The influence of non-linear frequency compression on the perception of music by adults with a moderate to severe hearing loss: Subjective impressions

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Objective. To date, the main direction in frequency-lowering hearing aid studies has been in relation to speech perception abilities. With improvements in hearing aid technology, interest in musical perception as a dimension that could improve hearing aid users' quality of life has grown. The purpose of this study was to determine the influence of non-linear frequency compression (NFC) on hearing aid users' subjective impressions of listening to music.
Design & sample. A survey research design was implemented to elicit participants' (*N*=40) subjective impressions of musical stimuli with and without NFC.
Results. The use of NFC significantly improved hearing aid users' perception of the musical qualities of overall fidelity, tinniness and reverberance. Although participants preferred to listen to the loudness, fullness, crispness, naturalness and pleasantness of music with the use of NFC, these benefits were not significant.
Conclusion. The use of NFC can increase hearing aid users' enjoyment and appreciation of music. Given that a relatively large percentage of hearing aid users express a loss of enjoyment of music, audiologists should not ignore the possible benefits of NFC, especially if one takes into account that previous research indicates speech perception benefits with this technology.

Keywords: Hearing loss, music perception, non-linear frequency compression, hearing aids, cochlear dead regions, subjective impression

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High-frequency hearing loss is by far the most common audiometric configuration found in individuals fitted with hearing aids (Nyffeler, 2008) and may adversely affect speech comprehension as well as the ability to detect and identify music and lyrics (Glista & McDermott, 2008). High-frequency hearing loss therefore excludes many people from the daily exposure to music, an integral part of life encountered on numerous occasions each day. Not being able to hear music is problematic as music enhances the quality of a person's life and serves as a medium that models social structures, facilitates the acquisition of social competence by young people and provides human interaction (Cross, 2006).

In attempting to improve music as well as speech perception, a common clinical practice in fitting hearing aids to individuals with high-frequency hearing loss is to provide additional amplification in the higher frequencies (Munro, 2007). Providing this additional high-frequency amplification is often problematic, since some people may unknowingly present with cochlear dead regions and perceive high-frequency amplification as distorted or noise-like in quality. Individuals with cochlear dead regions may have different frequency-gain requirements than those without dead regions; the diagnosis of the presence of dead regions may have important clinical implications for benefit from amplification, counselling and hearing aid selection (Munro, 2007).

Many researchers have suggested the possibility of frequency lowering as a means of making speech sounds audible for patients with dead regions (Bagatto, Scollie, Glista, Parsa & Seewald, 2008; Moore, 2001). These suggestions resulted in various research projects being conducted with frequency-lowering hearing aids in which the emphasis was placed on improved speech perception (Bagatto *et al*., 2008; Scollie, Glista, Bagatto & Seewald, 2011). Although research on frequency-lowering hearing aids and music perception is limited, a previous study reported that non-linear frequency compression (NFC) significantly improved hearing aid users' perception of timbre and melody (Uys, Pottas, van Dijk & Vinck, 2012) and therefore warrants further investigations with this technology to assist music-loving hearing aid users.

There has been an increase in people with hearing loss expressing an equal need for their hearing aids to be fitted optimally for listening to music and speech (Chasin, 2003). This escalating interest in musical perception accuracy and enjoyment is also reflected in publications of a variety of investigations utilising different experiments to assess performance on musical tasks (Uys & Van Dijk, 2011; Cooper, Tobey & Loizou, 2008; Gfeller *et al*., 2002; Looi, McDermott, McKay & Hickson, 2008; Nimmons *et al*., 2008).

Because of the complex nature of music, amplification of musical stimuli poses a challenge to audiologists and listening to music may give rise to a large variety of experiences that are based on interrelated emotional and cognitive processes in the brain (Kreutz, Schubert & Mitchell, 2008). For example, one individual's deepest appreciation of music may be based on the structural features of a musical work, whereas for another the emotional content of a musical piece may elicit strong experiences. Music processing probably depends on cognitive styles that vary between individuals, as well as numerous participative factors that influence enjoyment including personal preferences for musical genres, the situational context such as the listening environment and the listener's mood (Nimmons *et al*., 2008). These factors may all greatly affect music perception and render it difficult to measure.

The effects of hearing aid processing on musical signals and the perception of music have received very little attention in research (Hockley, Bahlmann & Chasin, 2010; Wessel, Fitz, Battenberg, Schmeder & Edwards, 2007) although listeners with a hearing loss are no less interested in music than normal-hearing listeners. Every person is immersed in an environment filled with sound, and being able to understand speech is not the only function of hearing. For most people, listening to music is also a significant and enjoyable experience. Therefore, it is not surprising that people with hearing aids frequently express a wish to be able to enjoy listening to music with their device instead of having to remove it when listening to music because of the reduced sound quality provided by the amplification device (Wessel *et al.*, 2007).

The field of audiology acknowledges the value of musical perception in quality of life. The benefits of music, as well as music therapy, in the physiological, psychological and social-emotional aspects of a person's life have been stressed. Therefore a modification of the output of conventional hearing aids in the form of NFC should be investigated as this technology might improve the music perception abilities of some adults with a hearing loss. This article focuses on how participants perceive the loudness, fullness, crispness, naturalness, overall fidelity, tinniness, reverberance and pleasantness of music when listened to with and without NFC. These musical qualities are defined as:

- Loudness – the music is sufficiently loud, as opposed to soft or faint.
- Fullness – the music is full, as opposed to thin.
- Crispness – the music is clear and distinct, as opposed to blurred and diffuse.
- Naturalness – the music seems to be as if there is no hearing aid and as I remember it.
- Overall fidelity – the dynamics and range of the music are not constrained or narrow.
- Tinniness – hearing the quality of tin or metal, a sense of cheap, low-quality sound.
- Reverberance – the persistence of sound after the original sound is removed, a series of echoes.
- Pleasantness – a feeling of enjoyment or satisfaction, as opposed to an annoying or irritating feeling.

Method

Aim

The aim was to determine the influence of NFC on participants' subjective impression of listening to music.

Study design

A survey research design was implemented and participants were asked to complete two short questionnaires. The first questionnaire obtained background information from participants while the second questionnaire elicited a subjective impression of participants' musical experiences with hearing aids when NFC was both active and inactive. Single blinding was used to remove any potential participant bias that could influence results as participants did not know whether the NFC algorithm was activated or not during the evaluation.

Ethical aspects

Ethical clearance for this study was obtained from the institutions involved. As the underlying foundation of ethical research is to preserve and protect the human dignity and rights of all the participants, the ethical principles of autonomy, beneficence, non-maleficence and justice were adhered to (Leedy & Ormrod, 2005).

Participants

A purposive convenience sampling method was implemented where participants were chosen on the basis of accessibility and because they articulated with the aims of the study. The hearing aid users (*N*=40) met the following criteria:

- Bilateral, moderate to severe sensory neural hearing loss, with a pure tone average of 41 - 90 dB at the frequencies 500 Hz, 1 000 Hz and 2 000 Hz.
- Normal middle-ear functioning.
- Participants had to be between the ages of 18 years 0 months and 64 years 11 months. This ensured that participants had matured central auditory systems (as the maturation of the central auditory nerve system is completed at the age of approximately 12 years (Bellis, 2003)) and participants were legally independent.
- Participants should not have had NFC hearing aids before and their current hearing aids had to be digital as opposed to analogue. Previous experience with NFC technology would possibly have influenced the participant's beliefs and attitudes towards frequency-lowering technology and therefore could have caused the participant not to be objective in the study; with the current use of analogue hearing aids one might measure the switch from analogue to digital and not the effects of NFC (Flynn, Davis & Pogash, 2004). The hearing aids used in this study were digital hearing aids; for participants already used to digital amplification, it might reduce adaptation problems and time to adjust to the new hearing aids.
- English language proficiency and literacy. This is a language in which the researcher is proficient and therefore the questionnaires, all instructions and explanations were provided in English. Furthermore, the 2001 South African Census indicated that English is the third most common primary language, the most common second language in Gauteng and the most commonly used language in South Africa (Napier & Napier, 2002).
- No minimal musical background or experience level was required.

Table 1 provides the biographical information of participants while Table 2 provides an overview on participants' musical background.

The average age of participants was 57.7 years (range 18 - 64 years) and all of them had postlingual onset of hearing loss.

Material and apparatus

Self-compiled questionnaires (Appendices A and B) were used to obtain background information from participants as well as information on their subjective impression of music with NFC.

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. Table 3 provides a presumption and literature reference of all the questions included in this questionnaire.

Questionnaire 2: The second questionnaire was in the form of a self-report questionnaire. The questions were revised from the Munich Music Questionnaire (Medel Medical Electronics, 2006) used to evaluate the listening habits of people with postlingual deafness after cochlear implantation and a five-point perceptual scale used by Chasin (2003) to obtain measures of sound quality. This five-point scale used is a modification of the work of Gabrielsson and colleagues and has been used extensively in the hearing aid industry (Chasin, 2003).

The prototype hearing aids used were Phonak Naida III Ultra Power behind-the-ear hearing aids. These hearing aids are digital and provide non-linear amplification in the form of multiband compression. They were selected because they make use of the NFC algorithm investigated and were available as loan devices from the manufacturer.

Reliability and validity

To obtain reliability to the highest possible degree the following steps were implemented (Leedy & Ormrod, 2005):

- 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.
- Questions in the questionnaires were formulated in such a way as to eliminate ambiguity and to ensure clear and precise wording and instructions.

To ensure validity, the following steps were taken (Leedy & Ormrod, 2005):

Table 1. Biographical information of participants

Participant	Age	Cause of hearing loss	Shape of hearing loss	Pure tone average (PTA)	Oto-acoustic emissions (OAEs)	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

Table 1. Biographical information of participants (continued)

Partici-pant	Age	Cause of hearing loss	Shape of hearing loss	Pure tone average (PTA)	Oto-acoustic emissions (OAEs)	Current hearing aids	Signal processing scheme	Time wearing hearing aids
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

Table 2. Participants' musical history

Participant	Musical training received	Formal musical qualification	Musical instruments currently playing/ played before	Currently sing or ever have sung in a choir or at social/ professional gatherings	Feel that enjoyment of music has decreased with hearing problems	Remove hearing aid when listening to music
1	2 years	-	-	No	No	No
2	-	-	-	No	Yes	No
3	2 years	-	Piano	No	No	No
4	-	-	Guitar, piano	Yes	Yes	No
5	-	-	-	No	No	Yes
6	-	-	-	No	Yes	No
7	-	-	-	Yes	No	Yes
8	5 years	Unisa grade 3	Piano	No	Yes	No
9	-	-	-	Yes	Yes	No
10	-	-	-	Yes	Yes	No
11	7 years	Unisa grade 8	Piano	Yes	Yes	No
12	-	-	Trumpet	Yes	No	No
13	-	-	-	No	Yes	No
14	-	-	-	Yes	Yes	No
15	20 years	-	Piano	Yes	No	No
16	5 years	-	Piano	Yes	Yes	No
17	-	-	-	No	No	No
18	6 years	-	Flute, keyboard, guitar	Yes	No	Yes
19	14 years	Unisa grade 6	Piano	Yes	Yes	Yes
20	-	-	-	Yes	Yes	No
21	6 years	Unisa grade 5	Piano, violin	Yes	Yes	No
22	-	-	-	No	Yes	No
23	-	-	-	No	No	No
24	-	-	-	Yes	Yes	No
25	-	-	-	Yes	No	No
26	2 years	-	Piano	Yes	Yes	Yes
27	-	-	-	Yes	Yes	No
28	20 years	Unisa grade 8	Piano	No	No	No
29	-	-	Piano	Yes	No	No
30	1 year	-	Violin	No	Yes	No
31	1 year	-	Piano, harmonica	Yes	No	No
32	-	-	-	Yes	No	Yes
33	3 years	Unisa grade 4	Piano	No	Yes	No
34	-	-	-	Yes	Yes	Yes
35	10 years	-	Guitar, piano, harmonica	Yes	Yes	Yes
36	2 years	-	Accordion	No	Yes	No
37	-	-	-	No	Yes	No
38	-	-	-	No	Yes	No
39	-	-	Piano	Yes	No	No
40	-	-	-	Yes	No	No

- 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 researcher included many participants in this study. The validity of a study increases with an increase in sample size.
- Biographical data were obtained from each participant to account for the possibility of a person's musicality having an influence on the results.

Furthermore, 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. To ensure construct validity, the researcher tried to keep all instructions, language use and the format of the questionnaires as simple as possible and avoided ambiguous as well as biased questions. Because of the lack of existing evaluation material for this study, the questionnaires used in this study could not be compared to other questionnaires and therefore criterion validity could not be obtained.

Table 3. 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, Schubert & Mitchell, 2008). It has been found that **music training** improves the processing of tonal music in the left hemisphere (Van Egmond & Boswijk, 2007). **Training** specific to music perception can improve scores on music perception tests (Cooper, Tobey & Loizou, 2008). It was found that subjects with **musical training** were more capable of recognising nursery songs, both with and without vocal elements (Leal *et al.*, 2003). **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.*, 2005). 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).
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). 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, Oleson, Jiang & Gfeller, 2009).
3	Do you currently sing, or have you ever sung, in a choir or at social/professional gatherings?	People who 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** improves 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).
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 for Question 1.
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).
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 formalised auditory tests of pitch perception indicates that absolute pitch **aggregates in families** (Baharloo, Service, Risch, Gitschier & Freimer, 2000).
8	What role does music play in your life?	A person who is more exposed to music, demonstrates a greater interest in music and spends more time listening to music will be more 'trained' (trained ear) to evaluate music and participate in certain tasks of music perception, e.g. 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.*, 2005). 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).
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)?		

Table 3. Presumptions and literature references for questions included in Questionnaire 1

QUESTION		PRESUMPTION	LITERATURE REFERENCE
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). 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) from a background (music), nearly always a challenge for people with hearing loss (Leek *et al*., 2008).
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, e.g. 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).
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; Chasin, 2003). 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).
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; Chasin, 2003).
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). 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 recognise melodies** and **volume changes in music** (Leek *et al*., 2008).

Procedure

In order for the researcher to obtain subjective data, participants visited the practice three times. During their **first** visit participants underwent a hearing evaluation to determine candidacy. This included otoscopic examination, immittance testing, oto-acoustic emissions, pure tone and speech audiometry. Participants' current hearing aids were verified with real-ear measurements to ensure that they were optimised to reflect current best practice (Flynn *et al*., 2004) and to ensure that positive changes could be contributed to NFC and not to optimisation of the current hearing aids. In the case where a participant's current hearing aids were not well fitted, extra time was provided to adjust to the optimised fitting without NFC and the study commenced for these participants after an acclimatisation period of 3 weeks.

Participants were then divided into 4 groups of 10 persons each. A randomised schedule was implemented in order for half of the participants to start with NFC active and the other half with the algorithm inactive. The prototype hearing aids were fitted with the Audioscan Verifit to accurately match the prescribed DSL v5.0 targets for adults. The DSL fitting prescription was 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). All automatic sound features such as noise reduction and adaptive directionality were turned off to prevent these systems from interpreting the music as noise or feedback, which may affect the sound quality that participants perceive (Hockley *et al*., 2010). Fine tuning adjustments were made according to participants' preferences by adjusting the cut-off frequency (determines the start of the upper band of NFC) and the compression ratio (determines the amount of frequency compression applied to the upper band) of the NFC algorithm. The cut-off frequency and compression ratio were determined on an individual basis using the Phonak fitting software suggestions (Bagatto *et al*., 2008). Default settings were only changed if participants had complaints about the sound quality. Participants were asked to complete the questionnaire that provides background information and wear the hearing aids for 4 weeks after which they returned to the practice. Previous NFC research indicated that benefits are best achieved with an acclimatisation period of at least 4 weeks (Nyffeler, 2008).

Participants' **second** visit started with the electro-acoustical verification of the prototype hearing aids to ensure that they were working properly (Flynn *et al*., 2004). They were then asked to complete the second questionnaire and give feedback on how they experienced listening to music during the 4 weeks that they wore the NFC hearing aids. Participants were asked to hand in the completed questionnaire before leaving the practice. At the end of the session the hearing aid settings were switched – participants who had their hearing aids with NFC active now had this algorithm deactivated and vice versa.

During participants' **third** visit to the practice the hearing aids were once again verified electro-acoustically. Participants were again asked to complete the second questionnaire and reflect on their musical listening experiences during the past 4 weeks. Again the completed questionnaires were handed in at the end of the session. Results obtained with NFC active and inactive were evaluated and compared for each participant.

Data recording

Every questionnaire received a respondent number to ensure participants' anonymity, ranging from 01 to 40 for each completed group of questionnaires (Questionnaire 1, Questionnaire 2 after second visit and Questionnaire 2 after third visit). All questionnaires were checked to ensure that they were completed in full. 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 was 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.

Data analysis

Descriptive statistics were used during this study to classify, organise and summarise the observations in a manner convenient for numerically evaluating the attributes of the available data (McMillan & Schumacher, 2006). 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. In order to determine whether the application of NFC resulted in significant benefits for the different musical qualities, the Wilcoxon matched-pairs signed rank test was used. This test is appropriate for studies involving repeated measures in which the same subjects serve as their own control (Maxwell & Satake, 2006). It was therefore applicable to the results obtained from the second questionnaire because this questionnaire was non-parametric owing to the ranking scale used. Participants had to complete the questionnaire twice as they were asked to give their impression on the different musical qualities with and without NFC. Analysed data were visually presented in the form of graphs.

Results

As the musical genres that people listen to can influence their perception of the quality of music, participants were asked to indicate which musical genres they prefer. These preferences are displayed in Figure 1.

Most of the participants prefer to listen to folk/country music (67.5%) followed by classical music (62.5%). Folk/country music often focuses on stories of everyday life with lyrics being a key aspect of this musical genre while classical music can be categorised into broad styles with distinct structural features (e.g. Baroque music, classical music, romantic music) and tends to have more complex, sophisticated melodic, harmonic and rhythmic structures than those found in other musical genres (Gfeller *et al*., 2005). The musical genres least preferred by participants were rock music (17.5%) and jazz/blues (12.5%).

Participants were then asked to complete the rating scale included in Questionnaire 2 which assessed the musical qualities of loudness, fullness, crispness, naturalness, overall fidelity, pleasantness, tinniness and reverberance. Whereas a higher score for the adjectives loud, full, crisp or clear, natural and pleasant indicates better sound quality, a higher score for the adjectives constrained or narrow, more tinny and echoing generally indicates less desirable sound quality.

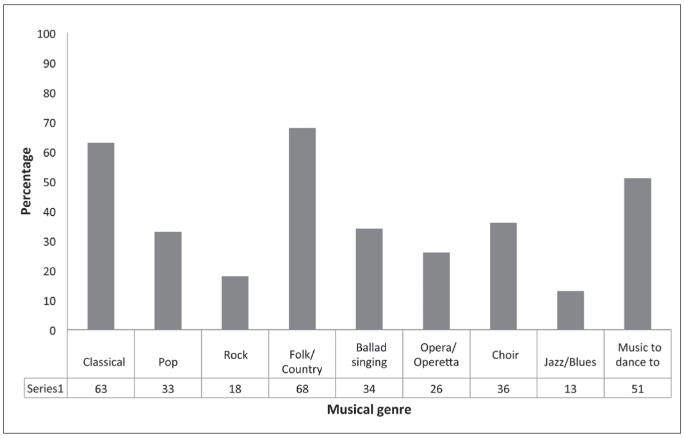

Fig. 1. Participants' musical genre preferences.

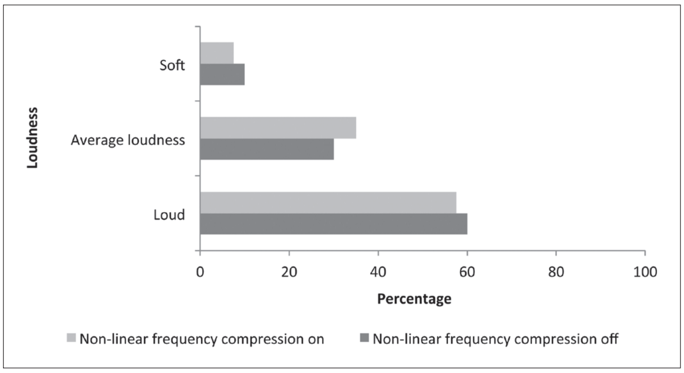

Fig. 2. Participants' perception of musical loudness with NFC off versus NFC on.

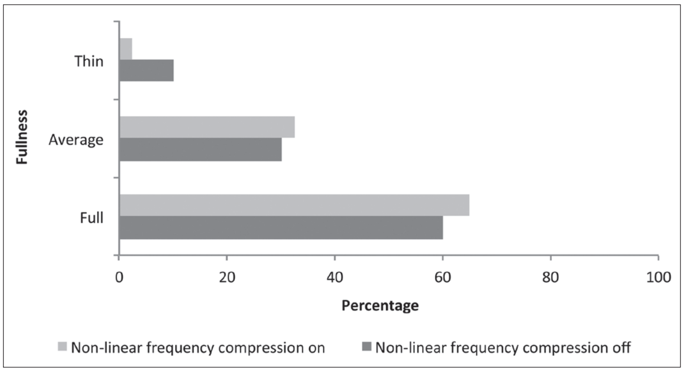

Fig. 3. Participants' perception of the fullness of music with NFC off versus NFC on.

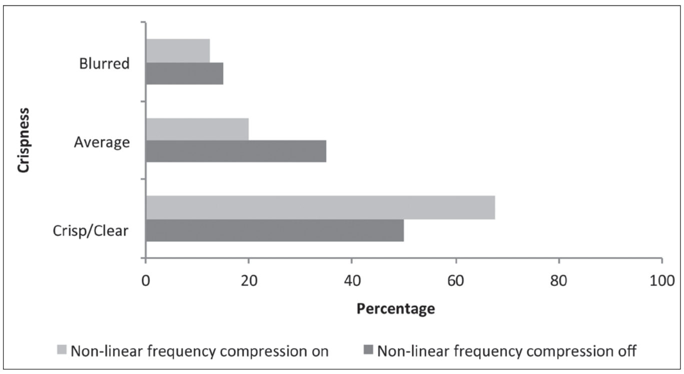

Fig. 4. Participants' perception of the crispness of music with NFC off versus NFC on.

The first musical quality to be assessed was **loudness**. Participants' perception of the loudness of music is displayed in Figure 2.

Most participants felt that music was sufficiently loud with the hearing aids and there was only a slight difference in the loudness quality

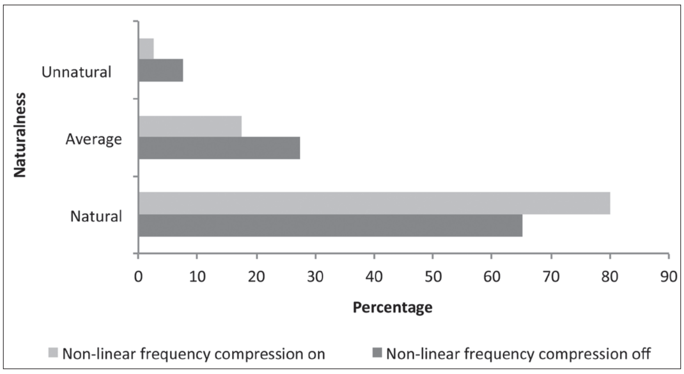

Fig. 5. Participants' perception of the naturalness of music with NFC off versus NFC on.

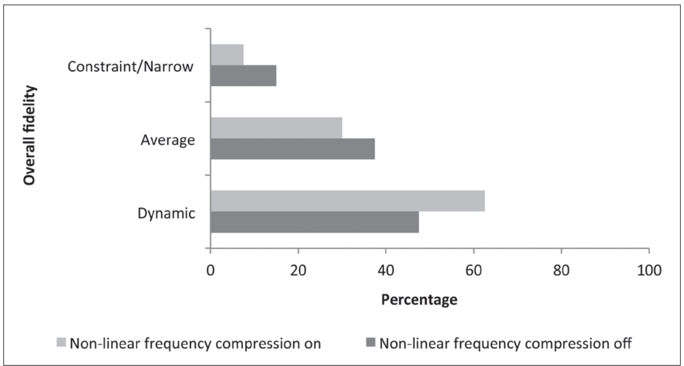

Fig. 6. Participants' perception of the overall fidelity of music with NFC off versus NFC on.

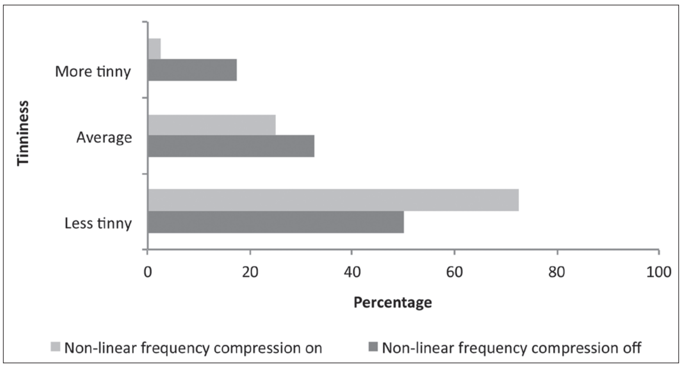

Fig. 7. Participants' perception of the tinniness of music with NFC off versus NFC on.

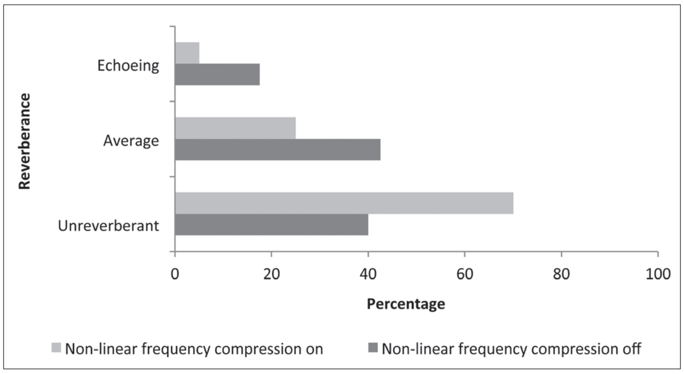

Fig. 8. Participants' perception of the reverberance of music with NFC off versus NFC on.

rating with NFC inactive versus active. As results for the different NFC settings were very similar no significant benefit (p=0.43) was obtained with the activation of this algorithm.

Results for assessment of **fullness** are displayed in Figure 3.
With NFC active, there was a slight improvement in participants' rating of musical fullness compared with NFC inactive. This improvement was

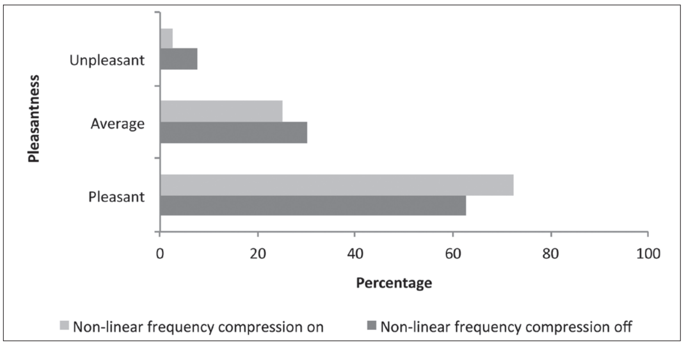

Fig. 9. Participants' perception of the pleasantness of music with NFC off versus NFC on.

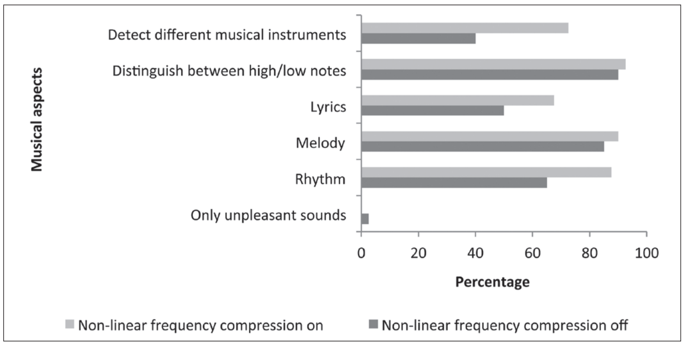

Fig. 10. Participants' ability to discriminate between different musical aspects with NFC off versus NFC on.

however not statistically significant (p=0.31) as 65% of the participants indicated that the music sounded full as opposed to thin with NFC active compared with 60% when NFC was inactive.

Musical **crispness** results are displayed in Figure 4.

When asked about the crispness of music, 67.5% of the participants concluded that music was clear and distinct with NFC active compared with 50% with NFC inactive. Again the improved quality experienced with NFC was not significant (p=0.11)

Information on the **naturalness** of music is presented in Figure 5.

Figure 5 displays that 80% of the participants experienced the quality of music as natural with NFC active compared with 65% who were satisfied when NFC was inactive. Again it seems that music sounds more natural with the activation of NFC but the benefit was not statistically significant (p=0.09).

Participants' ratings of the **overall fidelity** of music are presented in Figure 6.

More participants (62.5%) described music as sounding dynamic with NFC active, compared with NFC inactive (47.5%) but the more dynamic quality of music obtained with NFC was however still not statistically significant (p=0.04).

Participants' perceptions of the **tinniness** of music are displayed in Figure 7.

A statistically significant benefit (p=0.01) with the activation of NFC was obtained with regard to the tinniness of music as most participants found music to sound less tinny with NFC active (72.5%) compared with it inactive (50%).

Participants were also asked to rate the musical quality of **reverberance** (Figure 8).

Again the ratings for NFC active were more positive than those obtained with NFC inactive and resulted in participants experiencing a statistically significant benefit (p=0.005).

Hearing aid users frequently complain that they have forgone a formerly enjoyable aspect of their lives as they cannot enjoy music to the same extent as before their hearing loss (Leek, Molis, Kubli & Tufts, 2008). Therefore, hearing aid users in the present study were asked to rate the **pleasantness** of music (Figure 9).
Overall the pleasantness of music was rated more positively with NFC active than inactive although this benefit was not of statistical significance (*p*=0.13).

Participants' ability to discriminate between different musical instruments, distinguish between high and low notes, as well as discriminating the lyrics in a song was also assessed. These data are displayed in Figure 10.

While it seems that participants were able to discriminate more positively between different musical qualities with NFC active as opposed to NFC inactive, a statistically significant benefit was only obtained for participants' ability to detect different musical instruments (*p*=0.003) and discriminate the rhythm (*p*=0.015) in a musical piece. Although slight benefits with NFC were observed for participants' ability to distinguish between high and low notes (*p*=0.18), discriminate the lyrics (*p*=0.09) and melody (*p*=0.28) in a song, these benefits were not statistically significant.

Discussion

Studies of music enjoyment by persons with a hearing loss are rare in the literature (Leek *et al*., 2008) and it is not known how common it is for persons with a hearing loss to find music unpleasant or distorted, or how debilitating and distressing this reaction might be. With regard to the musical qualities assessed in the current study, the following were observed:

Loudness: Most of the participants were satisfied with the loudness of music as the hearing aids used in this study were power hearing aids with an 80 dB of peak gain and 141 dB maximum power output (Nyffeler, 2008). Two of the complaints most commonly voiced by hearing aid users are that music is either too loud or too soft overall (Leek *et al*., 2008). If one takes into consideration that music is louder than speech (Chasin & Schmidt, 2009) and all participants used the same programme for listening to both music and speech, some participants could easily have experienced the music as being too loud. A possible explanation for their satisfaction with the loudness of music might be that all hearing aids were fitted on target as verified with real-ear measurements; by doing that the researcher ensured that sounds were not uncomfortably loud. If one considers that the loudness of the sound produced by the hearing aid is determined by the gain and maximum power output of the hearing aid, it is not unexpected that NFC did not have a big influence on loudness.

Fullness: Normal-hearing listeners tend to judge sounds richer in harmonics as fuller whereas cochlear implantees have often described the quality of musical instruments as sounding thinner or shriller compared with how instruments sounded prior to deafness (Gfeller *et al*., 2002). No research on how hearing aid users described music in terms of fullness could be found with which to compare the results of the current study. Overall, hearing aid users in the present study seemed to be relatively happy with the fullness of music and there was a slight preference towards listening with NFC. The contribution of NFC towards the fullness of music can be explained by the fact that participants hear the high-frequency sounds of music which they previously missed. Although the majority of music pitches exist in the lower half of the auditory spectrum, with corresponding fundamental frequencies at approximately 1 000 Hz and below, the higher frequencies are also important for music (Revit, 2009). Resonances occurring above the fundamental frequency of musical notes help the listener to distinguish the sound of one instrument from another and add harmonicity to the sound. Instrumental harmonic resonance may occur at much higher frequencies than 3 000 Hz; for example, the highest notes of a harmonica can have significant harmonics as high as 10 000 Hz (Revit, 2009). Music however is very dynamic and the variety in instrumental timbre (e.g. the more characteristically hollow sound of the clarinet versus the very rich and deep sound of a cello) contributes to the novelty and beauty that listeners seek in music; thus, one sound being judged more empty than another is not inherently undesirable (Gfeller *et al*., 2002).

Crispness: Hearing aid users often complain of music being blurred and distorted and that melodies are therefore difficult to recognise (Leek *et al*., 2008). Normal-hearing listeners have judged sounds having more low-frequency energy as duller or blurred in quality, whereas sounds having more high-frequency energy were judged as sharper (brilliant) or crisper (clear) in quality (Gfeller *et al*., 2002). With this in mind, it is not unusual that participants rated music as being crisper and clearer with NFC as they were then receiving high-frequency information otherwise missed. The balance between the amounts of high- and low-frequency amplification should however still be good as hearing aid users do not consistently prefer extended high-frequency responses for listening to music (Wessel *et al*., 2007).

Naturalness: It is not clear whether people with hearing loss who wear hearing aids can separate the effects of the loss from the alterations in music produced by the hearing aids (Leek *et al*., 2008) and therefore their definition of naturalness can easily be compared with what they are used to (not hearing all the sounds in music and when presented with more sounds than they are used to, it does not seem natural any more). This is especially possible for persons with a longer onset of hearing loss and persons who have been wearing hearing aids for a longer period of time. No data with regard to the perception of naturalness of music by hearing aid users could be found with which to compare the results of the current study. It is assumed that the naturalness of music will influence participants' perception of the pleasantness of musical stimuli and therefore this aspect should be viewed in conjunction with participants' assessments of pleasantness, which are discussed later.

Overall fidelity: Normal-hearing listeners have rated sounds with more noise as sounding more scattered or narrow (Gfeller *et al*., 2002) while hearing aid users often complain that some musical instruments sounded odd, as if they could not hear the whole spectrum of an instrument's sound (Chasin, 2003). Results of the present study indicate a definite preference for music being more dynamic with NFC. Again this can be contributed to the high-frequency musical sounds that participants missed without NFC and therefore they are not able to hear the whole spectrum of some musical instruments, e.g. the harmonics of a violin which often exceeds 5 000 Hz (Revit, 2009). Being able to hear the whole spectrum of a different instrument's sound will add to the aesthetic experience of music (Hockley *et al*., 2010) and therefore one can conclude that the activation of NFC adds to the unique and rich timbral representations of music.

Tinniness: Participants' perception that music sounds less tinny with NFC is actually unexpected if one considers that NFC provides listeners with more high-frequency audibility, and previous research indicated that persons with a hearing loss did not necessarily like a high-frequency emphasis when listening to music (Leek *et al*., 2008). It is also evident that with frequency compression hearing aids, speech may take on a lisping quality or sounds might have a tinny sound when lowered too much (Scollie *et al*., 2011). One possible explanation for the indication that music sounds less tinny with NFC might be that the NFC setting for each participant was left on the default setting determined by the hearing aid fitting software and was only adjusted when participants complained about sounds being too tinny or uncomfortable. By doing this the researcher ensured that none of the participants received too much high-frequency amplification and therefore avoided sounds that have a tinny quality.

Reverberance: Perceptions regarding this musical quality are similar to the way participants experience the tinniness of music, as too much high-frequency amplification often causes sounds to have an echo. Again it is unexpected that fewer participants complained about hearing echoes with NFC as they were exposed to more high-frequency information. A possible explanation for this phenomenon might be that the researcher ensured that the NFC setting was comfortable for each participant without causing any disturbances in sound quality.

Pleasantness: As music can be very complex and there is no single identity that determines the pleasantness of music (Leal *et al*., 2003), one can assume that all the musical qualities described above contribute to the way listeners will experience music. From the discussion above it is evident that participants rated the fullness, crispness, naturalness, overall fidelity, tinniness and reverberance of musical stimuli to be more pleasant with NFC and therefore it is not surprising that they rated music to sound more pleasant with NFC. This is important as most people choose to listen to music for personal pleasure and enjoyment (Gfeller *et al*., 2002).

Conclusion

One can conclude that participants demonstrated a subjective preference for listening to music with NFC. It is however important to understand that listening to music may give rise to a variety of experiences (Kreutz *et al*., 2008) and therefore every individual will perceive the same musical stimulus differently. It may be of value to determine the effect of NFC for specific musical instruments in future research. As some musical instruments place more emphasis on high-frequency information compared with others, NFC may be more beneficial to certain musicians, depending on the instrument they are playing.

Given that a relatively large percentage of participants still expressed a loss in enjoyment of music, audiologists should routinely ask patients about their music listening habits and should work with them to provide the best possible amplification options for both speech and music listening. Results obtained from this study can enable audiologists to improve their service to performing musicians and other people who wish music to be part of their lives. Musicians depend on audiologists to enabling them to successfully practise 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 continually gain information about new hearing aid technologies as well as fitting preferences and to share this information. If audiologists realise this, they will have reached a new level of success in their profession (Chasin & Revit, 2009).

This paper has not been presented at any professional meetings.

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Appendix A.

THE INFLUENCE OF NON-LINEAR FREQUENCY COMPRESSION ON MUSIC PERCEPTION

QUESTIONNAIRE 1: BACKGROUND INFORMATION **For office use only**

V1 [ ][ ] 1
Respondent number

V2 [ ][ ] 4
[ ][ ]
[ ][ ]
Pt Date of birth

Please read the following questions carefully *and answer them by placing a written response in the space provided or tick in the appropriate column/columns. Should you wish to add any comments, space has been provided at the end of the questionnaire.* ***Please do not leave any question unanswered****.*

1. For approximately how many years did you receive musical training (instrument and/or voice lessons)?

______________________________ V3 [ ][ ] 11

2. Please specify the musical instruments that you are currently playing, or have played before:

______________________________ V4 [ ][ ] 14
______________________________ V5 [ ][ ] 17

3. Do you currently sing, or have you ever sung, in a choir or at social/professional gatherings?

YES [ ] **NO** [ ] V6 [ ] 20

4. Please specify your highest musical qualification:

______________________________ V7 [ ][ ] 22

5. Do you consider yourself to be a person with musical talent or musical sense?

YES [ ] **NO** [ ] V8 [ ] 25

6. Do other people consider you to be a person with musical talent or musical sense?

YES [ ] **NO** [ ] V9 [ ] 27

7. Please specify the relationship to you of any persons in your immediate family with an extraordinary musical talent?

______________________________ V10 [ ][ ] 29
______________________________ V11 [ ][ ] 32

8. What role does music play in your life? Please circle the applicable answer.

A big role 5 4 3 2 1 Does not play a role V12 [ ] 35

9. How often do you listen to music? Please circle the applicable answer.

A lot 5 4 3 2 1 Never V13 ☐ 37

10. How many hours do you usually listen to music on a work day?

______________________________ V14 ☐☐ 39

11. How many hours do you usually listen to music on a day that you are not working (for example over weekends)?

______________________________ V15 ☐☐ 42

12. In which situations do you listen to music? Please tick all the applicable answers.

Over the television	☐	At formal music events	☐	V16	☐☐	45
On the computer	☐	On the radio in the car	☐	V18	☐☐	49
At social events	☐	Hi-fi/Ipod/MP3	☐	V20	☐☐	53

13. Which musical genre(s) do you listen to?

Classical music	☐	Opera/Operetta	☐	V22	☐☐	57
Pop music	☐	Choir music	☐	V24	☐☐	61
Rock music	☐	Jazz/Blues	☐	V26	☐☐	65
Folk/Country music	☐	Music to dance to	☐	V28	☐☐	69
Ballad singing	☐			V30	☐	73

14. Do you feel that your enjoyment of music has decreased since you started experiencing hearing problems?

YES ☐ **NO** ☐ V31 ☐ 75

15. Do you usually remove your hearing aid when you listen to music?

YES ☐ **NO** ☐ V32 ☐ 77

16. What do you find most annoying when you listen to music with your hearing aid?

______________________________ V33 ☐☐ 79
______________________________ V34 ☐☐ 82

17. Please state any additional comments you may have regarding this subject.

______________________________ V35 ☐☐ 85
______________________________ V36 ☐☐ 88

PLEASE READ THROUGH THE QUESTIONNAIRE TO ENSURE THAT ALL THE QUESTIONS WERE ANSWERED.

THANK YOU FOR YOUR CO-OPERATION

Appendix B.

THE INFLUENCE OF NON-LINEAR FREQUENCY COMPRESSION ON MUSIC PERCEPTION

QUESTIONNAIRE 2: IMPRESSION OF MUSIC PERCEPTION

For office use only

V1 [ ][ ] 1
Respondent number

V2 [ ] 4
Compression on/off

Please read the following questions carefully *and answer them by placing a written response in the space provided or tick in the appropriate column/columns. Should you wish to add any comments, space has been provided at the end of the questionnaire.* ***Please do not leave any question unanswered****.*

The following questions are regarding your musical experience with the hearing aids as used during the last 4 weeks.

1. To which musical genre do you listen to mostly (your favorite musical genre)?

Classical music	[ ]	Opera/Operetta	[ ]	V3 [ ][ ]	6
Pop music	[ ]	Choir music	[ ]	V5 [ ][ ]	10
Rock music	[ ]	Jazz/Blues	[ ]	V7 [ ][ ]	14
Folk/Country music	[ ]	Music to dance to	[ ]	V9 [ ][ ]	18
Ballad singing	[ ]			V11 [ ]	22

2. How does listening to your favorite musical genre generally sound with the hearing aid? Please circle the applicable answer.

2.1 **Loudness**: The music is sufficiently loud, as opposed to soft or faint.

Loud 5 4 3 2 1 Soft V12 [ ] 24

2.2 **Fullness**: The music is full, as opposed to thin.

Full 5 4 3 2 1 Thin V13 [ ] 26

2.3 **Crispness**: The music is clear and distinct, as opposed to blurred and diffuse.

Crisp/Clear 5 4 3 2 1 Blurred V14 [ ] 28

2.4 **Naturalness**: The music seems to be as if there is no hearing aid, and the music seems as 'I remember it'.

Natural 5 4 3 2 1 Unnatural V15 [ ] 30

2.5 **Overall fidelity**: The dynamics and range of the music is not constrained or narrow.

Dynamic 5 4 3 2 1 Constrained Narrow V16 [ ] 32

2.6 **Pleasantness**: A feeling of enjoyment or satisfaction, as opposed to annoying or irritating.

Pleasant 5 4 3 2 1 Unpleasant V17 [ ] 34

2.7 **Tinniness**: Hearing the quality of tin or metal, a sense of a cheap, low-quality sound.

Less tinny 5 4 3 2 1 More tinny V18 [ ] 36

2.8 **Reverberant**: The persistence of sound after the original sound is removed, a series of echoes.

Un-reverberant	5	4	3	2	1	Echoing	V19	☐	38

3. If you listen to music, which elements can you hear? Please tick all the applicable answers.

Pleasant tones, but no melody	☐	Melody	☐	V20 ☐☐	40
Only unpleasant sounds	☐	Lyrics	☐	V22 ☐☐	44
Rhythm	☐			V24 ☐	48

4. Can you distinguish between high and low notes?

YES ☐ **NO** ☐ V25 ☐ 50

5. Can you detect different musical instruments in a musical piece?

YES ☐ **NO** ☐ V26 ☐ 52

6. Can you discriminate the lyrics (words) in a song?

YES ☐ **NO** ☐ V27 ☐ 54

7. What did you find most annoying when you listened to music with the hearing aid?

______________________________ V28 ☐☐ 56

______________________________ V29 ☐☐ 59

8. Please state any additional comments you may have regarding this subject. If you require the results of this study, please indicate it here.

______________________________ V30 ☐☐ 62

______________________________ V31 ☐☐ 65

9. Do you require the results of this study?

YES ☐ **NO** ☐ V32 ☐ 68

PLEASE READ THROUGH THE QUESTIONNAIRE TO ENSURE THAT ALL THE QUESTIONS WERE ANSWERED.

THANK YOU FOR YOUR CO-OPERATION