

## Chapter 7

### CONCLUSION AND RECOMMENDATIONS

**Chapter aim:** The aim of this chapter is to clarify the conclusions drawn from the results of this research project, critically evaluate the findings and formulate recommendations for future research.

#### 7.1 INTRODUCTION

The hearing industry has made great strides towards providing effective solutions for people with hearing loss. It seems, however, that an important group of people with a hearing loss, namely musicians and music lovers with a hearing loss, has been neglected and denied easy access to already existing technology that could effectively address their needs (Chasin & Revit, 2009:10).

Audiologists need to improve their service to performing musicians and other people who wish music to be part of their lives (Chasin, 2010:27). Musicians count on audiologists for successfully practicing their profession and music lovers for the improvement of their quality of life. Over the last few years more information regarding music perception with hearing aids and different hearing aid technologies has become available. It is every audiologist's responsibility to continuously gain new information about new hearing aid technologies as well as fitting preferences and to share this information. If audiologists can realize the above, they will have reached a new level of success in their profession (Chasin & Revit, 2009:10).

Previously, the inherent technical challenges of hearing aids limited audiologists' potential to succeed. This is no longer the case (Chasin & Revit, 2009:10). As audiologists develop the technology and skills to serve music loving listeners, all clients may benefit from hearing aids. In order to provide some information regarding the efficacy of non-linear frequency compression, this study aimed to determine the influence of this signal processing strategy on the perception of music in adults presenting with a moderate to severe hearing loss. The purpose of this chapter is to formulate conclusions based on the results discussed in Chapter 6 and to discuss its

implications. A critical evaluation of the study, followed by recommendations for future research, concludes this chapter.

## 7.2 CONCLUSIONS

Music differs dramatically from speech and is therefore a potential challenge for hearing aid fittings (Hockley *et al.*, 2010:38). Assessments of music perception with amplification devices like hearing aids are important, since most people listen to music for personal pleasure and enjoyment and therefore need to be able to hear music in order for music to be part of their lives and improve their life quality. For this reason music perception was used to measure the efficacy of non-linear frequency compression in adults with a moderate to severe hearing loss, and to provide some indication of the efficiency of this type of technology. These outcomes can be summarized as follow:

- The MPT served as a reliable data acquisition instrument for determining the influence of NFC on music perception.
- Results of the present study indicate that the benefit obtained with the activation of NFC for the perception of rhythm was just short of significant.
- Participants obtained a statistically significant benefit with the activation of NFC in the perception of timbre.
- Hearing aid users did not experience a clear advantage or disadvantage with the use of NFC when performing pitch tasks.
- A statistical significant improvement in the perception of melodies was experienced by participants when NFC was activated.
- Subjectively participants rated music more positively with NFC, which implies that, with the activation of NFC, participants found music to sound fuller, clear and distinct, natural, less constrained or narrow, less tinny, without echoes and therefore sounding more pleasant.
- Slight improvements in participants' performance on the MPT was seen after using NFC for an extended period of time, which is an objective indication that they may perceive rhythm, timbre, pitch and melody better after extended use of this algorithm.

- When asked to subjectively rate music after the extended use of NFC, participants indicated that music sounded fuller, crisper, more natural and pleasant than earlier. They also indicated an improvement in the loudness of musical stimuli, heard less echoes when listening to music, found music more dynamic and less constrained. The only quality not to have improved after the extended acclimatization period was the perceived tinny quality of music, which participants rated very similar to their initial assessment.

From the discussion above, it is clear that objective and subjective music perception assessments confirmed that hearing aid users benefit from NFC when listening to music and that this algorithm does not influence the perception of music negatively. It further seems that hearing aid users with a more severe hearing loss in the mid and high frequencies as well as hearing aid users with a sloping hearing loss benefitted even more from the application of NFC when listening to music.

The above results warrant a trial period with NFC hearing aids combined with regular music perception assessments for every music loving adult with a moderate to severe hearing loss in order to obtain more scientific data and thereby improve the quality of audiological services to these persons.

### **7.3 CLINICAL IMPLICATIONS**

Clinically the findings above first of all indicate that the MPT can successfully be used as an evaluation tool to assess music perception in hearing aid users. Using a test like this in the hearing aid industry may result in more accountable hearing aid fittings, specifically focusing on music perception. The test can further be used as a counseling tool to assist audiologists and their clients in understanding the problems they experience with music perception; it may also be used for music training in areas where audiologists experience problems in customizing individual fittings. In the current study the test was used to determine the influence of non-linear frequency compression on music perception, but in future the test may also be used to evaluate other algorithms and hearing aid functions to determine their influence on music processed by hearing aids.

Furthermore, it is evident that an accurate assessment of music perception requires that objective as well as subjective information be obtained from patients. Such information regarding different aspects of music renders insight into the problems that hearing aid users experience when listening to music and will enable audiologists to better understand complaints by hearing aid users about listening to music. Listening to music gives rise to a large variety of experiences (Kreutz *et al.*, 2008:57) and therefore it is evident that each individual experiences music differently. It is therefore important to obtain a subjective music evaluation from each patient in order to adequately address individual difficulties.

The findings indicated that hearing aid users with a moderate to severe hearing loss demonstrated a clear preference to listen to music with NFC, as was confirmed by their increasingly improving performances in the objective evaluations. With this taken into account, the importance of providing the highest level of amplification technology that is financially attainable for music loving adults with a hearing loss cannot be ignored, especially if one takes into account that previous research also indicated benefits for the perception of speech with this technology.

Non-linear frequency compression technology in hearing aids may improve music perception for some adults with a hearing loss. It is evident, however, that significant individual differences come to the fore when music perception is investigated and therefore it may be necessary to individually confirm music perception benefits with NFC. The large inter-subject variability with regard to the performance on the various sub-tests warrants the individualization of fittings and consideration of each individual's unique experience of music. However, because the results of this study indicated that NFC is not disadvantageous for music perception, it cannot be dismissed as an option for individuals to increase music enjoyment. A trial fitting of the hearing aids for conducting assessments similar to the ones done in this study, but on individual adults, may determine the efficacy and efficiency of this type of technology for a specific adult.

#### **7.4 CRITICAL EVALUATION OF THE RESEARCH**

A reflection on the positive and negative aspects of this study is necessary in order to gain perspective on and insight into the music perception abilities of adults with a moderate to severe hearing loss using NFC technology.

The main **strength** of this study is that it attempts to provide evidence regarding the use of NFC in adults with a unique focus point. The main focus of current research on the use of frequency lowering, specifically NFC, in international studies is on speech-related matters; this study, however, provides information regarding the use of NFC and **different stimuli**, namely **music**. As there are to date no studies available on the subject of NFC and music perception, this study contributes towards knowledge in this field and assists audiologists to provide evidence-based services to their music loving clients. It also serves as background for future research.

Since the main aim of this study was to determine the influence of NFC on the perception of music by adults presenting with a moderate to severe hearing loss and no existing music perception test could be found in the literature to use as data-acquisition material, another contribution of this study was the **development of the MPT** for hearing aid users. After completion of the study, this test can be used as data-acquisition material in future hearing aid studies, especially within the South African context where a need for such a test currently exists.

The main focus of research on the use of NFC technology in international studies is on severe to profound hearing loss, specifically with known cochlear dead regions. Another strength of this study therefore is that it also provides information regarding the use of NFC in adults with **different configurations of hearing loss**; it was found that adults with a moderate to severe hearing loss may benefit from NFC, and if not, this algorithm will not be disadvantageous to their enjoyment of music.

Several other measures were taken throughout conducting this study to ensure a reliable outcome and thereby contribute to the strengths of the study. This includes the **single blinding** strategy that was applied in the research process that implied that only the researcher knew which group a participant was assigned to. Blinding is essential if subjective judgments such as questionnaires or rating scales are used as outcome data and may also be important for many objective tests (Cox, 2005:428). By not informing participants of the current settings of the hearing aids (NFC active or inactive), the reliability and validity of the results were improved. Furthermore, the researcher consulted with statisticians throughout the study and a **randomized schedule** for fitting participants with NFC was established using statistical programs. This was important,

because the lack of randomization is another common weakness in amplification research (Cox, 2005:428). A **pilot study** was also conducted prior to the main study to determine the effectiveness of the MPT and questionnaires and to identify necessary changes to be made to these data acquisition materials. By including participants with a hearing loss in the pilot study, the validity and reliability of the results of the main study was improved (Maxwell & Satake, 2006:62). Another positive aspect of the research process is that sufficient time was provided for participants to **acclimatize** to the NFC technology as evaluations were only done after participants have been wearing the hearing aids for a period of four weeks (Stuermann, 2009:2).

Lastly, this study included **40 participants**. A minimum number of 30 participants were stipulated but the researcher aimed at including more than 30 participants to account for possible dropouts; Cox (2005:428) explains that not accounting for dropouts is one of the most common weaknesses in amplification research. In order to encourage participants to take part in the study, the researcher aimed to ensure that the MPT and questionnaires were **well structured and user friendly**. This contributed to the correct and appropriate completion of the documents and therefore provided valid and reliable data after completion and analysis (McMillan & Schumacher, 2006:210). Although questionnaires instead of personal interviews or focus groups were used to obtain subjective information from participants, there was a **100% return rate** for all the questionnaires, because participants were asked to complete them in the presence of the researcher and return it before leaving the premises. This is seen as an advantage, because a low response rate, as often found with mailed questionnaires, holds negative consequences for the quality of the research (Bless & Higson-Smith, 2000:109).

The main **weakness** of the study is that the researcher did not make use of the **TEN test** to diagnose cochlear dead regions. The results of a study by Vinay and Moore (2007:238), however, indicated that cochlear dead regions are rare for any frequency in the range from 500 Hz to 4 kHz when the audiometric threshold is 60 dB HL or better and, should the information be available directly from the audiogram, additional testing may be unnecessary (Summers, 2004:1423). Therefore, to avoid administering the TEN test unnecessarily, a useful rule to apply would be to test only when the audiometric threshold exceeds 60 dB HL at one or more frequencies (Vinay & Moore, 2007:232). Due to the severity of hearing loss presented by

participants included in this study it was assumed that most participants had cochlear dead regions for at least the high frequencies.

Furthermore, it could be argued that more participants should be included in the study as the use of a **bigger sample** may improve the possibility of generalizing the results to the larger population. However, providing devices to participants on loan has always been a financial challenge to privately funded researchers. To date, no state funding has been made available for studies involving the provision of hearing aids to participants.

The lack of **double blinding** in the research design could also be viewed as a weakness of the study. The researcher did, however, implement a single blinding approach but could not implement double blinding due to the fact that only one audiologist was available for all the fittings and assessments. However, the researcher remained unbiased in her conduct throughout the study and avoided influencing participants' perceptions with the different hearing aid settings.

Lastly, to use the MPT effectively within the South African context, it should be performed on a larger sample that is **representative of the country's demographics**. When research is done with the aim of using a newly developed test and collecting normative data for such a test, participants of all ethnic groups should be included.

The final decision about the validity of the evidence produced by a particular study is made on the basis of a consideration of the inherent strengths of the research design and any weaknesses that could compromise the quality of execution (Cox, 2005:430). Although this study had certain limitations, it is obvious that several strategies were implemented to contribute to the strength and quality of the research design which ultimately lead to attaining accurate and valid results.

## **7.5 RECOMMENDATIONS FOR FUTURE RESEARCH**

Not only is the technology for music input still in its infancy, but the research and clinical knowledge and understanding of what music lovers need to hear are also still not fully

established (Chasin & Russo, 2004:35). Based on the above and on the findings of this study, the following recommendations for future research are proposed:

- A similar study with a larger sample size may yield conclusive evidence regarding the efficacy of the use of the MPT as well as NFC for music perception and would increase the statistical power of the current research (Bentler & Duve, 2000:637).
- In the current study, one NFC signal was presented to both ears. The amount of NFC applied was calculated according to the thresholds of the better ear, but this is not ideal because it does not allow for asymmetrical hearing thresholds (Simpson *et al.*, 2005:291). Furthermore, the appropriate fitting of hearing aids remain unclear where the extent of dead regions differs across the ears; in this regard research has shown that, while subjects can learn to interpret frequency lowered information, it may be more difficult if the shift is mismatched across the two ears (Robinson *et al.*, 2007:307). It is arguable that more audibility (with a stronger NFC setting) could have been provided to the poorer ear. However, the alternative position is that symmetry in the frequency domain may prevent binaural integration of sound (Scollie *et al.*, 2008:7). Research should investigate adjustments to accommodate binaural hearing differences and investigate whether fittings will be improved or degraded with a more ear-specific strategy.
- It may be of value to determine the effect of NFC for specific music instruments since some musical instruments place more emphasis on high frequency information compared to others. NFC may, for instance, be beneficial to certain musicians, depending on the instrument they are playing, whilst for others it might not be.
- Further research is necessary to establish the role of age-related auditory plasticity when measuring benefit change scores, as well as other factors that may contribute to different rates of auditory acclimatization with NFC. In this regard Glista *et al.* (2009:643) indicate that a larger acclimatization effect may be associated with a more severe hearing loss.
- Adult-child differences with NFC should be investigated to determine if the fitting approach used for children and adults should be different. This may be the case because adults are able to extract some useful information from off-frequency listening as demonstrated by their ability to benefit from amplification up to one octave inside a dead region and normal adult listeners were found to rather quickly learn to make use of high frequency information that was shifted to lower frequencies (Munro, 2007:14).



- The alerting statistics on hearing loss emphasize the importance of further research in this field to better understand the influence of hearing loss on people's lives and to ensure optimal hearing aid use in all situations for these people. Furthermore, it was found that improving consistency of communication success (through amplification) narrows the discrepancy in stress levels experienced by people; a survey conducted in the New York Times showed that 64% of the general population listened to music to relax (Kuk & Peeters, 2008: par. 3). It therefore is incumbent upon health care professionals, including audiologists, to understand how music has an effect on the overall well-being of people. The above should encourage audiologists to do their best to ensure the consistent and comfortable use of music by people with a hearing loss for purposes of entertainment as well as for therapeutic benefits.

Obtaining scientific data regarding the abovementioned topics will elevate audiologists' clinical care of patients as well as elevate our profession, promote better fitting practices, result in greater patient satisfaction and eventually reduce the hearing aid return rate (Valente, 2006:33).

## **7.6 CLOSING STATEMENT**

In the current approach to audiological management much focus is being placed on hearing aid technologies and fitting schemes. With rapid advances in component miniaturization and digital processing algorithms, there is an assumption that the majority of hearing losses can be managed and that all hearing aid related problems can be addressed (Bentler, 2006:89). With a reported 17% of return-for-credit rate for digital hearing aids and another 16% of aids in dresser drawers, it may be time to abandon the assumption that most users can't hear the difference in bandwidth, response smoothness, time constants, and overload for high-level sounds (Killon, 2009:30) and to discard the notion that hearing aid wearers should be satisfied with their hearing aids in all listening situations, including the enjoyment of music, even though audiologists do not have scientific data on which fittings can be based. Therefore, it is hoped that hearing aids will soon offer considerably improved accessibility for listening to music and that this study contributes to a better understanding of listening to music so that every person with a hearing aid will be able to conclude with the words of this famous song:



Thank you for the mu-sic, the songs I'm sing-ing. Thanks for all the joy they're bringing.

Who can live with-out it? I ask in all ho-nes-ty. What would life be

with-out a song or dance, what are we? So I say

thank you for the mu-sic, for giv-ing it to me.

(Retrieved from [http://www.lyricsfreak.com/a/abba/thank+you+for+the+music\\_20002662.html](http://www.lyricsfreak.com/a/abba/thank+you+for+the+music_20002662.html))