Flat	R: 88 dB L: 85 dB	Absent for both ears.	R: Supero 411 L: Supero 411	dLim	17 years
33	62 years	Unknown	R: Sloping L: Sloping	R: 67 dB L: 83 dB	Absent for both ears.	R: Savia 311 L: Savia 411	dWDRC	6 years
34	47 years	Unknown	R: Flat L: Flat	R: 63 dB L: 63 dB	Absent for both ears.	R: Certena P L: Certena P	dWDRC	10 years

35	63 years	Presbycusis	R: Sloping L: Sloping	R: 65 dB L: 68 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Eleva 311 L: Eleva 311	dWDRC	3 years
36	64 years	Presbycusis	R: Sloping L: Sloping	R: 60 dB L: 53 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Certena P L: Certena P	dWDRC	6 years
37	58 years	Trauma	R: Flat L: Flat	R: 58 dB L: 68 dB	Absent for both ears.	R: Extra 311 L: Extra 311	dSC	4 years
38	60 years	Unknown	R: Sloping L: Sloping	R: 62 dB L: 72 dB	Absent for both ears.	R: Eleva 311 L: Eleva 311	dSC	7 years
39	31 years	Unknown	R: Sloping L: Sloping	R: 63 dB L: 63 dB	Absent for both ears.	R: Solo prog L: Solo prog	dWDRC	12 years
40	63 years	Noise-induced	R: Sloping L: Sloping	R: 63 dB L: 57 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Maxx 311 L: Maxx 311	dWDRC	6 years

The average age for hearing aid users in Phase 2 and Phase 3 was 57.7 years (ranging from 18 years to 64 years). All of them had a post-lingual onset of hearing loss and in most cases the cause of the hearing loss was unknown. In cases where participants were familiar with the etiology of their hearing loss, it was mostly contributed to presbycusis. Virus infections, trauma and exposure to excessive noise were also indicated as the cause of hearing loss in limited cases. The majority of participants (n=28) had a hearing loss with a sloping configuration[13] while other participants' (n=10) hearing loss were characterized by a flat configuration[14]. For two participants, the hearing loss in one ear had a sloping configuration while the hearing loss in the other ear was characterized by a flat configuration. Participants included in the study all had a moderate to severe hearing loss which can be described in more detail as:

- Moderate (pure-tone average of 41 dB to 55 dB)
- Moderately severe (pure-tone average of 56 dB to 70 dB)
- Severe (pure-tone average of 71 dB to 90 dB)

With the above clarification taken into account, one can conclude that of the 40 subjects (80 ears) that participated in the study, 11 ears had a moderate hearing loss, 45 ears had a moderately severe hearing loss and 24 ears had a severe hearing loss.

4.6 MATERIAL AND APPARATUS FOR THE COLLECTION OF DATA

The material and apparatus described below were utilized for the acquisition of data in this study. The same material and apparatus were used in all the phases of the study.

4.6.1 Material

The assessment material used in the current study for obtaining data included the MPT and questionnaires compiled by the researcher. For an assessment to be meaningful and useful, it

[13] Shows progressively greater hearing loss for higher test frequencies (Mueller & Hall, 1998:959)
[14] Hearing loss which neither increases nor decreases in relation to frequency (Mueller & Hall, 1998:925)

must have foundational integrity which may be assured if the assessment and assessment material adheres to the following principles (Shipley & McAfee, 2008:4):

- A good assessment is thorough: In order to accomplish thoroughness, the MPT and questionnaires were designed to elicit as much relevant information as possible to enable the researcher to obtain accurate and appropriate information.
- A good assessment uses a variety of assessment modalities: The data-acquisition phases of the current study included a combination of formal and informal testing by means of the MPT and questionnaires. This enabled the researcher to obtain both objective and subjective information on how participants perceive music.
- A good assessment is valid and reliable: Several measures were taken to ensure the validity and reliability of the MPT and questionnaires. These measures are described in detail in the sections to follow.
- A good assessment is tailored to the individual client. The MPT and questionnaires were compiled to be appropriate for the participants' age, skill level and ethno-cultural background.

4.6.1.1 Music Perception Test

Music involves a complexity of rhythm, melody, harmony, and dynamics (Galvin *et al.*, 2007:316). The choice of measures to access musical skills is limited because most music tests are designed to examine the skills of individuals undergoing formal music training (Don *et al.*, 1999:158). There are very few studies focusing on the perception of music through hearing aids (Looi *et al.*, 2008b:421) as most studies (Gfeller *et al.*, 2005; Kong *et al.*, 2005; Gfeller *et al.*, 1997; Gfeller & Lansing, 1991) and study material for the evaluation of music perception in persons with a hearing loss focus on cochlear implantees. Therefore, due to the shortage of available material to reach the aims of this study, the design of a music perception test was necessary. The MPT was compiled in conjunction with sound engineers and musicians and contained the necessary music stimuli to meet the aims of this study. Specific components were selected based on existing literature (Gfeller *et al.*, 2005; Gfeller *et al.*, 2002; Gfeller *et al.*, 1997; Gfeller & Lansing, 1991) and also on consensus between the researcher, sound engineers and musicians.

4.6.1.1.1 Purpose of the Music Perception Test

The MPT was compiled to use as data-acquisition instrument in order to obtain objective information about the influence of non-linear frequency compression on music perception.

4.6.1.1.2 Guidelines from literature for the development of the Music Perception Test

The relevance of all the sub-tests included in the MPT is corroborated by the references provided in Table 4-5.

Table 4-5: Literature references to demonstrate the importance of all the sub-tests included in the Music Perception Test

SUB-TEST	LITERATURE REFERENCE
Sub-test 1: The **rhythm identification** task required participants to determine where in a pattern of long inter-pulse intervals they perceived a short inter-pulse interval.	a) The perception of brief intervals is a pre-requisite for rhythmic precision while the perception of long intervals is necessary for keeping tempo (Rammsayer & Altenmuller, 2006:28). b) Melody recognition depends on rhythm cues (Galvin *et al.*, 2007:313). c) Adults with a hearing loss increase their reliance on temporal cues as for most hearing losses frequency resolution is lost, while temporal information remains intact (Flynn *et al.*, 2004:480). d) This was proved as an important part of rhythm perception by international studies (Rammsayer & Altenmuller, 2006; Kong *et al.*, 2004; Gfeller *et al.*, 1997) in which a similar approach was followed.
Sub-test 2: For the **rhythm discrimination** task participants were required to indicate whether pairs of rhythm sequences were the same or different.	a) See literature reference b) at Sub-test 1. b) See literature reference c) at Sub-test 1. c) Rhythm discrimination is a typical rhythm assessment task (Leal *et al.*, 2003:827). d) Rhythm discrimination was proved as an important part of rhythm perception by international studies (Cooper *et al.*, 2008; Looi *et al.*, 2008b; Leal *et al.*, 2003; Gfeller & Lansing, 1992) in which a similar task was conducted.
Sub-test 3: In the **rhythm recognition** task participants listened to two-phrase sequences played in duple or triple meter and had to indicate 'march' or 'waltz'.	a) See literature reference b) at Sub-test 1. b) See literature reference c) at Sub-test 1. c) Rhythm recognition was proved as an important part of rhythm perception by another international study (Cooper *et al.*, 2008) which included a similar task for the assessment of music perception in cochlear implantees and normal hearing listeners.
Sub-test 4: The **rhythm perception** task required participants to indicate which of two melodic sequences was played rhythmically in time.	a) See literature reference b) at Sub-test 1. b) See literature reference c) at Sub-test 1.
Sub-test 5: In the **timbre identification (single instrument)** task, a melodic sequence played by single instruments was presented to participants who had to identify the musical instrument.	a) Timbre identification was proved as an important part of timbre perception by international studies (Looi *et al.*, 2008b; Nimmons *et al.*, 2008; Leal *et al.*, 2003; Gfeller *et al.*, 2002; Fujita & Ito, 1999; Gfeller & Lansing, 1991) in which a similar task was performed.

SUB-TEST	LITERATURE REFERENCE
Sub-test 5: The **timbre identification (multiple instruments)** task asked participants to identify all the instruments that played together in different melodic sequences.	a) Timbre identification was proved as an important part of timbre perception by another international study (Looi *et al.*, 2008b) which included a similar task for the assessment of music perception in cochlear implantees.
Sub-test 6: For the **number of instruments** task participants had to indicate how many different instruments they could distinguish in a piece of music.	a) This was proved as an important part of timbre perception by another international study (Medel Medical Electronics, 2006) which included a similar task for the assessment of music perception in cochlear implantees.
Sub-test 7: In the **pitch identification** task participants were presented with a tone at the reference frequency and a higher/lower pitched tone. They were asked to identify whether the second tone was higher or lower in pitch than the first one.	a) Music perception depends on pitch cues (Galvin *et al.*, 2002:35). b) Cochlear damage leads to changes in perceived pitch or reduced pitch perception accuracy (Ricketts *et al.*, 2008:169; Moore, 1996:143). c) The ability to determine the direction of pitch change is a fundamental ability in perception of melodic contour (Gfeller *et al.*, 2002:35). d) Pitch identification was proved as an important part of pitch perception by international studies (Looi *et al.*, 2008b; Medel Medical Electronics, 2006; Leal *et al.*, 2003; Gfeller *et al.*, 2002; Vispoel & Coffman, 1994) in which a similar task was performed.
Sub-test 8: The **pitch discrimination** task required participants to determine whether a pair of melodic patterns was the same or different.	a) See literature reference b) at Sub-test 7. b) Listeners with a hearing loss make use of pitch information to assist with the identification of familiar melodies (Gfeller *et al.*, 2002:30). c) Pitch discrimination was proved as an important part of pitch perception by international studies (Medel Medical Electronics, 2006; Gfeller & Lansing, 1992) in which a similar task was performed.
Sub-test 9: The **musicality perception** task presented participants with pairs of melodic sequences and required them to indicate which of the sequences were musical.	a) Hearing loss has a significant impact on melodic perception (Gfeller & Lansing, 1992:21). b) Listeners make musical interval judgments on the basis of differences in pitch height or ratio relationships between the fundamental frequencies of notes comprising the interval (Pijl, 1997:370). c) Musicality perception was proved as an important part of melody perception by another international study (Cooper *et al.*, 2008) which included a similar task for the assessment of music perception in cochlear implantees.
Sub-test 10: For the **melody identification** task participants had to identify well-known melodies with and without rhythm cues from a closed set.	a) The rationale for testing familiar melody recognition is that not only does it efficiently test whether listeners are able to hear distinguishing features of the melody but it also tests whether listeners hear them correctly (Nimmons *et al.*, 2008:153). b) See literature reference a) at Sub-test 9. c) Melody identification was proved as an important part of melody perception by international studies (Singh *et al.*, 2009; Nimmons *et al.*, 2008; Looi *et al.*, 2008b; Galvin *et al.*, 2007; Gfeller *et al.*, 2005; Kong *et al.*, 2005; Kong *et al.*, 2004; Leal *et al.*, 2003, Gfeller *et al.*, 2002; Fujita & Ito, 1999) in which a similar task was performed.
Sub-test 11: In the **music-in-noise song identification** task participants were asked to identify movie sound tracks presented in the presence of background noise.	a) An average person daily spends roughly two hours in a car where one of the only things to do is to listen to the radio. The background noise level in most cars at 70 mph (113 km/h) is about 70 dB (A), which makes a good music-in-noise listening test (Killion, 2009:28). b) Cochlear hearing loss involves damage to outer hair cells (Moore, 1996:133) and consequences of outer hair cell loss include difficulty understanding speech, especially in background noise (Kluk & Moore, 2006: par. 5). Therefore one may assume that hearing aid users would also experience difficulty understanding music presented in the presence of background noise. c) See literature reference a) at Sub-test 9.

Table 4-5 clearly shows that all the sub-tests included in the MPT are of high importance in attempting to gain a holistic view of music perception.

4.6.1.1.3 Format of the Music Perception Test

The MPT consisted of 4 sections with a total of 11 sub-tests. The test is nine pages long and available in English only. It took participants approximately 55 minutes to complete the test. Space is provided for a respondent number to be added after completion of the test. Stimuli of the MPT were recorded on a compact disc and therefore no adaptive procedure was necessary. Instructions for the completion of the test are provided on the first page of the test and are recorded on the compact disc. All the answers in the MPT was from a closed set, requiring participants simply to selected the correct answer from the options provided. This has the advantage of restricting possible answers, making comparison of answers easier. Furthermore, it simplifies the analysis of answers (McMillan & Schumacher, 2006:197). A written response was required for each stimulus in the test. Every sub-test included two practice items preceding the actual test items. No feedback was provided during or after the test. A copy of the MPT is included in Appendix E and a copy of the marking sheet of the MPT can be found in Appendix F.

4.6.1.1.4 Content of the Music Perception Test

The MPT includes sub-tests for rhythm, timbre, pitch and melody assessment. As explained in Chapter 2, these areas were included because international research already proved the importance of these aspects in the perception of music (Deutsch, 2007:4473; Iakovides *et al.*, 2004:4). Although music cannot be fully defined by means of tests and questionnaires (Leal *et al.*, 2003:834) the researcher endeavoured to present stimuli from different parameters of music in order to obtain a more holistic picture of music perception with non-linear frequency compression hearing aids. A summary of these parameters is provided in Figure 4-2.

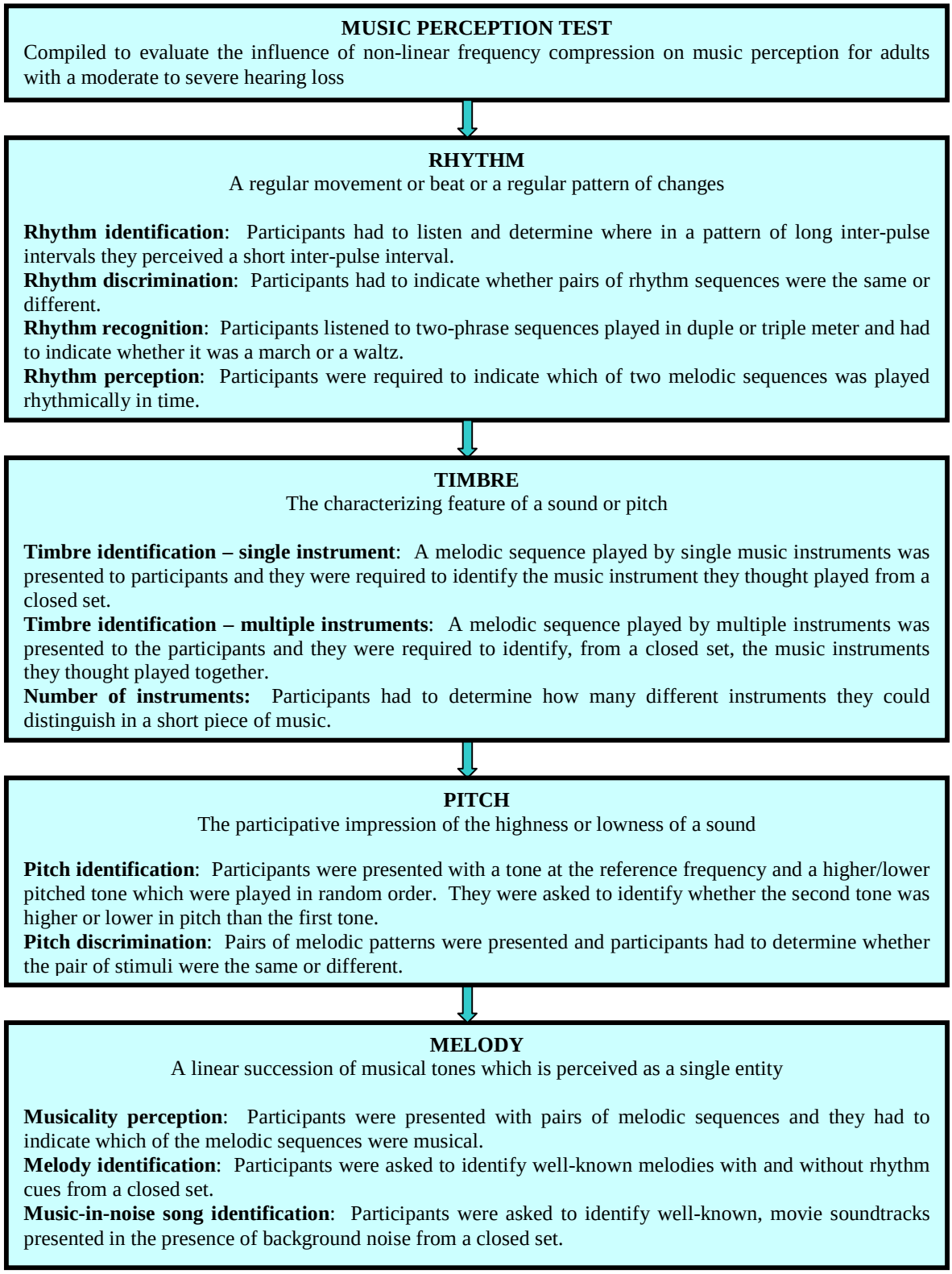

Figure 4-2: Schematic representation of the content of the Music Perception Test

Figure 4-2 presented a summary of the MPT. The sections that follow provide detailed descriptions of all the areas mentioned in Figure 4-2 and are described according to the different sections of the MPT which include rhythm (Section A), timbre (Section B), pitch (Section C) and melody (Section D).

Section A: Rhythm

In most rhythm related tasks, the participant is required to detect a deviation from regular periodic click-to-click intervals (Rammsayer & Altenmuller, 2006:38). This principle was applied to the rhythm identification as well as the rhythm discrimination tasks in this study. The rhythm section also included a rhythm recognition and rhythm perception task.

♬ Sub-test 1: Rhythm identification

Five groups of pulse tones (each with a duration of 1s768ms) consisting of five pulse tones (each of 43ms in duration) spaced 369ms apart from one another, except for two pulses which are grouped together with a space of 32 ms in between were presented. Pulse tones did not differ in frequency. Five different patterns were used, each distinguished by the position of the short inter-pulse interval. The first group of rhythmical patterns starts with close spacing of the tones at the beginning of the group. In the second group, two of the tones are closely spaced at the second pulse tone and the same pattern is followed for the remaining patterns. Figure 4-3 below presents a visual example of the short inter-pulse interval at position four:

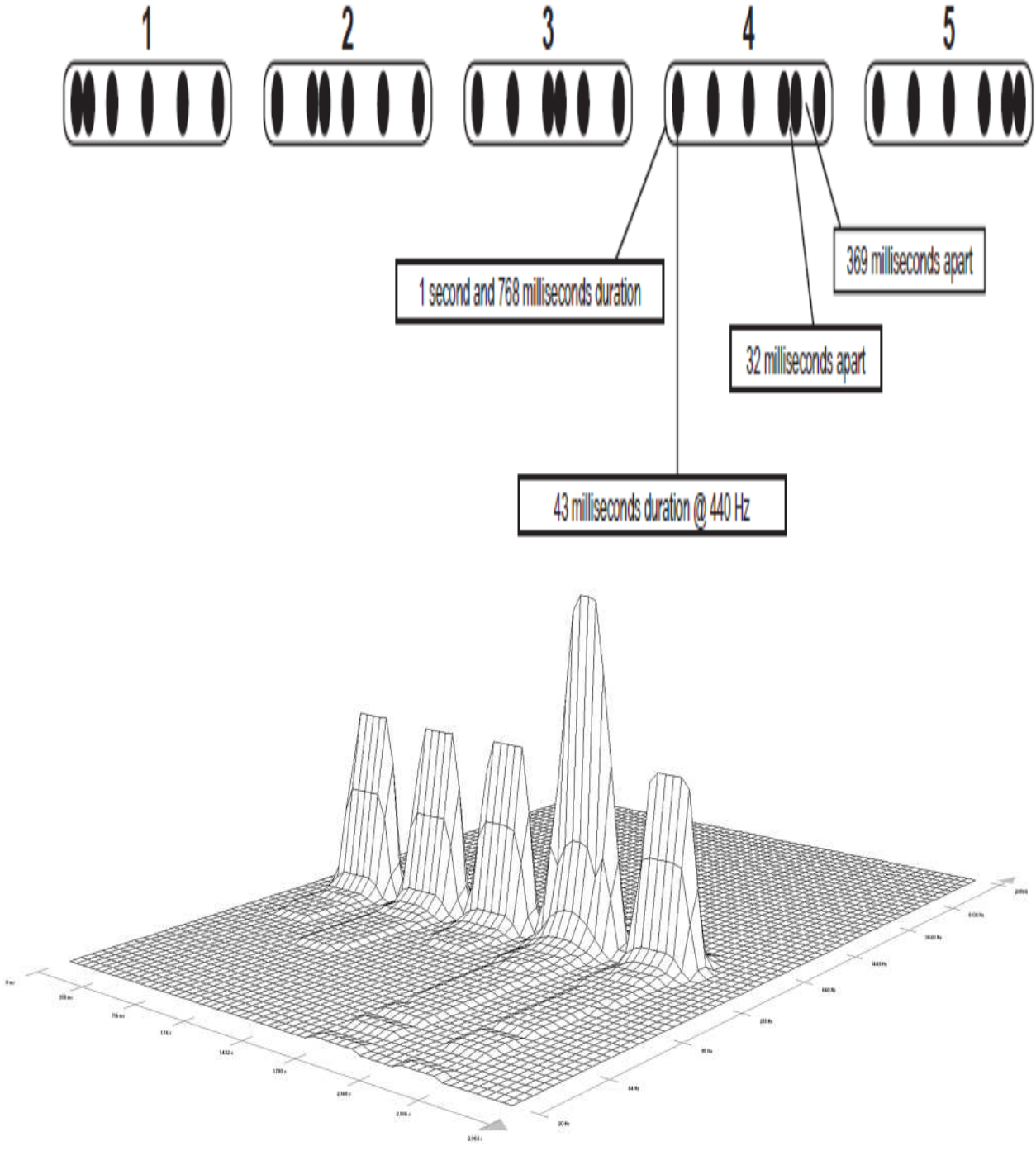

Figure 4-3: Visual representation of short inter-pulse interval at position four

Participants were provided with a visual representation of the different patterns on the answer sheet. Only *one* of the five groups was randomly played for each test, and participants were asked to identify which group they heard. To register their response, they marked the visual representation similar to the item heard with an X immediately below the representation. A total of twelve items were included in this test.

This task was similar to the six-pulse task described by Gfeller *et al.*, (1997) i.e. a given pattern consisting 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 shorter than the long inter-pulse interval and termed the short inter-pulse interval. The perception of brief intervals is a prerequisite for rhythmic precision while the perception of long intervals is necessary for keeping tempo (Rammsayer & Altenmuller, 2006:38). Another similar task was conducted by Rammsayer and Altenmuller (2006) in which participants were also presented with rhythmic patterns, each consisting of a sequence of clicks marking five beat-to-beat intervals. Four of the intervals were of a constant duration while one interval was variable. The participants' task was to decide whether the presented rhythmic pattern was perceived as regular (all beat-to-beat intervals appeared to be the same duration) or irregular (one beat-to-beat interval was perceived as different).

Kong *et al.*, (2004:177) conducted a closely related study in which tempo discrimination was measured. Seven one-bar rhythmic patterns using permutations of quarter, eight, and sixteenth notes were presented to the participants. All patterns were in a 4/4 time signature. In these patterns beats one, three and four always contained the same quarter note but beat two was varied to contain one of the seven possible patterns. These patterns were played at four standard tempos, namely 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 mentioned above. Participants were asked to choose the musical notation corresponding to the rhythmic pattern they heard. For this test, all participants had to be trained to read basic music notation (Kong *et al.*, 2004:177).

♬ Sub-test 2: Rhythm discrimination

In a typical discrimination task participants are required to indicate whether pairs of sound sequences are the same or different (Leal *et al.*, 2003). This test determines participants' ability to distinguish temporal rhythms and evaluates changes in duration of notes by presenting twelve pairs of short rhythmic pulse patterns separated by five seconds of silence. All pulses were presented at the same frequency (B6 (+4 cents)/3959.8 Hz and the patterns were spaced 1.5 seconds apart. The short pulses ranged from 130 ms - 167 ms, the medium length pulses from 252 ms – 457 ms and the long pulses from 500 ms – 752 ms. The amplitude for the loud pulses was at -25.4 dB and for the soft pulses at -30.4 dB. After listening to each pair in turn, participants had to indicate whether a pair of rhythm patterns was the same or different by marking 'Yes' on the answer sheet if they were the same, or 'No' if they were different.

♬ Sub-test 3: Rhythm recognition

Participants were presented with twelve melodies in various key signatures, which were rhythmically structured as either a waltz (melodic pattern in triple meter) or a march (melodic pattern in duple meter). Melodies used in this test were specifically composed for this test and have sufficient complexity to guarantee processing as a meaningful structure rather than as a simple sequence of notes. Rhythmical patterns were varied across melodies and the tempos used varied between 100, 120, 150, 180 and 200 beats per minute. The melodies consisted of between eight and fourteen notes and were played on a piano between D4/293.7 Hz and A6/1760 Hz. A second track with rhythmical chords played on an electric piano was added to assist with the indication of the time signature (4/4 or 3/4). There was five seconds of silence after each melody. Participants indicated their response to each item by marking with an X next to the applicable answer on the provided answer sheet.

This sub-test is similar to the meter test used by Cooper *et al.* (2008) in which they evaluated the music perception of cochlear implantees and normal hearing listeners by means of the MBEA test.

♬ Sub-test 4: Rhythm perception

Participants were presented with twelve pairs of melodic sequences. In each pair, either the first or the second melody was played rhythmically out of time and would therefore not be musically rhythmical. Melodies were played on a piano with a frequency range of C5/523.3 Hz - G#6/1661 Hz. Both 4/4 and 3/4 time signatures were used and melodies were in various key signatures. The tempo range for the melodies was between 100 - 150 beats per minute. The melodies in each pair were spaced 1.5 seconds apart, with five seconds of silence after each pair. Participants were required to indicate which melodic sequence was played rhythmically in time by selecting 'First', 'Second' or 'Both' on the answer sheet.

Section B: Timbre

Timbre is defined as the characterizing feature of a sound or pitch (Brink, 1997:486). This test evaluated timbre identification with single instruments and multiple instruments playing together.

♬ Sub-test 5: Timbre identification (Part one)

This test evaluated timbre perception by requesting participants to identify single musical instruments. The timbre stimuli used in test five (Part one and Part two) included eight different musical instruments that are:

- commonly known to non-musicians (this was established through surveys of hearing and music experts and from earlier studies in which many of the same instruments have been used successfully (Gfeller *et al.*, 2002; Gfeller *et al.*, 1997; Gfeller & Lansing, 1991);
- representative of three different fundamental frequency ranges (low: 36.7 Hz – 293.7 Hz, mid: 293.7 Hz – 523.3 Hz, high: 1175 Hz - 4186 Hz);
- representative of four different instrumental families based on the principles of sound production (brass, woodwind, pitched percussion, strings).

Given the dependent variable of recognition, less commonly known instruments that could have represented a particular frequency range for a given instrumental family were not included (e.g. the viola, a mid-range string instrument, which is often confused with the violin) (Gfeller *et al.*, 2002:136). The trumpet (medium) and trombone (low) represented the brass family and the piccolo flute (high), clarinet (medium), and saxophone (low) represented the woodwind family. The string instruments were represented by the violin (high) and cello (low). Pitched percussion was represented by the piano, which was played in two different frequency ranges (medium and high). Both of these ranges are equally characteristic for the piano (Gfeller *et al.*, 2002:137). Each of these instruments was presented in its characteristic frequency range.

Past studies of timbre with adults with normal hearing have often used synthesized or highly controlled samples of isolated pitches in timbre testing (Gfeller *et al.*, 2002:137). Isolated and synthesized tones have the advantage of greater experimental control but there are difficulties extrapolating the findings from such isolated stimuli to contextualized experiences of real-life music listening or in making it ecologically valid (Gfeller *et al.*, 2002:137). Synthesized stimuli of each instrument playing the same, standardized connected melodic sequence, which include transients that are important cues for recognition, were used for this study.

The melodic pattern played by each instrument was composed specifically for use in this test. It consisted of a short melodic piece played by each instrument in C major at a tempo of 100 beats per minute. The melody consisted of seven quarter notes, each with equal length. The frequency range for each instrument is stipulated below:

- CELLO: D2/73.42 Hz - C3/130.8 Hz
- CLARINET: D4/293.7 Hz - C5/523.3 Hz
- PIANO: D4/293.7 Hz - C5/523.3 Hz & D6/1175 Hz -C7/2093 Hz
- PICCOLO FLUTE: D7/2349 Hz - C8/4186 Hz
- SAXOPHONE: D4/293.7 Hz - C5/523.3 Hz
- TROMBONE: D1/36.71 Hz - C2/65.41 Hz
- TRUMPET: D4/293.7 Hz - C5/523.3 Hz
- VIOLIN: D6/1175 Hz -C7/2093 Hz

To ensure that *identification abilities* were being assessed and not musical knowledge, each participant's familiarity with the instruments was verified before testing (Looi *et al.*, 2008b:426). Participants were given a picture of each instrument accompanied by the instrument's name. They were instructed to mark all the instruments they were familiar with sound before the onset of the test. Although instruments were chosen that were considered well-known to the general public, musical training and experiences differ considerably across the general population (Gfeller *et al.*, 2002:137). It is therefore possible that a person may be unfamiliar with one of the instruments included in the test. Instruments which an individual was not familiar with (as determined through this preliminary step) were accounted for in the analysis of the data.

After completion of the practice items, each instrument was presented twice (for a total of 16 items) in random order for identification form a closed set. After each melody was played, sufficient time was allowed for the individual to select the instrument that he/she thought produced the sound just heard. Test results were reported as a percentage correct of those instruments known by their sound (as indicated in the preliminary step referred to above).

♬ Sub-test 5: Timbre identification (Part two)

This task extended the investigation of timbre perception beyond the single-instrument identification tasks used in most previous studies and is similar to the research done by Looi *et al.*, (2008b). The additional instruments in this sub-test increased the complexity of the sound. It consisted of 16 ensembles, where different combinations of the same instruments as in the previous test played the same melodic piece in unison. Participants were asked to identify which of these instruments were playing together in each item. They had to rely on the timbre qualities of each instrument to identify them in the ensemble. Instruments were panned to various positions (from left to right) in the stereo field to help the participants in identifying them. A maximum of three and a minimum of two instruments played together. To minimize any unwanted effects of loudness cues, the levels of the four extracts of each instrument or ensemble were randomized over a 6 dB range below the participant-determined comfortable loudness level. Test results were again reported as a percentage correct of those instruments familiar by sound as indicated in the preliminary step in the previous test.

♬ Sub-test 6: Number of instruments

This test determines how many different instruments participants can distinguish in a short piece of music. Participants were presented with five different instruments (cello, piccolo, snare drum, trumpet and xylophone) each selected to have a timbre as different as possible from the others. They heard a short solo excerpt from a musical piece composed specifically for this test, played by each instrument before the onset of the actual test. Eight variations of the full piece of music (17.5 seconds in duration) played by a selection of the instruments were presented to the participants. They were asked to identify how many instruments were playing together by relying on the timbre quality and character of each instrument. Participants were required to write down the number of instruments they thought played together for each item on the answer sheet provided.

Section C: Pitch

The participative impression of the highness or lowness of a sound is called the pitch and it is known as the psychological correlate of frequency (Martin & Clark, 2000:66). The researcher determined beforehand that candidates understood the concept of 'pitch' when they explained it as 'frequency' or 'highness' or 'lowness' of a tone and differentiated it from other qualities like loudness (Fujita & Ito, 1999:634).

♬ Sub-test 7: Pitch identification

This task included discrimination of complex pitch direction change and is similar to the pitch test produced by Nimmons *et al.,* (2008). As mentioned previously, music perception depends strongly on pitch cues (Galvin *et al.*, 2007:303) and the ability to determine the direction of pitch change is a fundamental ability in perception of melodic contour (Gfeller, *et al.*, 2002:35).

Participants were presented with pairs of two tones each, generated by a combined Saw Square wave which has been shaped by a filter to produce a synthetic tone close to that of a piano. Digitally synthesized complex tones were chosen because they are representative of real-world

acoustic tones in which fundamental frequency and overtone information are relevant cues for pitch discrimination (Nimmons *et al.*, 2008:151). The synthetic tones had identical spectral envelopes derived from a recorded piano note at middle C (262 Hz) and uniform synthetic temporal envelopes to eliminate any temporal envelope cues that might be present. Each tone had a duration of 934 milliseconds. Each pair consisted of a base tone of F#4/370 Hz, C3/130.8 Hz, E3/164.8 Hz or G3/196 Hz. A second tone ranging between D4/293.7 Hz and G5/784 Hz followed after 1.5 seconds of silence and was either higher or lower than the base tone, in a range of one semitone to 12 semitones.

The pitch direction test was implemented using a two-alternative, forced-choice test. On each presentation, a tone at the reference frequency and a higher/lower pitched tone were played in random order. Participants had to identify whether the second tone was higher or lower than the base tone. Each pair was separated by five seconds of silence.

Many studies of music have focused on pitch perception, identification or discrimination tasks (Limb, 2006:441) and similar pitch tests were done by Looi *et al.* (2008b); Leal *et al.* (2003); Medel Medical Electronics (2006); Gfeller *et al.* (2002); Moore and Peters (1992) as well as Vispoel and Coffman (1994) who conducted pitch tests where examinees had to indicate if the pitch became higher or lower or in which of two pairs one of the tones was higher than the other.

♬ Sub-test 8: Pitch discrimination

This test determines a participant's ability to distinguish differences between pitch. Participants were presented with twelve pairs of short melodic sequences (consisting of two to five notes). The melodies were played on a piano in a range of C5/523.3 Hz - A7/3520 Hz at a tempo of 80 beats per minute. The item pairs have equivalent rhythmic patterns; however, those item pairs that are 'different' vary in frequency on one or more notes. The differences within the pairs vary from gross differences to extremely subtle ones where only a single note is being flattened. The melodies in each pair were separated by 2.5 seconds of silence. Each pair is separated by five seconds of silence. Participants were asked to indicate whether the melodic sequences in each

pair were the same or different. They indicated their answer by selecting 'Yes' if they were the same or 'No' if they were different.

Section D: Melody

A melody, also tune, voice or line, is a linear succession of musical tones which is perceived as a single entity (Brink, 1997:301). This section includes musicality perception, melody identification and music-in-noise song identification tasks.

♬ Sub-test 9: Musicality perception

Participants were presented with twelve pairs of short melodic sequences (two to four bars long). The melodies were played on a piano in a range of C#5/554.4 Hz - B6/1976 Hz at tempos ranging from 90 to 160 beats per minute. Melodies were played in various key and time signatures (4/4 and 3/4) to make the test more interesting. Some of the melodies in the pairs were random notes, making no musical sense, while others were musical pieces with a clear melodic structure. Participants had to indicate which of the melodic sequences were musical. In some pairs, both pieces were melodic while in other pairs none were melodic. The sequences were separated by 1.5 seconds of silence and each pair by five seconds of silence.

♬ Sub-test 10: Melody identification

The rationale for testing familiar melody recognition is that not only does it efficiently test whether listeners are able to hear distinguishing features of the melody but it also tests whether listeners hear them correctly (Nimmons *et al.*, 2008:153). For example, misperceiving any part of the melody (the component pitches, the pitch interval changes, or the overall melodic contour) can completely change the melody. Recognition is a high-level task that is expected to be difficult, and yet, fundamental properties in their combined music and cultural exposure enable adults with normal hearing to identify melodies with high levels of accuracy (Nimmons *et al.*, 2008:153).

The term 'melody test' is arguably a misnomer because real melodies have varying durations and may have accompanying lyrics (Nimmons *et al.*, 2008:153). These are important cues for song recognition that were intentionally omitted in this study because the focus was on the recognition of pitch and pitch patterns as, since these are poorly represented and are implicated in other important skills such as perception of speech in noise, understanding of tonal languages, and sound localization.

Many studies of music have focused on melody perception and discrimination tasks (Limb, 2006:441). In this sub-test participants were asked to identify common melodies with and without rhythm cues from a closed set. The melodies were selected for their general familiarity as determined through discussions among hearing and music professionals, and also from earlier studies in which recognition tests demonstrated that the melodies were familiar for persons with normal hearing and cochlear implantees (Kong *et al.*, 2005; Looi *et al.*, 2008b). To maximize cross-cultural recognition, input was solicited from individuals from different ethnic backgrounds. All the melodies were truncated at 12 to 15 notes to prevent song length as a potential cue (Nimmons *et al.*, 2008:151). To eliminate rhythm cues for melody recognition the melodies were created by repeating all longer notes in an eight-note pattern, yielding isochronous melodies.

Before testing, the participants were presented with an alphabetical list of the names of ten well-known melodies and were asked to indicate their familiarity with each song. This was done to ensure that it was *identification* abilities being assessed and not musical knowledge (Looi *et al.*, 2008b:426). The melodies were played on a piano in a range of A5/880 Hz – C8/4186 Hz. The stimulus set contained two presentations of each of the ten melodies. Each melody was presented with its rhythmical structure intact and again where each note had a duration of 400 milliseconds, leaving the structure of the melody intact with only pitch as a cue for melody identification (meaning that there was no rhythmical structure). The playing of the melodies was randomized, but each melody was played twice, once rhythmically intact and once not. After two practice items participants were asked to identify the melody on both occasions from a closed set. Participants responded by writing the number corresponding to the melody title they heard on the answer sheet. Participants were allowed to request that the melodies be repeated a maximum of

three times. The final score was reported as a percentage of correct responses on the melodies with which the listener was familiar. Missed items were cross checked with the list completed beforehand. If an item was missed, and it was not listed as familiar, that item was eliminated from the analysis.

It is difficult to select one exemplar melody that represents the entire corpus of melodies familiar to South African adults. Individual melodies vary considerably from one another in the total frequency range as well as interval changes from one note to the next. Prior research indicates that some particular melodies may be more difficult than others to recognize under degraded conditions (Gfeller *et al.*, 2002:35). From the standpoint of hearing aids, wearers vary considerably in their ability to discriminate pitches, demonstrate intra-participant differences across different frequency bands, and show more or less orderly relations between frequency and pitch. Thus, the interaction between particular melodic features and individual performance is impossible to predict. Therefore, the researcher included ten familiar melodies that represented a variety of melodic features, thereby rendering a more realistic representation of how persons with hearing aids may function across a range of items.

A limitation of melody identification tasks is that the test assumes previous knowledge of the songs (Nimmons *et al.*, 2008:153). The test, then, might not be valid for pre-lingually deafened individuals but no persons with a pre-lingual hearing loss were included in this study. The familiarity factor is difficult to control but in an attempt to limit this effect extremely common melodies were selected. The melodies included:

- '7de Laan' theme song (Theme song of a most popular TV soap in South Africa)
- Happy birthday to you
- Jingle Bells
- Mary had a little lamb
- 'Nkosi Sikelel’ iAfrica' (South African national anthem)
- *Nokia* ring tone (Popular cell phone ring tone in South Africa)
- Old MacDonald had a farm
- Twinkle, twinkle little star

- ♬ Wish you a merry Christmas
- ♬ Wedding march (Composed by Felix Mendelssohn)

Furthermore, in recall tasks, the 'tip-of-the-tongue' phenomenon is a commonplace occurrence (Gfeller *et al.*, 2002:37). This is when a particular melody may be truly familiar, but the person is unable to retrieve from long-term memory the actual title of the melody. For this reason a structured response protocol that provided alternative categories of responses was used to assist the respondent in the recall of truly familiar items. If the respondent could not recall the exact title, they were asked if they recalled lyrics form the song, or finally, the topic or occasion associated with the song (e.g. for the song 'Wedding March' the response could be 'getting married').

♬ Sub-test 11: Music in noise song identification

A need expressed by Killion (2009:24) states that since we are stuck with human ears and brains, the challenge is to find a collection of sound samples that can be used by patients and audiologists to rate the suitability of hearing aid fittings for music processing within a few minutes. This sub-test aimed at providing evaluation material that are representative of real-life experiences and will therefore be able to give information on hearing aid processing in a real-life situation. Killion (2009:28) used an informal listening test to evaluate the suitability of a hearing aid for reproducing music. These musical materials included singing, playing a piano, a high quality violin, a trumpet, and listening to music in a car.

Stimuli used in this sub-test were 'real-word music', which is explained as excerpts from recordings of music that can be heard through popular media sources in everyday life (Gfeller *et al.*, 2005:240). The selection of naturalistic, 'real-world' musical stimuli for test purposes is challenging, given the seemingly infinite combinations of structural features in music, as well as the range of listening experiences that potential participants may bring to the testing situation. The researcher decided to include familiar film soundtracks. By doing this the researcher aimed at enlarging the possibility of participants being familiar with the songs since they are available on radio but can also be heard when watching movies.

There are thousands of compositions from musical tracks used in movies from which to choose test excerpts. As musical experiences vary considerably from one person to the next, and because recognition requires familiarity, a systematic process of selecting items that were likely to be familiar to many South Africans was used. Briefly, compositions were selected using published rankings of exposure and popularity, which offered quantifiable evidence of item exposure and familiarity to a relatively large segment of the adult South African population. Some of the included melodies have been found to be familiar by Spitzer *et al.* (2008) although they targeted the United States population. Table 4-6 presents the songs included in this sub-test:

Table 4-6: Songs included for the music-in-noise sub-test

Songs included	Film	Song titles included in list but not used as stimuli in test	Film
Beauty and the Beast	Beauty and the Beast	A whole new world	Aladdin
Chariots of fire	Chariots of fire	Climb every mountain	Sound of music
Don't cry for me Argentina	Evita	Hungry eyes	Dirty dancing
I've had the time of my life	Dirty dancing	I finally found someone	The mirror has two faces
Leaving on a jet plane	Armageddon	I say a little prayer for you	My best friend's wedding
My heart will go on	Titanic	Diamonds are forever	Diamonds are forever
Purple rain	Purple rain	Lara's theme	Doctor Zhivago
Singing in the rain	Singing in the rain	Pink Panther theme	Pink Panther
Unchained melody	Ghost	Summer nights	Grease
Stayin' alive	Saturday night fever	Take my breath away	Top Gun

Because musical training and experience are unevenly distributed among the general population, it is possible that an individual may have no prior exposure to, and therefore is unfamiliar with a specific item in the test, despite the fact that the excerpt is well-known to the general public (Gfeller *et al.*, 2005:242). Therefore, to rule out lack of familiarity as a factor in item recognition, an alphabetized list of melodies was included to identify the songs known to participants. This list included 20 well-known movie soundtracks of which only ten were included as test stimuli.

An average person spends between two and a half to three hours in a car daily. This is due largely to the factors of traffic congestion and urban sprawl. While driving, one of the only

things to do is to listen to the radio, mostly playing music. The background noise level in most cars at 70 mph (113 km/h) is about 70 dB (A), which makes for a good music-in-noise listening test (Killion, 2009:28). The researcher therefore decided to compile a music-in-noise test as part of this test battery to simulate a real life situation for listening to music. For this purpose a simulated noisy environment, namely that of the interior of a car driving in traffic, was created to mask ten of the songs. A difference of 6.2 dB and 10.2 dB was determined between the peak loudness of the music and the peak loudness of the noise which peaks at 0 dB. Only a well-known section (20 seconds, with 4 second fade in and 4 second fade out) of each song was played. The songs were separated by ten seconds of interior car noise only.

Before testing took place, participants had to indicate which soundtracks they were familiar with. They were asked to identify the soundtracks by writing the corresponding number on the answer sheets. No evidence of such a test could be found in the literature.

4.6.1.1.5 Reliability and validity of the Music Perception Test

The reliability and validity of the MPT would influence the extent to which important information could be obtained from the study, the probability to obtain statistical significance in data analysis and the extent to which meaningful conclusions could be drawn from the collected data (Leedy & Ormrod, 2004:29). Several measures were taken to increase the reliability and validity of the MPT as discussed below:

Reliability means that results are replicable and therefore, when administered properly, a test will render consistent results on repeated administrations or with different interpreters judging the same administration (Shipley & McAfee, 2008:6). To obtain reliability to the highest possible degree, the following measures were implemented:

- A thorough study of previous music perception tests described in the literature was conducted. This enabled the researcher to make informed decisions on material to be included in the MPT.

- By conducting the MPT on persons with normal hearing, preliminary norms for this test were compiled. This also enabled the researcher to compare the results of the participants with a hearing loss to those of normal hearing listeners.
- In order to control for central auditory processing disorders, an inter-subject analysis was used. When the results of a person with central auditory processing disorder are compared to those of a person without central auditory processing disorder the results might not be reliable, since the presence of central auditory processing disorders might be the cause of poor performance on the test. By comparing each participant's data with itself the reliability of the results of the MPT was improved.
- Rater-reliability refers to the degree to which the same person or different people obtain the same or very similar results after administering a test (Shipley & McAfee, 2008:6). Intra-rater reliability was established as the test results were consistent when the researcher administered the test on more than one occasion, i.e. participants that scored high the first time also scored high the second time and vice versa.
- Agreement as coefficient of reliability refers to the extent to which two or more persons agree about what they have rated (McMillan & Schumacher, 2006:186). In the current study, professionals in the music and audiology industry provided similar ratings for different aspects of the MPT. This agreement in ratings therefore improved the reliability of the test.

As the purpose of the study was to determine the influence of non-linear frequency compression on music perception and not to develop a test for the assessment of music perception, the MPT was not administered multiple times to the same group of people in order to compare their results. Therefore test-retest reliability was not obtained but, as mentioned before, this was outside the scope of the current study. Furthermore, inter-rater reliability could not be obtained because the researcher was the only audiologist available to perform testing and therefore the test could not be administered by various persons. Lastly, parallel reliability, also known as alternate reliability, could not be obtained as there is no music perception test for hearing aid users available to compare the newly compiled test (MPT) to (Shipley & McAfee, 2008:6).

Validity means that a test truly measures what it claims to measure (Shipley and McAfee, 2008:5). The following steps were taken to validate the MPT (Downing & Haladyna, 1997:64-71):

- The content of the test was defined by documenting the selection of items and the methods used. Additional aspects implemented in the development of the content of the test, and aiming at optimizing its validity, were the following:

  - The high quality of the MPT recordings contributed to the validity of the test and to the results of the study since the test was recorded in a professional music studio by professional musicians and sound engineers.
  - Wherever possible, the stimuli have been recorded to render a range from gross differences to very subtle changes. By their very nature, speech tests evaluate performance and are susceptible to ceiling affects, but differences in musical stimuli can be so subtle that many normal hearing listeners might be stretched to recognize them (Medel Medical Electronics, 2006:1).
  - Where applicable, piano tones were used for stimuli in the MPT since piano tones are more commonly available in music. Due to their ecological validity they are therefore typically used in music perception tasks (Cooper *et al.*, 2008:625).
  - A calibration tone was inserted at the beginning of the recording and the alerting phrase 'Are you ready?' was inserted prior to each test. Recognizing that music is highly variable in intensity, care was taken to maintain a minimum intensity level within 10 dB of the calibration tone.
  - Recordings were consistent in terms of characteristics. If the duration of a given excerpt is long, it is likely that the timbre and spatial characteristics will vary in time and listeners might find it difficult to 'average' the quality over time and random errors may occur (Zielinski, Rumsey & Bech, 2008:431). Therefore short and consistent stimuli were used in the MPT.
  - The researcher obtained objective results with the test and did not make use of affective judgments. The long-term stability of affective judgments is poor as listeners preferences may drift over time due to, for instance, changes in fashion, changes in listening habits or

changes in the technical quality of available products (Zielinski *et al.*, 2008:433). Furthermore, listeners' affective judgments may also be biased by the appearance of the equipment, the price of the hearing aids and branding (Zielinski, 2008:433).

- Test specifications were constructed by documentation of specifications for the test and form part of the MPT manual that is available in Appendix H.
- Item content verification was provided. This was done by providing a reference list of sources used in the development of the MPT as well as a peer content review. The peer content review was conducted in the form of a rating scale to verify the quality of included items as well as the relevance of the test to the field being assessed. A copy of the evaluation sheet used for the peer content review is provided in Appendix I. Various aspects were addressed in the MPT evaluation sheet which, after completion by professionals in the audiology and music industry, provided the following aspects of test validity (Shipley & McAfee, 2008:5-6):

  - Face validity – this implies that the MPT, based on its appearance, seemed to measure what it claimed to measure.
  - Content validity – this refers to the completeness of the MPT as a valid test for the assessment of music perception on the grounds of the entire spectrum of skills that are tested which included rhythm, timbre, pitch and melody.
  - Construct validity – this refers to the MPT's ability to measure a predetermined theoretical construct, in this case music perception, which is an explanation of a behaviour or attribute based on empirical observations.
  - Criterion validity – this implies validity of the MPT as established by the use of external criteria obtained from the peer review.

- Editing of test items. By reviewing items, the clarity and appearance of items were enhanced. This was done in Stage 2 of the first phase where items with high error rates were rejected. A copy of the first version of the MPT can be found in Appendix G and include the original items before item editing was done. All items that needed editing were professionally edited.
- The test was reviewed to identify bias-sensitivity since one source of invalidity could be measurement error caused by the language used in the test. A thorough and systematic review

of the test items for potentially biased words, phrases, situations or content was done in order to eliminate potential culturally biased words, phrases and situations that might be offensive to some individuals. This was done by presenting the test to a mix of racial and ethnic groups. An exact match of the South African demographics could not be obtained, but Downing and Haladyna (1997:70) indicated that an exact match to the demographics of the target examinees is unnecessary.

- Items were tried out and pre-tested in the pilot study, thereby enhancing item validity. Subsequently item analysis-type data were calculated and the performance characteristics of the items such as item difficulty were assessed. The pilot study enhanced the validity of the test as it gave an indication of the effectiveness of the test. Furthermore, by validating the results of the MPT, the reliability of the test was increased, giving it more feasibility and utility.
- Lastly, test security of items was ensured. This is an essential element in the validity of examinations as invalidity is introduced to the test when some examinees have access to test items whilst others do not. The researcher ensured that the examination was secure and that careful documentation, record keeping and a method of systematic routine reporting of documentation took place.

The use of a test like the MPT may however have pitfalls. Most notably, there is likely to be a *cultural specificity* to the items selected (Spitzer *et al.*, 2008:63). Furthermore, *familiarity with melodies* may be affected by access, both on the basis of national origin as well as listening experience resulting from hearing loss or other factors. To maximize cross-cultural recognition, input was solicited from individuals from different cultural backgrounds for Sub-test 10 (Melody identification) and Sub-test 11 (Music-in-noise song identification). This was done by providing them with a list of 25 well-known songs and asking them to select the ten songs with which they were the most familiar. Furthermore, very early *onset of deafness* may effectively eliminate the ability to respond to certain stimuli in this test, therefore no pre-lingually deafened adults were included in this study. Another issue is that the ability to perform well on a music perception test does not imply *musical satisfaction* (Spitzer *et al.*, 2008:63). In an attempt to compensate for this, each participant also completed questionnaires to give a subjective impression on how they perceived musical stimuli with the hearing aids. Lastly, random errors are commonly observed in

the results of listening tests as they manifest themselves by a scatter of scores for a given experimental condition. These errors are predominantly caused by inconsistency of individual listeners in the assessment of audio quality and they may also originate from inter-listener differences in the evaluation of audio quality (Zielinski *et al.*, 2008:427).

4.6.1.2 Questionnaires

A questionnaire is defined as a set of questions on a form to be completed by targeted persons for the purpose of research (McMillan & Schumacher, 2006:194). Self-report questionnaires and inventories to assess performance with assistive devices have a long and honourable history (Gatehouse & Akeroyd, 2006:98) and are often used to evaluate the success of hearing aid fittings (Bentler, 2006:89). Such questionnaires usually take the form of presenting the respondent with a list of scenarios which he/she is asked to rate on one or more dimensions, usually via some form of fixed scale or response alternatives (Gatehouse & Akeroyd, 2006:98).

Due to a shortage of available material to attain the aims of this study, it was necessary to design appropriate questionnaires. The questionnaires were designed by the researcher and contained the information needed to reach the aims of this study. The researcher made use of two questionnaires. After the hearing aid fitting questionnaires were handed to each participant to be completed personally in a verification session and in the presence of the researcher. This procedure ensured personal contact and subsequent higher response rates (Delport, 2005:168). This is seen as an advantage, because a low response rate, as often found with mailed questionnaires, impacts negatively on the quality of the research (Bless & Higson-Smith, 2000:109).

4.6.1.2.1 Motivation for the use of questionnaires

There are several advantages to the use of a questionnaire. A questionnaire is relatively economical, provides the same questions to all subjects and can ensure anonymity (McMillan & Schumacher, 2006:194). The participant further requires little (if any) training to complete the questionnaire and tends to give more honest opinions during the completion of a questionnaire

than during an interview. If the instructions and questions in a questionnaire are clearly formulated, the information obtained may be viewed as accurate and valid as it was personally provided by the participant (McMillan & Schumacher, 2006:195).

There are, however, some drawbacks to the use of questionnaires of which one of the most common is the often encountered low response rates which may negatively influence the quality of the research (Maxwell & Satake, 2006:225). In this study, however, high response rates were ensured by having respondents complete the questionnaires in the presence of the researcher before they left the facility. In compiling the questionnaires the researcher also implemented several guidelines from literature which facilitated completion, thereby optimizing the response rate. Still another disadvantage of questionnaires is that it often provides a limited view of some aspects because participants are not given the opportunity to address additional aspects (Maxwell & Satake, 2006:226). To minimize this phenomenon, participants were provided ample space to motivate or comment on their answers; the questionnaires also included a question where participants had the opportunity to provide additional information.

4.6.1.2.2 Guidelines provided by literature for the development of questionnaires

By structuring and grouping questions to logically follow on each other, a well constructed questionnaire will form an integrated, holistic unit. Some of the main principles that items in a questionnaire should comply with is that it should be based on clearly defined objectives; it should also be clear, relevant, short and uncluttered (McMillan & Schumacher, 2006:210). Furthermore, biased items and terms should be avoided. If the questions are constructed according to these guidelines, they will provide valid and reliable data after completion and analysis (McMillan & Schumacher, 2006:210).

To ensure participation and increase the response rate of the questionnaires, the following guidelines were followed in the construction of the questionnaires (McMillan & Schumacher, 2006:194-203; Maxwell & Satake, 2006:225-231):

- Participants were provided with a letter requesting informed consent beforehand. This letter explained the purpose and procedures of the study and ensured that participation would be voluntary.
- Indications of the time it will take to complete the questionnaires were also provided in the aforementioned letter. This was made possible conducting a pilot study before the main study commenced.
- Clear and simple instructions were provided at the beginning of the questionnaires.
- Relevant questions were grouped together and questions were organized in a logical sequence.
- Double-barrelled and lengthy questions were avoided.
- Biased questions were avoided and the researcher formulated questions in such a way that there was no hint for a certain response.
- The first part of the questionnaires consisted of more general questions while more sensitive questions were placed towards the end of the questionnaires.

4.6.1.2.3 Description of questionnaires

The first questionnaire consisted of 17 questions and the second questionnaire of nine. Both questionnaires were two pages long, consisting of one section and available in English only. Each questionnaire took approximately ten minutes to complete. The questions were logically organized to provide structure to the questionnaire, to orientate participants and to simplify analysis. The questionnaires provided space for a respondent number; this was added after completion of the questionnaires. On the right hand side of the questionnaire the usual space for coding, with the heading 'For office use only', was provided. Instructions for the completion of the questionnaires were provided to each participant. A copy of Questionnaire 1 is provided in Appendix J and of Questionnaire 2 in Appendix K.

4.6.1.2.4 Purpose and content of the questionnaires

The following information was included in the questionnaires:

Questionnaire 1: This questionnaire aimed at obtaining information regarding the participants' musical background as this might influence the results of the study and assist in the interpretation of the obtained results. It was the first questionnaire handed to the participants for completion, the assumption being that non-deceptive and relative easy questions may act as ice breakers and motivate participants to further complete the questionnaire (Singleton, Straits & Straits, 1993:154).

The first seven questions requested information regarding participants' musical background, whether they received any musical training or participates/d in any musical activities. The next six questions obtained information about the importance of music in the participant's daily living and provides data on musical preferences that the participant might have. These questions were included to assist with the interpretation of the results of the MPT because music skills may cause participants to perform better on the test. Lastly, participants were asked about their musical experiences when listened to with their hearing aids on. This rendered valuable information regarding current difficulties participants might experience when listening to music with hearing aids, and highlights aspects to which the researcher should pay attention when evaluating music perception with the non-linear frequency compression hearing aids. The last question gave participants the opportunity to add, should they wanted to, any additional related information. The rationale for including the last mentioned question is to give participants the opportunity to expand or provide information that wasn't necessarily targeted in the questionnaire, but could assist in the analysis and interpretation of the results (Singleton *et al.*, 1993:59).

Table 4-7 provides a presumption and literature reference for all the questions included in the first questionnaire. Information obtained through this questionnaire enabled the researcher to orientate herself regarding the participants and facilitated analysis and interpretation of the results of the study.

Table 4-7: Presumptions and literature references for questions included in Questionnaire 1

	QUESTION	PRESUMPTION	LITERATURE REFERENCE
1	For approximately how many years did you receive musical training (instrument and/or voice lessons)?	People with musical training will perform better on different tasks of music perception than people with no musical training.	♬ Previous research has identified factors influencing music processing that include **music background and training** (Kreutz *et al.*, 2008:58). ♬ It has been found that **music training** improves the processing of tonal music in the left hemisphere (Van Egmond & Boswijk, 2007:31). ♬ **Training** specific to music perception can improve scores on music perception tests (Cooper *et al.*, 2008:624). ♬ The ability to detect musical aberrations is likely to be dependent on cultural musical upbringing, degree of innate musicality, presence of tone deafness, and degree of **musical training** (Limb, 2006:438). ♬ Precise judgments of interval size require listeners to have received considerable **formal musical training** (McDermott, 2004:66). ♬ Musicians' superior performance on perceptual temporal tasks that do not require reference memory processes, suggests that **extensive music training** may exert a positive effect on timing performance by reducing variability or noise associated with the timing process (Rammsayer & Altenmuller, 2006:42). ♬ It was found that subjects with **musical training** were more capable in recognizing nursery songs, both with and without vocal elements (Leal *et al.*, 2003:834). ♬ **Formal musical training** in high school, college and beyond was found to be a significant predictor for music perception where the listener must rely on spectral information (Gfeller *et al.*, 2008:132). ♬ Respondents with **musical training** were more likely to report a loss in their enjoyment of music since developing a hearing loss (Leek, Molis, Kubli & Tufts, 2008:520).
2	Please specify the musical instruments that you are currently playing, or have played before.	People who are able to play any musical instrument/s might perform better on certain tasks of music perception, especially related to timbre.	♬ Results do not necessarily indicate that **instrument training** or ear training does not improve one's performance in experimental tasks, but some listeners' aptitude for tonic identification seems to be higher. Consequently, these listeners need less music training to reach the same skill level than less talented listeners (Van Egmond & Boswijk, 2007:34). ♬ Trainee factors can affect the rate of learning in auditory rehabilitation. For example, life experiences in music listening and the **knowledge of musical instruments** prior to and throughout training can influence rehabilitative benefit (Driscoll *et al.*, 2009:73).
3	Do you currently sing, or have you ever sung, in a choir or at social/professional gatherings?	People that are singing or have sung on a more formal level might perform better on certain tasks of music perception as this indicates a high probability of having musical talent.	♬ Results do not necessarily indicate that instrument training or **ear training** does not improve one's performance in experimental tasks, but some listeners' aptitude for tonic identification seems to be higher. Consequently, these listeners need less music training to reach the same skill level than less talented listeners (Van Egmond & Boswijk, 2007:34).
4	Please specify your highest musical qualification.	A person with a higher musical qualification will perform better on different tasks of music perception than a person with no musical qualification. People with formal musical training will evaluate the quality of music in a more strict matter.	♬ See literature references at Question 1.

	QUESTION	PRESUMPTION	LITERATURE REFERENCE
5	Do you consider yourself to be a person with musical talent or musical sense?	If one considers him/herself or other people consider him/her as a person with musical talent or musical sense and this person do not have any formal musical training, it might be that he/she can still perform better on certain aspects of music perception compared to a person who is not considered to be musical.	♬ Another factor that may affect scores on music perception tests is the **musicianship** of the participant (Cooper *et al.*, 2008:624).
6	Do other people consider you to be a person with musical talent or musical sense?		
7	Please specify your relationship to any persons in your immediate family with an extraordinary musical talent?	A person who has an immediate family member with extraordinary musical talent might have a genetic predisposition to perform better in certain tasks of musical perception, especially pitch-related tasks.	♬ Auditory testing of siblings of individuals who score exceptionally well on formalized auditory tests of pitch perception indicates that absolute pitch **aggregates in families** (Baharloo, Service, Risch, Gitschier & Freimer, 2000: 758). ♬ Music perception and creativity in music are linked to the same phenotypic spectrum of human cognitive social skills, like human bonding and altruism both associated with **AVPR1A chromosome** (Ukkola, Onkamo, Raijas, Karma & Jarvela, 2009:1).
8	What role does music play in your life?	A person that is more exposed to music, demonstrates a greater interest in music and spent more time listening to music will be more 'trained' (trained ear) to evaluate music and participate in certain tasks of music perception for example familiar melody identification.	♬ Predictors related to musical training and **experience** included: **music listening habits**, amount of formal musical instruction in elementary school, and amount of formal music instruction in high school and beyond (Gfeller *et al.*, 2010:31). ♬ Trainee factors can affect the rate of learning in auditory rehabilitation. For example, **life experiences in music listening** and the knowledge of musical instruments prior to and throughout training can influence rehabilitative benefit (Driscoll *et al.*, 2009:73). ♬ Cochlear implant users' music perception may be greatly improved with training and **music listening experience** (Galvin *et al.*, 2007:312). This should be investigated for hearing aid users.
9	How often do you listen to music?		
10	How many hours do you usually listen to music on a work day?		
11	How many hours do you usually listen to music on a day that you are not working (for example over weekends)?		
12	In which situations do you listen to music?	The situations in which a person listens to music might influence his/her enjoyment of music and the musical quality he/she perceives.	♬ Listening to music is an important part of life and most often music is recorded and played on a **CD player**, the **radio**, the **television**, an **MP3 player**, or a **computer** (Minnaar, 2010:38). ♬ Many respondents indicated they listened to music on the **radio** and **television**, two media which typically use only one sound source for both music and lyrics. The task of understanding lyrics then becomes one of separating a speech signal (lyrics) form a background (music), nearly always a challenge for people with hearing loss (Leek *et al.*, 2008:525).
13	Which music genre/s do you listen to?	The musical genre/s a person is exposed to can influence his/her performance on different tasks of music perception for example a person who listens to classical music might perform better on timbre identification tasks.	A continuum of simple to complex compositions can be found within all three (**pop, country** and **classical**) of these genres. However, in general, classical selections tend to have more complex, sophisticated melodic, harmonic and rhythmic structures than those found in typical pop and country favourites. For example, structural analysis of many pop and country pieces reveals a predominately homophonic structure (a predominant melody line over a harmonic progression in a rhythm similar to that of the melody), relatively simple and redundant harmonic progressions and repetitive rhythmic patterns. These characteristics contrast with the complex harmonic progressions (e.g. deceptive cadences, complex and rapid tonal modulations, counterpoint, etc.) intricate rhythms, and sometimes timbre blends of large classical compositions (Gfeller *et al.*, 2005:241).

	QUESTION	PRESUMPTION	LITERATURE REFERENCE
14	Do you feel that your enjoyment of music has decreased since you started experiencing hearing problems?	People with a hearing loss will complain of a decrease in enjoyment of music.	♬ 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 (Wessel *et al.*, 2007:1; Chasin, 2003b:36). ♬ Respondents with musical training were more likely to report a **loss in their enjoyment** of music since developing a hearing loss (Leek *et al.*, 2008:520).
15	Do you remove your hearing aid when you listen to music?	Most people remove their hearing aids when they listen to music.	♬ People complained about the reduced sound quality of music heard through hearing aids 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).
16	What do you find most annoying when you listen to music with your hearing aid?	Hearing aid users will have difficulty understanding the words of songs.	♬ 79% of respondents felt that their hearing loss hindered their enjoyment of music. Complaints included **difficulty understanding the words** of songs as well as **distortions of pitch and melody** (Leek *et al.*, 2008:521). ♬ The two complaints that were most commonly voiced were that the music was either **too loud or too soft overall** or that it was **difficult to understand the words** in the music. Other complaints included **difficulty to recognize melodies** and **volume changes in music** (Leek *et al.*, 2008:523).

The table above summarizes the information included in the first questionnaire and highlights its importance.

Questionnaire 2: The second questionnaire was in the form of a self-report questionnaire and was designed with the purpose of obtaining subjective information form participants regarding their experience with the non-linear frequency compression hearing aids while engaging in different musical activities. Through the second questionnaire the researcher obtained subjective information about the participants' hearing aid preferences when listening to music and this information could assist the researcher in evaluating the efficacy of these amplification devices for musical stimuli (Auriemmo *et al*, 2008:50). The questions in this questionnaire were revised from the Munich Music Questionnaire (Medel Medical Electronics, 2006) used to evaluate the listening habits of people with post-lingual deafness after cochlear implantation and a five-point perceptual scale used by Chasin (2003b:38) to obtain measures of sound quality. This five-point scale used by Chasin (2003b) is a modification of the work of Gabrielsson and colleagues and has been used extensively in the hearing aid industry (Chasin, 2003b:38).

The first question determined the participant's favourite musical genre and is similar to a question form the Munich Music Questionnaire. The second question was divided into eight sub-

questions, each obtaining measures of sound quality. Participants were asked to rate the sound from 1 (poorest) to 5 (best) on eight perceptual scales. The first five perceptual scales (Loudness, Fullness, Crispness, Naturalness and Overall fidelity) are similar to the ones used by Chasin (2003b:38) while the following three perceptual scales (Pleasantness, Tinniness and Reverberant) were adapted from the Munich Music Questionnaire. The following five questions were directed towards specific musical discriminations that participants could or could not detect, for example to discriminate between different musical instruments, high and low notes, the lyrics of a song, etc. The second last question left space for additional comments that the participants might wanted to add and in the last question participants were provided the opportunity to indicate whether they would like to receive the results of the study or not.

4.6.1.2.5 Format of questionnaires

In both of the questionnaires the researcher included more closed ended questions because they make for more effective data acquisition, data processing and data analysis (Leedy & Ormrod, 2005:113). However, the researcher did not use closed ended questions exclusively, as this may provide insufficient results in some cases due to participants possibly not agreeing with the answers provided (Leedy & Ormrod, 2005:110). In the case of closed ended questions the participant is expected to select an appropriate answer from a list of specified options, whereas in the case of open ended questions the participant is expected to formulate his/her own answer. The use of open ended questions might however make comparison of responses between respondents more difficult (Leedy & Ormrod, 2005:114).

The use of closed ended questions has the following advantages (McMillan & Schumacher, 2006:197; Leedy & Ormrod, 2005:110):

- Participants find it easier to understand the meaning of a question because the provision of possible answers limits the participant's choices.
- Participants find it easier to answer because they only have to select one of the provided answers.

- The possible answers are restricted and therefore facilitate comparison of answers between respondents.
- The answers are easier to analyze.
- It limits the possibility of respondents' providing double-barrelled answers.
- Participants can answer the items more quickly.

Disadvantages of closed ended questions is that a structured item cues the respondent with respect to possible answers and if categories are created that fail to allow the participant to indicate their feelings or beliefs accurately, the item is not very useful (McMillan & Schumacher, 2006:197). Participants may also develop an affinity for a certain response, for example, to mark every second block – this will cause the validity of the results to be questioned. In order to avoid this, test items had various degrees of difficulty.

The researcher made use of different types of closed ended questions in both questionnaires. The following response categories can be differentiated (Leedy & Ormrod, 2005:115):

- Multiple choice questions where the respondent's opinion was determined by him/her selecting the most appropriate choice according to his view (Questionnaire 1: Questions 12-13; Questionnaire 2: Questions 1 and 3);
- Yes/No questions were used to determine whether a participant agreed with a given statement or not (Questionnaire 1: Questions 3, 5-6, 14-15; Questionnaire 2: Questions 4-6, 9);
- Self-report questions with a list of scenarios which the respondent had to rate in terms of a fixed scale (Questionnaire 1: Questions 8-9; Questionnaire 2: Question 2).

In addition to closed ended questions, open ended questions were also included in both questionnaires (Questionnaire 1: Questions 1-2, 4, 7, 10-11, 16-17; Questionnaire 2: Questions 7-8). Open ended questions imply the least amount of control over the participants and provided them with the opportunity to give specific opinions or perceptions (McMillan & Schumacher, 2006:198).

4.6.1.2.6 Reliability and validity

Reliability is a term that refers to an instrument's ability to obtain the same results every time that it is performed and this will therefore lead to test-retest reliability (Delport, 2005:163). To obtain reliability to the highest possible degree the following steps were implemented:

- Each participant was contacted personally, telephonically or by e-mail to explain the purpose of the study and to obtain their consent to participate.
- A qualified audiologist performed all test procedures and real-ear measurements (Valente, 2006:33).
- Questions in the questionnaires were formulated in such a way as to eliminate ambiguity and to ensure clear and precise wording and instructions (Delport, 2005:163).

The **validity** of a measurement instrument refers the extent to which the instrument measures what it is supposed to measure (Leedy & Ormrod, 2004:28). According to Struwig and Stead (2001:136) it refers to the degree to which the research design is scientifically sound and appropriately conducted. To ensure validity as far as possible, the following steps were taken:

- The aims of the study were clearly and precisely formulated.
- A literature study was conducted to ensure that the questions included in the questionnaires were relevant to the validation of the hearing aid fitting process and music perception.
- The pilot study enhanced the validity of the verification measurements as it ensured the researcher's acquaintance and skills with the procedures that were followed assisted in the accurate interpretation of the results. In addition, the pilot study added to the validity of the questionnaires as it gave an indication of their effectiveness.
- The researcher included many participants in this study. The validity of a study increases with an increase in sample size (Leedy & Ormrod, 2004:28).
- Biographical data was obtained from each participant to account for the possibility of a person's musicality having an influence on the results of the MPT.

After the implementation of the above-mentioned steps, the questionnaires were valid regarding the following:

- **Content validity**: This is concerned with the representativeness of the content of the questionnaires and confirms that the questionnaires appropriately evaluate the behaviour and knowledge, in this case music perception, which it is supposed to (Delport, 2005:160). The use of relevant literature and discussions with professionals in the music industry concerning the design of the questionnaires ensured that content validity was obtained.
- **Face Validity**: Face validity concerns the superficial appearance of the questionnaires, and the way in which appropriate language was used in order to reach the aims (Delport, 2005:161). This is imperative when a questionnaire is used; Neuman (2003:284) clearly states that a 'professional appearance… and good layout improves accuracy and completeness and helps the questionnaire flow'. The questionnaires were professionally designed. A literature review and results obtained from the pilot study were integrated in the final selection of items and layout with the aim of guiding the participant in providing accurate and complete responses. Instructions and questions were also formulated in such a manner that it could easily be understood by all the participants. Furthermore the researcher presented the questionnaires to participants in a pilot study to determine whether or not it could be used as suitable research instruments in this study.
- **Construct validity**: Construct validity is concerned with the meaning of the questionnaires and thus involves validation of the instruments themselves as well as the theory underlying it (Delport, 2005:162). To increase the validity of the questionnaires the researcher tried to keep all instructions, language use and format as simple as possible and avoided ambiguous questions and statements. The researcher also took care to avoid biased questions.
- **Criterion validity**: This is determined when an instrument is compared to existing instruments that are valid (Bless & Higson-Smith, 2000:96). Due to the lack of valid evaluation material for the conduction of this study, the questionnaires used in this study were compiled by the researcher. These questionnaires could therefore not be compared to other questionnaires.

4.6.2 Apparatus

Apparatus used in this study consisted of audiometric and music equipment. The same apparatus was used in all the phases of the study and is discussed in Table 4-8.

Table 4-8: Data collection apparatus and procedures

Apparatus	Requisite	Justification	Procedure
Audiometric Apparatus			
Heine Mini 2000 CE otoscope	The otoscope had new batteries to ensure optimum performance and was used with appropriate, sterilized specula.	The purpose was to evaluate the integrity of the external auditory meatus and tympanic membrane. It also enabled identification of possible abnormalities, strange objects or excessive wax which might have been present in the external ear canal or middle ear (Martin & Clark, 2000:234).	• The appropriate size speculum was selected for each participant. • The participant's ear was pulled up and backwards while performing the otoscopic examination to improve visibility (Katz, 2002:17). • The audiologist looked for any malformations in the external auditory meatus or tympanic membrane, signs of trauma or infection and ruled out any obstructions or excessive cerumen in the auditory meatus (Katz, 2002:17). • If any abnormalities were observed, the participant was referred to an ear, nose and throat specialist (Katz, 2002:17) and did not take part in any further testing until the problem was cleared.
GSI Tympstar immittance meter	The immittance meter was calibrated according to the requirements of the South African Buro of Standards (SABS) to ensure that reliable and correct results were obtained. The appropriate probes were selected for each participant to ensure a proper fit. All the probes were sterilized before use.	Tympanometry provides information regarding the ear canal volume, compliance (mobility) of the tympanic membrane as well as pressure within the middle ear (Martin & Clark, 2000:152). It is highly sensitive to conductive pathologies.	• Immittance testing only took place if the ear canal was clear of any occluding earwax or foreign objects as determined with the otoscopic examination (Martin & Clark, 2000:154). • Verbal instructions were given to the participant. • Tympanometry was conducted with a low-frequency probe tone of 220 Hz to 226 Hz (Martin & Clark, 2000:156). • The ear tip was pressed into the ear canal, a tight seal was obtained and the measurement was taken for both ears. • If no airtight seal could be obtained, resealing with a different sized tip took place. • Measurements of the pressure, volume and compliance were obtained. Values between 0.30 and 1.60 cm^3 were considered the normal range for static compliance and ±100 daPa was representative of normal middle ear pressure (Martin & Clark, 2000:155). • If any abnormal results were obtained, the participant was referred to an ear, nose and throat specialist and did not take part in further testing until the problem was cleared.
GSI Audera oto-acoustic emission instrument	This instrument was calibrated according to the requirements of the SABS to ensure that reliable and correct results were obtained and all the probes were sterilized before use. The	Oto-acoustic emissions are sounds emanating from the cochlea that can be detected in the external auditory canal with probe-tube microphones (Martin & Clark, 2000:330). It allows for the study of cochlear function and will be un-recordable in the case of any	• Verbal instructions were given to the participant. • A probe containing a miniature loudspeaker to present the evoking stimulus and also a tiny microphone to pick up the emission and convert if from a sound into an electrical signal was placed in the ear canal (Martin & Clark, 2000:178) and measurements were obtained for both ears. • Acoustic control of the test environment as well as subject noise levels was taken into account. If subject noise levels are too high they may mask the emission, since the sensitive

	appropriate probes were selected for each participant to ensure a proper fit.	conductive hearing loss. DPOAEs were measured for each ear to determine whether outer hair cell function was abnormal at frequencies corresponding to expected dead regions (Moore & Alcantara, 2001:271).	microphone used cannot differentiate one acoustic signal from another (Martin & Clark, 2000:178). • The presence of an OAE suggests there is very little or no conductive hearing loss caused by middle ear abnormality. It further suggests that responding frequency regions of the cochlea are normal or exhibit no more than a mild hearing loss and often compare favourable with voluntary audiometric results, provided that the hearing loss does not exceed 40 to 50 dB (Martin & Clark, 2000:177). It is also useful in differential diagnosis of cochlear versus retro-cochlear disorders (Martin & Clark, 2000:179).
GSI 61 two channel clinical audiometer	The audiometer was calibrated according to the requirements of the SABS to ensure that reliable and correct results were obtained. The test was conducted in a double walled soundproof test room.	This instrument was used to test peripheral hearing sensitivity for pure tones and speech and allows for a comparison of any person's hearing thresholds to that of an established norm (Martin & Clark, 2000:47). The purpose therefore is to specify the amount of a participant's hearing sensitivity at various frequencies and determine the degree of hearing loss (Martin & Clark, 2000:81).	• Verbal instructions were given to the participant. • Testing started in the better ear – this was determined by asking the patient. • Testing began at 1 kHz because this frequency is easily heard by most people and has high test-retest reliability. • The audiologist tested 1 kHz initially, tested lower frequencies (250 Hz and 500 Hz) in descending order, retested 1 kHz and then tested higher frequencies (2 kHz, 4 kHz and 8 kHz) in ascending order. • Information from all these frequencies were necessary in order to calculate the amount of frequency compression that was applied for each participant's individual hearing loss. • Mid-octave points were only tested when a difference of 20 dB or more was seen in the thresholds at adjacent octaves. • A pure tone was presented initially at 30 dB HL. If no response was obtained, the level was raised to 50 dB HL, introduced, and raised in 10 dB steps until a response was obtained or the limit of the audiometer was reached for the test frequency. • After a response was obtained, the level was lowered in 10 dB steps. When the tone was lowered below the patient's response level, it was raised in 5 dB steps until it was audible again, then lowered in 10 dB steps and raised in 5 dB steps until the 50% correct threshold response criterion has been met. The threshold is the lowest level at which the patient can correctly identify three out of a theoretical six tones. • Thresholds were obtained at each frequency, was recorded on an audiogram and the pure-tone average (PTA) (the average threshold levels for each ear at 500, 1000 and 2000 Hz) was calculated (Martin & Clark, 2000:83-84).
Sound-isolated room	The door of the room was solid and closed with a tight acoustic seal. The inside was covered with soft materials to help absorb sound and limit reverberations. The room had adequate ventilation and the lighting was incandescent (Martin & Clark, 2000:76-78).	Participants were tested in a sound-isolated room as it was acoustically isolated from the rest of the building in which it is housed and the noise in the room were kept below the level of masking that would cause a threshold shift in persons with normal hearing (Martin & Clark, 2000:76).	• The participant was seated properly inside the sound-isolated room – not to observe the clinician's movements during testing (Martin & Clark 2000:80).

Telephonic TDH-50 earphones	The earphones were sterilized before use for each participant.	Earphones were used for the presentation of pure tones. The earphones consist of a magnetic device that transduces the electrical translations supplied by the audiometer to a small diaphragm that vibrates according to the acoustic equivalents of frequency and intensity. Around the earphone was a rubber cushion that fitted over the ear (supra-aural). The movement of the earphone diaphragm generated the sound, which entered the ear directly, resulting in an air conduction signal (Martin & Clark, 2000:48).	• Earphones were placed properly with the headband directly over the top of the head. • All interfering hair was out of the way and earrings were removed when possible (Martin & Clark, 2000:82). • Eyeglasses were removed to avoid lifting the cushion of the earphone away from the ear. • The phones were positioned so that their diaphragms were aimed directly at the opening into the ear canal and the size of the headset re-adjusted for a tight fit (Martin & Clark, 2000:82). • The researcher checked for outer ear collapse which can cause an artificial conductive hearing loss which usually is characterized by poorer sensitivity in the higher frequencies, to avoid a misleading diagnosis (Martin & Clark, 2000:82).
Phonak Naida III Ultra Power (UP) digital behind-the-ear (BTE) hearing aids	Hearing aids were tested by a technician to ensure that they were in good working order, that there was no distortion and that the maximum output and gain were according to the specification sheets provided by the manufacturer. Listening checks were also performed with the use of a Stethoclip.	These instruments are digital and provide non-linear amplification in the form of multi-band compression. Furthermore, the hearing aid has an 80 dB of peak gain and 141 dB maximum output (Bohnert *et al.*, 2010:2). The hearing aid also has a unique combination of non-linear frequency compression (NFC), power processing and BassBoost to provide an extra-ordinary level of audibility and clarity.	• Every hearing aid was a behind-the-ear hearing aid connected by standard #13 tubing to a full shell acrylic ear mould with appropriate venting. • Hearing aids were connected to a HiPro NoaHlink (which was connected to a Mecer Celeron personal computer) with the programming cables from the hearing aid company. • Initial amplification values were calculated using the iPFG 2.6 software provided by the hearing aid company. • Hearing aids were fitted to the subject according to the DSL v5 method and adult targets were selected. • Besides the feedback canceller, all noise reduction systems were turned off, bass boost was not applied and all instruments were set to have an omni-directional microphone. The occlusion manager was adjusted to the desired subjective level and the start-up program was set to calm situations.
Audioscan Verifit verification instrument	This instrument was calibrated according to the requirements of the SABS to ensure that reliable and correct results were obtained. Probe tubes were sterilized before use.	The Audioscan Verifit was used to do real-ear measurements and verify the output from the hearing aid to ensure that prescriptive targets were matched within 3 dB/octave and to check whether distortion levels of the hearing aids were within acceptable levels (Ching, Hill & Dillon, 2008:469; Preves, 1994:369). It was further used to perform the specific REM (real-ear measurements), namely speech mapping, a real-ear measure to determine the SPL (sound pressure level) at the eardrum as well as the MPO (maximum power output) and gain of the hearing aid by using a speech input signal. The speech mapping is an	• Careful otoscopic examination was performed routinely every time before conduction of REM. This is considered an important first procedure as excessive cerumen and middle ear pathology might have a significant effect on probe-microphone measurements (Mueller, Hawkins & Northern, 1992:48) and also influence the ear canal's natural resonance characteristics that are important in the fitting of hearing aids. • Verbal instructions were given to the patient. • During measurements, placement specifications of the patient, as determined by the equipment's specifications were followed. The participant was seated in a chair one meter from the equipment, directly facing the loudspeaker of the equipment. • Probe microphone measures are the preferred method for verifying the real-ear performance of hearing aids (Valente, Bentler, Seewald, Tine & Van Vliet, 1998:6). The probe tube from the probe microphone was marked specifically according to the length of each participant's ear mould in order to ensure adequate depth in the ear canal after insertion of the mould into the ear canal. • To obtain the target speech mapping, the participant's

		important part of verification of the fitting of digital hearing aids since new technology centre on the amplification of speech (Mueller, 2005:22, Mueller, 2005:450).	audiometric data was entered into the Noah software as well as into the Audioscan Verifit hearing aid analyzer (Glista & Scollie, 2009b: 2). The DSL v.5 software (adult targets) was used to generate target values for gain and output to which the measured values were compared. The same DSL fitting parameters were selected for both the software and hearing aid analyzer. The DSL fitting algorithm only provides targets for frequencies up to 6 kHz, therefore the 6 kHz targets also were used to set the gain at 8 kHz (Stelmachowicz, Lewis, Choi & Hoover, 2007:484). • The first measurement involved the natural unaided response (resonance) of the ear without the hearing aid in place. This is referred to as the real-ear unaided response (REUR). A short burst of pink noise was presented at a level of 65 dB SPL and was stored as the unaided response. In the normal adult ear, the REUR has an amplitude peak of approximately 18 dB at 2.8 kHz (Katz, 2002:713). • Based on recent recommendations, REM of speech mapping measures were conducted because it utilized a speech input signal and therefore was more representative of the everyday situations faced by hearing aid users. Moore (2006:26) emphasizes this by stating 'the gains actually achieved for real-life signals such as speech and music differ considerably from the steady signals (of a probe microphone) such as tones and noise'. The recommended speech input level of 65 dB SPL was used to measure gain performance as 65 dB is considered equal to conversational level speech by evidence-based reviews (Mueller, 2005:459). • The fit to targets for soft (55 dB SPL), average (65 dB SPL) and loud (75 dB SPL) speech signals were evaluated with NFC inactive. • The MPO were verified with NFC inactive. • NFC was turned on. • The shape and gain of the hearing aid were verified using conventional measures of running speech with frequency compression at default settings. The researcher began by using the default setting provided in the manufacturer specific software, adjustments to increase or decrease the strength of the setting could be completed after considering further electro-acoustic measurement results and subjective feedback. • The fit to targets for soft (55 dB SPL), average (65 dB SPL) and loud (75 dB SPL) speech signals were evaluated. Fit-to-targets were only evaluated within the pass band of the device when NFC was active. The measurement becomes invalid beyond the upper bandwidth of the compressed signal where the hearing aid response rolls off. This is because gain is no longer applied to the region where the input signal has been compressed to a lower output signal. • Using a modulated speech signal, the verification at 65 dB was repeated and the researcher ensured that the curve above the cut off frequency has shifted to the left and was within audible range. • Measures of live voice productions of [s] and [sh] were used to assist in the evaluation of the audibility and/or separation of speech sounds. This was done by producing a sustained

			phoneme into the microphone of the connected hearing aid for S-REM. These measurements were done with and without NFC to illustrate the effects thereof and to evaluate the approximate audibility of different phonemes. • The MPO was verified with NFC active and results above the cut-off frequency were ignored. • A listening check was performed. Another aspect to take in consideration with NFC active is that the sound quality of speech may be different than with conventional sound processing. The phonemes [s] and [sh] may have been lowered in frequency, and the [s] may sound slightly like [sh] (a mild lisping quality). However, if the [s] sounds entirely like the [sh], fine tuning was done to reduce the strength of the NFC algorithm. The vowels and vocal tone may also be slightly altered, although each vowel should still be clearly identifiable (Glista *et al.*, 2008:5). When adverse sound quality effects were present, the researcher adjusted the NFC setting to make it weaker. • The evidence-based findings of Mueller (2005:459) and Fabry (2004:9) were taken as parameters to establish if measures met target values. Hence, REAR's of gain within 5 dB of the target gain value were accepted as on target.
Music equipment			
Sony D-FJ041 audio player	The researcher ensured beforehand that the audio player was in working order to avoid difficulties during testing.	The Music Perception Test (MPT) was presented with the audio player.	• The audio player was connected to the audiometer with the necessary cords provided from the manufacturers. • Stimuli of the MPTest were presented through the speakers in the audiometric booth according to the instructions of the test.
GSI Grason-Stadler speakers	The researcher ensured beforehand that the speakers were in good working order to ensure that the optimum sound quality is presented and to avoid distortion.	Stimuli of the MPT were presented through the external speakers at 75 dB SPL and hearing aid users were permitted to adjust the volume on their hearing aids for maximum comfort. Sound was presented at the same intensity for all hearing aid users, regardless of individual hearing thresholds. This was done as all participants had a moderate to severe hearing loss and therefore no drastic differences in audiometric thresholds were expected.	

4.6.3 Material and apparatus for data analysis

Responses were quantitatively coded and analyzed with computer software. Data was processed with the use of an HP Intel Core 2 3.0 GHz processor and Microsoft Windows Vista as well as Microsoft Office software.

4.7 PROCEDURE

Research was conducted using the following data collection, data recording and data analysis procedures:

4.7.1 Data collection procedures

The data collection process consisted of the pilot study and the main study. Participants in the main study were divided into four assessment groups which were assessed separately.

4.7.1.1 Pilot Study

A pilot study was conducted prior to the main study and comprised a small-scale administration of the main study and the use of the same procedures that are to be used in the main study (Struwig & Stead, 2001:135). The results of the pilot study were not used in the main study.

4.7.1.1.1 Purpose of the pilot study

The pilot study gave the researcher the opportunity to gain experience in the test procedures and enabled her to determine the time it will take to complete the test procedures (Maxwell & Satake, 2006:62). Furthermore, it enabled the researcher to test the accuracy and reliability of the MPT as a measuring instrument as well as to evaluate the validity and efficacy of the questionnaires (Maxwell & Satake, 2006:62). It also provided the opportunity to determine whether it was necessary to make changes to the MPT, instructions, test procedures and/or questionnaires. The pilot study served as a validation for the MPT and comprised stages two and three of the first phase of this study. The conduction of a pilot study improved the validity and accountability of the results of the main study. As mentioned before, validity of the MPT was ensured by several measures implemented in the development of the test, by obtaining criterion input and testing a target group. The description of validity implemented in the development of the test is provided in section 4.6.1.1.5 and will therefore not be addressed again. This section will focus on the description of validity by criterion input and the description of validity by testing a target group.

4.7.1.1.2 Participants

Two groups of participants took part in the pilot study: One group was included in the description of validity by criterion input and the other was included in the description of validity by testing a target group.

- *Participants included in the description of validity by criterion input*

Seven professionals in the audiology and music industry participated in this stage of the pilot study and were requested to complete the MPT evaluation sheet. These participants met the following criteria:

- Formal training in either Audiology and/or Music.
- Working actively at the time of the study as an Audiologist, Musician or Music teacher.
- Proficient and literate in English.

Audiologists were selected from the researcher's place of work while participants with music training were selected from a school to which the researcher had access. From the seven participants who took part in the peer review, four were Audiologists with an honours degree in Audiology, while the other three had a formal degree in music education. By selecting participants that were familiar to the researcher, communication between the researcher and the participants were enhanced and it was hoped that participants would be comfortable enough to provide honest feedback. This was also time effective and logistically convenient for the researcher.

- *Participants included in the description of validity by testing a target group*

In the first phase of this study fifteen normal hearing adults and four hearing aid users participated in Stage 2 and four adults with normal hearing as well as twenty hearing aid users in stage three. It was important to initially verify the MPT with a group of normal hearing listeners

to ensure that the test was appropriate for administration with participants with a hearing loss (Looi *et al.*, 2008b:423).

The normal hearing adults who participated in the second and third stages of Phase 1 met the following criteria:

- Bilateral hearing thresholds for octave frequencies between 125 Hz and 8 kHz at 20 dB HL or better (Van Deun, Van Wieringen, Van den Bogaert, Scherf, Offeciers, Van de Heyning, Desloovere, Dhooge, Deggouj, De Raeve & Wouters, 2009:180).
- English language proficiency and literacy.
- No minimal musical background or experience level was required.

The mean age of the normal hearing adults that participated in Stage 2 and Stage 3 of Phase 1 was 39.5 years (range between 22 and 64 years). Only four of the adults included in Phase 2 had formal musical training while one adult included in Phase 3 indicated that prior musical training was received. The amount of musical training received by these adults ranged between two and seven years (Phase 2: 4 years, 2 years, 3 years and 2 years; Phase 3: 7 years).

Participants with normal hearing were selected from the researcher's place of work. This was done to enhance communication between the researcher and the participants. By selecting participants that were familiar to the researcher, the researcher hoped that participants would feel comfortable with giving honest feedback on the MPT and questionnaires. This enabled the researcher to make as many corrections as possible to the MPT, questionnaires and test procedures and thereby increased the reliability of the results. This process was also time effective and logistically easy for the researcher.

To demonstrate the feasibility of the MPT for clinical application, persons with hearing aids were recruited for stages two and three of Phase 1. The same selection criteria as described in Table 4-3 (Section 4.5.2) and selection procedures (4.5.3) were applicable to hearing aid users who participated in the pilot study. Table 4-9 and Table 4-10 provides the biographical information of

the hearing aid users who participated in the pilot study. These data were obtained from the participants' files at the Audiology practice.

Table 4-9: Biographic information of participants with hearing aids included in Stage 2 of Phase 1

HEARING AID USERS INCLUDED IN STAGE 2 OF PHASE 1								
Biographic information	**P**	**Information**	**P**	**Information**	**P**	**Information**	**P**	**Information**
Age	1	64 years	2	64 years	3	43 years	4	60 years
Cause of hearing loss		Unknown		Noise-induced		Unknown		Unknown
Shape of hearing loss		R: Sloping L: Flat		R: Sloping L: Sloping		R: Flat L: Flat		R: Sloping L: Sloping
Pure tone average (PTA)		R: 75 dB L: 63 dB		R: 60 dB L: 60 dB		R: 63 dB L: 62 dB		R: 60 dB L: 60 dB
Oto-acoustic emissions		R: Absent L: Absent		R: Absent L: Absent		R: Absent L: Absent		R: Absent L: Absent
Current hearing aids		R: Extra 311 L: Extra 211		R: Extra 411 L: Extra 411		R: Una M AZ L: Una M AZ		R: Extra 33 L: Extra 33
Signal processing scheme		dSC		dSC		dWDRC		dSC
Time wearing hearing aids		4 years		5 years		10 years		9 years
Musical training received		None		None		3 years		1 year

The average age for hearing aid users in Stage 2 was 57.8 years (Range: 43 years to 64 years).

Table 4-10 provides the biographical information of the hearing aid users that participated in Stage 3. The average age of these participants was 55.9 years (Range: 33 years to 64 years). All of the participants had a post-lingual onset of hearing loss and were evaluated with their current hearing aids on an omni-directional microphone setting.

Table 4-10: Biographic information of participants with hearing aids included in Stage 3 of Phase 1

Partici-pant	Age	Cause of hearing loss	Shape of hearing loss	Pure tone average (PTA)	Oto:acoustic emissions (OAE's)	Current hearing aids	Signal processing scheme	Time wearing hearing aids	Musical training received
1	51 years	Unknown	R: Flat L: Flat	R: 70 dB L: 85 dB	Absent for both ears.	R: Eleva 33 L: Eleva 33	dSC	5 years	6 years
2	44 years	Unknown	R: Sloping L: Sloping	R: 55 dB L: 55 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Eleva 33 L: Eleva 33	dWDRC	6 years	4 years
3	34 years	Unknown	R: Sloping L: Sloping	R: 80 dB L: 80 dB	Absent for both ears.	R: Solo 411 L: Solo 411	dSC	10 years	none
4	33 years	Unknown	R: Flat L: Flat	R: 80 dB L: 70 dB	Absent for both ears.	R: Supero 411 L: Supero 411	dSC	8 years	none
5	64 years	Presbycusis	R: Sloping L: Sloping	R: 46 dB L: 44 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Extra 211 L: Extra 211	dWDRC	3 years	7 years
6	64 years	Presbycusis	R: Sloping L: Sloping	R: 50 dB L: 40 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Extra 311 L: Extra 311	dWDRC	5 years	none
7	63 years	Unknown	R: Sloping L: Sloping	R: 75 dB L: 40 dB	Absent for the right ear. Lowered at low frequencies and absent at high frequencies for left ear.	R: Una SP AZ L: Una SP AZ	dWDRC	9 years	none
8	61 years	Unknown	R: Flat L: Sloping	R: 85 dB L: 50 dB	Absent for the right ear. Lowered at low frequencies and absent at high frequencies for left ear.	R: Extra 411 L: Extra 211	dSC	5 years	none
9	63 years	Unknown	R: Flat L: Flat	R: 50 dB L: 45 dB	Absent for both ears.	R: Extra 311 L: Extra 311	dWDRC	2 years	1 year
10	61 years	Presbycusis	R: Sloping L: Sloping	R: 55 dB L: 60 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Extra 311 L: Extra 311	dSC	3 years	2 years
11	57 years	Unknown	R: Sloping L: Sloping	R: 45 dB L: 45 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Extra 311 L: Extra 311	dWDRC	4 years	none

12	60 years	Unknown	R: Sloping L: Sloping	R: 55 dB L: 55 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Solo prog L: Solo prog	dWDRC	3 years	2 years
13	63 years	Presbycusis	R: Sloping L: Sloping	R: 45 dB L: 40 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Solo prog L: Solo prog	dWDRC	4 years	1 year
14	53 years	Unknown	R: Sloping L: Sloping	R: 60 dB L: 40 dB	Absent for the right ear. Lowered at low frequencies and absent at high frequencies for the left ear.	R: Maxx 311 L: Maxx 211	dWDRC	5 years	1 year
15	60 years	Presbycusis	R: Sloping L: Sloping	R: 45 dB L: 40 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Una M AZ L: Una M AZ	dWDRC	2 years	1 year
16	55 years	Presbycusis	R: Sloping L: Sloping	R: 45 dB L: 45 dB	Lowered at low frequencies and absent at high frequencies for both ears.	R: Eleva 22 L: Eleva 22	dSC	5 years	4 years
17	48 years	Unknown	R: Sloping L: Sloping	R: 55 dB L: 55 dB	Absent for both ears.	R: Extra 311 L: Extra 311	dWDRC	4 years	none
18	64 years	Presbycusis	R: Sloping L: Sloping	R: 75 dB L: 80 dB	Absent for both ears.	R: Una M L: Una M	dWDRC	4 years	none
19	60 years	Unknown	R: Sloping L: Sloping	R: 85 dB L: 75 dB	Absent for both ears.	R: Extra 411 L: Extra 411	dWDRC	2 years	6 years
20	59 years	Unknown	R: Sloping L: Sloping	R: 50 dB L: 50 dB	Absent for both ears.	R: Una 22 AZ L: Una 22 AZ	dWDRC	3 years	none

4.7.1.1.3 Procedures for the conduction of the pilot study

Procedures for the conduction of the pilot study are described in two sections, namely procedures for the peer review and procedures for testing a target group.

- *Participants included in the description of validity by criterion input*

The following procedures were followed to obtain information from the peer review:

- Individual appointments were made with participants to describe the purpose of the study as well as the purpose of the evaluation of the MPT.
- After participants were informed of what was expected of them, they were subjected to the MPT.
- After completion of the MPT, participants were asked to complete the MPT evaluation sheet. Ample time was provided for the completion. Participants completed the evaluation sheet in the researcher's presence, before leaving the facility.
- After completion of the evaluation sheet, the procedures and content of the MPT and questionnaires were discussed with the participants. This was done in order to determine if it was relevant and whether any changes were needed.
- Participants were thanked for their time and participation.
- The data and comments were analyzed and interpreted to identify possible problem areas.
- The necessary changes were made to the test procedures, MPT and questionnaires.

- *Participants included in the description of validity by testing a target group*

Persons with normal hearing who participated in the pilot study were not fitted with the non-linear frequency compression hearing aids. The following procedures were followed for normal hearing participants:

- Individual appointments were made with participants to undergo a hearing evaluation to determine candidacy.

- The aim and procedures were explained to them. Participants were asked to provide comments regarding unclear or unnecessary procedures and questions and to comment on the time needed to complete the MPT as well as the questionnaires.
- After the hearing evaluation had been performed, the music perception testing took place.
- After completion of the MPT, participants were asked to complete the questionnaires. Participants were asked to complete both questionnaires even though not all questions were applicable because they did not wear hearing aids. In completing both questionnaires they could provide valuable feedback.
- Participants completed the questionnaires in the researcher's presence, before leaving the facility.
- After completion of the questionnaires, the procedures and content of the MPT and questionnaires were discussed with the participants. This was done in order to determine if it was relevant and whether any changes were needed.
- Participants were thanked for their time and participation.
- The data and comments were analyzed and interpreted to identify possible problem areas.
- The necessary changes were made to the test procedures, MPT and questionnaires.

Hearing aid users were evaluated according to the following procedures:

- Individual appointments were made with participants to undergo a hearing evaluation to determine candidacy.
- The aim and procedures were explained. Participants were asked to provide comments regarding unclear or unnecessary procedures and questions and to comment on the time needed to complete the MPT as well as the questionnaires.
- Prior to the hearing evaluation, each participant's current hearing aids were verified electro-acoustically to ensure that they were working properly and real-ear measurements were done to ensure that they were optimized to reflect current best practice (Auriemmo *et al.*, 2009:296; Flynn *et al.*, 2004:480).
- After the hearing evaluation, the MPT was administered to the participants who met the selection criteria.

- After completion of the MPT, participants were asked to complete both questionnaires. Participants completed the questionnaires in the researcher's presence, before leaving the facility.
- After completion of the questionnaires, the procedures and content of the MPT and questionnaires were discussed with the participants. This was done in order to determine if it was relevant and whether any changes were needed.
- Participants were thanked for their time and participation.
- The data and comments were analyzed and interpreted to identify possible problem areas.
- The necessary changes were made to the test procedures, MPT and questionnaires.

4.7.1.1.4 Results of the pilot study

The results of the pilot study were used to make the necessary changes to the test procedures, MPT and questionnaires. These results are discussed in detail in Chapter 5.

4.7.1.2 Main Study

Only persons who complied with the selection criteria in 3.5.2 were used as participants. In the procedures for data collection the following guidelines were strictly adhered to:

- *Phase 1: Presentation of the Music Perception Test*

Each participant was tested individually. Participants were seated in an audiometric test booth, facing the speaker at 45 degrees at a distance of approximately one meter. The stimuli were played on a Sony D-FJ041 audio player and presented via a Grason-Stadler GSI 61 two channel clinical audiometer to calibrated speakers (free field) simulating everyday listening experiences (Leal *et al.*, 2003:827). Conducting listening tests in a highly controlled environment, like an audiometric booth, has the advantage of higher sensitivity and accuracy of results (Zielinski *et al.*, 2008:431). The presentation level was 75 dB SPL for the calibration tone. The sound level was averaged at 75 dB SPL and hearing aid users were permitted to adjust the volume on their hearing aids for maximum comfort. Each participant was provided an answer sheet with a set of

written instructions for each test section. All instructions were also presented via the speakers before the onset of each test. The test took roughly 55 minutes and featured simple instructions. The same equipment, physical set-up of the room, and instructions were used in Phase 1 (Stages 2 and 3) and in Phase 2 for the presentation of the test.

- *Phase 2: Objective testing*

In the light of technological advances clinical trials are typically conducted in an attempt to quantify any incremental improvement. The clinical trials are designed in such a way that recent technology is compared to a single current technology or fitting scheme (Bentler & Duve, 2000:625). In this phase the researcher compared non-linear frequency compression technology to conventional hearing instrument settings in order to quantify improvements in music perception. The following procedures were followed to obtain data:

- An in depth literature study was conducted to determine present theoretical perspectives and previous, related findings relevant for this study (Leedy & Ormrod, 2004:64).
- An appointment for the first visit was arranged telephonically or via e-mail with each participant for a time and date suitable to the participant.

Participants underwent the following procedures during their **first visit** to the practice:

- Each participant underwent a hearing evaluation to determine candidacy. This included performing an otoscopic examination, immittance testing, oto-acoustic emissions, pure tone audiometry and speech audiometry.
- Prior to fitting the prototype hearing aids, each participant's current hearing aids were verified with real-ear measurements to ensure that they were optimized to reflect the current best practice (Flynn *et al.*, 2004:480). This was also done in order to make accurate comparisons between the different technologies and to ensure that positive changes could be contributed to the NFC technology and not to optimization of the current hearing aids.
- If a participant's current hearing aids were not well fitted it could imply that the participant is not used to a certain amount of amplification; should it then be provided to him/her in order to

match targets, he/she may experience discomfort and this could lead to extra time for acclimatization. Therefore, for all participants who had poorly fitted hearing aids at the start of the study, extra time was provided to adjust to the optimized fitting without the NFC algorithm activated. In this way participants could get used to overall audibility and not to two things at once. After three weeks of acclimatization, the study commenced for these participants and the same procedures were followed as for all other participants.

- All the participants' ear moulds were evaluated to ensure a comfortable fit and provide a good seal without the presence of feedback (Skinner, Holden & Binzer, 1994:271).
- Participants were divided into four groups of ten persons each, where every participant was fitted with the NFC hearing aids. The groups were not simultaneously assessed and followed one another. Statistical procedures were implemented to randomly determine which participants would start with NFC active and which participants would start with this algorithm inactive. At the end of the study, half of the participants started with NFC activated and the other half with NFC not activated.
- The prototype hearing aids were fitted to the participants according to the Desired Sensation Level (DSL) method v5.0. The DSL fitting prescription were chosen over the NAL-NL1 fitting prescription because DSL prescribes more overall gain than NAL-NL1 for all hearing losses and provides more high-frequency emphasis than NAL-NL1 for sloping and severe losses (Scollie, 2006:10; Stelmachowicz *et al.*, 2002:319; Martin, 2001:88). DSL v5.0 targets for adults were used, given that all the participants were adults.
- Hearing aids were fitted to accurately match the prescribed targets provided by the DSL algorithm in order to ensure that they provide audibility at a comfortable level across speech frequencies (Ching *et al.*, 2008:461; Scollie & Seewald, 2001:121). For listening to music, all automatic sound features such as noise reduction and adaptive directionality were turned off. This was done to prevent these systems from interpreting the music as noise or feedback, which may affect the sound quality that participants perceive (Hockley, Bahlmann & Chasin, 2010:33). As all the participants had hearing aids for more than two years, all of them were used to amplification and therefore the hearing aids could be fitted on target for most of the participants. A few participants preferred the hearing aids slightly below target as they indicated that the sound was too loud when the hearing aids were fitted on target. It is important to take note of this fact as the level of audibility may affect the results.

- The performance of the hearing aids was verified with the use of the Audioscan Verifit. Real-ear measurements were performed and the average real-ear-to-coupler values for adults were used. The data obtained from these measurements were recorded in the form of a printout by the Audioscan Verifit.
- Because NFC compresses the high frequencies above the cut-off frequency into a lower frequency range, verification graphs will look different compared to conventional graphs (Phonak, 2009:1; Glista & Scollie, 2009a: par.2; McDermott, 2008:1). Measurement of high frequency gain or output warrant special consideration as a paradox emerges when measuring a hearing aid with NFC active (Scollie *et al.*, 2008:5). It looks as though the hearing aid has less high frequency gain or output, compared to measurements without NFC. This paradox occurs because the speech energy that is present in the higher frequencies has been lowered to the lower frequencies prior to the output from the hearing aid. Therefore, the apparent 'cut' that is shown at the cut-off frequency is not in fact a cut at all. Rather, the energy has been shifted downwards in frequency and now in all likelihood exists within the pass band of the device. This is not directly portrayed by the verification screen itself, but instead must be conceptually overlaid by the clinician when interpreting the measurement (Scollie *et al.*, 2008:5).
- A similar phenomenon occurs during the evaluation of maximum output (Scollie *et al.*, 2008:5). To determine whether the maximum power output measurement met target, only the fit-to-targets below the NFC cut-off frequency should be interpreted. Above the cut-off frequency the maximum output of the device apparently drops precipitously. Again, the role of the NFC should be interpreted in the measurements. The input energy entering the hearing aid at the cut-off frequency exits the hearing aid at a much lower frequency. The hearing aid analyzer is only measuring energy in the cut-off frequency region, and therefore does not register the actual level of output for the test signal. Particularly for narrowband tests such as pure tone sweeps or tests of maximum output using narrowband test signals, these effects are very strong, and do not give valid information above the cut-off frequency of the test signal (Scollie *et al.*, 2008:5). This can be accomplished by measuring the maximum power output with the NFC processor temporarily disabled. The observed maximum output in this condition has not ever been exceeded by frequency-lowered signals once the NFC processor was re-enabled. Essentially, this is analogous to setting the hearing aid to have appropriate outputs in the conventional condition prior to enabling the NFC processor. Therefore it seems that an acceptable maximum

output setting without NFC also provides acceptable output limiting when NFC is activated (Scollie *et al.*, 2008:6).

- Although technology may provide the mechanism for accurate feature classification among different acoustic environments, fine-tuning to meet the auditory needs and preferences of individuals require additional optimization (Fabry & Tchorz, 2005:36). Therefore adjustments were made according to the participant's preferences as it is important to recognize that a prescription is a simple rule that is best for an average listener and is unlikely to be perfect for an individual at all times (Fabry & Tchorz, 2005:36; Ching *et al.*, 2001:149). There are two adjustable parameters of frequency compression that are programmable: First there is the cut-off frequency which determines the start of the upper band and secondly, the compression ratio, which determine the amount of frequency compression applied to the upper band. The cut-off frequency and compression ratio were determined on an individual basis using the Phonak fitting software suggestions (Bagatto *et al.*, 2008: par. 6). For most patients the NFC algorithm was left on the default settings and was only changed if participants had complaints about the sound quality.
- The participants were asked to wear the hearing aids for a period of four weeks after which they returned to the practice. Four weeks were allocated for acclimatization because research with non-linear frequency compression indicates that benefits are best achieved with an acclimatization period of at least four weeks (Stuermann, 2009:2, Nyffeler, 2008b:24).
- The researcher orientated each participant with the new hearing aids to ensure that they were competent to handle the hearing aids.
- Participants were asked to complete Questionnaire 1 and hand it back to the researcher before leaving the practice.
- The researcher contacted all the participants after three days to determine whether they were satisfied with the hearing aids and if they needed any adjustment to the settings. If they experienced any problems they were encouraged to revisit the practice for fine tuning.

During participants' **second visit** to the practice the following procedures were conducted:

- After four weeks participants returned to the practice and the hearing aids were verified electro-acoustically to ensure that they were working properly (Auriemmo *et al.*, 2009:296).

- The MPT was performed with the hearing aid on its original settings that the participant acclimatized to previously.
- After the MPT was performed, the hearing aid settings for the four groups of participants were switched – participants that had their hearing aids with NFC active now had this algorithm deactivated and vice versa.
- Digital hearing aids have the capacity to gather, by themselves, information about the environments within which they functioned as well as about the time that they were used and thereby provide audiologists with informed advice (Gatehouse & Akeroyd, 2006:105). The researcher therefore first checked the data logging on the hearing aids to determine the average time used per day for each participant.
- Participants were asked to complete Questionnaire 2 and hand it to the researcher before leaving the practice.
- Again participants were contacted after three days to determine their satisfaction with the hearing aids and were encouraged to revisit the practice should any fine tuning be needed.

Procedures conducted during the **third visit** to the practice included:

- All participants returned to the practice after four weeks; at this visit the hearing aids were once again verified electro-acoustically to ensure proper functioning.
- The MPT was again performed.
- The researcher again read the data logging from the hearing aids to obtain information about the wearing time by each participant.
- Participants were asked to complete Questionnaire 2 and leave it with the researcher before departing.
- Participants who decided to buy the hearing aids (at a discounted price) kept them. Additional fine tuning was done if needed for example, adding additional programs to the hearing aids.
- Participants who did not buy the hearing aids returned them and were fitted with the hearing aids they used before the study.
- The results obtained from the different sub-tests of the MPT with NFC disabled and enabled were evaluated and compared for each participant. It was important to evaluate the performance of the hearing aids without NFC so that the effects of its electro-acoustic

characteristics could be partially separated from the effects of the frequency compression (McDermott *et al*, 1999:1326).

The validity of the data was maximized by using a randomized cross design with single blinding. In single blinding, only the subject or only the researcher know which group a subject is assigned to (Cox, 2005:428). During the course of the evaluation, the participant did not know whether the NFC algorithm was activated or not. This prevented any participant bias to influence the results (Bagatto *et al.*, 2008: par. 5). The use of single blinding prevents extremely positive results from participants due to the Hawthorne and Halo effects, where the subject responds more favourably because of their participation in a research experiment (Bentler & Duve, 2000:636). With the placebo effect the related explanation for the perceived subjective benefit is the assumption that new treatment or technology is better – the participant expect to perform better with the newer technology and therefore responds more favourably with this technology (Cox, 2005:428).

- *Phase 3: Questionnaires*

Questionnaire 1 was only completed once during the initial visit, while Questionnaire 2 were completed twice (once with NFC active and once with the algorithm inactive) on the second and third visit to the practice. Sufficient time was left for the completion of the questionnaires. Participants were asked to hand in the completed questionnaires at the end of each session, before leaving the practice.

A summary of the alternating assessment schedule of participants in the main study is presented Table 4-11.

Table 4-11: Alternating assessment schedule

	Visit 1	ACCLIMATIZATION PERIOD 4 WEEKS	Visit 2	ACCLIMATIZATION PERIOD 4 WEEKS	Visit 3	ANALYSIS OF RESULTS
Group 1 Group 3	Otoscopy Tympanometry Pure tone audiometry Speech audiometry Oto-acoustic emissions Hearing aid check and DSL verification Fitting with NFC hearing aid with non-linear frequency compression algorithm **active.** Completion of Questionnaire 1.		Conduction of MPT with NFC **active**. Completion of Questionnaire 2. **Disable** non-linear frequency compression algorithm.		Conduction of MPT with NFC **inactive**. Completion of Questionnaire 2.	
Group 2 Group 4	Otoscopy Tympanometry Pure tone audiometry Speech audiometry Oto-acoustic emissions Hearing aid check and DSL verification Fitting with NFC hearing aid with non-linear frequency compression **inactive.** Completion of Questionnaire 1.		Conduction of MPT with NFC **inactive**. Completion of Questionnaire 2. **Activate** non-linear frequency compression algorithm.		Conduction of MPT with NFC **active**. Completion of Questionnaire 2.	

- *Phase 4: Objective and subjective evaluation after extended period of use*

Participants who bought the hearing aids after the completion of Phase 3 were contacted again after a period of 12 weeks elapsed. They were asked to revisit the practice to determine whether use over time of NFC contributes to improved objective and subjective music perception. During this visit, they were asked to once again be subjected to the MPT with the NFC algorithm active as they used it during the time that elapsed. They were also asked to give their opinion on music perception after extended use of NFC by completing the second questionnaire again. The results obtained from these participants in Phase 2 of the study were compared with the results obtained in Phase 4. This was done in order to establish whether any additional music perception benefit was perceived with extended use of NFC and acclimatization.

4.7.2 Procedure for recording of data

Data was recorded for the MPT and the questionnaires as described below.

4.7.2.1 Data recording for Music Perception Test

Test scores from the MPT were directly written on the answer sheet of test. Each answer sheet was marked with the respondent number to ensure participants anonymity. All the answer sheets were controlled to ensure that it was completed in full before participants left the practice. The answer sheets were hand scored because some melodies have alternative titles and there are often multiple versions of lyrics. Furthermore, individual assessment of Sub-test 5, Sub-test 10 and Sub-test 11 was required because participants were only assessed in these sub-tests on items familiar to them and therefore the total for each of these sub-tests differed for all participants. The researcher transformed all the data from the answer sheets into a Microsoft Excel work sheet.

4.7.2.2 Data recording for questionnaires

Every questionnaire received a respondent number to ensure participants' anonymity. The respondent number was the same as the one provided for each participant on the MPT answer sheet. The numbers of the completed questionnaires ranged from 01 to 40 for each completed group of questionnaires (Questionnaire 1, Questionnaire 2 after second visit and Questionnaire 2 after third visit). All the questionnaires were controlled to ensure that it was completed in full. Furthermore a coding system was used for recording the responses to the questions and a code was created for every possible answer. In the case of 'Yes/No' questions, the code 1 was assigned to the answer 'Yes' and code 0 to 'No'. Where there were various answers to a question, a code were allocated to each answer for example codes 1 to 5 for each of the possible five answers. This method facilitated statistical analysis of the results.

4.7.3 Procedure for data analysis

Descriptive statistics was used during this study to classify, organize and summarize the observations in a manner convenient for numerically evaluating the attributes of the available data (McMillan & Schumacher, 2006:280). Statisticians were consulted throughout the course of the study and a combination of statistical software packages such as Excel and the Statistical Package for the Social Sciences (SPSS) were used. Results were converted to percentages and were described in terms of percentages. Descriptions included the central tendency of data (mean[15], median[16] and mode[17] values) as well as measures of variability (the range[18], the variance[19] and the standard deviation[20]) (McMillan & Schumacher, 2006:289-293). These analyses enabled the researcher to determine whether or not statistical significant relationships between the different parameters existed. Analyzed data were visually presented in the form of tables and graphs which included bar graphs, histograms and frequency distribution curves.

4.8 CONCLUSION

Music is a very important means of communication – some deafened people may feel quite depressed at its loss. Many persons with hearing aids attempt to listen to music, but with varying degrees of satisfaction. The effectiveness of rehabilitation can be measured by a music perception test (Medel Medical Electronics, 2006:1) like the one compiled for the purposes of this study. A good test of music perception should reliably differentiate many levels of ability in musically relevant tasks (Nimmons *et al.*, 2008:154). As music perception is highly complex, subjective impressions of music perception should also be collected with the use of questionnaires.

The method for conducting this research was systematically and comprehensively described in this chapter and conducted in such a manner that reliability and validity of the obtained data was

[15] The arithmetic average value of the data
[16] The midscore value of the data
[17] The most frequently occurring value of the data
[18] The difference between the highest value and the lowest value
[19] The mean of the squared deviation from the mean
[20] The square root of the variance

ensured. The method used also provided the researcher with the opportunity to gain maximum information in an accountable and ethical manner. The importance of optimal service delivery, including the provision of audiological services to persons with hearing aids who enjoy music, can not be ignored. From this perspective the aims for this study were formulated and the research method implemented.

4.9 SUMMARY

This chapter provided an in depth description of the procedures implemented during this research to realise the aims of the study. The aims and research design of this study were described, followed by the selection criteria for participation and a description of the participants included in this study. A description of the material and apparatus used for the collection, recording and analysis of data followed. Ethical issues as well as validity and reliability of this study were highlighted.