UNIVERSITY OF SOUTHAMPTON

FACULTY OF ENGINEERING AND THE ENVIRONMENT

Institute of Sound and Vibration Research

A ‘MUSIC-RELATED QUALITY OF LIFE’ MEASURE FOR COCHLEAR IMPLANT USERS

by

Georgios Dritsakis

Thesis for the degree of Doctor of Philosophy

May 2017

Δρόμοι παλιοὶ ποὺ ἀγάπησα καὶ μίσησα ἀτέλειωτα
Κάτω ἀπ᾽ τοὺς ἴσκιους τῶν σπιτιῶν νὰ περπατῶ
Νύχτες τῶν γυρισμῶν ἀναπότρεπτες κι ἡ πόλη
νεκρὴ
Τὴν ἀσήμαντη παρουσία μου βρίσκω σὲ κάθε γωνιὰ

Κάμε νὰ σ᾽ ἀνταμώσω, κάποτε, φάσμα χαμένο τοῦ
πόθου μου
Κι ἐγὼ ξεχασμένος κι ἀτίθασος νὰ περπατῶ κρα-
τώντας
Ἀκόμα μία σπίθα τρεμόσβηστη στὶς ὑγρές μου πα-
λάμες.

(Καὶ προχωροῦσα μέσα στὴ νύχτα χωρὶς
Νὰ γνωρίζω κανένα κι οὔτε
Κανένας μὲ γνώριζε).

Πέντε μικρά θέματα, III

από τη συλλογή του Μανόλη Αναγνωστάκη *'Εποχές' (1945)*

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF ENGINEERING AND THE ENVIRONMENT

INSTITUTE OF SOUND AND VIBRATION RESEARCH

Thesis for the degree of Doctor of Philosophy

A 'MUSIC-RELATED QUALITY OF LIFE' MEASURE FOR COCHLEAR IMPLANT USERS

by Georgios Dritsakis

Outcome measures for adult cochlear implant (CI) users are needed to evaluate music rehabilitation tools. Music questionnaires developed for CI users may capture real-world music experiences better than music perception tests but have not been designed to measure outcomes. A new reliable and valid instrument measuring a wide range of music experiences and the impact of music on the quality of life (QOL) of adult CI users could be more appropriate for the assessment of music rehabilitation. This PhD thesis made steps towards the development of such a measure. Music-related Quality of Life (MRQOL) was defined as a function of music experiences and their importance in life. On the basis of this concept, two initial pools of questionnaire items were developed, one assessing musical abilities, attitudes and activities and another one assessing their importance. The items were generated using focus group data from 30 adult CI users and reviewed by 24 professionals for face validity and refinement. After completion of both sets of questions by 147 adult CI users, 18 items were selected for each set with the use of traditional psychometric techniques. The items grouped together into two meaningful domains (perception and engagement) with high reliability and some evidence for construct validity. Scores of 'music perception and engagement' and importance for the 18 items can be combined to measure the impact of music on QOL. The meaning of individual 'impact' scores and the ability of the questionnaire to measure changes have to be further studied. This thesis broadens the understanding of CI users' relationship with music and the effects of music on their QOL. Novel aspects of music experience were identified. The MRQOL measure has the potential to become a standard measure of music-specific outcomes and of the impact of music on the QOL of adult CI users and hearing-impaired adults in general, with potential clinical utility.

Table of Contents

List of Tables

List of Figures

DECLARATION OF AUTHORSHIP

I, **Georgios Dritsakis**, declare that the thesis entitled **"A 'music-related quality of life' measure for cochlear implant users"** and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;

2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;

3. Where I have consulted the published work of others, this is always clearly attributed;

4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;

5. I have acknowledged all main sources of help;

6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;

7. Parts of this work have been published as:

Dritsakis, G., van Besouw, R.M. and Verschuur, C.A. Generation of items for a 'music-related quality of life' questionnaire for adult cochlear implant users (in press, Journal of Academy of Rehabilitative Audiology)

Dritsakis G., van Besouw R.M., Kitterick, P. and Verschuur, C.A. A 'Music-Related Quality of Life' (MuRQoL) measure to guide music rehabilitation for adult CI users (in press, American Journal of Audiology)

Dritsakis, G., van Besouw, R.M. and O' Meara, A. (2017) Impact of music on the quality of life of cochlear implant users: a focus group study. *Cochlear Implants International*. 1-9

Signed: ....

Date: ....

Acknowledgments

Above anyone else I want to thank my parents, *Αντώνης Δριτσάκης* and *Μεταξία Δραπέτη*, because without their sacrifices I would not have achieved anything in life.

I am grateful to my supervisor, Rachel van Besouw, for giving me the opportunity to do this PhD and for her constant guidance and support.

Thanks to my amazing friends Tobias Göhring and Xin Yang for being patient with me, for encouraging me and for making me believe in myself. It is impossible to count the walks, the discussions and the (Costa) coffees we had throughout these years!

I want to thank Ayşegül Buğra because without her I would probably not have made it to the end of this journey.

Big thanks to my friend, Νικόλας Λαζάρου, for giving me courage, advice and for always being 'there' for me.

I also want to thank my colleagues Zoe Bevis and Matt Blyth for the glorious days we spent in the office and for their massive help throughout the PhD.

I thank Carl Verschuur not only for his guidance and positive energy but also for being a role model for me.

Finally, I would like to thank Daniel Rowan, Helen Cullington, Mike Wald, Judith Lathlean and Sarah Worsfold for their crucial help and contributions at different stages of this PhD.

Special thanks to Thalía Dominguez Bucio; her calmness, enthusiasm and encouragement helped me survive a tough viva!

Abbreviations

AB	Advanced Bionics
ACE	Advanced combination encoder
AQOL	Assessment of quality of life
CAMP	Clinical assessment of music perception
CI	Cochlear implant
CIFI	Cochlear Implant Function Index
CIS	Continuous interleaved sampling
CTT	Classical Test Theory
EAS	Electro-acoustic hearing
ECLiPS	Evaluation of Children’s Listening and Processing Skills
EQ-5D	Euro-quality 5 dimensions
F_0	Fundamental Frequency
FMI	Familiar melody identification
FSP	Fine-structure processing
GBI	Glasgow benefit inventory
GHSI	Glasgow health status inventory
HA	Hearing aid
HISQUI	Hearing Implant Sound Quality Utility Index
HL	Hearing loss
HRQOL	Health-related Quality of life
HPS	Hearing participation scale
HUI	Hearing Utility Index
IMAP	Interactive music awareness programme
IMBQ	Iowa Musical Background Questionnaire
IRQF	Index relative questionnaire form
IRT	Item Response Theory

MCI	Melodic contour identification
MRQOL	Music-related quality of life
MSP	Musical Stages Profile
MUMU	Munich music questionnaire
NCIQ	Nijmegen cochlear implant questionnaire
NH	Normal-hearing
NCIUA	National cochlear implant users' association
NRES	National research ethics Service
PQLF	Patient quality of life form
QALYs	Quality-adjusted Life Years
QOL	Quality of Life
SD	Standard Deviation
SF12v2	Short-form Health Survey 12-item Version 2
SF-36	36-item short form health survey
SPEAK	Spectral peak
TA	Template Analysis
UCMLQ	University of Canterbury music listening questionnaire
USAIS	University of Southampton Auditory Implant Service
WHO	World health organisation

Chapter 1. Introduction

"Since I've had an implant I hear bird song and I hadn't heard bird song for 50 odd years! You just said you could live without music and now I found the bird song lovely! I couldn't live without it..."

Cochlear implant user

1.1 Overview

The cochlear implant (CI) has benefitted nearly half a million people with severe or profound deafness since its advent at the 1970s. Offering a sensation of hearing to deaf ears is a tremendous achievement and it is not surprising that the CI has been commonly described by recipients as 'a gift', 'a miracle' or 'life-changing'. Numerous research findings have demonstrated the benefits of CIs for communication (speech perception and production) with subsequent benefits on psychosocial aspects of life such as self-esteem, emotions, activity and participation (e.g. Lassaletta et al. 2006). Improvements in CI technology have resulted in higher expectations from hearing and the perception and enjoyment of music is a desire expressed by many users (Philips et al., 2012). However, perception of music and as a consequence music enjoyment and activity are limited by physical limitations of the implant, auditory deprivation due to deafness and the complexity of music as opposed to speech (Limb & Roy, 2013).

Despite these limitations, adult CI users may be able to benefit from music-related recent advances in CI technology and auditory music training programmes (van Besouw et al., 2015). More evidence for the effectiveness of these music-focussed interventions is required to promote their use among clinicians and patients. Appropriate outcome measures are needed for the assessment of music rehabilitation outcomes. Traditionally, music-specific outcomes have been measured with music listening tests for the perception of fundamental features of music such as pitch, timbre, melody or rhythm. However, there is an increasing use, development and need of self-report subjective measures and quality of life (QOL) instruments in order to assess real-life outcomes that are not captured by music perception tests peformed in the lab. It has been demonstrated that self-report instruments need to be specific to the target population to be able to capture subtle effects (e.g. Hinderink et al. 2000; Looi et al. 2016). Previous music questionnaires developed for CI users, in particular, have two major limitations (section 2.3). First, the poor coverage of psychosocial aspects of CI users' relationship with music that are relevant to the QOL, such as feelings about music and participation in music-related social activities. A second limitation is the lack of psychometric properties necessary for a questionnaire to be a strong measure. Besides, it is proposed that measuring the impact of music experiences on the QOL of CI users can be more informative on rehabilitation outcomes than assessing only music perception and enjoyment. The relationship between music and QOL in CI users has been previously studied by correlating scores of different music and QOL instruments (Calvino et al., 2015). However, it is unclear if the correlations that have been found suggest an impact of music on QOL or vice versa.

A new music-specific self-report measure that addresses previous limitations and directly assesses the impact of music on the QOL of adult CI users would be more appropriate for the evaluation of music rehabilitation tools than existing CI-specific music questionnaires.

In this context, this thesis set out to achieve the following aims:

1. Develop a new questionnaire that overcomes limitations of previous music questionnaires designed for CI users (primary aim)
2. Assess the reliability and construct validity of the new questionnaire (primary aim)
3. Investigate the whole range of music experiences and introduce a new concept that will link music and QOL for CI users
4. Investigate the impact of music on the QOL of adult CI users and the measurement of this impact

In order to overcome limitations of previous studies, the present project built on both the music-CI and the QOL literature and used a combination of two approaches: (a) a person-centred approach with CI users strongly involved throughout the process of questionnaire development (item generation, item selection and questionnaire validation) and (b) the use of psychometric techniques that have been applied in the development and validation of health measurement scales (Bowling 2014: 51-55; Streiner et al. 2015). Building on the evidence for the effects of music on the QOL in the general population, it was proposed that mapping music experiences of CI users onto a QOL model could help developing a self-report measure that covers aspects of music experience poorly covered by previous music questionnaires. The concept of 'music-related quality of life' (MRQOL) was described and its relevant aspects were identified with the use of qualitative techniques. Based on these findings, a large pool of questionnaire items was generated. The items were reviewed by experts for face validity. Additional questions assessing the importance of music were developed. Items were selected with the application of psychometric techniques after the questionnaire was completed by CI users. Psychometric properties of the selected items supported the reliability and validity of the questionnaire. The reliability and validity of the questionnaire were further assessed using MRQOL responses, i.e. responses to the aforementioned questionnaire, from CI users and

NH listeners as well as CI users' responses to a Health-related Quality of Life (HRQOL) instrument. The appropriateness of the selected items for hearing-aid (HA) users and normal-hearing (NH) adults was assessed. Finally, a method for the measurement of the impact of music on the QOL with the combination of frequency and importance ratings was proposed.

1.2 Thesis structure

Chapter 2 of this thesis is a review of literature that is necessary background to the project: an introduction to CIs, a review of studies on the music perception, appraisal, enjoyment and listening habits of adult CI users, a critical analysis of the music questionnaires and the HRQOL measures for CI users, a review of the evidence for an impact of music on the QOL and for the potential of music rehabilitation for adult CI users, which was the motivation to the study and justifies the need for a new measure. Chapter 3 covers the formulation of the new MRQOL construct and a focus group study for the identification of relevant issues of music experience under the new construct and for the generation of prototype questionnaire items. Chapter 4 includes the development of the prototype questionnaire and the refinement of it with the use of expert feedback. Chapter 5 describes the selection of items with the use of statistical techniques. Chapter 6 is the assessment of construct validity of the final questionnaire and the assessment of applicability of the items for other groups. Chapter 7 discusses issues regarding the measurement of the impact of music on the QOL. Chapter 8 is a general discussion of the thesis and conclusions.

1.3 Contribution to the knowledge

The main contributions of this PhD research project were the following:

- The concept of MRQOL, i.e. the QOL of adult CI users to the extent that it is affected by music, was introduced together with its domains and themes. The new conceptual framework can be used in the future to study CI users' relationship with music.
- A comprehensive list of aspects of music experience of adult CI users that are relevant to QOL domains was established, including issues that are novel in the literature. This leads to a greater understanding of the music experiences of adult CI users.
- A list of questionnaire items for a new MRQOL measure were generated, refined and carefully selected. For each item assessing an aspect of music experience, a corresponding item assessing its importance was developed. The content and face validity of the items

was supported and evidence for the psychometric properties of the items, such as test-retest reliability, was provided.

- It was demonstrated that these items group together into two domains, music perception and music engagement, with the latter including music enjoyment, activity and participation. Both domains and the MRQOL questionnaire as a whole have high internal consistency.
- The construct validity of the MRQOL questionnaire was supported by a significant difference in scores between a group of adult CI users and a group of normal-hearing (NH) adults and by a correlation between the scores of the MRQOL questionnaire and a generic QOL measure, the Short-form Health Survey (SF12v2).
- The CI group rated music as important as the NH group on average, despite lower music perception and engagement. Within each of the adult CI user and NH adult groups, the importance of music was found to correlate with perception and engagement.
- This thesis improved the understanding of the importance of music for adult CI users and the impact of music on the QOL, e.g. by showing that importance of music for adult CI users is comparable to that of NH adults overall but varies among CI users.
- A method for the direct measurement of the impact of music on the QOL was proposed, through combining music perception and engagement scores with importance scores.

Chapter 2. Literature review

2.1 The cochlear implant

2.1.1 What it is and how it works

A cochlear implant (CI) is an electric device fitted to children and adults with severe or profound sensorineural hearing loss, who receive little or no benefit from conventional hearing-aids (HAs). Sensorineural hearing loss is usually characterised by a damage or loss of hair cells in the cochlea of the inner ear. The CI bypasses the non-functional hair cells and directly stimulates the auditory nerve with an electrode array surgically implanted into the cochlea (Clark 2003:238-239). Since CIs became commercially available in the 1980s more than 300,000 deaf people of all ages have benefited from the CI technology, with the number of devices that are being fitted dramatically increasing. In the UK, 1,166 children and adults were fitted with a CI between April 2014 and March 2015, with the total number of CI users exceeding 13,000 (British Cochlear Implant Group, 2015).

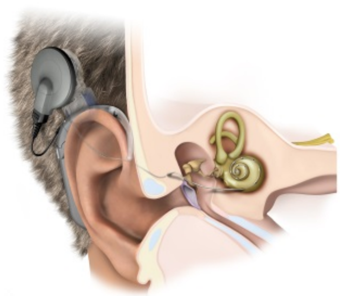


Figure 2.1 *The external and internal parts of a CI. External: a microphone-processor system is worn on the ear and the transmitter is connected to it and magnetically attached to the internal receiver-stimulator. Internal: the receiver-stimulation system placed under the skin and the electrode array placed within the cochlea. Photo: MED-EL.*

The CI system operates in the following way (Clark 2003:xxxii-xxxiii):

1. The sound is picked up by a microphone and converted into an electrical signal by a processor. Both the microphone and the processor are worn externally on the ear (Figure 2.1 above).

2. Within the processor, the signal is divided into a certain number of frequency channels and for each channel a number of electrical current pulses is generated. The processing of the sound is explained in detail below.
3. A transmitter that is worn externally and connected to the microphone/processor transfers the pulses through the skin to an internal receiver-stimulator system.
4. This system then transmits the pulses to the implanted electrodes sequentially. Each frequency band corresponds to one electrode. Current devices commonly use 16-24 electrodes sitting within the cochlea plus 2 ground ones used as reference electrodes to establish a potential difference between them and the electrode being stimulated.
5. The electrical current is then sent through the auditory nerve to the brain, which recognises it as sound.

The electrical representation of the input sound in the brain is determined by the speech-processing strategy and more specifically by parameters such as the rate of stimulation of the electrodes, the exact electrodes that are activated or the order of activation.

2.1.2 Speech processing strategies

Different coding strategies convey different features of the input sounds to the recipient. One of the most commonly used and basis of many other newer strategies is the 'Continuous Interleaved Sampling' (CIS). It uses a high stimulation rate and high envelope cut-off frequencies and transmits mostly temporal envelope information across a small number of widely-spaced channels (Figure 2.2 below).

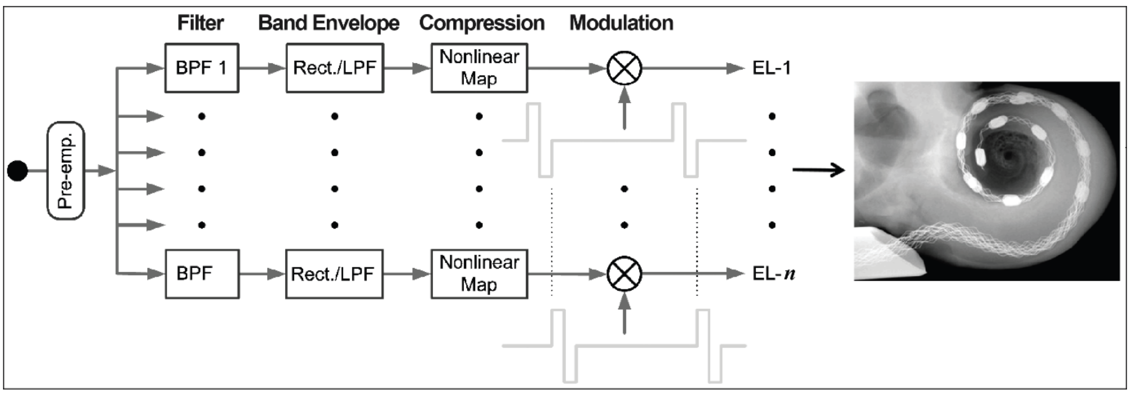


Figure 2.2 *The signal goes first through pre-emphasis (Pre-emph.) filters to attenuate very high amplitudes. Then band-pass filters (BPF) analyse the signal into different frequency bands. Full-wave or half-wave rectifiers (Rect.) and low-pass filters (LPF) extract the temporal envelopes*

of the filtered waveforms in each channel. The envelopes are compressed to fit the dynamic range of the electrodes. Finally, the envelopes are used to modulate biphasic pulses which are delivered to the electrodes (EL-1…EL-n). Originally published in: Wilson, B.S. & Dorman, M.F., 2008. Cochlear implants: Current designs and future possibilities. The Journal of Rehabilitation Research and Development, 45(5), pp.695–730.

Other strategies are based on the CIS but use different techniques to offer increased spectral and temporal detail. High Resolution (HiRes) strategies, implemented in Advanced Bionics (AB) and MED-EL devices, use the current steering technique, i.e. the stimulation of 2 adjacent electrodes at a time (Buechner et al., 2008). The 'Spectral Peak' (SPEAK) strategy employs low stimulation rate with many narrow 'analysis channels'. The (6 to 10) channels with the maximum amplitude in each cycle of the waveform are stimulated and the corresponding electrodes are activated. The 'Advanced Combination Encoder' (ACE) strategy is a combination of CIS and SPEAK. By combining a large number of channels with a high stimulation rate it aims at providing both information from the temporal envelope and spectral cues to the listener (Loizou, 2006). Both SPEAK and ACE have been implemented in Cochlear Ltd. devices.

A newer strategy that emphasises the transmission of fine-structure information is the 'Fine-Structure Processing' (FSP) strategy, used by MED-EL. For deeply-inserted electrodes (close to the apex of the basilar membrane of the cochlea, where the low frequencies are analysed), a series of pulse sequences is generated from the band-pass filtered output of each channel. The rate of these pulse sequences approximates the actual fine-structure fluctuation frequency of the signal. This way, low-frequency temporal and spectral detail (as opposed to the broad information from the envelope) is provided in these apical electrodes. In the standard FSP strategy, fine-structure information is provided for the 1 or 2 electrodes closest to the apex. Two novel coding strategies, the FS4 and the FS4-p can provide fine-structure for up to the 4 most deeply inserted electrodes (Riss et al., 2014). FS4-p also presents the pulses to the electrodes in parallel rather than sequentially. For the remaining higher-frequency channels, CIS is implemented to provide envelope cues (Hochmair et al., 2006; Arnoldner et al., 2007). Transmission of fine-structure information, especially at low frequencies, is useful at conveying pitch which is particularly important in the recognition of speech in noise or in the perception of music.

2.1.3 Speech perception with current-day CIs

Despite the differences between the strategies, CIs transmit mainly the temporal envelope of the signal and the relative amplitudes of the pulses across the channels provide a rough representation of the spectral content of the sound. Overall, this crude spectral representation and the information from the temporal envelope are sufficient for the understanding of speech in quiet listening environments for many adult CI users. Average performance for monosyllabic word recognition in quiet has been reported to be around 55% following 6 to 12 months of implant use and sentence recognition between 85% and 90% after 6 to 12 months post-implantation (Wilson & Dorman, 2008a).

However, the information provided by the implant is not adequate for other tasks in which a higher level of spectral detail and pitch information in particular, is necessary. In order to perceive the pitch of a complex sound, NH listeners extract mainly F_0 information (but also harmonics) from the place of the cochlea at which maximum excitation occurs for a specific frequency (place cues) and the phases of the waveform at which neural spikes are produced or repetition rate (rate cues). Both cues to the fundamental frequency (F_0) depend primarily on fine-structure information, especially from the low-order harmonics (Smith et al., 2002). In contrast, CI listeners can access pitch using mostly place cues and only from the amplitude modulations of the temporal envelopes in the low-frequency region at specific places. Although modern processing strategies can preserve and transmit the fine temporal detail of the original input signal to some extent, the ability of the listeners to resolve individual harmonics is hindered by factors such as the limited number of channels, the interaction between channels due to spread of current excitation from one electrode to another or the tono-topic mismatch as a result of electrode insertion depth. Speech perception tasks for which the spectral detail provided by the CI is not sufficient are speech recognition in background noise or in the presence of competing talkers (Stickney et al. 2007), the recognition of vocal emotion, gender identification, talker discrimination (Cleary et al 2005) or the recognition of speech in tonal languages (Looi et al., 2015).

High variability is reported in the speech recognition performance of adult as well as paediatric CI users, with top performers even achieving scores within the normal range (Wilson & Dorman, 2007). This variability can be partly attributed to the impact of patient-related and device-related variables, such as age at implantation (Houston & Miyamoto, 2010), amount of residual hearing before implantation, duration of deafness, duration of CI use, condition of the cochlea, rate and place of stimulation or electrode insertion depth (Donaldson et al., 2011).

Depending on whether deafness occurred before or after the acquisition of speech and language, adult CI users are categorised into prelingually deafened/deaf (i.e. severe to profound HL <3 years old, including congenitally deaf) or postlingually deafened/deaf[1]. Generally speaking, prelingually deaf adult CI users perform worse than the postlingually deaf in speech recognition tasks, although performance may vary depending on the amount of training received (Kaplan et al., 2003). Age itself can also affect speech perception scores. Sladen & Zappler (2015) showed that CI users >60 years old performed significantly worse than those < 60 years old in word and sentence recognition in quiet (Sladen & Zappler, 2015). Cognitive factors, such as verbal learning and phonological working memory should also be considered as a source of variability in speech performance (Heydebrand et al., 2007). Variability in speech understanding has been reported even within users of the same device, implying that patient characteristics may be more important than device characteristics for modern-day processing strategies (Teoh et al., 2004).

Also, bilateral CIs (CI in both ears) and electro-acoustic simulation (EAS) have been shown to significantly improve speech perception in adverse listening situations (Gifford et al., 2013; Rader et al., 2013). EAS is the combination of electric stimulation of higher frequencies and preservation of residual acoustic low-frequency hearing in the same ear by inserting a short electrode array or 'hybrid CI' (Gantz & Turner, 2003). For instance, it has been shown a bilateral implant received sequentially can result in significantly better speech perception in noise than with one implant (Härkönen et al., 2015). There is also evidence that EAS listeners perform significantly better than CI users on pitch-based speech tasks (Kong & Carlyon, 2007; Turner et al., 2004).

2.2 Music perception of adult CI users: the use of music tests

2.2.1 Introduction

In addition to pitch-based speech perception tasks, the perception of music is another task where CI users perform poorly. In fact, the case of music is much more complicated than speech and physical limitations of the implant are only one of the reasons that are responsible for poor music perception. Poor music perception by CI users has been attributed, among others, to the following three factors (Limb & Roy, 2013):

[1] Prelingually/postlingually 'deafened' and 'deaf' have been used interchangeably in the literature. The word 'deaf' is used throughout this thesis.

1. Technological limitations: poor temporal and spectral information (necessary for accurate perception of fundamental aspects of music) and restricted dynamic range transmitted through the implant
2. Biological limitations of the auditory system: deficits of the auditory system and lack of extensive exposure to music due to the hearing loss (auditory deprivation)
3. Acoustical limitations: complex acoustic features (e.g. musical pitch and timbre) are necessary for music perception as opposed to speech; CIs have been designed for speech and transmit these poorly

However, music is particularly important for many postlingually deaf CI users especially after basic speech recognition is achieved. CI users with prior normal-hearing exposure to music express a desire to hear and enjoy music again (Leal et al., 2003; Lassaletta et al., 2008b). In two studies around 1/3 of the participants reported that they would have undergone implantation just to be able to listen to music (Mirza et al., 2003; Migirov et al., 2009). In another study 68% of the respondents reported that they would choose a CI that would transmit music perfectly, if such a device was available (Philips et al., 2012).

While the accuracy in the recognition of phonemes, words or sentences are well-accepted outcome measures in speech perception, there is no accepted measure for music. Most music listening tests that have been used with CI users have measured the accuracy to perceive the fundamental elements of music, rhythm, pitch and timbre (Looi et al., 2012). Tests on the recognition of familiar melodies have also been used fairly often in music-related research. This section will review the music listening tasks used with CI users as well as the evidence for the music perception abilities of adult CI users and.

2.2.2 The perception of fundamental elements of music

Among the fundamental components of music, rhythm is particularly important for CI users. While pitch and timbre are poorly accessible through the implant, it is generally accepted that musical rhythm is accurately perceived. Studies that employed a control group of normally hearing (NH) adults demonstrated that the performance of CI users in rhythm discrimination tasks is comparable to that of NH listeners (Schulz & Kerber, 1994; Gfeller et al., 1997; Brockmeier et al., 2011). Kong et al. (2004) also found no significant difference between the scores of CI users and NH listeners in a tempo discrimination task where listeners had to choose which of two patterns was played in a faster tempo, i.e. beats per minute, than the other (Kong et al., 2004). Kim and colleagues demonstrated the accuracy of CI users to perceive rhythm with a temporally more demanding task, where listeners had to detect whether the last beat in a four-beat series was isochronous, early or late compared to the other three (Kim et al., 2010). Again, the performance of CI users and NH listeners was comparable.

Musical timbre is the quality that distinguishes one instrument playing the same notes at the same loudness from another. Accurate timbre perception requires the perception of both the temporal envelope and the spectral shape of the sound. The perception of musical timbre of CI users has been assessed with instrument recognition tests, where listeners have to identify the musical instrument playing, usually choosing from a closed set of items. There is consensus among researchers that CI recipients are significantly less accurate than NH listeners in musical instrument recognition, (Gfeller et al., 2002c; Kang et al., 2009; Leal et al., 2003; Looi et al., 2008a), although the mean scores vary potentially as a result of different stimuli and experimental settings (e.g. sample size). These results are also in agreement with subjective reports of CI users (Grasmeder & Lutman, 2006). Musical instrument recognition by CI users is further obscured when multiple instruments are added, e.g. in the case of background accompaniment or musical ensembles (Looi et al., 2008a; Brockmeier et al., 2011). The difficulty of CI users with multiple instruments has been also reported in the identification of melodic contours played by different musical instruments, where performance was negatively affected by the presence of a piano masker (Galvin III et al., 2009).

Musical pitch is the attribute of musical tones that correlates most closely with the physical dimension of frequency. In music, the succession of pitches constitutes melodies. The recognition of melodies requires accurate perception of the direction of pitch change (higher or lower pitch), the degree of the pitch change between notes (interval size) and the overall pitch movement (contour shape). A number of different tasks have been used to test musical pitch and melody perception by CI users, including tone discrimination and ranking, melody discrimination and melodic contour identification. In a pitch discrimination task the listener has to decide whether two tones are the same or different. For example, the tonal subtest of the Primary Measures of Music Audiation (Gfeller, Kate & Lansing, Charissa, 1992), measures listeners' ability to discriminate between pairs of melodies differing in one or more notes (Lassaletta et al., 2008b). In a pitch ranking task the listener has either to identify the higher tone or to decide if a specified tone is higher or lower than the other. CI users are generally significantly less accurate than NH listeners at pitch ranking pairs of sung vowels of from 1 to 12 semitones apart (Sucher & McDermott, 2007; Looi et al., 2004). In the pitch subtest of the UW-CAMP test battery the listener has to determine the complex tone with the higher pitch of a pair of tones in a two-alternative forced choice adaptive procedure. The mean thresholds were 3 semitones for 42 CI users tested and 1 semitone (which was also the smallest interval tested) for 10 NH listeners (Kang et al., 2009).

In the Modified Melodies Test, the listener is presented with two versions of a familiar melody, a normal one and another with a certain degree of pitch distortion. Their task is to decide which of the two versions of the melody is the correct one (Swanson, 2008). In the study by Swanson (2008), NH listeners achieved almost perfect scores while CI users scored at chance. The Melodic Contour Identification (MCI) test consists of nine 5-note sequences representing different melodic contours. Each note is a complex tone with the F_0 and the first two harmonics. Five between-note intervals (1, 2, 3, 4 and 5 semitones) and three root notes (A3-220 Hz, A4- 440 Hz and A5-880 Hz) are used. The task of the listener is to choose the shape of the melodic contour played in a 9-alternative forced-choice task. Using the MCI test Galvin et al. initially tested the identification of melodic contours by 9 NH and 11 CI listeners. While NH listeners achieved a mean score of 94.8% the performance of the CI users was significantly lower (Galvin et al., 2007). The high inter-subject variability for the CI users is especially emphasized by the authors. No correlations were found between MCI scores and the scores of a 'familiar melody identification' (FMI) test. However, the authors report that performance of NH listeners in the MCI test is comparable to their performance in FMI tests in previous studies.

2.2.3 Recognition of familiar melodies and listening strategies

The performance of CI users in pitch ranking of complex tones has also been significantly correlated with familiar melody recognition scores (Looi et al., 2008a; Nimmons et al., 2008; Kang et al., 2009). These results suggest that accurate perception of pitch is important for the recognition of melodies. CI users score significantly worse than NH listeners in melody or song identification, which can be explained by the poor perception of pitch through the implant (Brockmeier et al., 2011; Gfeller et al., 2012b). However, it has been reported that CI users score better in familiar melody recognition tasks when melodies are presented with rhythmic information, when rhythmic patterns are distinct between melodies or when songs have a particular rhythmic structure than when melodies have the same rhythm, rhythm cues are removed or melodies are rhythmically unstructured (Gfeller et al., 2002a; Kong et al., 2004; Galvin et al., 2007). These findings suggest that CI users can use rhythmic information, when available, to perceive music.

In addition to the rhythmic pattern of the melodies, CI users can sometimes use the lyrics for the recognition of familiar tunes or songs. The use of lyrics as a listening strategy for song recognition is well supported in the literature (Gfeller et al., 2008, 2012b). Interestingly, it has been shown that CI users can recognise familiar songs even when presented with only the vocal line (Gfeller, 2009). In the same study, female voice induced better performance in song recognition with lyrics. It is possible that the use of lyrics for the recognition of familiar songs is affected by the voice frequency range of the singer.

2.2.4 Background music as a masker

CI uses also experience the masking effects of background music on speech more severely than NH adults. Background music functions similarly to other types of background noise and makes speech recognition challenging for CI users (Gfeller et al., 2012c; Hossain & Assmann, 2012). It is still under debate whether the masking effects of music are more adverse than the effects of other types of noise not only for hearing-imaired but also for NH adults (Gordon-Hickey & Moore, 2007; Ekström & Borg, 2011; Nabelek et al., 1991; Russo & Pichora-Fuller, 2008). The masking properties of music have also been reported in the use of lyrics for the recognition of familiar songs by CI users. Although CI listeners were able to use lyrics (in the 'lyrics- only' condition) for song recognition almost as effectively as NH listeners, when there was a musical accompaniment the benefit of lyrics for the CI users was limited, compared to the NH listeners who performed as well as in the 'lyrics-only' condition. There is also evidence to suggest a differential effect of different types of background music on the perception of song lyrics by CI users (Gfeller et al., 2009).

2.2.5 Variability in music perception scores

Large variability has been reported for music perception scores among CI users. For instance, some CI users are able to detect pitch differences of one semitone while others unable to do so for one octave (Drennan & Rubinstein, 2008; Galvin et al., 2007). There is evidence that some recipients, commonly known as star performers, can even achieve scores comparable to those of NH listeners (Maarefvand et al., 2013). In addition to patient and device characteristics related to the variability in speech perception, additional music-related factors should be considered, such as music experience before implantation, music training, preferences or the relative importance of music for different individuals. For example, formal music training has been shown to be a significant predictor of CI users' pitch ranking, instrument recognition, familiar melody recognition and song recognition without lyrics scores (Gfeller et al., 2007, 2008).

2.2.6 Summary

Evidence from music listening tests performed in laboratory settings shows agreement that adult CI users perform significantly worse than NH adults in tests of pitch perception, musical instrument recognition and identification of familiar melodies. The difficulty of CI users to perceive the fundamental elements of music is related to physical limitations of the implant but also to auditory deprivation and the complexity of the musical signal and therefore may not be specific to CI users but also apply to other hearing-impaired adults. Rhythm perception is generally intact through the implant. In addition to poor perception of music through the implant, CI users are also adversely affected by the effects of background music. High between-subject variability exists in music perception scores of CI users.

2.3 Music experiences of adult CI users: use of report-based measures

2.3.1 Introduction

Although CI research has focused on measuring perceptual accuracy using music listening tests, several studies have asked listeners to report on various other aspects of the music they perceive and their music experiences. In the music-CI literature the term ‘music appreciation’ has been commonly used to refer to any other aspect of CI users’ relationship with music other than the accuracy to perceive fundamental or other elements of music (‘music perception’). However, the term has not been defined and it is not always clear which aspects of music experience it covers. In previous ‘music appreciation’ studies, CI users have been asked to assess the music they perceive in two ways. One of them is by directly rating attributes of music sound quality such as clearness, pleasantness and naturalness (music sound quality) or the degree of liking of musical excerpts [music appraisal] (Looi et al., 2012). CI users have also been asked to report on how much they enjoy music overall or on music listening habits, such as the time they spend for music listening (Looi et al., 2012). Music sound quality ratings, music appraisal ratings, enjoyment and music listening habits questions have often been presented to respondents separately, but they have mostly been part of music questionnaires.

This section will:

1. Review the evidence for the music appreciation of adult CI users
2. Review the music questionnaires developed for and used with adult CI users

2.3.2 Why use report-based measures for music?

In contrast to speech, music is not only meant to be understood but also enjoyed. Accurate perception of the specific acoustic features of music is important, especially for music professionals and in certain occasions, e.g. following film music to ensure coherence of a movie. However, accuracy does not necessarily lead to music enjoyment. Indeed, music perception accuracy scores of CI users have either been moderately correlated with music sound quality ratings (Looi et al., 2007) or not significantly correlated with music appraisal ratings (Gfeller et al., 1998a; Wright & Uchanski, 2012). Drennan et al. for instance, found weak relationship between the UW-CAMP scores and the Iowa Musical Background Questionnaire (IMBQ) sound quality scores of 145 postlingually deaf adult CI users (Drennan et al., 2014). Also Gfeller et al. showed that perceptual accuracy is not a significant predictor of music appraisal (Gfeller et al., 2008). For these reasons, it has been suggested that how positively CI users describe the music they perceive, the time they spend listening to it and music enjoyment should not be assumed but should be explicitly studied in concjunction with their accuracy to perceive rhythm, pitch, melody and timbre (Looi et al., 2012).

2.3.3 Music satisfaction and listening habits of adult CI users

In previous studies, CI users have been asked to rate the appraisal or music sound quality of musical instruments, rhythms, tunes or songs on rating scales. Overall, CI users find music less pleasant than NH listeners (e.g. Leal et al. 2003). However, ratings may vary depending on the melodies, musical instruments and music styles tested. Complex melodies, rhythms or timbres are rated less pleasant than simple ones. For example, single musical instruments playing solo have been rated more pleasant than instruments playing with background accompaniment or than music ensembles (Looi et al., 2007). Gfeller et al. reported significantly poorer music appraisal ratings for high-frequency instruments (e.g. flute) and those of the string family (e.g. violin) than NH listeners (Gfeller et al., 2002c). Among songs of three music styles (country western, pop, classical), classical melodies have been rated by CI users significantly lower than NH listeners (Gfeller et al., 2003).

It has been reported that postlingually deaf adult CI users are not satisfied with the music they perceive and listen to music less after implantation than before deafness (e.g. Leal et al. 2003). For instance, Lassaletta and colleagues reported a significant decrease of music enjoyment and time spent for music listening post-implantation (Lassaletta et al., 2008a, 2007). The same studies also reported that participants who listened to music with the implant more than two hours per week also gave high ratings for music enjoyment. This suggests that the time CI users spend with music is associated with the satisfaction they derive from it. Significant correlations between enjoyment or sound quality ratings and listening habits after implantation have also been reported elsewhere (Looi & She, 2010). However, it is unclear if CI users who enjoy music more tend to spend more time listening to it or if more time spent with music improves enjoyment. Enjoyment and music sound quality were also associated in the studies by Lassaletta et al. (2007, 2008a), with listeners giving high quality ratings reporting that they enjoyed music more.

Large variability has been reported in music appraisal and enjoyment ratings, similarly with the variability in music perception. Among other parameters, music appraisal and enjoyment is dependent on personal music preferences and musical background (Gfeller et al., 2008; Bartel et al., 2011). For example, Gfeller et al. (2008) found a strong positive correlation between music appraisal ratings and prior formal music training. However, music experiences may also have negative effects on music listening; CI users listen to music less after the implant because they are disappointed by the poor music sound quality contrary to expectations. In a study by Migirov and colleagues, 11/13 patients who played an instrument and 10/24 who used to sing before deafness, did not resume after the implant (Migirov et al., 2009).

Mixed evidence for music enjoyment and listening has been reported for prelingually deaf adult CI users. In an older study by Eisenberg, all of the 12 prelingually deaf adult CI users studied, reported that they listened to music after implantation (Eisenberg, 1982). However, no significant differences in music appreciation, as measured by the University of Canterbury Music Listening Questionnaire (UCMLQ), were recently reported between prelingually and postlingually deaf adult CI users with similar levels of hearing impairment (Moran et al., 2016). The music experiences of prelingually deaf CI users have been poorly studied and it is difficult to draw conclusions. However, it is likely that the prelingually deaf can enjoy the music they hear through the implant because they have poor or no NH exposure to music and therefore no memory of music to compare with, in contrast with the postlingually deaf who are more likely to be disappointed with the music they perceive because they expect it to sound as it did before deafness.

2.3.4 Music questionnaires developed for CI users

Table 2.1 below summarises the music questionnaires developed for CI users and gives details about their development and use.

Using a questionnaire with general questions about music enjoyment and music listening habits, Mirza et al. (2003) found a significant decrease in music enjoyment after implantation compared to before deafness. Twenty-four out of 35 respondents also reported that they were disappointed with how music sounds through their implant (Mirza et al., 2003). No details regarding how the questionnaire was developed were provided by the authors. A Hebrew version of this questionnaire was used in another study by Migirov and her colleagues (Migirov et al., 2009). In that study, music enjoyment dropped for 50.9% of 53 participants post-implantation. The above findings regarding a decline in overall music enjoyment after implantation were also confirmed by other authors (e.g. Philips et al. 2012).

The Iowa Musical Background Questionnaire (IMBQ), assesses music listening habits, perceived music sound quality and appraisal, music preferences and enjoyment of music in particular everyday listening situations in adult CI users (Gfeller et al., 2000a). It consists of 21 items using different question types (multiple choice questions, Likert scales, visual analog scales and open ended questions). It was based on a previous questionnaire for children developed by the same research group. The authors interviewed 35 adult CI users and developed new items related, among others, to attitude and preference for music sounds. The new items were reviewed by experts (patients and professionals, including 6 CI users) twice until the final version was created. Using the IMBQ, Gfeller et al. (2000a) found that time spent for music listening post-implantation was generally less than before deafness for postlingually deaf CI users. Fifteen out of 65 participants indicated little satisfaction from music both before and after implantation. Enjoyment of music in specific everyday listening situations was rated on a 4-point Likert-type scale. A strong positive correlation between these ratings and post-implantation listening habits was found. However, 28/65 participants reported that, although less pleasant, some music was better than no music and also an improvement of music sound quality over time. No NH group was included for comparison and no statistical analysis was included to analyse changes in musical style preferences pre- to post-implantation. Although the IMBQ covers various aspects of music experiences, it does not include aspects such as self-perceived music listening abilities, feelings about music or participation in social music activities. Another disadvantage is that it uses different response options, which makes scoring and therefore comparisons difficult. Drennan and his colleagues had to categorise the responses in the 'Sound Quality Ratings' and 'Attitudes Towards Music' sections of the IMBQ into positive, neutral and negative to aid the analysis of results (Drennan et al., 2014). The IMBQ is not publicly available.

Table 2.1 Music questionnaires developed for and used with CI users.

Questionnaire	Aspects covered	Question type(s)	Validation
Iowa Musical Background Questionnaire [IMBQ] (Gfeller et al., 2000a)	Music listening habits, sound quality, appraisal, preference, enjoyment	Multiple-choice, Likert scales, visual analogue scales, open-ended questions	Expert review (face validity and refinement)
University of Canterbury Music Listening Questionnaire [UCMLQ] (Looi & She, 2010)	Music listening habits, sound quality, recognition	Visual analogue scales, closed-set and open-ended questions	Expert review
Music Munich Questionnaire [MUMU] (Brockmeier et al., 2002)	Music listening habits, sound quality, recognition, enjoyment, music making and practice	Likert scales, multiple choice, closed-set questions	Expert review, pilot testing (sequence of questions changed)
(Mirza et al., 2003)	Music enjoyment, listening habits	Likert scales, multiple choice, closed-set questions	No details of development/validation reported
Musical Engagement Questionnaire [MEQ] (Gfeller et al., 2012a)	Music engagement (participation and attitude)	Likert scales, multiple choice, closed-set questions	Expert review
Musical Stages Profile [MSP] (Vickers et al., 2007; Edwards, 2014)	Musical activities and responses to music	5-point Likert-scale	Expert review, test-retest reliability, internal consistency

The Munich Music questionnaire (MUMU) includes questions on everyday music listening habits, music quality ratings, music recognition, music enjoyment, and music activity (music making, practice with music) of postlingually deaf CI users, before and after implantation. Its items were developed by the authors and 32 implant users and music experts were recruited to improve the format and the content of the questionnaire (Brockmeier et al., 2002). Like the IMBQ, a limitation of the MUMU is that no uniform response format is used, with open and closed-type questions, rating scales, multiple-choice and multiple-answer questions. As a result, the questionnaire cannot produce a single overall score or domain scores of the involvement of CI users with music. In a study by Veekmans et al. the authors changed the response options to a uniform 5-point Likert scale in order to be able to perform statistical analysis with the data (Veekmans et al., 2009). They also had to compare scores for each question separately. Another disadvantage of the questionnaire is that some questions are broad and might not be sensitive enough to capture subtle differences in music experience, e.g. rating the enjoyment of different music styles in general on a '1 (no enjoyment) - 10 (great enjoyment)' scale. Despite its limitations the MUMU is the only one to date to deal with aspects such as everyday practice with music listening and music making. It is freely available online at: www.medel.com.

The University of Canterbury Music Listening Questionnaire (UCMLQ), was designed with the aim to collect information for the development of an auditory music training programme (Looi & She, 2010). It includes questions on musical background, music listening habits, music preferences, music styles and factors affecting music listening enjoyment. Importantly, a section on self-perceived music perception is included. In two sections of the questionnaire the listener is asked to rate the appraisal and sound quality of musical instruments and music styles compared to how they would expect it to sound to a NH person. The UCMLQ was developed after interviews with three adult postlingually deaf CI users and then pilot tested with nine more CI users who completed the questionnaire and were then interviewed on the clarity and appropriateness of the items (face validity). Overall, the quality of most musical instruments was rated by CI users as significantly different from what they expected and classical music received lower appraisal and quality ratings than other musical styles (Looi & She, 2010).

All the above-mentioned questionnaires were designed for postlingually deaf adult CI users. Although the present thesis and literature review focuses on adults, two music questionnaires developed for children with CIs are worth reviewing here because they address limitations of adult questionnaires. The Music Engagement Questionnaire (MEQ), developed by Gfeller and her team (2012), was designed for prelingually deaf adolescents and young adults who were implanted before 18 years of age and emphasises participation in musical activities and attitude towards music (at home, at school or outside) including the feelings of young CI recipients about music (Q10-12).

The items were adapted from an older questionnaire and were reviewed by experts and by CI users and improved. Overall, the authors demonstrated that at least their particular group of CI users had a positive attitude towards music and involvement with music (Gfeller et al., 2012a). Another interesting finding is that almost 2/3 of the participants rated music as important or very important for their life. This is an interesting finding given that prelingually deaf CI users have no NH experience of music listening. It is likely that the importance of music in life as well as the musical involvement and attitude of prelingually deaf (adolescents or adult) CI users depends on the extent of musical engagement within the family while growing up. Indeed, in the same study the authors found that high attitude and participation with music was correlated with high music involvement of the family (Q14) or within the family (Q16).

The Musical Stages Profile (MSP) was designed to study the development of musical behaviour in CI children and compare that with NH children. It uses a 5-point Likert scale ranging from Never to Always. It was initially developed by Vickers et al. (2007) after parental interview questions in key musical skill areas and was first evaluated with 15 NH children and 25 children with CIs. It was further optimised and validated by Edwards (2014). Fourteen experts in music and hearing were given the questions with the domain headings removed and were asked to allocate items into domains and to assess the clarity of the questions. An optimised version of the MSP was completed by parents of 52 children and the test-retest reliability and internal consistency of the questionnaire were evaluated. The use of a uniform rating scale and the developmental and validation process followed are advantages of the MSP over other music questionnaires designed for adult CI users.

2.3.5 Limitations of existing CI-specific music questionnaires

Existing CI-specific music questionnaires have a number of limitations. Firstly, they are based on relatively narrow concepts, such as ‘music enjoyment’, ‘music listening habits’ and ‘music appraisal’ and they were not designed to approach CI users’ relationship with music holistically. Each one of them covers different aspect of music listening and music experience (e.g. music sound quality, preferences, listening habits) but none of them assess music experience as a whole. For example, the UCMLQ includes self-reported music perception but does not assess everyday music enjoyment or activity as in the IMBQ or the MUMU. Therefore none of them can be used as standard tool to assess CI users’ music experiences. In addition, aspects of the relationship of CI users with music, such as everyday music practice, feelings about music or social interaction that is related to music or participation in music-related social activities, remain poorly covered overall.

Secondly, they have been designed to investigate rather than measure and, with the exception of the MSP, no uniform rating scale or question type is used across sections. They are not organised into domains and they use different answer types which makes them difficult to score. As a result, responses cannot be easily quantified. Researchers have had to adapt their response options to facilitate statistical analyses (Drennan et al., 2014; Veekmans et al., 2009). Moreover, existing questionnaires ask CI recipients to either rate how music sounds through their implant compared to a reference point, for instance ‘before implantation’ in Leal et al. (2003), or to make two different judgments, one referring to before deafness and another one to post-implantation (Mirza et al., 2003). Comparative judgements do not clearly reflect how music is perceived and appreciated with the implant at present (e.g. CI users may find music less natural than before but still enjoy it). In addition, reference points are not well-defined. For example asking patients to rate sound quality according to ‘exactly as I want it to sound’ or ‘how you expect it to sound to a person with normal hearing’ might have caused confusion, especially to prelingually deaf individuals or those who have been deaf for a long time.

A major limitation is that previous music questionnaires designed for CI users have not been developed based on a psychometric approach and there is no evidence for their reliability and validity for the adult questionnaires, although there is reliability evidence for the MSP. Content and face validity has been assessed in most of them (IMBQ, MUMU, UCMLQ, MEQ), it is unknown if, for instance, they assess what they are intended to assess and if they are sensitive to differences or responsive to change, properties required for a strong measure in research and especially for a measure to be appropriate to measure change in a clinical setting.

Although some music questionnaires have touched on the enjoyment of music in specific everyday listening situations, it is worth noting here the ‘Hearing Implant Sound Quality Index’ (HISQUI). The HISQUI is another questionnaire designed for CI users, which, although it is not specific to music, covers a range of realistic daily listening settings perhaps better that any other instrument. In the HISQUI the respondents have to rate 29 questions describing everyday listening situations using a 7-point rating scale ranging from ‘Always’ to ‘Never’. The statements are related to the quality of speech and everyday sounds such as human voices or environmental sounds as perceived through a CI. Four questions are music-related. Another advantage of the HISQUI over the existing music questionnaires reviewed here is that it has a uniform phrasing and a single rating scale across items and so it can produce an overall score of listening abilities in everyday life. Although items were initially developed by experts, item selection was done using responses from CI users and with the use of psychometric techniques (Amann & Anderson, 2014). Evidence for the reliability and validity of the HISQUI was also reported in the same study.

2.3.6 Conclusion

Despite the variability in self-reported music experiences, overall many adult (particularly postlingually deafened) CI users are dissatisfied with the quality of the music they hear and enjoy and engage with music less than before implantation. How positively CI users rate music and the pleasure they derive from it cannot be predicted from their performance in music tests only. It is unknown to what extent music perception scores reflect music performance, enjoyment and the music listening habits of CI users in the real world. Music-specific report-based measures developed for CI users may be able to capture real-world music experiences more accurately than music listening tests. Existing music questionnaires developed to collect self-reports of CI users about music experiences, among other limitations, have been designed to collect information and not to produce scores and measure changes; CI users' relationship with music has also not been fully explored. No questionnaire currently exists that covers all aspects of music experience, can be used as a measure, is appropriate for different groups of listeners or has been fully validated. Existing questionnaires may be unsuitable for specific groups of CI users (e.g. prelingually deaf CI users who have no prior music experience), hearing-impaired or even NH adults, which could be used to collect information and explore between-group differences.

2.4 The quality of life

2.4.1 Introduction

In addition to the limitations of previous music questionnaires designed for CI users that were presented above, these questionnaires did not take into account the impact of music on the quality of life (QOL) and were not designed to measure this impact. To investigate the impact of music on the QOL of CI users and to inform the development of a new questionnaire that addresses this limitation, this section will review the evidence for the effects of music on the QOL of adults without hearing problems, highlight limitations of previous approaches to explore the relationship between music and QOL in CI users and introduce QOL measures which will be used for the development of the new questionnaire. The evidence presented in this section will support the need and formulation of the 'music-related quality of life' (MRQOL) concept, which is the focus of this thesis and basis of the new questionnaire.

No standard definition for the QOL exists in the literature, although the term is commonly used. It is a multi-dimensional concept widely used in different sciences (e.g. health or social sciences but also economics and advertising) to describe the impact of various factors, such as services, scientific or technological advances or even music and religion on different aspects of the life of individuals, communities or general populations (Schalock, 2004; Bowling, 2001). The QOL is closely related to concepts such as 'well-being' but different disciplines have approached the concept from different perspectives depending on their research aims. In social sciences, for instance, QOL has been used to investigate the effects of cultural activities, arts and sports on well-being (Galloway et al., 2006). In health sciences, it has been introduced to measure the effects of health interventions in domains other than those targeted by the intervention.

This section will:

1. Review the evidence for the impact of music on the QOL of NH adults
2. Review the evidence for the impact of music on the QOL of adult CI users
3. Review the HRQOL measures used with CI users

2.4.2 Measuring the 'health-related quality of life' of adult CI users

The primary goal of cochlear implantation is the improvement of hearing and listening skills and CI research has mainly focused on the measurement of speech understanding. However, the benefits of CIs are not restricted to speech but cover a broad range of physical, psychological or emotional and social aspects of life, which, in the context of health, are conventionally referred to as Health-related Quality of Life [HRQOL] (Bowling, 2014:45; WHOQOL, 1993). The World Health Organisation (WHO) has defined QOL as: "an individual's perception of their position in life" and as a concept that is affected "by the person's physical health, psychological state, level of independence, social relationships, and their relationship to salient features of their environment" (WHOQOL, 1993). Three types of patient-report instruments have been used for the measurement of the HRQOL of CI users: utility measures, hearing-specific HRQOL questionnaires and HRQOL questionnaires designed specifically for CI users. See Table 2.2 above for a list of the HRQOL questionnaires used with CI users.

Table 2.2 *Questionnaires used to measure the HRQOL of adult CI users. In parenthesis, the number of domains for each instrument.*

<table>
<tr><th>Instrument</th><th>Domains</th><th>Validated/reliable with CI users?</th><th>Sensitive/responsive with CI users?</th></tr>
<tr><td>36-item Short Form Health Survey (SF-36)</td><td>(8) Physical functioning, role limitations due to physical problems, role limitations due to emotional problems, social functioning, pain, mental health, vitality, general health</td><td>No evidence</td><td>Significant improvements post-implantation (Krabbe et al., 2000; Loeffler et al., 2010; Damen et al., 2007; Hirschfelder et al., 2008)</td></tr>
<tr><td>Hearing Utility Index (HUI3)</td><td>(8) Vision, hearing, speech, ambulation, dexterity, emotion, cognition, pain</td><td>Ability to discriminate between severity groups (Yang et al., 2013), no evidence on reliability</td><td>Significant improvements post-implantation, (Loeffler et al., 2010)</td></tr>
<tr><td>EuroQOL (EQ-5)</td><td>(5) Mobility, self-care, usual activities, pain/discomfort, depression/anxiety</td><td>Some ability to discriminate between severity groups (Yang et al., 2013), no evidence on reliability</td><td>No evidence</td></tr>
<tr><td>Hearing Participation Scale (HPS)</td><td>(3) Self-esteem, hearing-related social participation and hearing handicap</td><td rowspan="4">No published evidence</td><td rowspan="2">Significant improvement postimplantation (Hawthorne et al., 2004)</td></tr>
<tr><td>Assessment of Quality of Life (AQOL)</td><td>(5) Illness, independent living, social relationships, physical senses and psychological well-being</td></tr>
<tr><td>Glasgow Benefit Inventory (GBI)</td><td rowspan="2">(3) generic health, physical health, social support</td><td>Significant improvement postimplantation overall and in the physical domain (Lassaletta et al., 2006)</td></tr>
<tr><td>Glasgow Health Status Inventory (GHSI)</td><td>No published evidence</td></tr>
</table>

Instrument	Domains	Validated/reliable with CI users?	Sensitive/responsive with CI users?
		No published evidence	
IRQF	(5) feelings for patient, communication, how hearing loss affects life, safety and welfare, hobbies and activities	Valid, reliable (Mo et al., 2004)	Significant improvement postimplantation in 4 of 5 domains (Mo et al., 2004)
PQLF	(6) relations to close individuals, feelings of being a burden and of belonging, how communication and hearing affect life, isolation and relations to friends, work, hobbies		Significant improvement postimplantation in 4 of 6 domains (Mo et al., 2004)
Nijmegen Cochlear Implant Questionnaire (NCIQ)	(3) Physical, psychological, social + 6 subdomains	Valid, reliable (Cohen et al., 2004; Hinderink et al., 2000; Baumgartner et al., 2007)	Significant improvement postimplantation in all subdomains (Cohen et al., 2004; Hirschfelder et al., 2008; Damen et al., 2007; Krabbe et al., 2000)
Cochlear Implant Function Index (CIFI)	(1) Function/ability	Reliable (Coelho et al., 2009)	No published evidence

In health economics, utility is the usefulness of or the preference for a health intervention. Utility measures assess HRQOL on a number of dimensions and use algorithms (which take into account the level of health state and how important it is) to produce single utility scores. The utility algorithms are developed using different techniques for the evaluation of the preference for a specific health outcome. Scores range from 0 (poor health) to 1 (perfect health) and when they are used in a pre-/post-intervention context they reflect the level of health gained by an intervention. These values can be then combined with survival estimates for specific populations to generate Quality-adjusted Life Years (QALYs), which are useful in cost-effectiveness analyses (Bowling, 2001; Harris et al., 1995; Wyatt et al., 1995). That use of utility scores is what makes preference-based measures particularly useful for the assessment of health interventions. QUALYs can inform not only how many years an intervention can add to a person's life but also the quality of the life to be added.

The utility measures that have been most widely used with adult CI users are three: the Health Utilities Index (HUI), the EuroQOL 5 dimensions (EQ-5D) and the Short-Form Health Survey(s), e.g. the 36-item (SF-36). The SF-36 includes 36 general health questions categorised in eight domains. It was not initially developed as a utility measure but later on the authors reported that a utility algorithm can be used to adapt the HRQOL scores into utility scores that can be used in economic evaluations (Brazier et al., 2002). Items are rated on a 5-point Likert-type rating scale (Ware, 2000). A classification system, the Short-form 6 dimensions (SF-6D) is used to transform the domain scores into a single utility score. The SF-36 has not been validated with adult CI users but in a few studies it has detected HRQOL benefits after cochlear implantation (for a review, see Loeffler et al. 2010). Shortened versions of the questionnaire are the SF-12 with 12 items (Ware et al., 1996) and the SF-8 with 8 items (Maruish, 2012). The EuroQOL 5 dimensions (EQ-5D) questionnaire, developed by the EuroQOL research group in the Netherlands, measures five health dimensions with a single item per domain. In the latest version (EQ-5D 5L), five levels of severity are included in each dimension instead of the three in the original version (EQ-5D 3L) (Herdman et al., 2011). It has been shown that the EQ-5D has some ability to discriminate between groups of adults with different degree of hearing loss including CI users (Yang et al., 2013). The latest version of the Health Utility Index (HUI), the HUI3 measures 8 attributes of health (Francis et al., 2002; Feeny, 2005). There is a single questionnaire item per domain. Respondents are asked to choose their level of functioning in each domain on a rating scale. Recently, Yang et al. (2013) reviewed studies including the HUI, SF36 and EQ-5D and assessed the evidence for their reliability, validity and responsiveness with hearing-impaired patients including CI users. They concluded that according to the studies they reviewed the HUI3 was rated higher in responsiveness to hearing impairments, but the evidence for the other two, especially for the SF-36 was in fact too limited for comparisons to be made (Yang et al., 2013).

Although utility instruments have the advantages that they are adaptable, used in a variety of situations and useful in economic evaluations, it has been shown that instruments designed specifically for hearing-impaired individuals are more sensitive to the benefits of CIs (Loeffler et al., 2010). In a study by Mo et al. for example, only one of the eight scales of the SF-36 showed a significant improvement post-implantation for a sample of 27 CI users whereas two hearing-related instruments produced better results; there was a significant improvement in four of the six domains of the Patient Quality of Life Form (PQLF) and four of the five domains of the Index Relative Questionnaire Form [IRQF] (Mo et al., 2005). Both instruments are concerned with the effect of hearing loss on the patient's life. In the PQLF patients rate 43 questions on a scale from 1 to 5. In the IRQF a patient's relative reports on the life experiences of the patient for 31 questions on a scale from 1-5. They were divided into domains (see Table 2.2 above) after factor analysis and evidence for the internal consistency of these subscales was presented (Mo et al., 2004). The PQLF and the IRQF had been previously used in a study by Maillet et al. and both showed a significant improvement from pre- to post-implantation in scores for adult CI users (Maillet et al., 1995). The Glasgow Benefit Inventory (GBI) measures the change in health status experienced by patients after otolaryngological surgery. It consists of 18 questions divided in three subscales (Gatehouse et al., 1998). Items are rated on a 5-point rating scale and both a total score and a subscale scores can be produced. Lassaletta et al. used the GBI with a group of postlingually deaf adult CI users and found significant positive changes pre- to post-implantation overall as well as in the physical domain for the 30 users who participated in the study (Lassaletta et al., 2006). A current-state version of the GBI, the Glasgow Health Status Inventory (GHSI), measures the health status of the patient at the time it is completed (Gatehouse et al., 1998). Hawthorne and colleagues found significant improvement three and six months post-implantation with both the Hearing Participation Scale (HPS) and the Assessment of Quality of Life [AQOL] (Hawthorne et al., 2004). The HPS is a shortened version of the GHSI with 11 questions measuring the effect of an intervention in the dimensions of self-esteem, hearing-related social participation and hearing handicap. The AQOL is not hearing-specific but a 15-item utility instrument that measures five dimensions of HRQOL.

The Nijmegen Cochlear Implant Questionnaire (NCIQ) is a HRQOL instrument specifically developed for CI users. Items were developed by experts based on intuitive judgment. Traditional psychometric techniques (test-retest realiability, Cronbach α, factor analysis) were used for questionnaire validation. The NCIQ consists of 60 questions related to a physical, psychological and social domain (see Figure 2.3 below for the HRQOL framework of the NCIQ) using a 5-point Likert-type scale (Never - Always). Three questions in the physical domain are particularly concerned with music, i.e. melody perception, rhythm perception, music enjoyment. The three domains are further subdivided into 6 subdomains and a separate score for each subdomain can be computed (Hinderink et al., 2000). The NCIQ has been extensively used as a measure of post-implantation HRQOL, has been validated and proved reliable (Baumgartner et al., 2007; Hinderink et al., 2000; Cohen et al., 2004). Direct comparisons with other measures have demonstrated that the NCIQ is successful in detecting benefits in QOL after cochlear implantation that remain undetected with other instruments, such as the SF-36 (Hirschfelder et al., 2008) or the HUI (Krabbe et al., 2000; Damen et al., 2006) with the NCIQ consistently showing significant improvement in HRQOL in all 6 subdomains as opposed to other instruments.

Other questionnaires developed specifically for adult CI users do not fully measure the concept of HRQOL, but focus rather on more functional aspects. An example is the HISQUI, measuring listening abilities in a range of everyday situations, which has been discussed already (section 2.3.4). Four questions of the HISQUI refer to music: single/multiple instrument recognition, recognition of phone rining, speech recognition in background music. Another example is the Cochlear Implant Function Index (CIFI) developed by Coehlo et al. (2009). It focuses on auditory ability (i.e. the physical component of the HRQOL concept). It measures the abilities of CI users in 6 different everyday listening settings, such as in noisy environments, with or without visual cues or in public events, on a 5-point Likert-type scale ranging from Always to Never. The psychological and social HRQOL dimensions are not covered, with the exception of one item that refers to activity limitations in different situations due to the CI. The items were developed based on the authors' experience and were also pilot tested with 44 CI users and improved. The authors demonstrated high internal consistency, but no evidence for test-retest reliability or construct validity was reported (Coelho et al., 2009).

Although measures designed specifically for CI users are more sensitive than generic HRQOL instruments to the benefits of cochlear implantation, they have only been validated with patients who receive their first CI and are not sensitive enough to the benefits of receiving a second CI. For that reason, questionnaires specific to bilateral CIs have been developed. For example, King et al. (2014) developed the 'Comprehensive Cochlear Implant Questionnaire' (CCIQ), a questionnaire specific to assessing the changes in HRQOL after receiving a second CI. The authors generated items for the new questionnaire after interviewing CI professionals, reviewing the literature and adapting items from previous questionnaires, which suggests some content validity. They demonstrated good test-retest reliability and internal consistency, but no psychometric evidence for validity (King et al., 2014). The development and use of questionnaires for bilateral CIs points out the need for sensitive and specific outcome measures rather than generic ones.

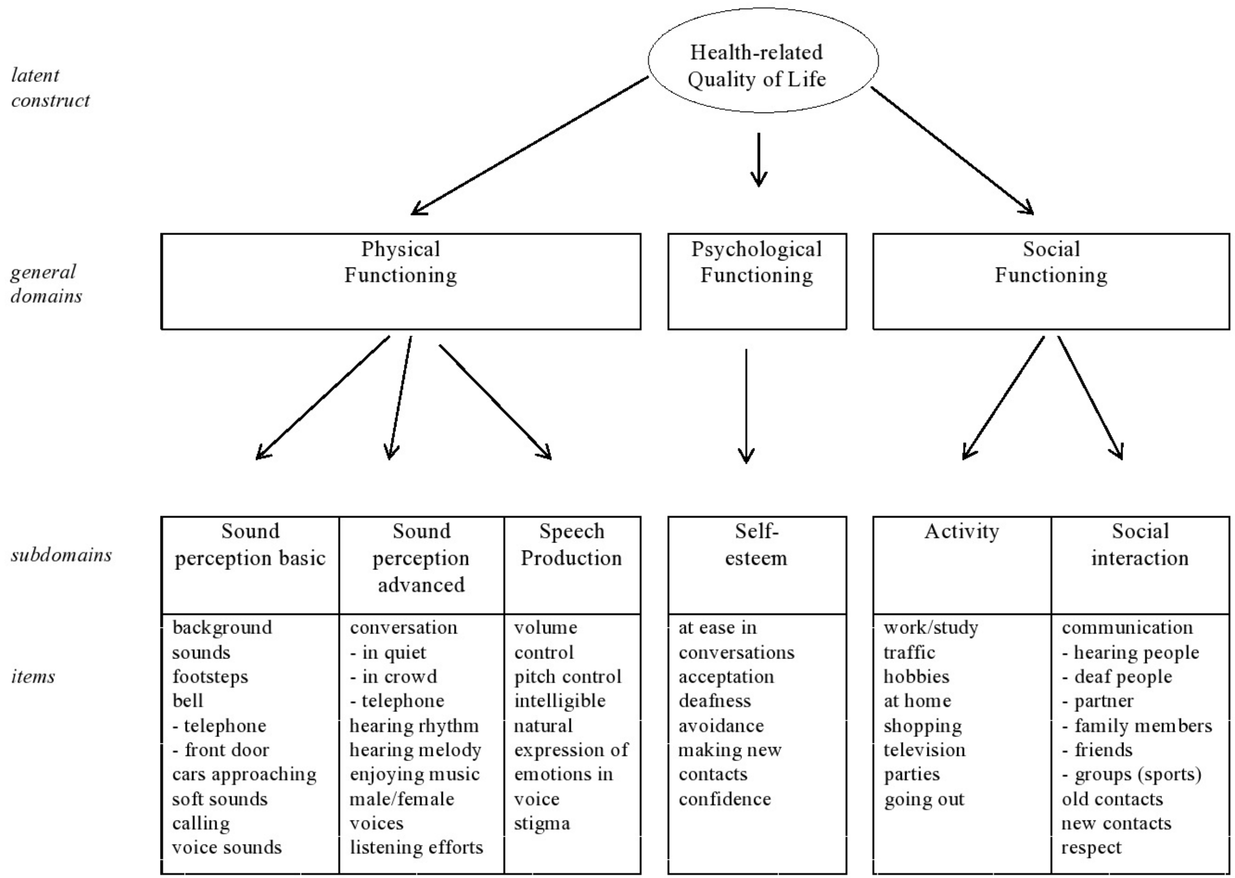


Figure 2.3 *Framework developed by Hinderink et al. (2000) as a basis for the development of the Nijmegen Cochlear Implant Questionnaire (NCIQ). Originally published in Hinderink JB, Krabbe PF, Van Den Broek P. Development and application of a health-related quality-of-life instrument for adults with cochlear implants: the Nijmegen cochlear implant questionnaire. Otolaryngol Head Neck Surg. 2000;123:756–65. © 2000 by the American Academy of Otolaryngology—Head and Neck Surgery Foundation, Inc.*

With regard to how music has been included in HRQOL studies, in addition to the three music questions of the NCIQ, other HRQOL questionnaires and also qualitative studies with CI users have also included music. Music perception or music sound quality is usually assessed under the physical domain (Zhao et al., 1997; Gatehouse & Noble, 2004). Music enjoyment and feelings about music, such as disappointment for the poor music perception and quality have been looked at in QOL studies involving CI users (Buhagiar, 2012; Zhao et al., 2008).

2.4.3 The impact of music on the QOL of NH adults

Studies in the broad area of music in life have used different methods [e.g. interviews (DeNora, 2000), neurophysiological evidence (Salimpoor et al., 2011)], age groups [younger (Laiho, 2004) and older adults (Laukka, 2007; Hays & Minichiello, 2005; Chan et al., 2012)], healthy adults or patients [e.g. with dementia (Cooke et al., 2010) or Parkinson's disease (de Dreu et al., 2012)], musicians and non-musicians and different settings [e.g. nursing home (Burack et al. 2002)]. Despite their differences though, all the studies in this area deal with aspects relevant to the QOL and agree that music can have positive effects on some aspect of the life of adults, especially by promoting psychological well-being.

A few of these studies have covered the concept of QOL directly by using either a QOL model or a QOL measure and have looked at the impact of music on different QOL domains (Lee et al., 2010; Coffman, 2002; Cooke et al., 2010; de Dreu et al., 2012). Coffman (2002) described QOL as a function of physical well-being (physical health and behavioural competence), psychological well-being (emotions, personal development and fulfilment), social relationships (interpersonal relations and social activities) and interaction with the environment, i.e. material comforts and life events (Figure 2.4 below). He reviewed music studies with healthy older adults and found evidence for the benefits of music listening and making activity on the psychological and social well-being. There was little evidence for effects on physical health (e.g. neural and psysiological responses to music) and no evidence for effects in the environmental QOL domain.

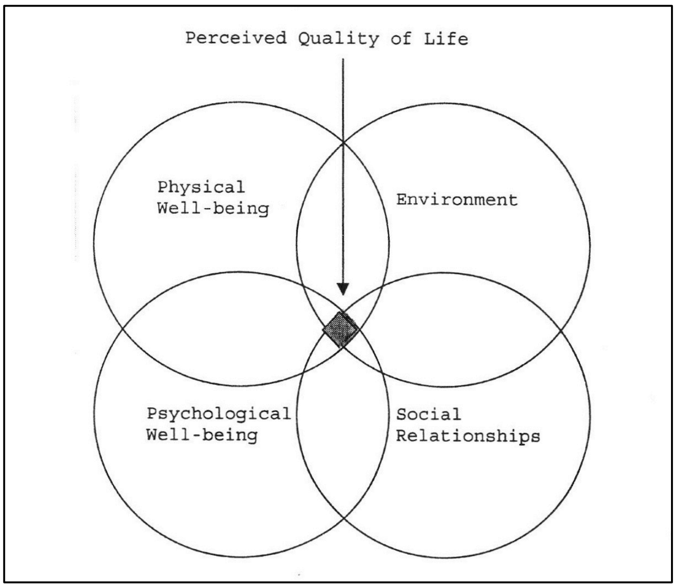


Figure 2.4 *The QOL model used by Coffman (2002) as a context to review studies on the impact of music on the QOL of older adults. Reproduced from: Coffman, D., 2002. Music and Quality of life in older adults. Psychomusicoloogy, 18, p.78. Printed with permission of the American Psychological Association.*

Other studies have used HRQOL instruments. For example, Lee et al. (2010) demonstrated the benefits of music interventions for the HRQOL of older adults using the Chinese version of the SF-36. In a randomised controlled trial two groups of 66 Chinese older adults (65-90 years old) either received a 30-minute home-based music intervention session per week for four weeks or had a four-week rest period[2]. In the music group QOL scores improved weekly. Overall, QOL scores were significantly higher for the music group compared to the control group. More specifically, in week 2 statistical differences between the music and the control group were found in the Physical Function (PF) subscale, in week 3 for (PF), Role-physical (RP) and General Health (GH) and in week 4 for all the 8 subscales: PF, RP, GH, Bodily Pain, Vitality, Social functioning, Role-emotional and Mental Health (Lee et al. 2010). Hilliard used a HRQOL measure specifically designed for patients with cancer to test the effects of music therapy on 80 hospice patients diagnosed with terminal cancer in a randomised controlled study. Participants in the experimental group who received music therapy sessions in addition to their routine hospice care achieved significantly higher HRQOL scores in the psychophysical function subscale than control subjects (routine hospice services only). HRQOL scores of the experimental group also improved over time

[2] Therefore, the improvement in the treatment group was likely to be due to a placebo effect.

as music therapy sessions continued. No significant effect as found for the other two HRQOL domains, functional and social (Hilliard, 2003). Although the studies on the therapeutic uses and the functions of music that were reviewed do not directly address the concept of QOL, in fact the issues covered correspond to the three main QOL domains. The benefits of music for physical health can be categorised under the physical QOL domain, the psychological functions under the psychological/emotional domain and the social aspects (e.g. ability of music to promote social connection and belonging) can be thought of as influence of music on the social QOL domain. Table 2.3 below is an organisation of issues related to music and QOL that were found in the literature according to the three main QOL domains, physical, psychological and social.

Other studies have covered concepts similar to the impact of music on the QOL, such as the functions of music (e.g. Schäfer et al., 2013) or music engagement (Chin & Rickard, 2012). Some of these studies come from the area of music therapy and look at how music can be used as a therapeutic method to improve QOL. For example, providing music therapy to adults diagnosed with depression in addition to their standard clinical care has been shown to reduce depression and anxiety symptoms and increase general functioning scores (Erkkilä et al., 2011). Studies in music psychology have looked at the different functions of music and the reasons why people listen to and make music. Laiho suggested that music in adolescence affects psychological well-being by enhancing identity, the sense of agency (i.e. concept related to control, competency, achievement, empowerment or self-esteem) by supporting interpersonal relationships and creating emotions (Figure 2.5 below). Recently, Schafer et al. provided further evidence about the psychological functions of music by proposing that music can help to regulate arousal and mood, increase self-awareness and the expression of social relatedness (Schäfer et al., 2013). Chin & Rickard (2012) suggested that people can engage with music also for cognitive purposes, as a social connection as well as for physical exercise (Chin & Rickard, 2012). Benefits of music for physical health have also been reported, especially for adults with physical disabilities e.g. supporting movement and rehabilitation in Parkinson's patients (de Dreu et al., 2012).

Table 2.3 *Organisation of the aspects of QOL on which music has an impact found in the literature and based on the QOL model of Coffman (2002). The 'Environment' domain was not included because no evidence was found for an impact of music on environmental aspects on the QOL and emotions were dinstinct from personal development factors, such as identity and agency.*

IMPACT OF MUSIC ON THE QUALITY OF LIFE			
Physical well-being	**Psychological well-being**		**Social relationships and activities**
	Emotions	**Personal development and fulfilment**	
Balance and movement (de Dreu et al., 2012)	Positive feelings (Burack et al., 2002; Laukka, 2007; Wood & Smith, 2004; Salimpoor et al., 2011)	Self-esteem, identity, meaning to life (Schäfer et al., 2013; Laiho, 2004; Ruud, 1997; Cooke et al., 2010)	Belonging-social relatedness (Cooke et al., 2010; Schäfer et al., 2013; Chin & Rickard, 2012)
Physical exercise (Chin & Rickard, 2012)	Entertainment and relaxation (Hays & Minichiello, 2005; Laiho, 2004; Forsblom et al., 2009)	Arousal, vitality, motivation (Schäfer et al., 2013; Laiho, 2004; Ruud, 1997; Forsblom et al., 2009; Wall & Duffy, 2010; Weller & Baker, 2011)	Social interaction (Laiho, 2004; Ruud, 1997; DeNora, 2000; Forsblom et al., 2009)
Supports physical rehabilitation (Weller & Baker, 2011; Sarkamo & Soto, 2012)	Reduces negative feelings (Chan et al., 2012; Wall & Duffy, 2010; Erkkilä et al., 2011; Sung et al., 2011)	Cognitive regulation, spirituality (Chin & Rickard, 2012)	Engaged production (Chin & Rickard, 2012)
Relieves pain reduces postoperative symptoms (Nilsson, 2008; Guetin et al., 2009)		Memories (Hays & Minichiello, 2005)	Action-general functioning (DeNora, 2000; Erkkilä et al., 2011)

Very few studies have explored the extent the impact of music on QOL is compared to that of other activities. For instance, it has been repored that for teenagers (13-14 years old), listening to music is more important in life than other indoor but not outdoor activities (North et al., 2000), whereas undergraduate students (M_{age}=20 years old) would spend significantly more money each month on music than on any other of the nine activities investigated [indoor or outdoor] (Lonsdale & North, 2011). It is likely that the impact of music on the QOL is affected by individual differences such as degree of music training, age and preferences. With regard to age, in the same study by Lonsdale and North (2011) it was repored that overall people <30 years old found music significantly more important and were spending significantly more time with music than older participants, which was attributed not to age directly but to age-related change in preferences. There was a decrease in music listening overall for participants >30 years old. However, social interaction was still an important reason for participants up to 50 years old (and then less important for >50).

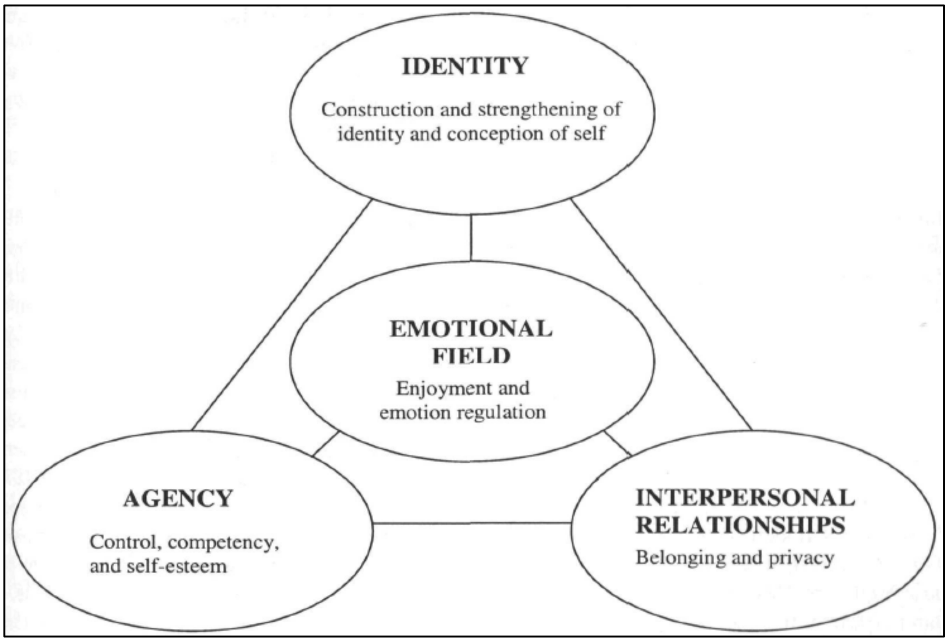


Figure 2.5 *Laiho's categorisation of the psychological functions of music in adolescents (Laiho, 2004). Reproduced with permission from: Laiho, S. (2004). The Psychological Functions of Music in Adolescence. Nordic Journal of Music Therapy. 13 (1). p.pp. 47–63.*

2.4.4 Music and QOL in adult CI users

Very few studies have investigated the relationship between music and QOL in adult CI users and only by correlating music ratings and QOL scores obtained from different measures (Lassaletta et al., 2007; Zhao et al., 2008; Fuller et al., 2013). Two of these three studies have demonstrated significant positive correlations between music enjoyment or music sound quality ratings and QOL. Zhao et al. (2008) reported that for 11 out of 24 profoundly deaf adults who participated in the study, improvement in the QOL pre- to post-implantation was significantly positively correlated with an improvement in the enjoyment of music. Music enjoyment was rated on a single visual analogue rating scale ranging from 0-100 and participants used a similar scale to rate the effect of their hearing loss on their QOL. A significant correlation between perceived music quality and QOL was found in two studies by Lassaletta and colleagues (Lassaletta et al., 2007, 2008a). Both studies used a modified version of the IMBQ, to assess musical sound quality and listening habits pre- to post-implantation and the Glasgow Benefit Inventory (GBI) to evaluate changes in QOL after implantation. A significant positive association between perceived musical sound quality and QOL was found in both studies with CI users who gave positive scores for the adjective descriptors 'sounds like music-doesn't sound like music', 'natural-mechanical' and 'easy to follow-difficult to follow' having higher GBI scores. In the 2007 study it is also reported that QOL scores were higher for users who spent more hours listening to music after implantation. It remains unclear, however, whether an association between the two suggests that improved perceived music sound quality or more hours listening to music result in an improvement in QOL or vice versa. Yet, these findings confirm anectodal comments by postlingually deaf CI users about the importance of music and the benefits for the emotional and social aspects of their life and offer further support for the impact of music on the QOL of CI users (Gfeller et al., 2000a). For example, CI users in the study by Gfeller et al. (2000) reported that music brings back something that was missing from their life, helps them feel connected to the hearing world and enjoy life more and allows them to participate in social events, such as holiday celebration or concerts.

In contrast to the above-mentioned findings, no correlations have been found between music enjoyment and QOL for prelingually deaf adults implanted in adolescence (Fuller et al., 2013). Music enjoyment was measured by the Dutch Musical Background Questionnaire (DMBQ); a Dutch and modified version of the IMBQ, and QOL with the (NCIQ). The absence of a correlation between music enjoyment and QOL was attributed by the authors to the specific characteristics of the CI group tested. Prelingually deaf, late-implanted CI users not only have very limited – if any – experience with music before deafness but also a prolonged period of deprivation before being implanted. It is possible that they perceive and interpret music in a different way than other CI users. Indeed, 12/ 20 participants reported music to sound pleasant after implantation. It can also be assumed that due to long-term limited exposure to music, music has a small impact on their perceived QOL.

2.4.5 Summary

Three conclusions can be drawn from this section:

1. Studies in the area of music and QOL agree that music has a positive impact on the lives of adults without hearing problems, although the variety of methods used makes it difficult to draw conclusions about the quality and strength of the evidence.
2. CI-specific HRQOL questionnaires are more sensitive to the effects of cochlear implantation than generic or hearing-related ones. HRQOL measures include music poorly and as a result they are unable to capture music-specific changes.
3. A few studies have demonstrated that music enjoyment and perceived music sound quality is significantly correlated with HRQOL. However, it is unknown if these correlations can be interpreted as impact of music on the QOL. It is also unknown in what way music affects the QOL of CI users, e.g. which music experiences are important for each individual or which aspects of the QOL music impacts on.
4. The following knowledge gaps follow from the above: ‘Can a concept incorporate both music and QOL?’, ‘Can a new psychometric instrument measure the impact of music on the QOL?’

2.5 The need for a new music-specific outcome measure: evaluation of music rehabilitation

2.5.1 Introduction

CIs offer reasonably good speech recognition in favourable listening environments to some recipients, with subsequent psycho-social benefits (Lassaletta et al., 2006). However, the large variability in speech outcomes indicates that the improvements in speech performance do not generalise to the CI population as a whole. Also speech understanding in noisy environments and the accurate perception of music remain challenging. Poor perception of music results in difficulty to enjoy music and therefore to a decrease in music listening habits. Although for speech perception some benefit can be obtained by incidental everyday experience, in the case of music perception and enjoyment incidental everyday exposure with the implant does not seem to produce benefits for the majority of CI users (Gfeller et al., 2010).

Given these limitations, Limb and Roy (2013) have suggested that improvements in music perception and enjoyment may be achieved through (a) technological advances in CI design and (b) music auditory training. This section reviews the evidence about the potential of new technologies and auditory training to benefit music perception and enjoyment. The need for music-specific outcome measures in clinic is also discussed.

2.5.2 Technological advances in CI design

There is evidence that bilateral implants, bimodal listening (combination of a CI and a contralateral HA) and EAS can offer better music perception and appreciation than conventional CIs. In the case of contralateral HA or EAS this is due to the use of residual acoustic hearing. In a study by Gfeller et al. (2006) users of hybrid CIs scored significantly better in the recognition of songs and in musical instrument recognition than users of conventional long-electrode implants. In another study, Veekmans et al. (2009) used the MUMU to investigate the potential benefits of bilateral CIs for music enjoyment and listening habits. They reported that the responses of bilateral CI users were generally more positive than unilateral CI users and that responses to most questions were more similar to those of NH adults than unilateral CI users. However, the way the MUMU responses were quantified and how differences between groups were measured both need to be considered (see section 2.3.4). It has also been reported that adults with a HA contralateral to the implant perform better in pitch perception and melody recognition than those with a CI only, due to the use of residual hearing (Peterson & Bergeson, 2015).

Other CI technologies with the potential to improve music perception and enjoyment are related to processing strategies. Although it is not clear yet whether speech processing strategies offering higher spectral detail can have a positive impact on the appraisal of music sound quality or on musical activities, new processing schemes with emphasis on pitch information have been found to improve performance in music perception tasks. Laneau et al. (2006) demonstrated that providing finer F_0 information can improve musical pitch discrimination and familiar melody recognition. A study by Rosslau et al. (2012) further showed that better activation of low frequencies can result in better discrimination between different emotions in music. Another strategy with emphasis on low frequency information, the FSP from MED-EL, has potential to offer better music sound quality perception than high-definition continuous interleaved sampling (Roy et al., 2015; Looi et al., 2011). Adams et al. compared the AB HiRes 120 (offering increased temporal and spectral detail) with older strategies with regard to music perception and presented evidence that HiRes 120 can result in better scores for self-reported music listening and enjoyment (Adams et al., 2014). More evidence for the benefits of new processing strategies on music perception and enjoyment comes from Li et al. (2013) who found that a new processing strategy with emphasis on conveying pitch cues resulted in significant improvement in timbre recognition and some improvement in melody recognition (Li et al., 2013).

The effects of improvements in electrode design (von Wallenberg & Briggs, 2014) and the effects of increasing the number of effective channels or the rate of excitation (Wilson & Dorman, 2008b) on the perception and enjoyment of music yet need to be investigated . Di Nardo et al. (2011) showed evidence for an improvement in MCI and also in self-reported melody perception after individual frequency mapping. The authors acknowledged the need for self-report measures to detect real-life CI outcomes that cannot be captured with music listening tests (Di Nardo et al., 2011). Other authors have also presented evidence to suggest that customising the frequency allocation of the processor based on pitch perception has the potential to improve music perception (Grasmeder & Verschuur, 2015). At the same time, novel techniques such as the combination of auditory with vibro-tactile information has potential to offer an alternative towards improving music perception and perhaps appreciation for CI users (Papadogianni-Kouranti, 2014).

2.5.3 Auditory music training for adult CI users

For adult CI users, 'auditory training aims to produce the maximum benefit for the listener given the physical limitations of the implant' (Clark 2003:654). To achieve this, CI users need to adapt to auditory sensations that are not only poor, but in the case of postlingually deaf adults, also different from those experienced before hearing loss. There is some evidence that training can significantly improve performance in formal speech perception tests for hearing impaired adults, although there is little evidence for generalisation of the improvement to untrained outcomes and for functional benefits (Henshaw & Ferguson, 2013).

Auditory training may also have potential to provide benefits with music perception and enjoyment. The potential of auditory music training is supported by the better performance for musicians over non-musicians (Kraus & Chandrasekaran, 2010) as well as by the so-called star performers, i.e. CI users who achieve scores comparable to NH listeners (Maarefvand et al., 2013).

There is also some evidence that short-term computerized auditory music training[3] can produce significant improvements in music appraisal/satisfaction as well as in the perception of some aspects of music by adult CI users, especially the identification of musical instruments.

The first study to show such benefits was back in 2000 by Gfeller and her colleagues who examined the effects of a home-based music training programme, consisting of forty-eight 30-minute sessions scheduled four times per week and including melody recognition training and recognition of musical instruments. They reported significant pre- to post-training improvement for the recognition and appraisal of complex melodies as well as in the recognition scores and sound quality and appraisal ratings of musical instruments (Gfeller et al., 2000b, 2002b).

In the 'melodic contour identification' (MCI) training programme designed by Galvin et al. (2007) participants were repeatedly exposed to five-note melodic sequences comprising nine different pitch contours. The difficulty level was increased by introducing smaller between-note intervals when the participant achieved a certain level of correct responses. At the end they were tested also with a closed set MCI. Six adult CI users were trained at home or in the lab for 1½ hour or 3 hours per day everyday for a period ranging from 5 days to two months. Mean MCI performance was significantly improved pre- to post-training for all subjects, for all intervals. The benefit was largely retained one month (and for two subjects two months) after training. Mean performance in a familiar melody identification (FMI) task was significantly improved which suggests some generalisation of the training benefit to non-trained tasks. Anecdotal reports of the participants suggest improvement in the appreciation of music (Galvin et al., 2007). However, it is unclear whether the benefits demonstrated in both studies can generalise to real-word benefits because the same stimuli or tasks were used for training and testing.

Another study confirmed that short-term music training can produce benefits for musical instrument recognition by using CI simulations. Driscoll and colleagues compared the effects of three training approaches on the ability of NH listeners to recognise CI simulations of musical instruments (Driscoll et al., 2009). Greatest improvement was found for the 'direct instruction' group (maintained benefit after training), the 'feedback training' group achieved the next highest level of improvement and the 'repeated exposure' group showed modest improvement but no maintenance of the benefit. Significant improvements occured with three weeks of instruction, however, further and sustained benefits were only observed after five weeks of training. The results

[3] Short-term perceptual training provided to CI users and other hearing-impaired individuals as part of aural rehabilitation and should by no means be confused with long-term training in the form of music classes received by musicians.

of this study also supported training methods which include some kind of feedback rather than pure exposure to musical stimuli.

More recently, in line with the findings by Gfeller et al. (2002), van Besouw et al. (2015) reported significant improvement for musical instrument recognition after training with the Interactive Music Awareness Program (IMAP). They also showed some retention of the benefit after 12 months. The IMAP is a computer-based music rehabilitation resource with 24 half-hour structured sessions with listening exercises allowing users to manipulate music, subtitled video tutorials, written instructions, YouYube listening tasks and music perception tests. In a randomised, controlled crossover trial, sixteen adult CI users completed 12 weeks of training at home with two-half hour sessions per week. They were tested before receiving the training, halfway through the 12 weeks and at the end of the trial on instrument recognition and melodic contour identification (with different stimuli to those used during training), speech-in-noise perception and also gave sound quality ratings and reported music listening habits (van Besouw et al., 2015). No statistically significant difference was observed for these measures but anectodal feedback at the end of the trial suggested positive impact that could not be captured with the outcome measures used.

2.5.4 Need for report-based measures in clinic

The evidence presented above suggests that report-based measures may be useful at capturing real-life outcomes of music rehabilitation. In addition to this, in clinic, report-based tools can also overcome limitations of speech recognition tests, such as that they are language-specific or that they are not appropriate for prelingually deaf recipients (Harris et al., 2013). It has also been shown that questionnaires can sometimes capture clinical differences or symptoms more accurately than formal listening tests. For example, Barry et al. (2015) showed that their 'Evaluation of Children's Listening and Processing Skills' (ECLiPS) questionnaire was more sensitive to the cognitive aspects of 'Auditory Processing Disorder' than behavioural measures (Barry et al., 2015).

However, use of questionnaires in clinic poses a number of difficulties. In order to be clinically informative and appropriate to be used in routine clinical appointments, report-based measure need to be efficient, sensitive, specific and psychometrically robust, i.e. reliable and valid. Sensitivity refers to the ability to detect existing differences between individuals or differences before and after an intervention, while a specific measure should find differences only when they exist and not detect irrelevant differences. While these requirements are not unique to clinical questionnaires, efficiency is particularly important in clinic, due to the limited time of routine appointments. Efficiency refers to practical features: a clinical tool should be brief and easy for the patient to complete and for the clinician to administer, score and interpret. Also, the psychometric properties required for a questionnaire to measure individual differences in clinic are different than those needed for the measurement of group differences in research studies. Specific requirements have been recommended, e.g. test-retest reliability of >0.90 and Cronbach α (for internal consistency reliability) of 0.90 – 0.95 (McHorney & Tarlov, 1995). Due to these requirements, as well as the lack of efficiency, research tools are rarely appropriate to use in clinical practice. Instead, there is a tendency for tools to be developed specifically for the clinic. Such tools are not meant to be comprehensive but they should be practical and should indicate rehabilitation needs; they are often clinician-administered.

Existing music questionnaires designed for CI users may be inappropriate to use in the clinic for reasons explained earlier (e.g. lack of validity, difficult to score). Drennan et al. (2014) performed a large scale study in a clinical setting including the IMBQ and suggested that the IMBQ is appropriate to use in clinic. However, the difficulty to score and the time for completion (may be as long as 25 minutes) could be an issue (Drennan et al., 2014). In addition to evaluating the wider impact of a music-focused intervention on music experiences, a new measure that captures music experiences in a holistic way could have a number of other clinical applications. For example, it could be used by clinicians as an additional assessment to monitor progress with music and inform the patients themselves about their progress. With the provision of distant rehabilitative services in audiology gradually increasing (Swanepoel & Hall, 2010), it could also be a tool for remote self-assessment via the internet, e.g. as an alternative for patients who are unable to come to the clinic.

2.5.5 Summary

Auditory music training, new processing schemes and other technologies have the potential to improve music perception performance for adult CI users, but strong evidence for their real-world effects (e.g. increased participation and QOL) in needed. Such evidence, in addition to evidence for an improvement in music perception scores, could promote the use of music rehabilitation in clinic and inform clinicians, patients and health funders with regard to how much time and money they should invest for aural music rehabilitation (Limb & Roy, 2013). Existing music questionnaires developed for CI users are inappropriate to measure benefits of music rehabilitation in research or clinic for reasons explained earlier, e.g. lack of validity (section 2.3.4). Although some of the existing music questionnaires have been used to measure CI outcomes in laboratory settings (Brockmeier et al., 2007) and in the clinic (Drennan et al., 2014), analysis of the results was problematic. There is a lack of a music-specific outcome measure suitable for assessing benefits of music rehabilitation; such a measure could also potentially be a tool for routine clinical assessments.

Chapter 3. Overview of questionnaire development

3.1 The research problem

Adult CI users achieve satisfactory speech comprehension at least in favourable listening environments despite the physical limitations of the implant. However, the poor transition of spectro-temporal information makes pitch-based tasks such as speech recognition in noise or the perception of acoustic musical elements challenging for most CI users. With regard to music, there is evidence that adult CI users score poorly in tests of pitch, timbre and melody perception, although they perform similarly to NH adults in rhythm perception. In addition, CI users report poor music quality through the implant, poor music enjoyment and limited musical activity post-implantation. These outcomes have been linked with poorer QOL scores but the impact of poor music perception and enjoyment on the QOL of CI users has not been directly examined.

There is some evidence that new music-focused CI technologies and auditory music training have the potential to improve CI users' music perception and enjoyment. However, at the moment there is poor evidence regarding their effectiveness, which makes the provision of music rehabilitation limited. While music perception tests can detect improvements in the perception of fundamental elements of music, self-reports can record real-world changes in music experiences, which may also be related to the QOL. Although many validated music perception tests and batteries exist and are being widely used, existing music questionnaires that have been designed for adult CI users (IMBQ, MUMU, UCMLQ) may not be appropriate to be used as outcome measures because, among other reasons, they have not been assessed for their psychometric properties (reliability and validity), which are required for an instrument to be a strong measure. It is also unknown whether music experiences have been fully explored to date. Besides, existing instruments do not assess the impact of music experiences on the QOL; it is crucial to detect improvements in the QOL as this is the ultimate goal of aural rehabilitation. The importance of music and the impact of music on the QOL of CI users is not yet fully understood.

In this context, it is proposed that a new music-specific self-report instrument that would be appropriate for measuring music rehabilitation outcomes and the impact of music experiences on the QoL is needed.

3.2 Aims

This thesis set out to fill the gap for a new validated music questionnaire for adult CI users that overcomes limitations of previous ones and assesses the impact of music on the QOL.

In particular, the aims of this thesis were to:

1. Develop a new questionnaire that overcomes limitations of previous music questionnaires designed for CI users (primary aim)
2. Assess the reliability and construct validity of the new questionnaire (primary aim)
3. Investigate music experiences and introduce a new concept that will link music and QOL for CI users

Investigate the impact of music on the QOL of adult CI users and the measurement of this impactThese aims address the knowledge gaps and research problems described in 1.1, chapter 2 and 3.1 above.

3.3 Methodology, rationale and developmental process

Two approaches have been used for the psychometric development of questionnaires, classical test theory (CTT) and item response theory (IRT). CTT dominated the field of psychometrics until at least the 1950's. It has been popular and widely used because it is appropriate in most situations and its techniques for scale construction are relatively easy to apply. However, it has a number of limitations, which are primarily related to assumptions about the data (Streiner et al., 2015:273-275). For example, CTT assumes that respondents treat the interval scales of all items as equal and therefore all items contribute equally to the total score. To address such limitations of CTT, a new framework has been developed, which is commonly referred to as item response theory (IRT). In contrast to CTT, which is based on averages of the items, IRT focuses on information of the individual items; each item corresponds to an underlying attribute and the performance of a subject on a test depends on how much of the attribute a person must have to endorse an item and how much of the attribute they have. The amount of the attribute that an item needs in order to be endorsed, the amount of the attribute a person has and the relationship between them, i.e. the probability of a person endorsing an item depending on how much of the attribute they have can all be calculated using mathematical models which also take into account the type and number of response categories (Reeve & Fayers, 2005). Among the advantages of IRT over CTT are the interval-level properties of the scale. However, it is still under debate if and when the assumptions made in CTT can be justified and to what extent a scale developed based on CTT has interval-level properties or not, especially with large sample sizes (Streiner et al., 2015:299). Moreover, IRT uses complex mathematical processes which require experience to apply correctly and assumes unidimensionality whereas the MRQOL construct was proposed to be multidimensional.

In this context, CTT was considered more appropriate for the purpose of the present project. In addition to the above, use of CTT allowed the use of standard psychometric techniques extensively used in the development of HRQOL and hearing-related measures, as well as questionnaires for CI users, e.g. the NCIQ, the HISQUI or the ECLiPS (Hinderink et al., 2000; Amann & Anderson, 2014; Barry et al., 2015). This ensured that the development and validation of the MRQOL questionnaire builds on previous studies and established approaches in the area of hearing-related questionnaires. Yet, it differed from previous studies and approaches on the development of music questionnaires for CI users in particular in ways that will be explained in the following chapters (e.g. involving CI users in the item generation stage, assessing the reliability and validity of the new questionnaire, proposing a method to assess the impact of music on the QOL).

CTT for questionnaire development includes (1) the generation of a large pool of items, (2) completion of these items by the population of interest, (3) selection of items with the use of psychometric techniques, (4) assessment of the psychometric properties of the questionnaire, i.e. reliability and validity (Streiner et al. 2015: chapter 5). In this thesis, a focus group study was conducted to allow item generation (chapters 4 and 5), questionnaire responses were collected for psychometric item selection (chapter 6) and a combination of approaches was used for validation (chapter 7). See Figure 3.1 for a flowchart of the developmental process.

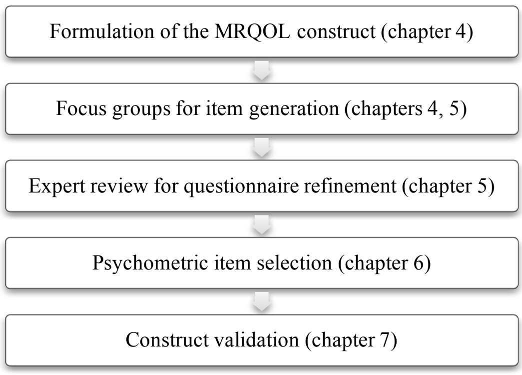


Figure 3.1. *The process of the MRQOL questionnaire development.*

3.4 Reliability and validity

Reliability and validity are statistical properties used to describe the measurement abilities of a scale (Streiner et al. 2015: chapter 5). Reliability is the ability of a questionnaire to produce the same results under the same conditions. It is usually measured by testing the same people over time (test-retest reliability or repeatability) or whether different parts of the questionnaire produce similar scores (homogeneity or internal consistency). Validity is the ability of a questionnaire to measure what it is intended to and can have different types (Hays, R. & Revicki, 2005; Streiner et al., 2015: chapters 8, 10). See Table 3.1 below for the different types of validity. Poor repeatability means poor precision of a measurement and reduced ability to detect changes, whereas validity refers to whether the true value is measured. Another psychometric property that is necessary for a questionnaire to be good measure, especially in clinic, is sensitivity or responsiveness to change. It is usually assessed separately from validity but it has been argued that it is essentially an aspect of it (Streiner et al., 2015). It is the ability of a measure to discriminate between individuals or groups who actually differ in the construct of interest. Use of these psychometric techniques for item selection and questionnaire validation purposes is common among HRQOL questionnaires (e.g. Hinderink et al., 2000). However, in the development of music questionnaires for CI users, use of psychometric techniques is limited (Looi & She, 2010; Gfeller et al., 2000a; Brockmeier et al., 2002; Edwards, 2014).

Different reliability standards have been recommended depending on whether a questionnaire is intended to be used to compare groups or individuals. For an investigation at the group level, where mean scores rather than individual scores are used, reliabilities between 0.70 and 0.80 are sufficient. However, when individual scores matter and small score differences between individuals can make a difference in making decisions regarding a treatment, a reliability of at least 0.90 is required to minimise measurement error (Nunnally & Bernstein, 1994: 264-265).

Table 3.1 *Types of validity required in scale development (Streiner et al. 2015: chapter 10).*

Content validity	The extent to which the items of a questionnaire are sufficient and relevant for the population it is intended to cover and the issues under examination
Face validity (type of content validity)	Whether the items of a questionnaire appear to be measuring what they are supposed to ‘at face value’
Criterion validity	The performance of a measure is checked against a ‘criterion’. Ideally measured by comparing measurements to real-world observations but usually by assessing how well the new questionnaire correlates with an established measure of the same attribute that is treated as a gold standard
Construct validity	Whether a questionnaire measures the theoretical construct of interest. Usually assessed in two ways: either by assessing how well it predicts differences between two groups known to differ in the attribute of interest (known groups) or by seeing how well it correlates with another questionnaire that measures the same or different construct (convergent and discriminant validity, respectively)

Factorial validity (type of construct validity)	Do items cluster together into meaningful factors?

3.5 Ethical considerations

All the studies reported in this thesis were approved by the UK National Research Ethics Service (NRES) [14/EM/0140, Appendix A.1], the University of Southampton Faculty of Engineering and the Environment Ethics Committee and the University of Southampton Ethics and Research Governance Office (ERGO) [8264]. A substantial amendment was submitted to both NRES and ERGO and approved before the beginning of Study 3 (ERGO amendment ID: 17065).

Chapter 4. MRQOL concept and focus groups

This PhD research intended to develop a questionnaire that would approach music experiences of CI users from a holistic perspective. This chapter first introduces the concept of music-related quality of life (MRQOL), which was the basis of the questionnaire development. The rest of the chapter covers a focus group study with adult CI users, which, on the basis of the MRQOL concept investigated music experiences under the scope of the study, produced the MRQOL framework. The focus groups findings were then used as a basis for the generation of items for the new questionnaire (Chapter 1.).

4.1 Formulation of the MRQOL concept: the theoretical basis of the project

The distinction between music perception (perception of rhythm, pitch, timbre and melody measured with formal music tests) and music appreciation (self-reported music appraisal, sound quality, enjoyment, background and listening habits) that is traditionally used in the adult CI literature has already been discussed in section 2.3 (Looi et al., 2012). Additional concepts have been used in the paediatric literature to describe CI users' relationship with music, e.g. music engagement (attitude and participation) or music activities and responses to music (Gfeller et al., 2012a; Edwards, 2014; van Besouw et al., 2011) [also see section 2.3.4]. However, all these concepts are relatively 'narrow' and do not fully cover CI users' music experiences. This has already been discussed as a limitation of existing music questionnaires designed for CI users that were based on such concepts (section 2.3.4). As a consequence, dimensions of music experience such as feelings about music or social participation have not been fully investigated and understood so far. Therefore, there was a need for a new concept.

Concepts and conceptual frameworks are useful at explaining the key things to be studied and the relationships between them. In the development of measurement scales, defining a concept and its component domains is common when no appropriate concept or no standard definition of a concept exists. For example, Mullensiefen et al. (2014) defined the concept of 'musical sophistication' and suggested its hypothetical facets, before generating items for the 'Goldsmiths Musical Sophistication Index' (GOLD-MSI). Sometimes a concept is approached from a different angle and its content needs to be reconsidered. The NCIQ was a HRQOL designed specifically for CI users, therefore the subdomains and themes of HRQOL had to be adapted for CI users (Hinderink et al., 2000). The construction of new concepts and frameworks is usually based on literature review and expert input, as in the studies above.

The assumptions behind the new concept were based on three pieces of evidence seen in the literatrure review, namely that music has an impact on the QOL of adults without hearing problems (section 2.4.3), that the music enjoyment/appraisal/listening of adult CI users has been associated with their HRQOL (section 2.4.4) and that a few HRQOL questionnaires and studies have included music, e.g. the three music questions of the NCIQ (section 2.4.2).

Based on this evidence, the following hypotheses were made:

1. Mapping the music experiences (listening tasks, enjoyment, activities) of adult CI users onto a HRQOL model (i.e. the physical, the psychological and the social dimensions of HRQOL) may allow aspects of music experience poorly addressed so far to be explored
2. The performance of CI users in certain music listening tasks, the degree they enjoy music, how positively they evaluate the quality of the music or their music-related activity have an impact on HRQOL
3. The impact of music on the QOL can be directly measured

In this context, it was proposed that 'Music-related Quality of Life' (MRQOL) of CI users refers to aspects of the QOL[4] of CI users that are related to music (multidimensional concept) and to the QOL of CI users as a function of music or the impact of music on the QOL. The impact of music on the QOL of CI users would be relative to the importance each individual assigns to the various musical abilities, feelings or activities. When music was important, it would have a high impact on the QOL and when it was not important it would have a low impact on the QOL. This approach is similar to QALYs used in economic evaluations whereby individuals assess not only aspects of the QOL but also the preference of individuals for them (Brazier & Deverill, 1999). Also see section 2.4.2.

[4] The WHO has defined QOL as 'an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns' (WHOQOL, 1993). The WHO definition of QOL is used throughout this thesis.

Table 4.1 *Schematic representation of the hypothetical dimensions of the MRQOL construct. The domains and subdomains were adapted from the NCIQ HRQOL framework (Hinderink et al., 2000).*

Construct	**Music-related Quality of Life**					
Domains	**Music- related physical functioning**			**Music-related psychological functioning**	**Music-related social functioning**	
Subdomains	Music perception basic	Music perception advanced	Music production	Music-related self-esteem	Musical activity	Music-related social interaction

Hypothetical MRQOL dimensions had to be defined as a first step towards discovering the aspects of QOL of CI users that are relevant to music. The HRQOL framework used for the development of the NCIQ was used and its domains and subdomains were adapted to be music-specific. This formed the hypothetical MRQOL dimensions (

Table 4.1):

Music-related physical functioning: physical properties of music and the ability of CI users to accurately perceive fundamental (basic music perception) or other elements of music (advanced music perception) as well as to make music as intended (music production). It corresponds to some extent to what has been commonly referred to in the CI literature as music perception.

Music-related psychological functioning: internal positions of CI users about music, such as feelings about music or the impact of music on how CI users feel about themselves. It covers what is traditionally known as music appreciation and enjoyment. It could also cover the appraisal of music sound quality.

Music-related social functioning refers to active engagement with music and to the ability of music to promote social interaction. It partly overlaps with some of the issues studied under ‘music listening habits’ in the CI literature.

These hypothetical MRQOL domains and subdomains served as a basis for the analysis of the focus group data in the next step of the MRQOL questionnaire development; music-specific themes were generated. The framework developed as data were collected and analysed and as the questionnaire was developed. This process would also verify whether the NCIQ domains and subdomains were appropriate to classify music experiences of CI users. Very few studies that developed hypothetical domains for the development of a new questionnaire have actually verified them with empirical data (Müllensiefen et al., 2014). The underlying assumptions of the MRQOL construct, i.e. if the construct assesses what it intends to assess (construct validity), also needed to be validated.

4.2 Focus groups with CI users (Study 1): background and aims

After defining the MRQOL concept, collection of qualitative data was necessary to explore music experiences under the scope of the study and to determine the exact aspects of QOL that are related to music for CI users. It has already been discussed (section 2.4.4) that the relationship between music and QOL in CI users had been poorly investigated previously. It was unknown if the impact of music on the QOL and the areas of QOL that music had an impact for CI users are the same as for other groups, e.g. NH adults. Therefore, the music experiences and the role of music in the life of CI users in particular had to be explored. Generally, the use of input from the population of interest in questionnaire development ensures that the content and the language of the questionnaire are appropriate for the target population and helps the researcher gain a better insight and broader view of the topic (McColl, 2005).

Focus groups on everyday music experiences were run with adult CI users, with a view to determining items for the new instrument. ‘Focus groups’ are small discussion groups where people focus on a specific topic by interacting with each other. The interaction between the participants is their advantage over individual and group interviews where no communication between participants exists or is encouraged. In a focus group participants can, among others, express and explain their opinion and highlight different aspects of the topic under discussion. A downside is the lack of confidentiality, which can potentially create embarrassment to some of the participants especially when discussing sensitive topics (Kitzinger, 2006). In health sciences, focus groups are particularly popular among the different qualitative research methods (Kitzinger, 2006). In previous music studies involving CI users though, where qualitative methods were used for the selection of questionnaire items, individual interviews were preferred (Looi & She, 2010). Focus groups were thought to be the most appropriate method for the present study, because it was believed that CI users would be more encouraged to share personal experiences and feelings about music in a focus group than in an interview setting. Van Besouw et al. (2013) demonstrated that interaction between CI users in a focus group[5] setting can offer useful information on their attitude towards music. Participants themselves can benefit too, from realising that their problems are common among CI users (Plant, 2012).

The aims of the focus groups were:

1. To investigate music experience under the new scope
2. The generation of a large pool of items for a prototype questionnaire
3. To test the assumptions and evaluate the hypothetical domains and subdomains developed in section 4.1

The rest of the sections in this chapter refer to the focus group study.

4.3 Design

4.3.1 Recruitment

One-hundred and three (103) postal and 181 email invitations were sent to patients of the University of Southampton Auditory Implant Service (USAIS) who satisfied the inclusion and exclusion criteria (Table 4.2 below). Nine USAIS patients, attendees of a music workshop were invited separately. A study advert was also sent to the chairman of the National Cochlear Implant Users Association (NCIUA) for circulation to their members. No special interest in music or certain level of music experience was required.

4.3.2 Participants

Thirty (30) adult CI users (12 male, 18 female, mean age: 49.5, age range: 18-87) participated in six focus groups on everyday music experiences and the role of music in their life (see Appendix

[5] The use of the term ‘music focus group’ in the music rehabilitation literature usually refers to sessions of music activities (i.e. a ‘music workshop’) where group discussion is only a secondary activity. This should not be confused with the use of the term focus group as a qualitative research method, which is adopted throughout the present thesis.

B.1 for focus group participant demographics). Five participants were prelingually deaf (i.e. congenitally deaf or deaf < 3 years old) and nine reported that they had received some music training. Seventeen had a CI in one ear, two had bilateral implants and 11 had a HA contralateral to the implant. Twenty-two of the 30 participants were over 58 years old which had implications for the representativeness of the findings (Figure 4.1 below). Twenty-eight participants were recruited through the University of Southampton Auditory Implant Service (USAIS) using postal or email invitations. One participant was recruited through the NCIUA after responding to a study advert and one participant indicated an interest to participate in the study directly to the researcher.

Table 4.2 *Inclusion and exclusion criteria of the focus group study.*

Inclusion criteria	**Exclusion criteria**
- Adults (>18 years old) - CI users - Fluent in spoken English - Able to read English - Able to travel to the USAIS - Capable of giving informed consent - 50% or higher in the BKB sentences speech test or any other test of speech perception in noise used or self-reported ability to communicate in a focus group setting	- Communicating with British sign language or need of an interpreter - Visual impairments that would hinder performance in written tasks - Unable to read English - Cognitive deficits that would hinder discussion or performance in written tasks

There is no agreement in the literature about the ideal sample size of a focus group. The amount of data that is generated and whether the range of the sample is appropriate for the topic of interest are perhaps more important than the sample size itself (Kitzinger 2006). The sample size of the present study was considered sufficient and representative of the relationship of adult CI users with music, because of the amount of data collected, the diversity of the groups (in terms of age and other characteristics) and the repetition of certain patterns across sessions. The number of participants per focus group was between 4 and 6 (M=5). For topics considered important by the participants and where participants are expected to be willing to share their opinion and feelings, a group size of 5-6 people has been recommended (Krueger & Casey 2009: 67).

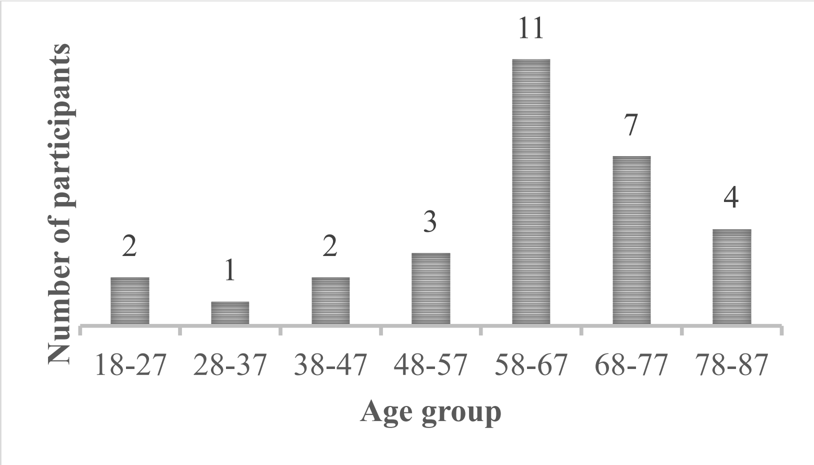


Figure 4.1 Age distribution of focus group participants.

4.3.3 The focus groups

Six sessions were held in a seminar room at the University of Southampton campus between June and July 2014. The sessions were 2-hour long and were divided into two parts. The first part was a group discussion on everyday music activities, the challenges of music listening, feelings about music and the role of music in everyday life. One researcher was present, who acted as the facilitator by asking broad open-ended questions to help the discussion and ensure that aspects of the HRQOL that were related to music were addressed, i.e. music listening (questions 3, 4), music enjoyment difficulties, feelings about music (1, 4, 5) and limitations in activity, participation and socialisation (1, 2). The questions were developed by the researcher after consultation of members of the USAIS staff. In the first session the researcher was accompanied by a trained audiologist. Discussions lasted between 45 minutes and 1 hour and were audio-recorded upon consent. The recordings were transcribed verbatim between June and September 2014 by the researcher and fully anonymised. For parts of the recordings where the researcher was unsure, a native English speaker was consulted.

The second part of the focus group was a written evaluation of selected relevant items from existing questionnaires (Appendix B.3). Participants were given a list of statements describing music listening tasks and activities and were asked to rate each of them according to how important the task or activity is in their everyday life as well as make optional comments on the wording of each statement. The purpose was to assess the degree to which items of existing music or CI questionnaires were appropriate for use in the new measure. Participants' ratings supplemented the discussion data and were also explained by it. The results of the existing item evaluation informed the generation of items and were presented and discussed in section 5.1.2.

4.4 Data analysis

4.4.1 Discussion data

The transcribed data from the discussion were analysed based on the theory of ‘template analysis’ (King, 2012). ‘Template analysis’ is a particular type of ‘thematic analysis’[6] of qualitative data where themes are organised into a coding template. The codes are organised hierarchically so that broad, high-level codes can contain codes representing narrower themes in the data. This type of ‘hierarchical’ coding helps the researcher to better explore participants’ experience. It is possible to include codes in the template that do not represent themes but help in grouping other themes together. The analysis often starts with pre-defined a priori themes, reflecting areas expected in advance to be important for the analysis, in contrast with purely inductive techniques such as the original grounded theory (Glaser & Strauss, 1976) where themes are identified only in the data. A priori themes are used tentatively and can then be modified depending on how well they explain the data. This differentiates TA from purely deductive approaches, e.g. the framework approach (Pope et al., 2006). An ‘initial template’, incorporating a priori and new themes, is produced after the coding a sample of the data and it is then used for the analysis of the rest of the data. The final version of the template developed at the end of the coding process is then used by the researcher as a tool to interpret the data.

Among the various qualitative data analysis techniques, template analysis was considered as the most appropriate method for the present study because:

- It is ‘thematic’, which was necessary for the development of questionnaire items through themes
- It combines both inductive and deductive techniques which allowed both the hypothetical MRQOL dimensions to be used and new themes, domains and subdomains to arise from the data
- It is more flexible than e.g. grounded theory, where theoretical sampling has been recommended (Pope et al., 2006)

[1] When used without a reference the term ‘thematic analysis’ refers to any way of analysing the content of qualitative data using themes or categories. When it refers to a particular technique reference will be given.

- The use of a template would result in a MRQOL framework that could be further developed. For that reason it was preferred over the general thematic analysis described by Braun and Clarke (2006).

The analysis of the data was performed on paper and using Nvivo 10 (QSR International Pty Ltd., 2012). Coding the data on paper faciliated additional comments and links between parts of the data and therefore better understanding. This was particularly useful at the initial stages of coding. The use of Nvivo helped organise comments together into themes, themes into domains and subdomains and finally result in a final template; it also helped to modify codes and subdomains during the coding process.

In 'thematic analysis', the importance of a theme does not necessarily depend on the number of occurrences in the data but rather on how well it captures something crucial in relation to the research question (Braun & Clarke, 2006). In the present study, the range of themes that were identified was more of interest than the popularity of individual themes because the themes would be transformed into questionnaire items that would all be equally important.

A comment was coded as a theme if it could be measured on a rating scale, it was particularly related to music and was related to limitations of the deafness or the cochlear implant. Themes were determined according to the MRQOL concept and hypothetical dimensions: according to the music dimension measured. For example, the physical MRQOL domain covered physical aspects of music perception. Or in the case of self-esteem or feelings it was how confident CI users feel with music that was of interest to the MRQOL concept. Comments were not coded as themes when they referred to music preferences, musical background, music listening strategies (e.g. use of subtitles or direct input), the importance of music in life or whatever participants reported as unimportant.

4.4.2 The quality of the data analysis

Despite the subjective nature of qualitative research, it has been argued that when qualitative analysis is used for practical applications, such as health policies, an assessment of the quality is necessary (Yardley, 2000). Whether the quality criteria used in quantitative research (reliability and validity) can be applied in qualitative research is under debate and many researchers have proposed alternative criteria (Bryman, 2012). Among the quality checks that have been recommended for and used with template analysis in particular are critical comparison between researchers and the provision of audit trails, i.e. a detailed report of the steps of the analysis (King, 2012).

In the present study, quality checks were performed at all stages of the data analysis:

1. Specific coding criteria were used and the development of the template was reported in detail, ensuring that the analysis was done systematically
2. The coding was discussed with an expert in music and CIs who was involved in the study. The expert critically assessed the themes for their content (i.e. whether they were coherent and appropriate) and to ensure that they were distinct from each other. As a result of this review, changes in the template were made. This process was repeated several times from the initial coding to the end of the analysis.
3. It was necessary to ensure that all the relevant themes were identified in the data, because the analysis of the focus group data aimed to the generation of questionnaire items covering a wide range of music experiences. For that reason, a researcher with experience in qualitative research and in working with hearing-impaired adults who was not involved in the current project, coded a sample of the data (two focus group transcripts) using the final template with the code definitions and assessed the template in terms of how well it represented the data. Disagreements in coding and potential changes to the template were discussed.

No statistical calculation of inter-rater agreement was used, because agreement between raters on the coding of specific comments was less important than the range of themes identified. Although independent coding for the purpose of critical comparison is common in template analysis (Lewis, 2014), inter-rater reliability calculation has not been recommended because it violates the assumption that qualitative data is open to a variety of interpretations[7].

4.4.3 Evaluation of items from existing questionnaires

Statements rated as 'important' or 'very important' by ≥80% of the participants were considered for use in the protptype questionnaire. This percentage was decided by convention and was informed by questionnaire expert review studies (Arranz et al., 2004; Hyrkäs et al., 2003). The participants comments and ratings also informed the content and wording of the questionnaire items. The combination of this method with the focus group discussion data ensured that that the questionnaire built on existing instruments. For the results of the existing item evaluation and how they informed the item generation, see section 5.1.2.

[7] http://www.hud.ac.uk/hhs/research/template-analysis/technique/quality-and-reflexivity

4.4.4 Producing the template

The hypothetical MRQOL subdomains (section 4.1,

Table 4.1) were used as broad a priori categories to organise themes that were identified in the data and ensure that musical abilities, attitudes and activities corresponding to important QOL dimensions were not overlooked. However, a priori categories were treated as tentative and subject to changes to avoid limiting the scope of the analysis.

An initial template was developed after coding of the first transcript (Appendix B.4), in the following way:

- Comments corresponding to one of the a priori subdomains were coded as such and themes were identified within each subdomain; at this stage all the *a priori* categories were retained. Then the transcript was read again for new themes, i.e. comments that did not correspond to any of the a priori categories, to be identified.
- Two new subdomains were developed under the 'Music-related Psychological functioning' domain: 'Feelings about music' and 'Music appraisal'. This was in order to cover issues not strictly related to self-esteem, such as pleasure or enjoyment of music or the frustration about how music is perceived through a CI. Self-esteem refers to how individuals feel about themselves, e.g. how satisfied they are with themselves or if they think they are good at something or useful (Warner-Czyz et al., 2015; Kobosko et al., 2015). However, the 'Self-esteem' subdomain of the NCIQ model also included items such as irritation, anxiety or happiness.
- Three themes would not fit in any of the subdomains or form a new subdomain on their own and were grouped as 'Uncategorised' at this stage: 'Music is relaxing', 'Concentration/Listening effort', 'Casual music listening'.

The initial template was then used for the coding of the rest of the transcripts and the following changes were made:

- In the physical domain the distinction between 'basic' and 'advanced' perception which was used by Hinderink et al. (2000) for speech, was replaced by: 'perception of elements of music' and 'perception in particular listening scenarios'.
- The 'music production' subdomain was deleted and the theme 'ability to sing in tune' was merged with 'ability to play a musical instrument in tune' into: 'ability to hear yourself singing/playing a musical instrument in tune' under the 'perception of elements of music' subdomain. Poor ability of CI users to sing or play a musical instrument in tune reflects difficulty to hear whether they are in tune or not, rather than motor or other difficulties in production.
- In the 'psychological functioning' domain, the subdomain 'general attitudes towards music' was inserted to include 'avoidance' and 'perseverance' which were not related to self-esteem, feelings or appraisal of music.
- The themes 'dancing' and 'participation' moved from the 'activity' subdomain to the subdomain 'social interaction' whose scope was extended and it was renamed 'participation and social interaction'.
- The theme 'music making' formed a subdomain on its own and in addition to 'singing' it included 'musical instrument playing' and 'music lessons'.
- From the uncategorised themes, 'concentration-listening effort' and 'casual music listening' were merged and formed the theme 'ability to hear music casually with little effort or concentration' under 'physical functioning' > 'music perception in particular listening scenarios'.
- 'Music is relaxing' was merged with 'pleasantness'.

After these changes the final template was developed (Appendix B.5).

Overall, the independent researcher considered the final template sufficient to describe the data but raised several issues:

- Overlap between themes, e.g. frustration with music' and 'annoyance by music sounds'
- Potential confusion between themes, e.g. 'ability to recognise musical instruments' and 'ability to distinguish between musical instruments' or 'ability to understand audio-only music in quiet' and 'in noise'. A suggestion to avoid this was either to clarify the theme labels or to put emphasis on the important words.
- Themes under 'negative feelings' could be split into smaller themes in the same way as 'enjoyment' themes
- Overlap between Music sound quality attributes such as 'discordance' and 'perception of elements of music'.

These issues were discussed would be considered together with the feedback from professionals, the patients and the NH adults in the next stages.

4.5 Results

Only the findings from the analysis of the focus group discussion data are presented here. The results of the evalualtion of existing items from the focus group participants (Part of the focus groups) and how they informed the generation of items are presented in section 5.1.2.

Three MRQOL domains and nine subdomains were developed and themes were identified in each subdomain. The MRQOL of CI users is a function of their 'music listening abilities', 'attitudes towards music' and 'musical activity' (Appendix B.5). These three domains were assumed to correspond to the physical, psychological and social HRQOL domains according to the hypotheses and proposed MRQOL concept described in 4.1. The purpose of this hypothesised correspondence was to allow a broad investigation of music experiences and identification of psychosocial aspects poorly covered previously. The validity of the three-dimensional construct (i.e. a construct with three dimensions/domains) was verified later at the item selection stage with the factor analysis and internal consisntency of the new questionnaire.

In this section, the presentation of selected themes and their discussion is organised around the three domains and illustrated with quotes from the participants.

MUSIC LISTENING ABILITY

This domain corresponds to the 'physical' HRQOL domain because it refers to the perception of the physical properties of the music. It also corresponds to what is referred to in the CI literature as 'music perception'. Themes were grouped under two subdomains. The subdomain 'Perception of elements of music' refers to the ability to perceive what has been referred to as 'fundamental features', i.e. pitch, rhythm, melody and timbre (McDermott, 2004). For example, the ability to detect pitch differences when listening to music has been assessed by music perception tests (Kang et al., 2009) and by questionnaires, such as the Music Munich (MUMU) questionnaire (Brockmeier et al., 2002): "can you distinguish between high and low notes?". The difficulty to perceive pitch can also affect an individual's ability to sing or play an instrument in tune:

> *"But I realise there are a lot of people who know the songs and we know, we would love a chance to do it but we have to keep quiet because it's not in tune"* (P8)

('Ability to hear yourself singing in tune')

The difficulty of CI users to sing in tune should be interpreted as the result of poor ability to perceive pitch differences of their own voice rather than physical singing limitations:

> *"Do you know of wrong notes? You don't know if a note is wrong."* (P11)

The perception of timbre has been traditionally assessed by musical instrument recognition tests and questionnaires in previous studies (e.g. "Are there musical instruments you can recognise?" (Looi & She, 2010), "which instruments can you detect well?" (Brockmeier et al., 2002)). A more advanced timbre perception ability was identified in the present study:

> *"Still, as I say, classical music, you know, concertos, is still very difficult. Cause I can hear, I can't. It's very difficult to get the full benefit of it as it used to be because you can't differentiate all the different sounds"* (P3)

('Ability to distinguish between different musical instruments in a mixture')

Other components of music included in the 'Perception of elements of music' subdomain are:

- The lyrics of songs:

> *"And I think when I listen to music now I'd like to be able to try to hear the words"* (P1)

('Ability to hear the words in music')

- The emotion in music:

> *"I think it's sometimes getting the emotion just, you know you've said it earlier. Cause a lot of songs do have meanings. Whether it is a happy song or a sad song or about a topic in particular like you said singing on a football terrace is. And I think that's a thing you want to try and get from it isn't it? What the song is about? What kind of emotion you should be feeling. Just because it's got maybe enough beat doesn't mean it's a happy song. You know the lyrics can be downright, depressing."* (P7)

('Ability to perceive the emotion of music')

The perception of the emotion of music refers to the accuracy of CI users in perceiving the emotional content of music, i.e. whether a piece of music sounds happy or sad. For example, Ambert-Dahan and colleagues (2015) showed that the performance of postlingually deaf CI users in judgements of musical emotions was poorer than that of NH adults for some (happy, scary, sad) but not all emotion categories (e.g. not for peaceful excerpts). CI users were also poorer than NH adults in perceiving the arousal of musical pieces, i.e. how relaxing or stimulating music is, but there was no difference between the groups in the perception of pleasantness (Ambert-Dahan et al., 2015). The emotional content of music should not be confused with the emotions evoked by music, i.e. the feelings of the listener after listening to a piece of music, as in Rosslau et al. (2012). Support for the classification of the perception of emotion of music under the physical domain of MRQOL comes from evidence that the tempo (beats per minute) and the mode or key of the music are the most prominent acoustic cues to emotions, with the happy-sad distinction being the most robust (Lantz & Cuddy, 2002; Dalla Bella et al., 2001). Brockmeier et al. (2011) confirmed these findings by reporting a high correlation between the tempo of the piece and its emotional response.

The ability to perceive music can also refer to the general understanding of music in various everyday situations. For instance, participant 12 says:

> *"We go to bands' concerts at Eastbourne bands, which is near to us and more often they can strike up a tune and I'll be trying to hear what it is and I often say to V2, what are they playing?"*

('Ability to understand music in public music events')

The challenge here was not the perception of a specific element but rather the ability to recognise music in a concert. Such listening tasks were coded under 'Perception of music in particular listening scenarios'. This subdomain covers among others the perception of music in different listening environments, included in the Iowa Musical Background Questionnaire (IMBQ) of Gfeller et al. (2000). Other themes in the same subdomain are:

- 'Ability to understand music using audio-visual media', which refers to listening to music with additional visual cues, e.g. watching music on television:

  > *"Even when I watched Songs of Praise on television and I was saying to him "I don't get anything out of this"* (P2),

- 'Ability to understand familiar music', i.e. music that you have heard before:

"I've been to the theatre a few times and I came home and I thought "well I should have known two, at least two of those songs". And I didn't recognise them" (P4),

- 'Ability to hear music casually without effort or concentration'

"Well I really have to concentrate on listening to music. I don't just have the radio on on music as I'm moving from room to room or working in the kitchen or anything like that. If I want to listen to music I might sit down and either watch and listen to it on television" (P15).

In a study by Bartel et al. (2011), the attention that CI users have to pay while listening to music was found to play an important role in the perception and enjoyment. In the same context, respondents of the Munich Music questionnaire (MUMU), were asked to indicated whether they listen to music as their main focus of concentration (Brockmeier et al., 2002).

The word 'understand' was not used here strictly with the meaning of comprehend or interpret, but had a broader meaning and was rather used as synonym of perceive, follow, or recognise. It was preferred over these because it was commonly used by the participants in the context of:

- Recognise a familiar song:

"Don't laugh but one of them was taking off all the Beatles songs which I liked and I could understand what they were." (P25)

"My wife plays her CDs all the time. Some I understand, the old-fashioned ones." (P14)

"But basically the institute, when I first had my implant they told me to listen to nursery rhymes so we got some from the library in there but a lot of the nursery rhymes I've not even heard of. I could only understand like humpty dumpty and Jack and Jill and things like that" (P19)

- Identify musical instruments:

"I wouldn't have known you're deaf, you understand all the bits, all the instruments in it" (P16)

- Recognise lyrics:

"so I mean I may not understand all the lyrics" (P18)

- *Follow the tune:*

  "But I still enjoy it cause I can understand the tune." (P3)

- Most often it was used a general term and may refer to any of the above:

  "But some things on CDs aren't very good for me at all, on a CD player, I don't understand now." (P23)

  "So you could bring more percussion in, which is easy to hear, into the song and therefore they made it easy to understand." (P3)

  "But I think I'm fine on the radio. It sort of helps my memory working. I listen without thinking hard so I can actually understand some of the music." (P6)

ATTITUDE TOWARDS MUSIC[8]

This domain describes the internal positions of a CI user with regard to music and refers to qualities of music one can appreciate and engage with. It roughly corresponds to the psychological HRQOL domain since it covers feelings of CI users about music as well as feelings about their own music listening abilities (music-related self-esteem). Feelings about music can be positive, such as pleasure:

> *"I have to say I've enjoyed 'Britain's got talent' recently cause it's, you know, there's a lot of people been singing on it and, like you say, it's something that I've been able to follow, it's been quite... [smiling]"* (P5)

('Enjoyment of music listening')

Music enjoyment was here defined as the degree to which a CI user derives pleasure from listening to music, making music or participating in public music events. The enjoyment that CI users derive from music listening overall has been assessed by questions like: "How much did/do you enjoy

[8] The term 'attitude' has been previously used in one of the domains of the IMBQ' the 'Attitudes about music' domain included questions about whether CI users listen to music or avoid it, how important it is for them and if they enjoy it (Drennan et al., 2014).

listening to music?", "Listening to music after your CI, are you [Very disappointed – Very satisfied]" (Mirza et al., 2003). Music enjoyment in specific listening environments, such as on the radio or at live concerts has also been assessed before (Gfeller et al. 2000).

There are also negative feelings about music, such as disappointment or frustration, which have also been previously reported by several authors (Gfeller et al., 2000a; Mirza et al., 2003; Migirov et al., 2009; Plant, 2012):

> *"I shouldn't have music with other noise, with speech or whatever, I find that incredibly tiring and upsetting that you go in to a restaurant and there's background noise. No-one is listening to it I want to say: "One in six people have a hearing deficit. Why are you playing it when no-one is listening to it?". It doesn't give ambience to me. It actually causes me a lot of distress"* (P29)

('Frustration with music')

This comment also highlights the function of background music at a restaurant to create ambience. Other functions of background music (at the restaurant as in the example but also in a film or on TV) are to set the scene or convey a mood (Boltz et al., 1991).

The confidence of CI users with their ability to understand music is an example of a self-esteem issue:

> *"I still stand at the back of my gym class when the music is playing and people are doing the, you know, sort of keep fit stuff and there's Zumba dancing because I need to watch everybody else, I'm not confident enough to… I hear it but I'm not sure I'm hearing exactly the same as everybody else. And so I stand at the back as I've done for quite a lot of years now and just make sure that I can follow everybody else"* (P27)

With the exception of music enjoyment, the feelings of CI users about music have been poorly addressed by existing music questionnaires.

In addition to the purely emotional issues the 'attitude' domain includes what CI users think about the quality of music sounds and their general attitude towards music. Participant 9 for example, says:

> *"But I did not enjoy that Carol service. And it put me off and I was a bit reluctant to go"*

('Avoidance of music')

Although it is commonly reported that CI users listen to music less post-implantation than before deafness (Leal et al., 2003; Lassaletta et al., 2007) and even less so for older compared to younger adults (Mirza et al., 2003; Looi & She, 2010), only Gfeller et al. (2000) informally reported that CI users actively avoid music post-implantation. Participant 10 also says:

> *"I've not tried hard enough with music. I've been sort of concentrating on other things in my life rather than music. My husband bought me a radio which I'm ashamed to admit but I never turned it on but I'm going to now, sorry"* .

('Perseverance with music').

The persistence of CI users in music listening was touched on by Bartel et al. (2011) who identified 'determination' as a theme in their interviews (Bartel et al., 2011).

The 'Music appraisal' subdomain includes comments referring to how positively or negatively participants describe the way music sounds to them and not to preferences or 'liking' of particular music sounds (e.g. musical instruments).

Participants reported finding music annoying in certain listening situations, e.g. background music in public places:

> *"That's the only time I won't appreciate the music on is if it's if I am you know having dinner or trying to talk to my friends we're just at the table and they've got like normal people do they might have put a CD on and then I don't like it…" (P28)*

('Annoyance by background music in public places')

Background music was addressed separately from music as a main activity or active music listening also in the *activity* domain below.

'Annoyance by music sounds' refers to how acceptable specific music sounds or types of music are, e.g.:

> *"High pitch irritates me"* (P6)

('Annoyance by high pitch')

It is therefore different from negative feelings like frustration, which are overall attitudes towards music.

The sound quality of the music may also affects CI users' enjoyment of and the general attitude of CI users towards music:

> *"But on the radio I switch it off because it sounds racket, that's the best word I could use" (P20)*

('Music sounds/does not sound like noise')

> *"If it sounds discordant which it often does particularly if there's a lot of strings then I switch it off."* (P29)

('Music sounds/does not sound discordant')

Musical harmony is the quality of music that determines how discordant it sounds. In CI users, perceived harmony has been assessed with ratings, where listeners are asked to rate musical chords from harsh (dissonant) to melodious (consonant) (Brockmeier et al., 2011; Rosslau et al., 2012).

Another theme related to music sound quality is:

> *"I think this is maybe why I don't listen to it, because it's not how I feel it should sound" (P10)*

('Music sounds/does not sound "as it should"')

This corresponds to tasks where listeners rate the naturalness of a musical stimulus on a rating scale or questions about whether music sounds 'as before' (Looi et al., 2011; Looi & She, 2010; Gfeller et al., 2000a; Brockmeier et al., 2002). Because both concepts are usually relevant to postlingually deaf CI users only, a phrasing appropriate to congenitally deaf CI users, who have no prior normal-hearing memory of music, was chosen. The difference between prelingually and postlingually deaf CI users was raised by participants:

> *"But because you've been deaf from birth you have no way of knowing whether what you are hearing is the same as somebody else's hearing who hasn't got a hearing loss. This is my problem at the moment, I don't know whether I'm … I'm not hearing what other people are hearing but I'm enjoying it." (P22)*

and the scope of the theme was broadened to cover occasions where music does not sound right or correct:

> *"And hear like the men and then women and their voices sound as they should be." (P10)*

> *"I don't like it if it doesn't sound correct." (P29)*

Music sound quality was classified here under the psychological domain to be consistent with the music-CI literature where music sound quality has been studied under music appreciation.

MUSICAL ACTIVITY

This domain corresponds to what is commonly referred to in the music-CIs literature as music listening habits (Gfeller et al., 2000a; Looi et al., 2012). CI users' music listening habits have been assessed in previous music questionnaires with broad questions about the frequency ("How often do you listen to music now?" (Mirza et al., 2003)), the amount ("When you are/were listening to music, how long do/did you listen?" (Brockmeier et al., 2002), "Amount of time spent listening to music" (Looi & She, 2010)) or the environment of music listening ("Where have you listened to or do you currently listen to music?", "Have you/Where have you practiced listening to music with your implant?" (Brockmeier et al., 2002)).

Musical activity can be music listening, music making or participation in music-related social activities. Music listening activities are grouped here according to the reason or motivation for listening to music in each case. Participants reported listening to specific pieces of music, usually music of their preference:

> *"Well at Christmas time, from you know from sort of 12 days before Christmas every single day I put Nat King Cole, I've got a record of Nat King Cole and that's what I'm doing all day, all week. You know up to Christmas and in Christmas morning I've got Nat King Cole again but I don't listen to music that much now you know. Mostly I put the television on that's what I do"* (P13)

('Listening to music actively')

In this case, music listening is done on purpose (e.g. to practice or as a link to the past), carefully and usually includes effort:

> *"But I really listen to those and try to pick things up." (P11)*

> *"I put on a CD of Elgar's cello concerto and just sat down to listen to it." (P22)*

Participants also reported listening to music while they are travelling, (e.g. in the car), in order to make journeys more pleasant:

> *"I listen to it in the car all the time, how to pass the journey" (P18)*

('Listening to music whilst travelling')

Some CI users also tend to have music on in the background when doing other non-musical activities, whereas others do not, like P4:

> *"But I just want to, you want to listen to music and do other things. But you can't if you are connected with the headphones. You just have to sit there and listen to it. As you said, we don't just want to sit there. And I would like to just turn the radio on and do other things and be listening to them"*

('Having music on in the background while doing something else')

In contrast with active listening, having music in the background does not involve effort or attention. It is used for relaxation, it accompanies everyday activities (such as cooking, painting etc.) or simply, as P11 puts it:

> *"it's noise, it's something in the house"*

Relevant to listening to music in the background is the question of the MUMU about whether CI users listen to music as their main focus of concentration or in the background.

The 'music making' subdomain includes comments about activities such as:

- 'Singing (alone or with others)':

  > *"I keep wishing I would have a terrible cold and recover from this cold and then I find my voice… I just love it but that's my disappointment in life, not being able to sing"* (P13)

- or 'playing a musical instrument':

  > *"and yeah sometimes I try to play keyboard myself and I find the time"* (P11)

Music instrument playing and singing have also been covered by existing questionnaires: "Do/did you sing/play a musical instrument?", "What/where do you sing?", "What instrument do you play?" (Brockmeier et al., 2002; Mirza et al., 2003).

Another activity covered by the music making subdomain is formal music training:

> *"and I have even thought about even having a sort of singing lessons with somebody that I wouldn't be embarrassed with, he would tell me what my pitch was like and everything." (P11)*

('Music lessons')

Music making activities in the form of music classes have been assessed in previous questionnaires such as the MUMU and the IMBQ.

In addition to the above activities, another dimension of music listening, which was poorly addressed by previous studies was brought up by the participants:

> *"There's a social side to it too. You can go out with somebody and listen to music or talk about music."* (P11)

The subdomain 'participation & social interaction' refers to the function of music as a means of socialising, communication, development of interpersonal relationships and relationships with the environment in general. Themes identified here are related to participation in public musical events, e.g.:

> *"But having said that, I love going to anything to do with music. We've been to a couple of concerts since I've had the, and it's been a magic experience. We went to the opera - that was absolutely splendid"* (P1)

('Going to public music events')

or participation in social activities not specifically musical but where music might be played, such as:

> *"I've been finding myself - you're probably going to laugh - having two young children - I've got a 7 and a 4-year-old, they quite like watching the music channels on the tv - and because now that I'm starting to hear the beat, I will be mucking about with them, just starting to, not really dancing, but just mucking about with them, and that's now becoming part of our weekend and stuff, and there's laughing and "mummy's being silly", but yeah I think that's quite good though."* (P5)

Music as a source of social interaction was also highlighted:

> *"And sometimes I said 'oh I don't think it's a happy song'. And they said 'oh why'? So it's good to talk about it"* (P6)

('Talking about music to others')

4.6 Discussion

To the author's knowledge, the present study was the first to map the music experiences of CI users onto a HRQOL model. Overall, this approach was successful in exploring music experiences in greater depth than previous studies. The study demonstrated aspects of CI users' relationship with music that had not been addressed previously (Table 4.3 below):

Table 4.3 *Novel aspects of music experience identified as themes in the focus groups. For the subdomains of each domain and the rest of the themes in the template, see Appendix B.5.*

Domain	Themes
Music listening ability	Ability to understand the meaning of music
	Ability to hear the words in music
	Ability to hear yourself singing/playing a musical instrument in tune
	Ability to tell if a musical performance is good or bad
Attitude towards music	Embarrassment with music
	Annoyance by music-like everyday sounds (such as bird singing)
	Confidence with music
Musical activity	Talking about music to others
	Listening to music whilst travelling
	Taking part in social activities where music is potentially played

The study also highlighted aspects of music experience that previous studies or questionnaires had not investigated in depth. For example, the concept of having music in the background while doing other activities or paying attention to the music, had only been touched on before, e.g. in the MUMU where respondents are asked if they listen to music as their only focus of concentration or in the background. Moreover, attention in music listening had emerged as a theme in the interviews of Bartel at al. (2011) but the findings of the present study clearly addressed not only two different types of music listening, listening actively and having music in the background, but also the effort or concentration required. In addition, aspects of music listening that had been commonly investigated together in music appreciation studies, e.g. music enjoyment and music listening habits, were here grouped separately under the 'attitude' and the 'activity' domains; this way each of these dimensions could be explored in more detail. The above findings improve the understanding of the everyday music experiences of CI users.

The findings confirmed the hypothesis that a HRQOL model can be used to organise music experiences of CI users and to some extent verify the hypothetical domains and subdomains developed on the basis of the NCIQ conceptual framework (section 4.1). Yet, in order to be used for music, HRQOL dimensions need to be carefully adapted. Although every effort was made to consider the a priori categories as tentative, flexible and subject to changes when necessary, it is acknowledged that the researcher may have been biased by the use of adapted NCIQ domains and subdomains as a priori categories and either may have failed to recognise when an a priori theme was not the best way to code the data or may have overlooked material unrelated to a priori categories.

Certain themes that arose in the framework, e.g. listening environment (e.g. listening to music in noise versus in quiet), familiarity with music (listening to familiar or unfamiliar music) and the presence of visual cues (audio-only music vs audio-visual music) are factors that have been previously reported to affect music listening and enjoyment (Gfeller et al., 2000a; Looi & She, 2010). Including these factors in the questionnaire supports content validity, ensuring that relevant and important issues are addressed.

The study was one of the largest music-related qualitative studies with adult CI users. Previously, Looi and She (2010) interviewed 3 adult CI users for the development of the UCMLQ and Bartel et al. (2011) interviewed 5 CI users to explore music experiences. Gfeller et al. (2000) recruited a larger sample when they interviewed 35 CI users for the development of the IMBQ but the scope of that study was limited since the interviews were conducted to modify an existing questionnaire.

In addition to the word 'understand' which was discussed earlier , another word that was of interest was the word 'appreciate'. In the literature *music appreciation* has been used as a general term to refer to anything else other than the music perceptual accuracy measured by formal music perception tests. Here, some participants used 'appreciate' in a context similar to 'enjoy':

> *"and that was how I taught myself to appreciate music again, by listening to CDs in the car…" (P28)*
>
> *"I think when we say appreciate we mean we enjoy it" (P15)*

However, another meaning was also added:

> *"Appreciate, thankful? Thankful that we can hear? Appreciate?" (P16)*

> *"Well appreciate, it can mean a lot of things. I mean appreciate, I appreciate it because I appreciate the fact that I'm deaf and I can listen to music therefore" (P18)*

The use of qualitative methods for item generation was an advantage of the present study over previous ones where generation of items was usually based on literature review and expert input (Amann & Anderson, 2014; Hinderink et al., 2000) or where CI users were consulted only to modify questionnaires and not from the beginning of the developmental process (Brockmeier et al., 2002; Gfeller et al., 2000a). Focus groups, in particular, were considered successful in achieving a deep understanding of participants' musical experiences, concerns and feelings about music. When recruiting participants it was specified that no special interest or prior experience with music is needed. The wide range in age, prior music experience, importance of music in life and duration of implant use also ensured sufficient diversity in the sample. However, it was likely that CI users with a special interest in music were more interested in participating and so the sample might not be random or representative of the whole adult CI population. It is also acknowlegded that the subjectivity of the data analysis techniques used (e.g. lack of external validation of the focus group data coding) may be a limitation of the study.

Among the benefits of the questionnaire items over previous music questionnaires are the use of no comparisons (which better assesses how music is perceived/enjoyed at present and makes the questions more appropriate for prelingually deaf CI users), the combination of positives and negatives which prevents response bias and the use of clear examples where necessary.

At this stage there was redundancy in the questionnaire and overlap between items, which was also highlighted by the independent researcher for the themes of the final template. Items would be selected and the number of items would be reduced with the use of expert feedback and statistical techniques in the next stage of the development.

The focus groups also provided rich evidence about the impact of music on all dimensions of the QOL of CI users, especially on the psychological domain by inducing positive emotions. This evidence was proof of the MRQOL concept whereby music has an impact on the QOL and this impact can be measured.

> *"I listen to it if I'm feeling a bit miserable, to cheer me up or I might listen to it to calm me down, relax too. There's a social side to it too. You can go out with somebody and listen to music or talk about music." (P11)*

Chapter 5. Questionnaire development and refinement

The focus group data of Study 1 helped (a) the identification of aspects of music experience relevant to QOL domains and (b) the development of a prototype questionnaire of 53 items assessing music listening abilities, attitudes and activities on a 5-point Likert scale. The generation of the items with input from CI users ensured content validity. As a next step towards the development of a questionnaire that is (a) easy to complete, (b) has potential to measure the impact of music on the QOL and (c) has certain psychometric properties, the prototype questionnaire was tested for face validity, an addition importance scale was developed and items were selected with the use of statistical techniques.

5.1 Development of the prototype questionnaire (Version 1)

The prototype MRQOL questionnaire consisted of 53 items grouped under 3 domains and 9 subdomains (Appendix B.6).

Specific principles applied to the generation of questionnaire items:

- Items were all phrased in a similar way and were suitable for a ‘frequency’ Likert scale (Never - Always)
- The same response options were used throughout
- Items were phrased as questions [and not statements, e.g. (Müllensiefen et al., 2014)]
- Items asked about present music experiences and did not ask respondents to make comparative or retrospective judgements
- Items were phrased in a way to reflect limitations related to the CI or hearing loss and not preferences

The phrasing of the questions largely followed the NCIQ and was informed by the vocabulary used by participants in the discussion and by their written comments in existing items. The use of the vocabulary used by the participants in the wording of the questions ensured that the language used was appropriate for the users (content validity). The questions were carefully phrased to be appropriate for both congenitally deaf or postlingually deaf CI users with or without musical training. Also, lay language was preferred to CI-specific terminology where possible, because the questionnaire would be administered to NH adults and adult HA users.

Based on these rules, items were developed in two ways:

- New items were generated from the themes that were identified in the discussion (5.1.1)

- Items from existing measures were modified based on participants' ratings (5.1.2)

5.1.1 From focus group themes to questionnaire items

- In most cases one theme was transformed into one questionnaire item (e.g. Theme: "Ability to hear the words in music" => Question: "Can you hear the words in music?").
- Some themes were split into two items (e.g. Theme: "Ability to understand music using audio-visual media" : Question: "Can you understand music using audio-visual media with subtitles?" & Question: "Can you understand music using audio-visual media without subtitles?")
- Others themes were merged into one item, e.g. Theme A6.1: Ability to hear yourself singing in tune + Theme 6.2: Ability to hear yourself playing a musical instrument in tune > Question 7. Can you hear whether you are singing or playing a musical instrument in tune (in tune with the music or with others)?
- Where needed, examples were added to clarify the question (e.g. Theme: "Avoidance of music" => Question: "Do you avoid music (e.g. avoid listening to music, avoid public music shows or social events where music is played)?").

5.1.2 CI users' feedback on existing questionnaire items

Part 2 of the focus groups presented in sections 4.3.3 and 4.4.3 was the evaluation of existing questionnaire items. The results of this evaluation and how they informed the generation of items are discussed here.

From the 19 existing items given to participants, 9 were rated 'Important' or 'Very important' by ≥80% of the participants (Appendix B.3) and were considered for use in the new questionnaire also depending on the participants' comments or the focus group discussion:

- The existing theme: 'Being able to recognise a movie's dialogue when music is playing in the background' (Existing item 7) was finally considered unsuitable because it is related more to recognition of speech in background music than to the function of background music and was not included. The use of subtitles, which was also mentioned by participants in the comments, was addressed by questions 16 and 17 of the prototype questionnaire (Appendix B.6).
- Existing item 6 formed Q11 of the prototype questionnsaire: 'Can you distinguish between different rhythms in music?' under the Music listening ability domain. 'Rhythmic patterns' was preferred over 'rhythm' to distinguish from the perception of the beat (Q1).

- Existing items 3, 10 and 11 formed Q13, Q37 and Q38 ,accordingly.
- Existing statement ‘Ability to recognise a phone’s ringtone’ (4) was incorprated into Q19
- Being patient when trying to understand a song (17) was already covered by Q27 and Q31

The other 10 statements that were not rated ‘Important’ or ‘Very important’ by ≥80% of participants were not considered for the generation of new items but they were in fact already covered by themes identified in the discussion and therefore by other items.

Participants’ comments to existing items also informed the generation of items in the following ways:

- In Q9 about recognising musical instruments in a mixture, ‘when they play together’ was preferred over ‘simultaneously’
- Participants’ confusion about the physical ability of playing and the ability to perceive pitch differences (existing item 12) justified the phrasing of Q7 and its position under a perception and not production domain
- Due to a similar confusion with the ability to dance/sing and dancing or singing skills (existing 12, 13), the ability to hear the beat so that you can dance in time with the music was included in Q1 and the ability to perceive the pitch accurately to sing in tune (Q7)
- The comments about understanding and meaning informed Q8 and questions in subdomain B
- Comments in ‘How important is it for you to be going to social events (e.g. parties) where music is played’ (existing 19) highlighted social and activity limitations of CI users as a result of poor music understanding and enjoyment, which supported the generation of an item addressing participation in non-musical social events where music is potentially played (Q48).

5.1.3 The choice of response scale[9]

The 5-point frequency Likert-scale used in the NCIQ was chosen: (1) Never – (2) Sometimes – (3) Regularly – (4) Usually – (5) Always. A non-applicable (N/A) option was also included to capture music listening tasks, feelings about music or musical activities that CI users would not do anyway

[9] In psychometrics, the term ‘scale’ can be used for the response options on which a number of statements is assessed (e.g. Likert scale) or for a questionnaire that uses a certain scaling technique (as opposed to open questions, for instance). In this section it refers to the choice of response options.

due to music preferences, musical backround or role of music in life and not as a result of the deafness or the physical limitations of the implant. In such cases, respondents were expected to choose N/A instead of Never.

The ‘Likert-scale’[10] is very common among the various scaling methods probably because it is easier for the respondents to understand and for the researcher to analyse compared to other methods, such as the visual analog scale. Likert-scales consist of series of statements and respondents indicate the degree to which they agree or disagree with the statements by choosing from a number of predefined responses. The response categories (indicating agreement, frequency, importance, quality, satisfaction etc.) and the number of response options (from dichotomous to 7-point scales) may vary.

There is no agreement about the optimal number of response options. Five-point and 7-point scales (Amann & Anderson, 2014; Maillet et al., 1995; Cox & Alexander, 1995) are most commonly used in hearing questionnaires. It is generally suggested that more response options increase sensitivity (as they can capture a greater variety of responses) and reduce measurement error [since respondents are more likely to find their preferred answer without looking for the next best alternative] (Streiner et al. 2015: 47-53). Yet, there is no evidence that a 7-point scale produces better results than a 5-point scale. A 5-point scale also required less cognitive effort. Among the 5-point Likert-scales that have been used with generic health and hearing-specific questionnaires (WHOQOL, 1998; Coelho et al., 2009; Maillet et al., 1995; Gatehouse, 1997), the scale used in the NCIQ was chosen because of the instrument’s validity with CI users. Also see Table 5.1 for the 5-point Likert scales used with CI questionnaires.

Table 5.1 *Examples of 5-point “frequency” Likert-type scales used in the literature. The order of the options (Never-always) may vary. The questionnaires where a N/A option was included are indicated with an asterisk.*

Questionnaire	**Response options**				
Nijmegen Cochlear Implant Questionnaire (NCIQ)*	Never	Sometimes	Regularly	Usually	Always
WHOQOL-Bref	Never	Seldom	Quite often	Very often	Always

[10] Scales developed on the basis of the original 5-point agreement Likert scale [‘Strongly agree - Strongly disagree] (Likert, 1932) should be referred to as Likert-type scales. However, throughout this thesis, the term Likert scale will be used for all of them by convention.

Questionnaire	Response options				
Patient Quality of Life Form (PQLF)* / Index Relative Questionnaire Form (IRQF)	Never	Seldom	Sometimes	Quite often	Very often
Comprehensive Cochlear Implant Questionnaire (CCIQ)	Never	Rarely	Sometimes	Usually	Always
Glasgow Health Status Inventory (GHSI)	Never	Rarely	Occasionally	About half the time	Frequently or all of the time
Cochlear Implant Function Index (CIFI)	Never	Rarely	Occasionally	Frequently	Always
Musica Stages Profile (MSP)	Never	Rarely	Occasionally	frequently	always

5.2 Expert review for the optimisation of the questionnaire (Study 2)

5.2.1 Introduction

At this stage, the prototype items were pre-tested with professionals for the improvement of the subscale structure and to assess face validity before they were administered to adult CI users in the next stage. Face validity is a type of content validity that ensures that the questions are understandable and relevant to the users. It is assessed by the group of interest or by professionals with expertise in the topic under investigation.

Expert assessment has been commonly used for the optimisation and assessment of the face validity of health questionnaires (Hyrkäs et al., 2003; Johnston et al., 2003; Arranz et al., 2004). It has also been used in the development of music questionnaires for CI users, for the optimisation of the questionnaires before they were administered to the patients (Gfeller et al., 1998b, 2000a; Brockmeier et al., 2002; Edwards, 2014; van Besouw et al., 2011). For example, 9 audiologists and professionals in the field of CIs evaluated two modified versions of the Iowa Musical Background Questionnaire (IMBQ). They assessed the clarity, appropriateness and comprehensiveness of the questions. Participants also recommended additional questions and response options as well as changes in the wording of the items (Gfeller et al., 2000a). Also, in a study by Edwards (2014) 14 experts in the field of hearing, speech and language therapy and musical development and education of children evaluated the Musical Stages Profile (MSP), a questionnaire for musical development of young normal-hearing and hearing-impaired children (Edwards, 2014). They allocated the items into domains and made comments about their clarity. Domain allocation agreement between participants indicated which items are critical in each domain.

In the present study, the expert review had three aims:

- To improve the prototype items of Version 1 of the questionnaire so that they are clear, understandable and relevant to CI users
- To remove redundant items from the prototype questionnaire
- To improve the subscale structure

5.2.2 Recruitment and participants

Personal invitations were sent to well known academics in the area of CIs and music, and also to clinicians, music therapists and musicians with experience of working with CI users. A study advert was circluated to implant centres in the UK, to the research departments of CI companies and via the AUDITORY mailing list. Study adverts were also distributed at the British Cochlear Implant Group 2015 meeting. The study was advertised through the British Association of Music Therapy. This way of recruitment ensured that professionals from a wide range of areas were approached. In order to participate in the online survey, participants had to be professionals in an area relevant to CIs and/or to have good knowledge of the challenges of CI users with music.

Twenty-four adult professoionals (9 male, 15 female, mean age: 39.5 years old) in an area relevant to CIs completed the online survey. The participants covered a wide area of expertise (Table 5.2). Based on the samples of expert evaluations of previous music questionnaires developed for CI users, the sample size was considered sufficient as it was the one of the largest expert review samples reported in the CI literature to date.

Table 5.2 Demographics of the expert review participants.

N_o	Age	Gender	Expertise
1	31	Female	CI Researcher
2	45	Male	ENT doctor
3	38	Female	Clinician
4	29	Male	CI researcher
5	35	Female	Audiologist
6	45	Male	CI researcher
7	55	Female	Bio-statistician, psychologist
8	38	Female	Speech and language therapist
9	45	Female	Audiologist

N_o	Age	Gender	Expertise
10	48	Male	ENT doctor
11	33	Female	Music therapist
12	29	Female	ENT doctor, researcher
13	58	Female	Clinician, rehabiliation specialist
14	33	Male	Composer
15	38	Female	Researcher
16	31	Male	CI researcher
17	38	Female	Audiologist
18	46	Male	CI researcher
19	34	Male	CI research engineer
20	37	Male	CI-music researcher
21	52	Male	Audiologist
22	29	Female	Audiologist, CI-researcher
23	55	Female	Hearing-music researcher
24	39	Female	Audiologist

5.2.3 The online survey

An online survey was conducted using University of Southampton software ‘iSurvey’[11]. Online surveys is a practical and efficient way to reach wide audiences. Although they require a certain level of IT skills, it was assumed that CI professionals (clinicians or academics) would have at least basic IT knowledge. Given their busy schedules, it was considered that an online survey was the most appropriate way to recruit as many of them as possible. At the end of the study participants were asked whether they are willing to further discuss the questionnaire with the researcher and two participants contacted the researcher with further comments.

[11] i-Survey uses the University of Southampton’s server and therefore was considered safe for the purposes of the present study. The following extract is copied verbatim from the ‘iSurvey’ website: “iSurvey uses secure encrpytion in the form of Secure Sockets Layer (SSL). This ensures that data sent by participants cannot be intercepted by third parties. Access to the admin interface is also secured using the SSL. Data is stored ON SITE, and therefore 3rd party hosting companies do not have access to your data.” (https://www.isurvey.soton.ac.uk/help/isurvey-features)

The survey began with a ‘welcome’ page containing brief information about the survey as well as a consent form with a link to the participant information sheet. Participants indicated their consent by ticking a box to indicate that they agree with a number of statements. A password, common for all participants, was required to start the survey. This was given to the participants by the researcher together with the link for the survey. It ensured that only invited participants took the survey. On the next page participants were asked to give personal details: their gender, age, expertise, affiliation as well as how they heard about the study. A page with detailed instructions appeared next and the questionnaire evaluation began. The 53 questionnaire items with their response options were presented in random order on the top of the page without the item numbers, each in a separate page.

The participants had to answer two questions for each item:

<u>Question 1:</u> To allocate the item to one of nine subdomains by choosing from a drop-down menu. This informed the structure of the questionnaire and supported content validity of the questionnaire since it ensured that items that best fit under the different subdomains were included.

It was intended that the 9 subdomains availble to the participants for domain allocation of the items would be the ones of the prototype questionnaire. However, subdomains A, B, E and F were instead made available to the participants as in Table 5.3.

Table 5.3 *Intended subdomains headings and the ones made available to participants in the online survey.*

	Original-intended subdomain heading	**Subdomain heading given to participants in online survey**
A	A. Perception of elements of music	Music listening ability
B	Music perception in particular listening scenarios	Music perception in particular listening settings
E	Feelins about music	Music-related feelings
F	Music appraisal	Appraisal of music sounds

<u>Question 2:</u> To make comments on the clarity and appropriateness of the item or make any other relevant comment in a text field. Open comments were preferred over rating scales to give participants more freedom and therefore collect more information (Johnston et al., 2003; Edwards, 2014). It was explained to the participants that the comments were optional and that they did not have to necessarily make comments on all the items.

5.2.4 Data analysis

The percentage of domain allocation agreement among participants was calculated for each item. Items that received less than 65% of domain allocation agreement were reconsidered (Edwards, 2014). This ensured that only items that are most useful for each domain are retained and further supported content validity. In cases of low domain allocation agreement, the subdomain headings and the organisation of items into subdomains were considered too.

The participants' comments were used for the improvement of the wording of the items. Items that were not considered clear or appropriate were modified, merged with others or even removed, also in combination with the domain allocation agreement results. The online survey results were also analysed in combination with the independent review of the themes of the focus group data analysis. Items receiving less than 65% agreement were reconsidered in combination with the participants' comments as well as the suggestions of the independent researcher.

5.2.5 Results and changes to the prototype questionnaire

The full domain allocation agreement results and the professionals' comments are presented in Appendix C.1. Based on these results, relevant changes were made to Version 1 of the questionnaire. Some of the changes were made directly in response to professionals' comments and others after considering the expert feedback overall, the independent researcher's feedback at the item generation stage (4.4.3) as well as the authors's judgement. These changes led to the development of the second draft (Version 2) MRQOL questionnaire (Appendix C.2).

In Version 2 the number of items was reduced from 53 to 46. There were still 3 domains and 9 subdomains but as a result of the subdomain allocation agreement, subdomains were rephrased (e.g. Appraisal), split or removed and items were moved across domains (Table 5.4 below). For instance, no item reached 65% agreement for the subdomain 'General attitude towards music', which was removed and its items were moved to the subdomains second in preference. With regard to the ability domain, abilities were finally split into basic and advanced. This built on the distinction of the prototype questionnaire with fundamental elements and music perception with scenarios and also complied with the NCIQ model with speech perception basic and advanced. 'Basic music listening ability' included what is referred to in the literature as 'perception of fundamental elements of music' (rhythm, pitch, timbre, loudness) with the addition of lyrics. The rest of the ability items, addressing more complex perceptual tasks, e.g. 'the perception of emotion', were considered *advanced* and grouped under an 'Advanced music listening ability' subdomain.

Table 5.4 Changes to the subdomains after expert feedback.

Prototype subdomain	Version 2
Perception of elements of music	Basic music listening ability
Music perception in particular listening scenarios	Advanced music listening ability
Music-related self-esteem	Same
General attitude towards music	Removed
Feelings about music	Music enjoyment
	Negative music-related feelings
Music appraisal	Appraisal of music sound quality
Music listening activity	Same
Participation and social interaction	
Music making activity	

Items were rephrased or merged to clarify questions or reduce overlap between items as in the examples below:

- The word 'hear' was replaced with recognise in question 2 to avoid confusion with sound detection.
- A less technical description was added for pitch in item 6.
- Examples were limited where it was likely that "different examples would yield different responses" (e.g. item 25) or added so that the question is more specific (e.g. item 49).

- Professionals also reported that it was unclear what the word *understand refers to;* 'understading' items were transformed into 'enjoyment' items so that the 'setting information', e.g. listening environment, presence of lyrics, in quiet or in noise, is addressed. This was in agreement with the independent researcher's comment about keeping settings only in 'enjoyment' to reduce overlap between ability and enjoyment items.
- Item 25 about the avoidance of music was merged with 48 because the three settings of item 25 (music listening, public music events, social events where music is played) were covered by other items in the 'Activity and participation' domain. Asking about avoidance may give more accurate information than asking about participation because these may be events where people may have to join for other reasons.
- Items 31 (frustration with music) and 34 (background music annoying) were merged. Here, in the new question addressing frustration music is unwanted, whereas in the disappointment item music is something the listener wants to hear but they cannot or it does not sound as it should.
- Similar items were put next to each other with the differentiating information emphasised (items 51-52) so that the difference is clear. This was because of comments (e.g. comment in item 1) about the potential confusion between rhythm and beat. This was also in agreement with the independent researcher's feedback, e.g. items 12 and 21 where 'in noisy environments' was highlighted in bold, to make the difference with item 21 ('in quiet environements') clear.
- Item 40: music sounding like noise is a concept very familiar to postlingually CI users but maybe not to prelingually deaf. Also, it is not clear what noise means, because depending on the music type, some music may be more 'noisy' than other. Therefore, 'like noise' was changed to 'just like noise'.
- Item 36 'Does music sound uncomfortable?' was initially intended to assess appraisal of music sound quality. However, without asking about the loudness[12] or the pleasantness of the music in particular, the question was considered unclear by the professionals. The item was rephrased into a music-related feelings item 'Does music make you feel uncomfortable?'.

[12] Similar questions, asking whether different everyday sounds (e.g. running water, construction work, alarms or screechig tires) sound uncomfortable or uncomfortably loud are included in the Abbreviated Profile of Hearind Aid Benefit (APHAB), a questionnaire for the evaluation of hearing-aid fitting (Cox & Alexander, 1995).

In addition the the above changes, a new 5-point Likert- scale was chosen, in response to comments about a potential confusion between ‘Regularly’ and ‘Usually’ and so that the “distance” between the response options is more distinct: (1) Never – (2) Rarely – (3) Occasionally – (4) Frequently – (5) Always. This scale has been previously used in the MSP and the Cochlear Implant Function Index [CIFI] (Coelho et al., 2009).

5.2.6 Conclusion

The changes made to the items of Version 1 of the questionnaire supported the face validity of the questionnaire by ensuring that items are clear and ensured that subdomains are meaningful and include only items that best fit in it them. The ambiguity of the items was minimised. This improved the subscale structure and further supported content validity. Although face validity was not assessed at this stage directly by asking CI users themselves, CI users’ feedback for the assessment of face validity was collected in study 3 (Chapter 1.) through the use of N/A responses, importance ratings and informal comments. It was acknolwedged that there was still overlap between items (e.g. in the use of similar settings between ability, appraisal and activity items) and subdomains (e.g. between the ‘Music making activity’ and the ‘Participation’ subdomain). The most useful of these items were selected in the next stage with the use of statistical techniques.

5.3 The assessment of importance

5.3.1 Background

The use of importance ratings is not new in HRQOL questionnaires. They were used as a weight to convert satisfaction scores into QOL scores in the Quality of Life Profile, developed by the Centre for Health Promotion of the University of Toronto (Raphael et al., 1996). Each item was rated for satisfaction and importance, both on a 5-point Likert-type scale. Between two items with the same satisfaction score, the one rated as more important produces a higher QOL score. This scoring system reflected the idea that the QOL is not just the degree a person enjoys different aspects of life, but is also relative to the importance they attach to the different dimensions of QOL. Using a different version of the questionnaire, Raphael and colleagues (1997) demonstrated high internal consistency for the importance scale with Cronbach’s α coefficient for all domain and subdomain scores being >0.90 (Raphael et al., 1997).

In another study, importance ratings were used to assess the importance of the different WHOQOL-Bref (short version of the WHOQOL 100-item questionnaire) items across different countries (Saxena et al., 2001). The authors demonstrated very good internal consistency for the importance scale. The importance of specific tasks for particular individuals was also assessed in two other hearing-related questionnaires. In the Glasgow Hearing Aid Benefit Profile (GHABP), respondents are first asked whether they experience a particular situation before they answer the relevant questions. In the Glasgow Health Status Inventory (GHSI) respondents are asked how their health problem affects their quality of life (Gatehouse, 1999).

5.3.2 Why assess importance?

In the present study, the assessment of the importance of music was in line with the definition of the MRQOL concept, whereby the impact of music on the QOL is a function of music perception/appreciation and the importance of music for different individuals.

The focus group discussion data (study 1) demonstrated strong differences between participants with regards to the role of music in life. For some participants music was a big part of their life:

> "So music plays a big part in my life, a very big part. Without music it's not the same. Music plays a very, very big part in my life." (Participant 2)

> "I think I'm a music nerd. I think music is so important in my life and the emotional movements are so… [*smiles*]. It's something I've really missed with becoming deaf." (Participant 8)

In contrast, other participants said:

> "I'm just, say, here listening taking it all in. Music's never been the part of my life." (Participant 10)

> "Yes I went to concerts, classical music concerts but it's never meant a lot to me. I can appreciate it but it's never meant a lot to me. […] But as I emphasise it doesn't matter to me whether I hear music or not. Yes it would be nice but it doesn't mean that much to me." (Participant 29)

It was assumed that musical abilities, attitudes and activities would have a different effect on the QOL for each of these CI users. Assessing importance as well as perception/appreciation would reflect the actual impact of music for the QOL. In order to capture this effect, for each item of Version 2 of the MRQOL questionnaire, an additional item was developed assessing the importance of the task/activity etc. described in each item. Importance items would help weighting the 'frequency' scores to measure the impact of music on the quality of life and were also used (a) to remove items rated unimportant (section 6.3.1) and (b) for construct validation of the questionnaire (section 7.2).

5.3.3 Construction of the importance scale

For each frequency item of Verson 2 of the questionnaire, a corresponding importance question was developed. The domain and subdomain structure was exactly the same as that of the frequency scale. The importance scale is presented in Appendix C.3.

Two changes were made to the items of the Version 2 MRQOL questionnaire while constructing the importance questions:

1. In item 25 the situations were put as examples in parenthesis to avoid very long wording in the importance question.
2. Item 27 was phrased positively ('in tune') instead of negatively ('out of tune') to avoid the double negative in the importance question.

So that the two questions corresponded, the phrasing of the frequency question changed as well.

Importance was rated on a 5-point Likert-type scale: (1) Not at all Important – (2) Not very important - (3) Somewhat important - (4) Very important – (5) Extremely important. A N/A option was also included as in the frequency scale. Here, the N/A would capture listening tasks, feelings or activities that respondents did not find relevant (and not just not important at all) to them for some reason (e.g. due to poor engagement with music) or items that were not clear or appropriately phrased. However, it was acknowledged that for the importance questions Not important at all and N/A were likely to be used interchangeably and were interpreted similarly.

Chapter 6. Use of psychometric techniques for item selection (Study 3)

6.1 Introduction

After the questionnaire was optimized as a result of the expert feedback and face validity was supported, it was completed by CI users for the selection of the items with the best measurement abilities and the determination of the subscale structure with the use of statistical techniques. This was a necessary step to arrive at the minimum number of items that yield scores with a certain degree of reliability and validity for the intended users and purpose of use, which is is the final goal in any scale construction.

The development and validation of the MRQOL questionnaire in the present project was based on the Classical Test Theory (CTT). According to CTT, the methods traditionally used for item selection are: analysis of items (e.g. distribution of responses per item, test-retest reliability of each item, inter-item correlations), assessment of internal consistency and factor analysis (Bowling, 2014:54-55; Streiner et al., 2015: chapter 5). The use of the above methods is common in the development of hearing or CI-specific questionnaires (Amann & Anderson, 2014; Buhagiar, 2012; Morris et al., 2009; Barry et al., 2015).

Briefly, the aims of this stage of the questionnaire development were:

1. To select items with the best psychometric properties
2. To decide on the subscale structure
3. To assess the test-retest reliability and internal consistency of the final set of items

6.2 Methods

6.2.1 Recruitement

Invitations were sent by email or post to 434 patients of the USAIS who fulfilled the inclusion and exclusion criteria (Table 6.1 below). Further invitations were sent to participants of the focus groups (Study 1) who had given consent to be contacted for future studies and to CI users who had previously expressed interest to participate in research to the researcher. The study was also advertised through the Ear Foundation, Action on Hearing Loss and by a clinician of the Hearing Implant Centre of St. Thomas' Hospital (London) in person at regular appointments. A £10 participation fee was offered to every participant.

Table 6.1 *Inclusion and exclusion criteria of the questionnaire administration study.*

Inclusion criteria	Exclusion criteria
>18 years old	Visual impairments
Able to read English	Have had their implant for less than 6 months
	Recent or upcoming clinical change (3 months for second implant, 1 month for processor upgrade and no change in the next 2 weeks)

In order to be able to perform factor analysis on the data, a relatively large sample was required. There is no rule regarding the ideal sample size for factor analysis of scales. In fact, the reliability of a factor analysis does not only depend on the number of participants but also on the response variance (Field 2014: 683-684). In previous studies using CI users or hearing-impaired adults, reliable factor analyses have been performed with 77 or even as few as 25 participants (Amann & Anderson, 2014; Buhagiar & Lutman, 2011). However, a sample of 45 participants was not adequate for factor analysis in the validation of the NCIQ (Hinderink et al., 2000). Samples as large as 124 subjects have also been employed, with hearing-impaired populations other than CI users (Morris et al., 2009). In the present study, because CI users are a specific and limited population and large samples are hard to get hold of, the aim was to recruit as many participants as possible within the recruitment timescale of the study.

6.2.2 Participants

One hundred forty-nine adult CI users (58 male, 91 female, M_{age}: 57 years, age range: 18-87, Standard Deviation $(SD)_{age}$: 16) completed the MRQOL questionnaire on paper or online (132 online, 17 on paper). Figure 6.1 below shows the age distribution of the participants. Thirty-six of them were prelingually deaf (i.e. congenitally deaf at least in one ear or went deaf < 3 years old), while 10 reported some formal music training. Eighty-seven out of 149 were unilaterally implanted, 9 had an implant in both ears, 47 had CI in one ear and a hearing-aid in the other ear and 3 used EAS. One hundred thirty-six (136) of the participants repeated the questionnaire two weeks after the first completion, in order to collect data for the assessment of test-retest reliability.

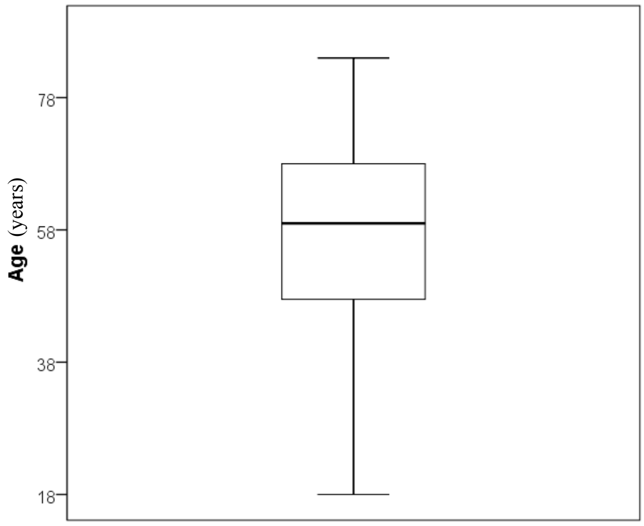


Figure 6.1 *Age distribution of the 149 adult CI users who completed the questionnaire. The median age was 59 years old.*

6.2.3 Test-retest analysis

Test-retest reliability measures the extent to which items of a scale produce the same results in subsequent administrations with the same respondents, when no clinical change happens in the meantime. This is crucial, especially if the questionnaire is intended to measure change of a specific intervention because it ensures that the change under examination can be attributed to the given condition.

The test-retest interval depends on the specific trait being measured. Previous studies using test-retest reliability for the development of hearing-related questionnaires have used intervals from as short as 24 hours to 1 month (Buhagiar & Lutman, 2011; Morris et al., 2009; Hinderink et al., 2000). For the present study, a relatively short interval of 2 weeks was chosen, because self-perceived music experiences were thought to be a trait that is sensitive to change depending on the person's everyday habits. The same interval was used by Edwards in the development of the MSP (Edwards, 2014). The 2-week gap was considered long enough for respondents not to remember their anwswers and short enough for no changes to the participants' music experiences to happen. In addition to the exclusion criteria, participants were asked to report on clinical change prior to completing the questionnaire the second time.

6.2.4 Questionnaire administration

The questionnaire (both frequency and importance questions) was made available in a paper and an online version. An online survey was created using software i-Survey[13]. The link and password were emailed to the participants. First, they were asked to tick a box to indicate that they agreed with a number of consent questions and then they were asked to give a number of personal information (such as duration of implant use) including their email for resending the survey the second time and to match test-retest responses. Frequency and importance questions were presented separately in one webpage/sheet each, as Part 1 and 2, respectively (Appendix C.5 and Appendix C.6), to prevent bias, i.e. the answer to one question affecting the response to the other. The response categories were given to the participants without the numbers to prevent confusion with the negatively phrased items. The N/A option was also included to inform regarding which questions were applicable to the majority of participants and therefore most useful to retain in the final version of the questionnaire and also about items that were not understandable. The 3 main domains were given to the participants to differentiate ability, attitude and activity questions and faciliate completion due to the length of the questionnare, but subdomains were removed to prevent bias.

6.2.5 Scoring the questionnaire

For scoring purposes, each frequency/importance response option corresponded to its 1-5 numerical value, i.e. 'Never' and 'Not at all important': 1, 'Rarely' and 'Not very important': 2, 'Occasionally' and 'Somewhat important': 3, 'Frequently' and 'Very important': 4, 'Always' and 'Extremely important': 5. For the 8 negatively phrased frequency items (18, 24, 25, 26, 28, 32, 33, 41) scores were reversed, e.g. 'Never' corresponded to a value of 5 and 'Always' to a value of 1.

The 1-5 Likert-scale data were treated as interval, to allow use of the statistical techniques of CTT, i.e. factor analysis and Cronbach's α. It was therefore assumed that respondents treated the response options as continuous and the intervals between them as equal; this assumption was supported by the scoring instructions ('*Never means a statement is true 0% of the time, Always 100% of the time*', Appendix C.5 and Appendix C.6). Whether Likert-scale data can be treated as

[13] While the survey was running and after it was advertised on 'Action on Hearing Loss''s website and Facebook page a number of non-genuine responses were received. The event was reported to the IT team of the University of Southampton and appropriate action was taken. It is unlikely that this event affected the study.

interval is still under debate; although there is no guarantee that the intervals between the response options are the same, it has often been shown that Likert-scale scores have linear properties and that these assumptions can therefore be justified (Streiner et al. 2015: 52-53). This is a common convention in the development of hearing-related and CI-specific questionnaires developed using CTT techniques (e.g. Hinderink et al., 2000; Amann & Anderson, 2014). However, it is acknowledged that this assumption may have implications for the validity of the results of the present study.

No combined MRQOL scores were calculated at this stage and the two scales (frequency and importance) were analysed, refined and validated separately and then combined at the end. This was because no assumptions could be made regarding the relationships between combined scores in order to plot them in a linear scale. For example, it was unknown if a score of 4 for frequency and 5 for importance would be higher than a score of 5 for frequency and 4 for importance. Linear scores were required for the application of CTT techniques for item selection.

6.2.6 Data analysis

Analysis of the data were performed using Miscrosoft Excel 2013 and IBM Statistical Package for Social Sciences (SPSS Statistics) Version 22. Questionnaires were used for analysis if ≥50% of the items in each set of questions were completed (Morris et al., 2009). Where ≥50% of the items were completed but there were missing values or N/A responses, pairwise (for correlations, factor analysis) or where necessary listwise (internal consistency) exclusion was applied. Because the sample size was relativelty large, substituting missing data was not necessary. Most of the analyses (e.g. internal consistency, factor analysis) were done on the frequency scale. When a frequency item was removed, the corresponding importance item was removed as well and vice versa. The following techniques were used:

Descriptive statistics: For each frequency item, the percentage of N/A responses, the range of scores (i.e. whether all the points of the scale were used) and the distribution of scores (i.e. percentage of scores at floor/ceiling) were calculated. The percentage of N/A responses was also checked for importance questions. Items with a high percentage of N/A responses, a limited range of scores or a high percentage of scores at floor/ceiling were considered for removal. The distribution of responses shows items that are not very informative or do not discriminate well between individuals. Importance items with a high percentage of low scores were removed. Despite content validity, not all items were expected to be applicable to all participants. A large number of N/A responses was considered as indication that the items were not appropriate or representative for the sample studied. There is no agreement in the literature regarding what percentage of N/A responses is large enough for an item to be considered for removal. Questionnaire items have been removed due to >10% or >20% N/A responses (Cott et al., 2006; Demers et al., 2000). In the present study, a reasonable cut-off percentage for an item to be considered for removal was determined after looking at the data.

Inter-item correlations: Correlations between items within the frequency scale were examined and items that correlated very highly or very poorly with other items were considered for removal (Field 2014: 685-686). Items that correlate highly are likely to give similar information and an item that correlates poorly with one or more items may not be tapping the same concept.

Test-retest reliability: The test-retest reliability of each frequency and importance item was looked at and items with low repeatability were removed. Test-retest reliability was measured using the 'intra-class correlation coefficient' (ICC), which measures systematic score changes over time by comparing differences within subjects with the total variance (Deyo et al., 1991). If individual subjects give similar judgements across time, the total variance is dominated by inter-subject variability and the ICC will be high. Values close to 1 indicate close agreement and close to 0 poor agreement between the two measurements. ICC is mathematically equivalent to kappa or weighted kappa coefficients (appropriate for nominal/categorical data). Values that have been recommended for the interpretation of kappa statistic were adapted here for ICCs (Landis & Koch, 1977):

- <0.00: "poor" repeatability
- 0.00 - 0.20: "slight" repeatability
- 0.21 - 0.40: "fair" repeatability
- 0.41 - 0.60: "moderate" repeatability
- 0.61 - 0.80: "substantial" repeatability
- 0.81 - 1.00: "almost prefect" repeatability

Factor analysis: Exploratory factor analysis identifies underlying factors within a scale, what percentage of the variance each of them explains and which items group together in each of these factors. It is used to determine the domain-subdomain structure of the questionnaire and identify items that fit best in these factors (Field 2014: chapter 17). Exploratory factor analysis was performed in the frequency scale. It helped (a) determine subdomains within the scale and (b) identify items that did not fit well within the subscales. These items were considered for removal.

Internal consistency: The homogenenity of the scale, i.e. whether the items measure the same construct. It can also be used to determine redundant items. Cronbach's α correlation coefficient was calculated for the frequency scale total and its subscales. Items reducing internal consistency were considered for removal.

6.3 Results

Two participants (36, 74) were excluded due to >50% N/A responses in the importance questions. Responses from 147 participants were included in the analysis (Table 6.2). Participants' numbers refer to the numbers in Appendix C.4. Item numbers throughout refer to the items of Version 2 (Appendix C.2).

Table 6.2 *Summary of characteristics of the 147 participants whose responses were included in the analysis.*

Age range	18-84 years old
Mean age	56.69 years old
SD age	16.017
Duration of CI use	4 months - 26 years
Mean duration	6 years and 9 months
SD duration	6.08
Gender	58 M, 89 F
Type of deafness	109 postlingually, 36 prelingually
Music training	10 training, 137 no
CI configuration	87 unilateral, 9 bilateral, 47 bimodal, 3 EAS
Type of administration	135 completed the questionnaire online and 17 by post

6.3.1 Descriptive statistics

Items 39, 45 and 46 were removed because they were rated 'Not very important' (2) or 'Not important at all' (1) by ≥60% of the respondents. Another three items (15, 18, 43) were excluded due to ≥10% N/A responses for frequency or importance. The choice of a 10% cut-off was based on previous literature and was also considered reasonable for the present study. All these items referred to music making which suggested that more than 2/3 of this particular sample of CI users did not consider music making important/applicable. Two participants informally reported that they found item 16 about the ability to recognise new music 'confusing'. It was also acknowledged by the author that its phrasing was likely to cause confusion. The item was removed. Table 6.3 shows the items selected for removal at this stage.

Table 6.3 *The seven items removed on the basis of descriptive statistics and the reasons for exclusion. For the questionnaire items, see Appendix C.2 and Appendix C.3.*

Item	Main reason for exclusion
15. Can you hear whether you are singing or playing a musical instrument in tune (in tune with the music or with others)?	13% N/A responses for importance
16. Can you recognise music that you have not heard before?	Unsolicited comments: confusing
18. Do you feel embarrassed when whistling, singing or playing a musical instrument with others present?	18% N/A responses for frequency and 11% for importance
39. Do you participate in 'music interest' groups (e.g. music workshops or music clubs)?	73% importance ratings 1-2
43. Do you dance or participate in fitness classes that use music?	10% N/A responses for importance
45. Do you sing, play a musical instrument or whistle when others are present?	63% importance rating 1-2
46. Do you choose to participate in music classes (e.g. singing lessons)?	71% importance rating 1-2 and 11% N/A responses for frequency

6.3.2 Test-retest analysis of individual items

In addition to the CI users who did not repeat the questionnaire and the two participants already excluded, participant 62 was also excluded from the test-retest analysis due to 58% missing questions in the frequency scale. Data from 133 participants[14] were included in the analysis. The data did not fully meet criteria for normality as was seen from the histograms and values of skewness and kurtosis of individual items (see Appendix C.7 for the values of skewness and kyrtosis of the 46 frequency and importance scores of the first administration). Despite that, the parametric ICC was preferred over non-parametric equivalents (kappa or non-parametric ICCs) because it is easier to compute and has a number of other benefits, such as that it can control for confounding factors affecting reliability or that it can handle missing data (Streiner et al. 2015:

[14] Eight participants underwent clinical changes (e.g. processor upgrade) between the two administrations that would possibly affect their music experience. Test-retest analysis without these participants yielded similar ICCs suggesting that even if there was a substantial test-retest change in these participants, it did not affect the repeatability of the items.

178-179). Data were actually not far from normality, which was retrospectively confirmed by the result of the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy of the factor analysis.

Table 6.4 *ICC values for the 7 items chosen for removal due to poor repeatability (ICC: <0.2). In brackets the lower and upper bound. For the questionnaire items, see Appendix C.2.*

Item (frequency scale)	**ICC (95% confidence interval, single measures)**
24. Does music make you feel uncomfortable?	-.087 (-222 to .078)
25. Do you feel disappointed with music (e.g. with the quality of the music, or if it is difficult to enjoy, recognise or follow music)?	-.102 (-.045 to .252)
26. Do you feel frustrated with background music at a shop or restaurant?	-.010 (-.099 to .094)
28. Does music sound 'just like noise'?	-.025 (-.121 to .086)
32. Do you find music-like every-day sounds (e.g. the ringing of your phone, the doorbell, bird songs or church bells) annoying?	-.061 (-.171 to .068)
33. Do you find high-pitched music (e.g. soprano singing, flute playing or whistling) annoying?	.022 (-.078 to .137)
41. Do you avoid social events or activities where music is played (e.g. parties or getting together with the family)?	-.081 (-.210 to .069)

Intra-class correlation coefficients (ICCs) were calculated for each item using a 2-way mixed effects model for absolute agreement. Analysis indicated seven frequency items with poor repeatability (i.e. <0.2), which were removed (Table 6.4 above). The rest of the frequency items had ICCs >0.6 and the rest of the importance items had ICCs > 0.4, suggesting at least moderate test-retest reliability (Appendix C.7). The lower repeatability in importance compared to the frequency items confirmed a difficulty to answer the importance questions that participants reported in the anectodal comments.

6.3.3 Inter-item correlations of the frequency items

The values for skewness and kurtosis (Appendix C.7) and visual inspection of the histograms for the remaining 32 items suggested that the data did not fully meet conditions for normality[15]. Therefore non-parametric correlations were more appropriate[16]. Spearman's rho was preferred over Kendall's tau because the sample was relatively large. Of 512 Spearman correlations between the 32 remaining 'Frequency' items, 124 were >0.6, 24 were >0.7 and 4 were >0.8. See Table 6.5 below for the 24 correlations >.7. All of them were statistically significant at the 0.001 level but this was interpreted with caution given the number of correlations. Examination of the bootstrapped confidence intervals of the correlation coefficients for the 24 correlations >0.7 provided support for genuine effects (they all had a lower boundary of >0.6). In each pair of items with correlations >0.7, one of them was considered for removal.

Meaning and emotion items: Question 9 (Can you distinguish different musical instruments when they play together?) correlated at 0.822 with question 10 (Can you hear the emotion of music (e.g. whether a piece of music is happy or sad)?), suggesting that the two were perceived similarly, and question 9 was removed because meaning is broader and can include emotion. This was in line with the suggestion of the independent coder to merge the two themes in the final template of the focus group data analysis (section 4.4.3).

---

[15] The Kolmorgov-Smirnov and Shapiro Wilk tests were both significant for all items which was attributed to the sample size. These tests have not been recommended for large samples because they are likely to be significant even for small and unimportant effects (Field, 2014: 5.3.2.2.). Therefore their results were interpreted in conjunction with the plots and the values for skewness and kurtosis.

[16] However, Pearson's correlations gave very similar results to Spearman

Table 6.5 *Selected Spearman correlation coefficients between items of the questionnaire. In red, the 24 correlations >.7. All correlations were significant (2-tailed) at the <.001 level. For the questionnaire items, see Appendix C.2.*

		Questionnaire items										
		7	**9**	**11**	**17**	**20**	**21**	**23**	**27**	**29**	**30**	**34**
Questionnaire items	**8**	**.729**										
	9	.596										
	10	.657	**.822**									
	11	.524	.670									
	17	.573	.570	.645								
	20	.463	.475	.649	.666							
	21	.413	.527	.581	.567	.565						
	22	.417	.483	.516	.601	**.712**	.661					
	23	.491	.537	.658	.630	.662	**.714**					
	27	.490	.603	.681	.669	.598	.563	.604				
	29	.538	.634	**.775**	**.742**	.641	.634	**.721**	**.742**			
	30	.512	.610	**.721**	**.700**	.616	.618	.677	.699	**.866**		
	31	.548	.627	**.734**	**.781**	**.736**	.590	**.753**	**.728**	**.841**	**.783**	
	34	.457	.483	.611	.595	**.706**	.526	.669	.579	.687	.639	
	35	.369	.369	.509	.578	**.753**	.471	.614	.523	.587	.541	**.823**
	36	.355	.438	.533	.477	.586	.498	.595	.402	.554	.547	**.717**
	37	.460	.485	.577	.558	.619	.599	**.779**	.505	.661	.613	.691
	40	.267	.411	.397	.386	.414	**.768**	.536	.359	.461	.408	.413

Music sound quality items: The sound quality items 29, 30 and 31 correlated highly (>0.8) with each other which suggested that they were perceived as overlapping. They were also correlated with questions 11 and 17 (>0.7) which may suggest that the listening effort and the confidence to hear music like others is affected by the quality of the music. Items 29 and 31 also correlated with 23 and 27 (>0.7). Items 29, 30 and 31 were removed. Item 27 (Does music sound out of tune?) did not correlate with other items and had to be retained to cover music sound quality. The overlap between the sound quality items and the removal of all three of them was supported by findings that CI users tend to give similar ratings to sound quality questions. For instance, high correlations between ratings for naturalnesss, pleasantness and clearness have been reported elsewhere and all three measures have been averaged (van Besouw et al., 2015).

Music listening activity items: Item 34 correlated highly with 35 (0.823) and 36 (0.717). Although these questions covered different aspects of music listening, it is likely that CI users who actively listen to music also use it in the background or while travelling. Music listening at home and in public events was also addressed by items 37 and 40. Items 35 and 36 addressed other functions of music so were retained.

Musical instrument recognition items: There was a correlation of 0.729 between items 7 and 8 about the recognition of individual and multiple musical instruments. Although the two questions covered different themes, there was potential overlap and one was retained to avoid redundancy. Item 8 was removed because it had a mean score of slightly above 3 confirming that the identification of musical instruments is already a challenging task for many CI users (Kang et al., 2009).

Music enjoyment items

- Items 20 was correlated with item 22 (0.712). It is likely that they were interpreted as covering listening in favourable environments. Item 22 was more simply worded and 20 also correlated with 31 (0.736), 34 (0.706) and 35 (0.753). Item 20 was removed.
- Item 23 correlated highly (0.779) with item 37 and item 23 was removed because it was more directly addressed the concept of listening to new music.
- Item 21 was highly correlated (0.768) with item 40, with both items referring to public music events. Item 21 was removed to ensure that at least one "participation" item was included and so that the concept of public music events was included in the questionnaire. It was then ensured that item 19 was retained so that the enjoyment of music in a challenging environment, i.e. noise without visual cues (in addition to enjoyment of music with visual cues – item 22) was covered.

The correlations of item 42 with all other items were weak (<0.3) and not significant; the item was therefore removed. It has been recommended that items of a scale that do not correlate with other items are likely not tapping on the same concept (Field 2014:685-686). This was retrospectively confirmed by reliability analysis, whereby Cronbach α decreased with the inclusion of item 42.

The correlations of item 44 with all but two of the other items were also poor (<0.3) and most of them not significant even at the 0.05 level. However, item 44 was retained to ensure that the concept of music making is addressed given that all of the other 'music making' questions had been removed. It also had a SD of 1.285 for frequency and 1.365 for importance suggesting good discrimination. See Table 6.6 for all items removed on the basis on inter-item correlations.

Table 6.6 *Items removed on the basis of inter-item correlations or high endorsement. For the questionnaire items, see Appendix C.2.*

Item	Reasoning	Additional reasons
8. Can you distinguish different musical instruments when they play together?	High correlations with 7	7 was already difficult
9. Can you hear the emotion of music (e.g. whether a piece of music is happy or sad)?	High correlation with 10	Meaning covers emotion
20. Do you enjoy music in quiet environments when visual cues are not available (e.g. music on the radio or on a CD player at home)?	High correlation with 22	22 simpler wording, correlations with 31 and 35
21. Do you enjoy music at public music events (e.g. music at a theatre, cinema, concert, music festival or church service)?	High correlation with 40	40 retained to address participation
23. Do you enjoy music that you hear for the first time (i.e. music that you have not heard before)?	High correlation with 23, 37	More directly addressing new music
29. Does music sound clear?	High correlation with 11, 17, 23 and 27	27 no other correlations, 11 and 17 addressing different concepts
30. Does music sound pleasant?	High correlation with 11 and 17	
31. Does music sound 'as you think it should sound'?	High correlation with 11, 17, 23 and 27	
34. Do you put music on to listen to (e.g. CDs, music on the radio/internet or musical shows on TV/DVD)?	High correlation with 35 and 36	Active music listening also addressed by 37 and 40
42. Do you talk about music with others (e.g. about music that you like or about problems that you have with music)?	Weak correlations with other items	

6.3.4 More descriptives

Of the 22 remaining frequency items, 5 (1, 2, 3, 13, 22) were highly scored (4 or 5) and 2 (17, 19) were poorly scored (1 or 2) by ≥60% of the participants. Two relatively "easy" and two relatively "difficult" items had to be retained for the detection of extreme cases, so the three items with the highest degrees of endorsement were removed in order to balance with the negatively scored items. These were items: 1 (85%), 3 (82%) and 13 (78%).

Although items 11 and 38 did not correlate strongly (0.386), they both addressed the concept of listening effort, so only one of them was necessary. Item 38 was removed because item 11 was more simply phrased and more directly addressed the concept of listening effort. Music listening without listening effort in fact assesses the real music perception abilities of CI users, because very often good performance in a listening task happens in parallel with high listening effort which means no success. When assessing benefits/performance the effort should be taken into account too.

6.3.5 Factor analysis of the frequency scale

Factor analysis was performed for the remaining 18 frequency items using the Prinicipal Component Analysis (PCA) technique for factor extraction with oblique rotation. PCA identifies the factors that account for the variance in the data. Each factor has an eigenvalue, which represents the power of the factor to account for the variance. Eigenvalues >1 are used by convention to determine factors. Rotation facilitates interpretation of the factors and discriminates better between factors. Oblique rotation was chosen given that the factors were unlikely to be completely unrelated to each other. Each factor has a factor loading, which shows the correlation between a factor and the items. Factor loadings are interpreted relatively to each other and an item with a higher loading on a factor than another is interpreted as fitting better to that factor. A value of 0.945 for the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy was within the range of 'marvellous' and suggested that the sample was adequate for the analysis to give reliable results (Field 2014: 17.7.1).

Table 6.7 *'Pattern matrix' showing the factor loadings (after rotation) for the 18 remaining frequency items. Factors were extracted using Principal Component Analysis and Varimax rotation with Kaiser Normalization was applied and converged in 3 iterations. Loadings >0.3 are reported. The eigenvalues and the % of the variance each factor explains are given. Items are ordered according to the loadings on factor 1. For the items see Appendix C.9. Also see Appendix C.8 for the 'Structure matrix[17]' of the factor analysis.*

[17] In factor analysis with oblique rotation, the pattern matrix shows the factor loadings and is easier to interpret; the structure matrix takes into account the relationships between the factors (Field, 2014:702-703).

Frequency Item	Component	
	1 Eigenvalue: 8.9 % of Variance: 49	2 Eigenvalue: 5.6 % of Variance: 31
5	.882	
7	.856	
4	.838	
14	.795	
12	.785	
11	.761	
27	.757	
6	.749	
17	.736	
10	.716	
2	.679	
22	.498	.364
19	.498	
35		.761
36		.722
37		.661
40		.641
44		.497

Analysis showed two factors with eigenvalues >1 that together explained 80% of the total variance (Table 6.7 above). Thirteen out of 18 items loaded more heavily on Factor 1. Nine out of the 13 items had initially formed the ability prototype domain. Factor 1 was interpreted as a music perception/listening ability MRQOL domain. Items 17 (confidence), 19, 22 (enjoyment) and 27 (music sounding in tune) had initially been grouped under the 'attitude' domain but now loaded more heavily in Factor 1 together with music listening ability issues. From them, items 17 and 27 clearly had higher loadings for Factor 1, which suggested that they were treated as music perception items. For item 27 this was in contrast with previous studies where music sound quality ratings have been treated as music appreciation issues and studied together with enjoyment and music listening habits. Item 17 was in the attitude-psychological prototype domain because it covered a self-esteem issue, but here it was rather perceived as a perception/ability task. Items 19 ('Do you enjoy music in noisy environments when no visual cues are available (e.g. at a party, at a restaurant or in the car over the engine/road noise)?') and 22 ('Do you enjoy music on TV, DVD or on the computer when visual cues are available?') had similar loadings for both factors, athough slightly higher for Factor 1. To understand this result better, factor analysis was also conducted with the other three enjoyment items that were removed earlier. When three or more enjoyment items in total were included, they were all loading clearly more heavily on Factor 2, suggesting that they were actually perceived as distinct from perception items. It was likely that when only two of them were included (as opposed to five activity items), the enjoyment items did not quite fit in Factor 2. Therefore, items 19 and 22 were finally grouped under Factor 2 despite the slightly higher loadings for factor 1. It has been recommended that the results of factor analysis are interpreted in the context of the research rather than taken at face value (Field 2014: chapter 17).

The remaining 5 items loading more heavily in Factor 2 were from the original activity/participation domain and were interpreted as reflecting the psychosocial apsects of MRQOL. Factor 2 was interpreted as a music engagement domain, covering music enjoyment and activity issues. This was in agreement with previous studies, whereby attitude towards music and participation have been grouped together under the concept of music engagement (Gfeller et al., 2012a). It was also in agreement with the general music literature. For example, the Active Engagement domain of the GOLD-MSI measure covers the enjoyment of writing about music (Müllensiefen et al., 2014). Finally, Factor/Domain 1 had 11 items and Factor/Domain 2 had 7 items (Table 6.8 below).

Although only the *pattern matrix* is reported here (where the factor loadings represent the correlations between the items and the factors), these results were confirmed by the *structure matrix,* which takes into account the relationship between the factors (see Appendix C.9 for the structure matrix and Field, 2014:702-704 for an explanation of the pattern and structure matrices). Please note that in the *structure matrix* several variables loaded highly on both factors, which shows that music perception and engagement are related to some extent. Although this is not surprising, music enjoyment or appraisal ratings have not always been associated with music perception scores, as discussed in 2.3.2. Music appreciation should be explicitly studied separately from music perception; this has been strongly suggested in the literature (Looi et al., 2012). Therefore, the relationship between the two factors as seen in the structure matrix by no means suggests that perception and engagement should not be considered as two separate domains.

Table 6.8 *The two subscales of the 18-item MRQOL questionnaire after factor analysis.*

Factor 1: music perception	Factor 2: music engagement
2. Can you distinguish different rhythmic patterns in music?	19. Do you enjoy music in noisy environments when no visual cues are available (e.g. at a party, at a restaurant or in the car over the engine/road noise)?
4. Can you follow the melody in music (i.e. follow the melody of a song or a familiar tune)?	22. Do you enjoy music on TV, DVD or on the computer when visual cues are available?
5. Can you hear differences in musical tone (i.e. how high or low music is)?	35. Do you choose to have music on in the background while doing something else (e.g. while reading, painting, doing gardening, exercising or just relaxing)?
6. Can you recognise the words in songs?	36. Do you listen to music whilst travelling (e.g. in the car)?
7. Can you recognise the sounds of different musical instruments when they play separately ('solo')?	37. Do you choose to listen to new music (i.e. music that you have not heard before)?
10. Can you hear the meaning of music (i.e. why it was created or what message it is trying to get across)?	40. Do you attend public music events (e.g. musicals, concerts or music festivals)?
11. Can you hear music without effort or having to concentrate?	44. Do you sing, play a musical instrument or whistle when you are alone?
12. Can you recognise familiar music (e.g. a song, singer or tune)?	
14. Can you judge the quality of a musical performance (e.g. singing or musical instrument playing)?	
17. Do you feel confident that you hear music like other people do?	
27. Does music sound in tune?	

6.3.6 Internal consistency of the frequency scale

Calculation of Cronbach's α reliability coefficient indicated excellent internal consistency of the 18-item questionnaire total ($\alpha = .943$) and the 'Perception' ($\alpha = 0.933$) and 'Engagement' ($\alpha = 0.860$) subscales (Table 6.9 below). No items were found to significantly increase internal consistency if deleted so no more items needed to be removed. Item 44, although it was found to correlate poorly with most of the the other items, was found to only increase Cronbach's α by 0.017 therefore it was conluded that it did not seriously affect internal consistency. It should be noted that the exact values of α for the scales and the individual items should be interpreted with caution; α is affected by the number of items in a scale in a way that the more the items in a scale, the higher the α of the scale and the individual items (for a discussion in the literature about the difficulty in the interpretation of α see: Streiner et al., 2015:85-88). It is acknowledged that the use of α coefficient is a potential limitation of the study due to the difficulty with its interpretation. However, it is suggested that this did not severely affect the interpretation of results because: 1) α remained very high even in the engagement subscale with only seven items and 2) the relative values of α for each item were more important than the absolute values for item selection.

Table 6.9 *Cronbach's α coefficients for the whole scale and two subscales as well the α if each of the items was deleted. The latter gives an indication of how each item affects the internal consistency of the scale(s). For the questionnaire items, see Appendix C.2.*

Scale total: (18 items)		**Subscale 1: perception (11 items)**		**Subscale 2: engagement (7 items)**	
Cronbach's α: .947		Cronbach's α: .940		Cronbach's α: .840	
Item	**Cronbach's α if item deleted**	**Item**	**Cronbach's α if item deleted**	**Item**	**Cronbach's α if item deleted**
2	.945	2	.939	19	.822
4	.942	4	.932	22	.809
5	.942	5	.932	35	.800
6	.944	6	.936	36	.806
7	.944	7	.935	37	.795
10	.942	10	.933	40	.819
11	.942	11	.933	44	.870
12	.943	12	.934		
14	.943	14	.934		
17	.942	17	.934		
27	.942	27	.934		
19	.945				

22	.943				
35	.945				
36	.945				
37	.942				
40	.945				
44	.952				

6.4 The final MRQOL questionnaire

The final MRQOL questionnaire consists of 18 items with the following characteristics:

- Test-retest reliability: All final 18 frequency or important items had at least moderate test-retest reliability (ICC>.4) with 11/18 frequency items and one importance item having almost perfect repeatability [>.8] (see Appendix C.7).
- Sensitivity: All 18 selected items had a SD of >1 for frequency or importance while 15 had SD>1 for both. This, together with the overall range of frequency and importance scores, suggests that the items have some ability to discriminate among CI users with varying levels of frequency/importance (Appendix C.7).
- Novelty: Five of the 18 selected items have not been included in previous CI questionnaires: perception of lyrics (item 6), meaning (item 10) and judging music quality (item 14), confidence (item 17) and listening to music whilst travelling (item 36). Item numbers refer to Table 6.8 above.

Changes can be made to some 'frequency' items (and to the corresponding 'importance' items) due to the elimitation of similarly phrased questions. It is recommended that:

- In item 2, 'rhythmic patterns' is replaced by 'rhythms'
- In item 7, 'when they play separately (solo)' is removed
- In item 19, 'when no visual cues are present' and 'in noisy environments' are removed
- In item 22, 'when visual cues are present' is removed
- Item 44: 'when you are alone' is removed

In addition to the test-retest reliability of individual items, the ICCs for the overall frequency and importance scales and subscales showed excellent repeatability (> 0.80) and were higher for *perception than engagement (Table 6.10). the lower bounds of the confidence intervals of the ICCs were also > 0.80 (except for frequency engagement), giving a high degree of certainty that the ICC is sufficiently high to justify the use of these scores at the group level, and at the individual level for the overall frequency scale (and perception subscale), where the lower bound for the ICC was > 0.9.*

Table 6.10 *Test-retest reliability of the MRQOL overall scales*

Measure	ICC (n=133)	Cronbach's α (n=147)
Frequency OVERALL	.964 (.950 - .974*)	.947 (.932 - .959*)
Frequency *perception*	.941 (.918 - .958*)	.940 (.923 - .954*)
Frequency *engagement*	.951 (.931 - .965*)	.840 (.796 - .878*)
Importance OVERALL	.850 (.795 - .891*)	.920 (.898 - .939*)
Importance *perception*	.802 (.732 - .855*)	.904 (.878 - .926*)
Importance *engagement*	.842 (.785- .885*)	.858 (.818 - .893*)

*95% confidence intervals

6.5 Discussion

This research is novel in using statistical methods for the selection of items in a CI-specific questionnaire. In previous music or HRQOL questionnaires for CI users item generation or selection was only based on expertise or content and face validity (Gfeller et al., 2000a; Looi & She, 2010; Brockmeier et al., 2002; Hinderink et al., 2000).

The 18 frequency and importance items selected have some ability to discriminate between CI users and high repeatability, as measured with group data. The results also supported the internal consistency and the test-retest reliability of the final MRQOL questionnaire as a whole. Elimination of inappropriate, unimportant or unclear questions on the basis of CI users' N/A responses, importance ratings and informal comments also supported the face validity of the questionnaire.

Although importance ratings were informally reported to be difficult, especially for participants with little engagement with music, it is likely that the problem was minimized after the item selection. Also the removal of all negatively-phrased questions on the basis of low test-retest reliability, inter-item correlations or descriptive statistics improved the face validity of the questionnaire (as they were informally reported as confusing) but could increase bias. It is necessary that the final set of items is administered to CI users for re-assessment of face validity.

To the knowledge of the author, this is the first study to use psychometric techniques to group music experiences of CI users into domains. The 18 selected items grouped together into two meaningful subscales with both subscales as well as the whole scale having high internal consistency. These results offer preliminary evidence for the internal consistency and construct validity[18] of the final questionnaire as a whole, since items clustered together into meaningful subscales. However, these results were interpreted with caution because they were based on responses to the selected final items that were collected from at Study 3. It is necessary that the 18-item final questionnaire is completed by CI users again for re-assessment of reliability and factor analysis.

The final 2-dimensional distinction is generally in line with previous CI-music studies where all aspects other than perception were referred to as music appreciation (Looi et al., 2012). However, self-perceived music sound quality was here grouped together with music perception/ability issues, in contrast with the traditional approach in the CI literature whereby music sound quality attributes have been assessed together with enjoyment and music listening habits. This may be more than a classification issue as it can have implications for the assessment of music sound quality attributes. For example, the question 'Does music sound in tune?' was likely to have been perceived as an ability/perception item, i.e. 'Can you hear whether music is in tune?' or 'Can you hear music in tune?'. The phrasing of music sound quality items should be considered. The hypothesis for a 3-dimensional MRQOL concept (ability, attitude and activity corresponding to physical, psychological and social HRQOL domains) was not empirically supported, at least with the 18 selected items (8 from ability, 4 from attitude and 6 from activity), as psychological and social aspects of music experience clustered together under the same factor.

The test-retest reliability (indicated by ICC) for all the frequency measures and the Cronbach's α for the overall frequency and importance scales and perception domain subscales exceed the 0.90

[18] Whether the measure is consistent with the MRQOL conceptual framework that it is intended to measure.

criterion that has been recommended for individual level measurements (McHorney & Tarlov, 1995). These results have implications for the appropriateness of the questionnaire for individual measurements and its clinical usefulness, which are thoroughly discussed in section 9.3. Overall, potential limitations of the use of CTT techniques and the corresponding assumptions (e.g. treating Likert scale data as interval) as well as the difficulty with the interpretation of α have been acknowledged (see sections 3.3, 6.2.5 and 6.3.6).

To the knowledge of the author, the sample of 147 adult CI users is the largest CI sample that has been reported in the literature for pilot-testing of CI questionnaires (Brockmeier et al., 2002; Hinderink et al., 2000). For example, responses from 75 adult CI users were used for the item selection and validation of the HISQUI (Amann & Anderson, 2014). In fact, the sample of the present study is one of the largest in the CI literature in general. For instance it is larger than the 145 CI users recruited by Drennan et al. (2014) in a large scale clinical trial in the US and Canada (Drennan et al., 2014). It is difficult to draw conclusions about the representativeness of the sample. The fact that there were twice as many females as males could be due to the recruitment strategy or the type of the study. In the USAIS for instance, the main pool of participants, when invitations were sent, there were 436 women implanted with a CI over 277 men. It is also likely that women may have been more interested in music or more willing to share their experiences than men. In fact, the prevalence of women in the NH sample (section 7.1 later) retrospectively supported these assumptions and suggested that the prevalence of women may not be specific to CI users.

The results show that the MRQOL questionnaire may not be equally applicable and informative for the whole range of CI users. For example participant 41, a prelingually deaf CI user who reported limited exposure to music post-implant, also reported finding a lot of the questions irrelevant. Specific items may be less applicable to prelingually deaf. For instance, frequency item 27 about music sounding in tune had more N/A responses than any other item and all from prelingually deaf, probably due to no perception of how music sounds in tune due to no NH memory of music. Another participant (74) who reported poor engagement with music and that the questionnaire did not apply to her, reported that she often used 'Never' and 'N/A' options interchangeably and that especially importance questions were difficult to answer. Another participant (36) informally reported frustration and difficulty to understand or appreciate music in any way, presumably due to a prolonged period of deafness (70 years old, congenitally deaf, implanted one year ago). Following what she described as an important change in her attitude towards music (meeting with musical family, having ukulele lessons), she only rated 2 out of 46 importance items as N/A at retest. This suggests that N/A responses can be informative. However, the potential overlap between 'Never' and N/A and the use of a N/A option, especially in the importance questions, should be considered.

With regards to the methods of administration, items were selected and the evidence for validity was collected using mainly online questionnaire data (135 participants completed the questionnaire online over 17 by post). The fact that most of the missing data came from paper questionnaires (e.g. participant 62 whose missing questions covered two questionnaire pages) may also suggest a benefit of online administration over paper questionnaires.

6.6 The revised MRQOL framework

After the final items were selected and the subscale structure was decided, the MRQOL conceptual framework that was built as a result of the focus group data analysis (Appendix B.5) was revised. The MRQOL is a 2-dimensional concept and the domains are those defined after factor analysis. The subdomains are those of version 2 of the questionnaire after expert review and were used to group themes corresponding to the 18 final items. The new conceptual framework has the potential to be a standard classification system that may guide research in the area of music and CIs and facilitate the study of music in relation to CI users from a broader perspective than previous studies. Use of a new conceptual framework for music and CIs would also be of clinical significance as it would contribute towards more holistic and accurate measurement of music-specific outcomes in CI users. See Table 6.11 for the final MRQOL framework.

Table 6.11 *The revised MRQOL framework.*

construct	**MUSIC-RELATED QUALITY OF LIFE (MRQOL)**			
domain	**Music perception**		**Music engagement**	
subdomain	Basic music perception	Advanced music perception	Attitude towards music	Music activity and participation
themes	• Rhythm • Melody • Lyrics • Timbre	• Meaning of music • Music sound quality • Familiar music recognition • Judging music quality	• Confidence with music • Enjoyment of music	• Having music on in the background • Listening to music whilst travelling • Listening to new music • Listening effort • Going to public music events

Chapter 7. Questionnaire validation

In Chapter 1. , 18 items with evidence for face validity, repeatability and sensitivity were selected. These items grouped together into meaningful scale and subscales with internal consistency. In this chapter, the validity of the final 18-item MRQOL questionnaire was further assessed. Ideally, the validity of a questionnaire (i.e. if it measures what it is intended to measure) is assessed by comparing the under-development instrument with a standard, validated one measuring the same construct, which is treated as a gold standard (criterion validity). However, because no existing questionnaire can be treated as a 'gold standard' for MRQOL, construct validity was used. Construct validity assesses the extent to which a questionnaire covers the intended concept. In the present study it was assessed in two ways: through the "known groups" technique and through convergent validity.

7.1 Validation with 'known groups': comparison with NH adults (Study 4)

7.1.1 Introduction

The 18 frequency and importance MRQOL questionnaire was completed by NH adults and their responses were compared with the CI users' scores. This way of construct validation is referred to as "known-group" or extreme group method (Streiner et al., 2015; Yang et al., 2013). A measure is valid if it gives significantly different scores for two groups that are known to be different on a specific concept.

An NH group was recruited and compared with CI users due to the absence of CI or hearing-impaired groups with established differences in music perception or appreciation. Benefits have been reported for music perception or appreciation post-implantation for bilateral/bimodal/EAS users as opposed to unilateral CI users, for HA users over CI users and for postlingually over prelingually deaf. For example, using a HA contralateral to the implant (as opposed to using a CI only) was also found to have a significant effect on music perception performance, especially melody recognition (Kong et al., 2005; Sucher & Mcdermott, 2009). Music appraisal with lyrics has been reported to be significantly correlated with the use of a bilateral implant and a contralateral HA (Gfeller et al., 2008). Benefits for music perception and enjoyment have also been reported for users of EAS compared to both unilateral and bilateral CI users (Gfeller et al., 2006, 2007; Driscoll et al., 2016). However, these differences are not consistent; better performance has been reported pre-implant for pitch perception and no significant differences pre- to post-implantation have been found in timbre and rhythm perception or in familiar melody recognition tasks (Looi et al., 2008b). Also Crew et al. (2015) reported no differences between bimodal listening and using a CI or HA alone and even reported that some participants performed better with the HA only. The evidence for the established differences between NH listeners and CI users in music perception ability, enjoyment and listening habits has been reviewed in sections 2.2 and 2.3 of this thesis.

The aim of this part of the MRQOL questionnaire validation was to compare CI users' scores with the scores of NH adults in order to (a) evaluate the validity of the MRQOL construct and (b) the ability of the questionnaire to detect differences. It was hypothesised that the MRQOL 'frequency' scores of NH listeners would be significantly higher than for CI users. This would suggest that the MRQOL questionnaire assesses a concept relevant to the music experiences of hearing-impaired adults. In addition to evidence for construct validity, the ability of the questionnaire to discriminate CI users from NH listeners would be evidence for the sensitivity of the measure.

7.1.2 Methods

7.1.2.1 Participants

The same version of the MRQOL questionnaire (46 questions, Version 2, Appendix C.2) that was completed by CI users in Study 3, was also administered to NH adults as an online survey. The study was advertised among students and staff (academic and non-academic) of the University of Southampton. Adults without known hearing problems were invited. In total, 142 participants (48 male, 94 female, mean age: 37, age range: 18-87) completed the survey (see Appendix D.1 for the demographics of the NH participants). Fifteen had received some music training. The CI users used for comparison were the same who completed the questionnaire in Study 3 (section 5.3). For both NH adults and CI users, the responses collected in Study 3 were used, but only for the selected 18 items. It is acknowledged that a new administration of the final/selected set of items could induce different answers. However, the questionnaire was not readministered and the same responses were used was due to the difficulty to recruit large numbers of CI users in a short period of time.

7.1.2.2 Matching the groups

A CI and a NH sub-group of 68 participants each were selected, who were matched for age, gender and professional music training (Table 7.1). The matching was performed as follows: CI and NH participants were sorted by age. For each CI age, a corresponding NH participant was selected and vice versa, in order to arrive at equal number of subjects per age group. When there were more participants in one group, the first ones were selected and when there was no participant for one age, the next closest age was chosen. Training and gender were also used to select participants in these cases.

Table 7.1 *Characteristics of the matched CI and NH groups.*

Age range	18-80 years
Mean age	45.8 years in the NH group and 45.9 years in the CI group, median age: 44.5 years for both groups
SD age	15 years
Gender	49 females and 19 males in the NH group, 51 females and 17 males in CI group
Music training	3/68 in both groups

Matching the groups was necessary due to the large differences in age distribution between the CI and NH samples (see Figure 7.3). The distribution of music training between the samples was similar (7% CI users, 11% NH adults).

A wide range of educational level was ensured in the NH group: 9 participants had graduated from high school only, 12 had some further education, 23 had completed an undergraduate programme, 17 had postgraduate studies and 6 participants had a PhD. No education information was available for the CI users. Background characteristics of the CI group can be found in Table 7.2.

Table 7.2 *Characteristics of the 68 CI users selected for comparison.*

Type of deafness	27/68 were prelingually deaf
Duration of CI use	Range: 1 month to as long as 23 years and 8 months, mean: 6 years and 6 months
CI type	5/68 were bilateral users, 24/68 bimodal and 39/68 unilateral users
CI manufacturer	13 were MED-EL users, 13 AB and 40 Cochlear users

7.1.2.3 Data analysis

The reponses from CI users used for comparison were the ones collected in Study 3 (section 5.3). For both CI and NH participants, the responses to the 18 final questionnaire items were used to produce subscale and scale total scores. Mean frequency and importance scores were calculated for the CI and NH group, for the 'scale total' (1), as well as for the perception (2) and engagement (3) subscales separately. For each of the three measures and for both frequency and importance scores, the choice of parametric or non-parametric tests for comparison between the CI and NH groups was based on the response distribution. 'Frequency' and 'importance' scores were also treated separately due to the difficulty to use combined scores for statistical analyses (see section 6.2.6). Statistically significant differences were expected in the 'frequency' scores between the groups for all the three measures. No hypothesis was made regarding the actual size of the difference in terms of Likert-scale points because this is a new questionnaire and the study was a first step towards exploring its measurement properties. Also no hypothesis was made for the 'importance' scores.

7.1.3 Results

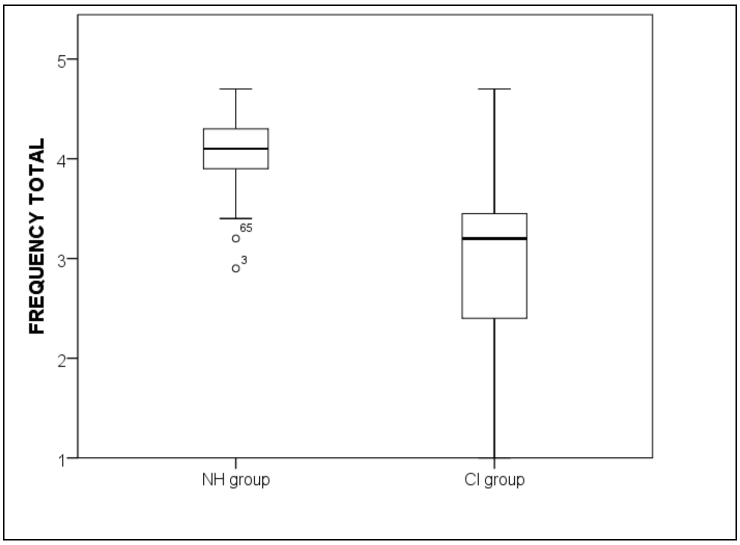
A combination of descriptive statistics, plots and normality tests for all frequency and importance measures (scale total and both subscales) for the matched CI and NH groups showed mixed results with regard to normality. The boxplots, histograms and Q-Q plots were roughly normal but the values of skewness and kurtosis and the Kolmogorov-Smirnov and Shapiro-Wilk tests suggested deviation from normality for most measures, especially for the NH group (Figure 7.1 below). Also Levene's test for the homogeneity of variance between the groups was significant for most measures. This suggested that one of the assumptions of parametric tests, equality of variances, was violated. For these reasons, non-parametric statistics were preferred.

The results of the Mann-Whitney test can be seen in Table 7.3. For all frequency scores (scale total, perception, engagement) the NH group has statistically significantly higher scores than the CI group. This effect was stronger for perception and for the total scale than for engagement. No statistically significant difference was found for importance; there were small differences between the median scores of the two groups for perception and scale total and these differences were in favour of the CI group.

Table 7.3 *Results of the Mann-Whitney test comparing the CI and NH group. The threshold for a large effect is set at: 0.5.*

Measure	Median	Mann-Whitney
Frequency overall	CI: 3.2, NH: 4.1	U=586.5 ($p<0.001$), R= -0.65
Frequency perception	CI: 3.2, NH: 4.4	U=421.5 ($p<0.001$), R= -0.71
Frequency engagement	CI: 3.1, NH: 3.7	U=1235.5 ($p<0.001$), R= -0.40
Importance overall	CI: 3.6, NH: 3.5	U=2474.5 ($p=0.478$), R= 0.06
Importance perception	CI: 3.7, NH: 3.6	U=2491 ($p=0.435$), R= 0.07
Importance engagement	CI: 3.4, NH: 3.4	U=2414.5 ($p=0.655$), R= 0.04

Also, larger variability was observed in the CI group, especially for frequency (Figure 7.1 below). The variability in the CI subgroup was very similar to that found in the whole CI sample (see Figure 6.4 in section 7.1.3) suggesting that the variance was not related to the selection of specific participants within the subgroups but rather to background variables of the CI sample. An exception was the importance-engagement subscale where the lower threshold was now slightly above 1 for almost all the participants. This drop of the lower threshold for the importance ratings of the engagement subscale in the whole sample, may be related to the different age range of the sample as opposed to the matched group. Effects of age were tested below.



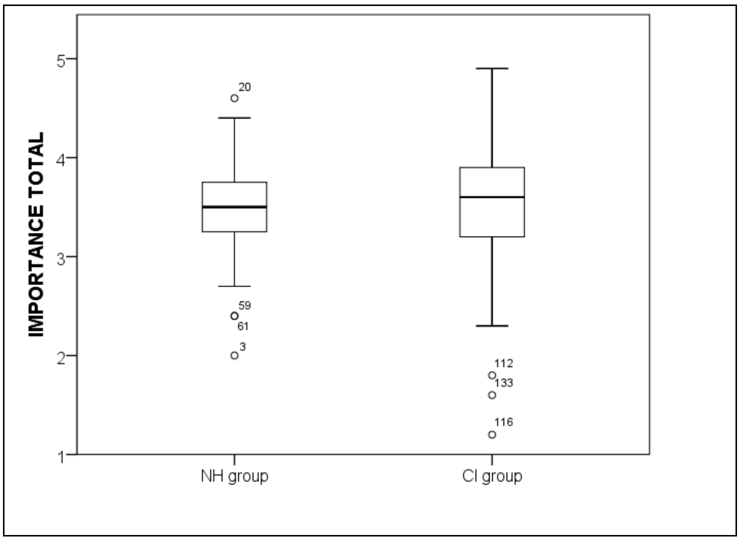


Figure 7.1 *Boxplots of 'frequency total' (top) and 'importance total' (bottom) scores for the NH and CI group (N=68). The boxes represent the interquartile range, i.e. the middle 50% of the observations, the whiskers are the top and bottom 25% of the scores, the horizontal bars are the medians and the circles show the outliers.*

7.1.4 Effects of background variables

In order to explain the variability in frequency scores in the CI group, partial correlations were examined between all background variables and Scale Total frequency scores to test for effects of background variables on the frequency scores; partial correlations were also looked at for importance scores to test for similar effects (Table 7.4). Out of 12 correlations, three were significant at the .001 level, those between age and frequency, training and importance, gender and importance. From them, the correlation between age and frequency was moderate (>.3) and negative.

Table 7.4 *Partial correlations between background variables and Scale Total frequency and importance scores. All correlations control for confounding effects of all other variables. The significance criterion was set at p <0.001.*

Measure	**Frequency total**	**Importance total**
Age	R: -.302, Sig. <.001	R: -.133, Sig. .114
Music training	R: -.058, Sig. .490	R: .200, Sig. .017
Type of deafness	R: -.117, Sig. .164	R: -.067, Sig. .428

Measure	Frequency total	Importance total
Type of CI	R: .068, Sig. .420	R: -.041, Sig. .629
Duration of CI use	R: .119, Sig. .159	R: -.070, Sig. .410
Gender	R: .060, Sig. .481	R: .172, Sig. .040

Regression techniques were used to confirm these findings and explore which combination of factors can best explain frequency and importance scores. Multiple linear regression with forced entry was performed twice, with dependent variables the Frequency Total and Importance Total score and predictors all the the background variables. The predictors were entered hierarchically. For the dependent variable Frequeny Total, type of deafness, age and professional music training were entered first. This was due to evidence from the literature for potential effects on music perception and enjoyment (Gfeller et al., 2008; Sladen & Zappler, 2015; Eisenberg, 1982) [also see sections 2.2 and 2.3] and also due to the results of the partial correlations. Duration of implant use, implant type and gender were entered afterwards. The same order was kept for Importance as a dependent variable.

Table 7.5 *Linear model predictors of Frequency (left) and Importance (right). Confidence intervals (reported in parentheses) and standard errors for beta are based on 1000 bootstrapped samples. Only Step 2 of the hierarchical forced entry model is reported, where all the predictors were included. Beta shows how much each predictor affects the outcome if the effects of the other predictors are held constant and is measured in units of measurement of each variable. Positive values indicate positive relationship between the predictor and the outcome and negative values, negative relationship. Standardised beta measures the number of SDs change of the outcome as a result of 1 SD change in the predictor and is therefore more useful for comparing between predictors because it is unaffected by different measurement units of the predictor. They both show the importance of each predictor. The p value tells if the predictor makes a significant contribution to the outcome.*

		Dependent Variable: FREQUENCY TOTAL				**Dependent Variable: IMPORTANCE TOTAL**			
Model		**B**	**SE B**	**Standardised Beta (β)**	**P**	**B**	**SE B**	**Standardised Beta (β)**	**P**
Step 2	**Age**	-0.015 (-0.25 - -0.06)	.005	-.310	.002	-0.008 (-0.017 – 0.001)	.005	-.181	.070
	Professional music training	-0.158 (-0.657 – 0.341)	.252	-.051	.531	0.557 (0.090 – 1.024)	.236	.193	.020
	Type of deafness	-0.138 (-0.495 – 0.219)	.180	-.076	.446	-0.201 (-0.535 – 0.133)	.169	-.119	.236
	Implant type	0.053 (-0.091 – 0.197)	.073	.066	.468	-0.016 (-0.151 – 0.118)	.068	-.021	.813
	Duration of implant use	0.015 (-0.007 – 0.036)	.011	.113	.188	-0.009 (-0.029 – 0.012)	.010	-.072	.401
	Gender	0.136 (-0.138 – 0.409)	.138	.083	.329	0.238 (-0.018 – 0.494)	.130	.157	.069

The results of the multiple regression can be seen in Table 7.5 above. All the factors together account for 11.9% (R^2: 0.119) of the variance of the Frequency scores and 11% (R^2: 0.110) of the variance of the Importance scores. However, one factor was a significant predictor for each of the dependent variables: age was a significant predictor of Frequency (Standardised beta: -0.310, p=0.002) and music training was a significant predictor of Importance (Standardised beta: 0.193, p=0.020). Figure 7.2 illustrates the relationship between age and frequency total scores. The significant effect of training on importance was interpreted with caution because there were only 10 subjects with music training over 137 untrained; the effect of unequal sample sizes was reflected in the wide confidence interval of the beta (Table 7.5 above). Figure 7.3 below illustrates the difference on the importance total score between trained and untrained participants.

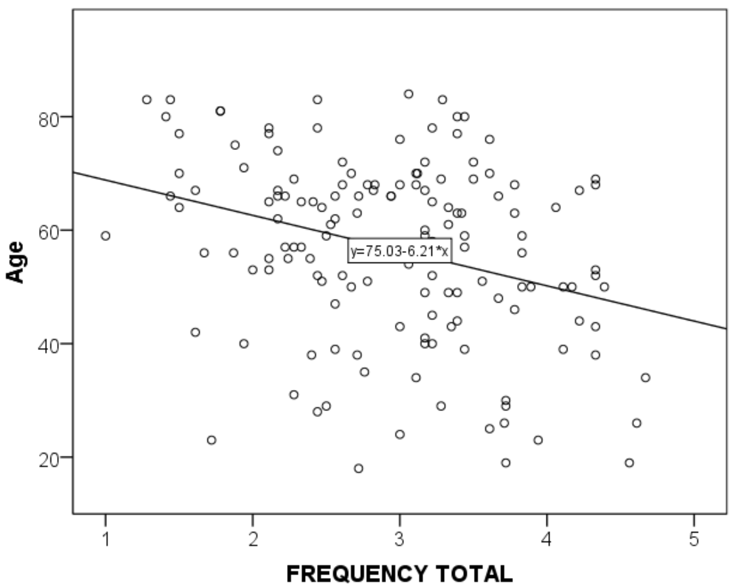


Figure 7.2 *Scatterplot illustrating a significant (p<.01) moderate negative correlation between age and the total scale frequency measure of the MRQOL.*

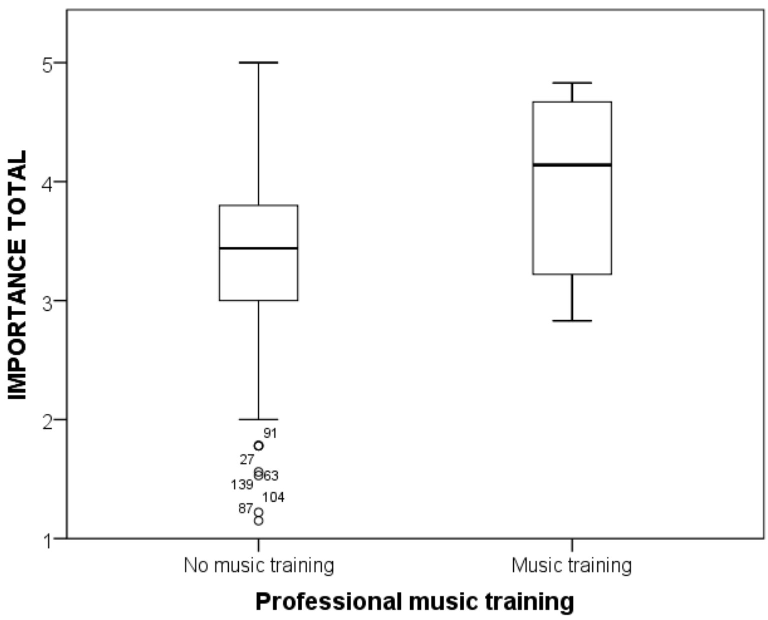


Figure 7.3 *Boxplot illustrating a significant (p<.05) difference between participants with music training (N=10) and those without (N=137). The boxes represent the interquartile range, i.e. the middle 50% of the observations, the whiskers are the top and bottom 25% of the scores, the horizontal bars are the medians and the circles show the outliers.*

7.1.5 Discussion

Study 4 was carried out to primarily assess the construct validity of the MRQOL questionnaire by examining differences between CI users and NH adults. The statistically significant difference in the frequency scores of music perception and engagement between CI users and NH peers shows that the MRQOL questionnaire can detect average differences between two groups which are known to differ in their music experiences and this way it supports construct validity. The result is in line with previous findings of Veekmans et al. (2009) who reported significantly better performance in the MUMU for NH adults than for unilateral CI users and generally better than bilateral CI users.

The NH population was selected for comparison on the basis of established differences between NH adults and adult CI users in music perception tests and due to the absence of other consistent differences in music experience between CI users and other groups (Gifford et al., 2010; Maglione et al., 2014; Crew et al., 2015; Moran et al., 2016; Gfeller et al., 2007). Two limitations of this approach have to be acknowledged: a) given the large disparity between CI users' and NH adults' music perception and appreciation (see sections 2.2, 2.3), differences between the two populations may be a weak support of construct validity and b) the large difference between NH adults and CI users in music perception may not necessarily be seen in self-reports (see 2.3.2 for a discussion of the poor association between music perception scores and self-reported music enjoyment or appraisal). Despite these limitations, the significant difference between the two groups in their MRQOL frequency scores was certainly some evidence that the questionnaire assesses a concept relevant to hearing impaired adults and also has implications for the ability of the questionnaire to detect differences.

The negative correlation between music perception/engagement and age is supported by the literature. For example, Gfeller et al. (2008) reported a negative correlation between song recognition with lyrics and age. Significantly worse performance of older adult CI users as opposed to younger ones has also been found in the timbre recognition task of the CAMP test (Sladen & Zappler, 2015). A negative association between age and music listening habits was also reported by Migirov et al. (2009). The correlation between importance and prior music training has to be interpreted with caution. However, although the importance of music for CI users has been poorly studied previously, Bartel et al. (2011) suggested that music is likely to play a more significant role for people with prior musical background.

The very small (if any) and non-significant group differences for importance were taken to suggest that CI users find music equally important as NH peers although they find it more challenging to perceive it, enjoy it and engage with it. It has also been reported elsewhere that music can be important for CI users despite poor perception, enjoyment and activity. For example, Frederigue-Lopes et al. (2014) adapted the MUMU into Brazilian Portuguese and used it with 19 postlingually deaf CI users. They found a decrease in listening habits post-implantation but music was still rated as important (Frederigue-Lopes et al., 2015). In fact, the slightly higher median importance perception scores for the CI group may suggest that when CI users have difficulty in perceiving music they value it more but these differences were too small (and not significant) to draw conclusions. The comparable importance scores suggest that when using the MRQOL with CI and NH adults, assessing importance is unlikely to contribute much to the impact of music on QOL and so assessing frequency alone would suffice.

The actual difference between the median frequency scores was at the level of 1 Likert-scale point (Table 7.3). No hypothesis regarding the size of the difference between the groups had been made, because this was the first study using the MRQOL questionnaire to compare between CI users and NH adults. In contrast with music perception tests, self-reports are influenced by a number of person-related factors such as expectations. For that reason, it is likely that CI users treated the response options in a different way than NH adults and gave more positive responses than it would have been expected, especially for items relating to music enjoyment or appraisal. For example, CI users who would perform poorly in a music perception test may report that they 'Frequently' or 'Always' enjoy music because either they have no NH memory of music to compare with (in the case of the prelingually deaf) or they appreciate being able to hear music again after a long period of deafness (for the postlingually deafened). This interpretation is supported by literature suggesting that some CI users are satisfied with the music they hear, continue engaging with music post-CI and report that '*some music is better than no music at all'* (e.g. Gfeller et al., 2000a). Therefore, an 1-point average difference between two groups which are likely to have completely different baselines, criteria and expectations could potentially be considered large and clinically important. This may suggest that the 1-point difference detected by the MRQOL can be considered as evidence for the discriminatory power of the questionnaire.

NH listeners' responses may have also been affected by individual variables; the mean NH frequency total score was not near ceiling, which suggests that self-perceived perception, enjoyment and participation of music does not only depend on hearing abilities but on other factors too, such as preferences, music training and age. This is in agreement with previous literature about the effects of such factors on music listening and enjoyment (Lonsdale & North, 2011). Importantly, large variability was found in CI frequency scores, with scores covering the whole range of responses (Figure 7.1 in section 7.1.3). Although most scores were around and below 3, many CI users scored similarly to NH adults and some even approached ceiling. This finding is in agreement with previous evidence in the literature about variability in CI outcomes with regard to music perception and self-perceived music experiences (Maarefvand et al., 2013; Gfeller et al., 2008). For instance, some CI participants in the present study scored comparably to NH subjects, which resembles exceptional CI users known as star performers (Maarefvand et al., 2013). Very little variability was explained by background factors overall. This was in accordance with previous reports that patient and device-related parameters can only account for a small amount of the variablility in CI speech outcomes. This is likely to be even less for music given the confounding effects of additional music-related factors. However, the significant negative effect of age on the frequency scores of the whole CI sample suggested that younger CI users scored more highly than older CI users.

It is unclear to what extent the MRQOL measure can be used to compare CI users and NH adults. In any case, the lack of average differenes for importance suggests that importance ratings would not help distinguishing between individuals so, if the questionnaire was used for that purpose, only frequency ratings could be used without importance. The use of average scores (for the subscales and overall scales) and how meaningful they are should also be considered. This is related to a general limitation of Likert scales, whereby the same total score can be obtained in different ways.

Scores of individual items may be more informative and it is recommended that they are used in combination with domain scores.

It should be noted that there was a drop in the lower threshold for importance-engagement of the whole sample (N=147) as opposed to the matched CI sample (N=68). This could potentially be due to the larger number of older participants in the whole sample but no overall effect of age was found on importance to support this assumption.

7.2 Convergent validity: relationship with a generic HRQOL measure (Study 5)

7.2.1 Introduction

Another way of assessing construct vaidity is to check if a questionnaire correlates with another one that measures the same concept (convergent validity) or if it does not correlate with one that measures a different concept (discriminant validity). Since there is no existing questionnaire incorporating music and QOL, there were two options for the assessment of convergent validity: (a) to compare with a music questionnaire designed for CI users (e.g. the IMBQ or the MUMU) or (b) to compare with a HRQOL measure. Due to limitations of previous music questionnaires explained in section 2.3 (e.g. unknown reliability and validity, mixed response options) none of the existing CI-music questionnaires was considered appropriate to be directly compared with the MRQOL. Instead, a HRQOL measure was employed for the assessment of convergent validity. For individuals who rate music as important, MRQOL was expected to positively correlate with their general HRQOL. This would suggest that MRQOL is part of the general HRQOL when music is important and would be evidence for the validity of the MRQOL construct. A correlation between MRQOL and HRQOL would also be evidence for the impact of music on the QOL of CI users.

The aim of the study was to examine whether the scores of the MRQOL questionnaire correlate with the scores of a generic HRQOL instrument in order to assess (a) the convergent validity of the questionnaire and (b) the impact of music on the HRQOL of CI users.

7.2.2 Methods

7.2.2.1 The choice of a HRQOL measure

An established, validated HRQOL instrument, suitable to produce utility scores was considered most appropriate for the purpose of this study. Utility measures have the benefit over other generic

HRQOL intruments that they are used in economic evaluations to inform health funders about the usefulness of health interventions. The three utility measures that have been used with CI users are the HUI, the EQ-5D and the SF-36 (Yang et al., 2013) [also section 2.4.2 for a review]. These instruments differ significantly in their underlying concept and the corresponding dimensions that they tap (see Table 7.6 below for a comparison). The SF-36 was preferred because it addresses the physical, psychological and social HRQOL domains. This was important for three reasons:

1. Music was expected to have an impact on these three QOL domains
2. The MRQOL questionnaire covers abilities, attitudes and activities, which correspond to the three QOL domains

The SF-36 has been shown sensitive to the benefits of cochlear implantation in different domains such as ‘General Health’ and ‘Mental Health’ (Loeffler et al., 2010).

A shorter 12-item version (SF-12v2) was preferred because it still covers the three main HRQOL domains (and all 8 SF-36 domains), closely replicates the Physical Component Sumamry (PCS) and Mental Component Summary (MCS) scores of the 36-item and is also shorter and therefore more time-efficient for a clinical trial, with an average completion time of less than three minutes (Ware et al., 1996). See Appendix A.2 for the SF12v2. The 12 items together with improved scoring algorithms have reproduced 90% of the PCS and MCS variance of the 36-item version. In the SF-12 the 12 items are grouped in eight domains as in the SF-36. The response options range from 3 to 5. The SF-12 version 2 has not been used with CI users or hearing-impaired adults in the UK but there is evidence for strong 2-week test-retest reliability for the PCS [ICC=0.86] and the MCS [ICC=0.77] of the SF-12 version 1 in the general UK population (Ware et al., 1996).

Table 7.6 *A comparison of the three health utility measures used with CI users.*

	HUI	SF-36 / SF-12	EQ-5D
Concept	"Within the skin" measure, sensory dimensions	Covers physical, emotional, social domains	"How health impacts functioning in life", mainly physical, slightly covers psycho- social aspects
Domains	(8) Vision Hearing Speech Ambulation Dexterity Emotion Cognition Pain	(8) Physical functioning Role-physical Bodily pain General health Vitality Social functioning Role-emotional Mental health	(5) Mobility Self-care Usual activities Pain/discomfort Anxiety/depression

7.2.2.2 Participants

The 147 CI users who completed the MRQOL questionnaire the first time in study 3 also completed the SF12v2 in the same administration. This way correlations between the two questionnaires could be tested using the same sample. One participant returned only the SF12v2 questionnaire (without the MRQOL questionnaire) and their responses were not included in the analysis. The SF12v2 questionnaire was administered on paper and online; the paper version as well as permission to replicate the SF12v2 online was given by Optum®. The SF12v2 was presented after the MRQOL to ensure that participants complete at least the MRQOL in case of fatigue or for any other reason despite recommendations in the literature to administer generic questionnaires before specific to prevent bias (Bowling, 2014).

7.2.2.3 Data analysis

The SF12v2 gives scores on a 0-100 scale per respondent for each of the 8 domains, two average scores, i.e. the Physical Component Summary (PCS) and the Mental Component Summary (MCS) as well a single utility score (SF-6D) which is useful in cost-utility evaluations. The PCS and MCS are averages of the more physical and the more psychological items, respectively (Table 7.7). Although the domains Physical Functioning (PF) and Role Physical (RP) best predict physical health and Role Emotional (RE) and Mental Health (MH) best predict mental health, all the scores are used to calculate the summary scores. PCS and MCS summary scores have been found to explain 80-85% of the SF-36 variance and to detect hypothesized differences in physical/mental health nearly 100% of the time (Ware et al., 1996).

For the MRQOL questionnaire, ‘frequency’ and ‘importance’ Scale Total and subscale scores were calculated for participants who rated music as at least ‘Somewhat important’. Correlations were explored between the SF12v2 PCS and MCS scores and the MRQOL ‘frequency’ scores of the Perception and Engagement subscales. A correlation between the MRQOL Scale Total ‘frequency’ score and the SF-6D utility score was examined. For participants who rated music important, positive correlations were expected between:

- The MRQOL Frequency-Perception score and the SF12v2 PCS and MCS scores
- The MRQOL Frequency-Engagement score and the SF12v2 PCS and MCS scores
- The MRQOL Frequency-Scale Total score and the SF6D utility score

No hypothesis was made regarding the size of the correlations. For participants who rated music not important, no association between MRQOL and SF12v2 scores was expected.

Table 7.7 *Domains contributing more to each SF12v2 component summary and their corresponding questionnaire items.*

Physical Component Summary (PCS)	Items	**Mental Component Summary (MCS)**	Items
Physical Functioning (PF)	2a,b	Vitality (VT)	6b
Role Physical (RP)	3a,b	Social Functioning (SF)	7
Bodily Pain (BP)	5	Role Emotional (RE)	4a,b
General Health (GH)	1	Mental Health (MH)	6a,c

7.2.3 Results

The two participants excluded in Study 3 due to ≥50% N/A responses were excluded here too. MRQOL and SF12v2 responses from 147 CI users were used for analysis. A combination of descriptive statistics, normality tests and plots showed that frequency and importance scores of the MRQOL perception and engagement subscales were relatively normally distributed with the exception of importance data for the perception domain where the Kolmogorov-Smirnov and Shapiro-Wilk tests were significant at <.01 indicating deviation from normality. See Figure 7.4 for the distribution of the frequency and importance total scales. The SF12v2 PCS and MCS scores did not meet conditions for normality. Therefore, non-parametric statistics were used.

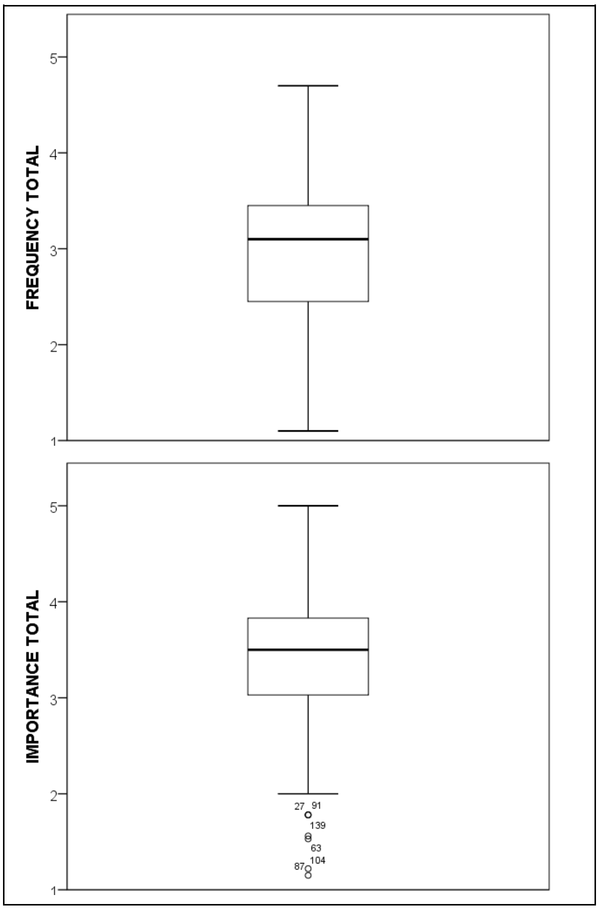


Figure 7.4 *Score distribution for the MRQOL frequency (top) and importance (bottom) scales total. The boxes represent the interquartile range, i.e. the middle 50% of the observations, the whiskers are the top and bottom 25% of the scores, the horizontal bars are the medians and the circles show the outliers.*

Five correlations between MRQOL frequency scores and SF12v2 scores were examined only for an average importance ≥3, that is when music is at least ‘Somewhat important’ or ‘Very important’. This was based on the assumption that the MRQOL would have an impact on or be part of general HRQOL only when music is considered important in life. The correlations can be seen in Table 7.8. Bonferroni correction was applied and the significance level was adjusted to: <0.01 (0.05/5, which is the number of correlations performed).

Table 7.8 *Spearman correlations between the MRQOL frequency measures and the Physical and Mental components of the SF12v2 for a MRQOL importance of ≥3 ('Somewhat important') for Perception and Engagement. Adjusted significance level: <0.01.*

Frequency Perception		**PCS (M_{imp}≥3)**	**MCS (M_{imp}≥3)**
	Spearman's rho	.150	-.058
	Sig. (2-tailed)	.099	.522
	N	122	122
Frequency Engagement		**MCS (M_{imp}≥3)**	**PCS (M_{imp}≥3)**
	Spearman's rho	.109	.229*
	Sig. (2-tailed)	.302	.029
	N	91	91
Frequency total		**SF6D (Mimp overall≥3)**	
	Spearman	0.092	
	sig	0.335	
	N	112	

A significant positive Spearman correlation was found between the frequency score of the MRQOL engagement subscale and the SF12v2 PCS for an importance score of ≥3 for the engagement subscale [r=.229, p<0.5] (Figure 7.5 below). The significance of the correlation was interpreted with caution due to the number of correlations tested. No other significant correlation was found (Table 7.8). Although the correlation between MRQOL frequency-engagement and SF12v2 PCS was weak, it may suggest that to some extent CI users who rate their enjoyment of music or their engagement with musical activities high, also score highly in aspects of physical health, as described by the PCS.

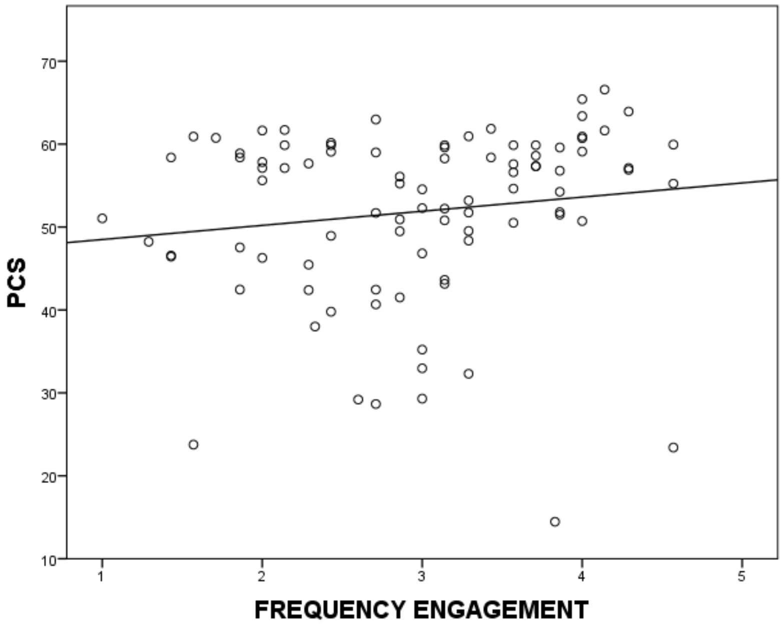


Figure 7.5 *Scatterplot showing a significant and nearly moderate correlations between the SF12v2 PCS and the Frequency score for the MRQOL Engagement subscale (7 items) for an Importance score ≥ 3 for Engagement (N=91).*

In order to understand the relationship between music enjoyment and activity and HRQOL, correlations were further examined between the MRQOL engagement frequency score and the 4 domain scores contributing more to the PCS: physical Functioning (PF), role physical (RP), bodily pain (BP) and general health (GH) [Table 7.9]. From the 4 correlations only one was significant, that with the SF12v2 Role Physical domain for an importance score of ≥3 for engagement (Spearman rho: .260 (p<.05) [N=91]). Although the correlation is again weak and the significance should be interpreted with caution due to the number of correlations tested, this result may suggest that music enjoyment and activity are to some extent associated with activity limitations (at work or any other daily activity).

When importance engagement was low (<3), the correlations between frequrency total and the SF12v2 RP (r=.083, p=.548, N=55) and PF (r=.065, p=.635, N=55) were not significant. This confirmed the assumption that MRQOL is a part of general HRQOL only when music is important and therefore has an impact on the QOL.

Table 7.9 *Spearman correlations between the MRQOL Frequency engagement scores and individual SF12v2 domains.*

SF12v2 domain	Frequency engagement
Role Physical (RP)	Spearman r: .260 p=.013 N=91
Physical Functioning (PF)	Spearman r: .225 p=.031 N=92
Bodily Pain (BP)	Spearman r.177 p=.092 N=92
General Health (GH)	Spearman r: .171 p=.103 N=92

7.2.4 Discussion

The aim of Study 5 was to look for correlations between the frequency scores of the MRQOL and a generic HRQOL questionnaire (SF12v2) to support construct validity and the impact of music on HRQOL.

The positive correlation between the Frequency- engagement (i.e. frequency score in the engagement subscale) MRQOL score and the SF12v2 RP dimension (which refers to activity limitations) for an Importance-perception score of >3 may suggest that music enjoyment and participation in musical activities has an impact on general social activity. For example, it is likely that poor music enjoyment and limited musical activity does not let CI users accomplish as much as they would like to in their everyday life. For those with a music-related occupation, this may reflect limitations in fulfilling their professional duties. However, it is unclear whether this correlation can be taken to suggest the effects of music on HRQOL or the effects of HRQOL on musical activity. Indeed, it is unlikely that music has an impact on daily activities such as moving a table or climbing stairs. It is more likely that the ability to perform everyday activities also allows CI users to participate in music-related activities; in other words, CI users who participate more in everyday activities (for reasons unrelated to music) enjoy music more and engage more with musical activities. This could be due to more exposure to music. It is acknowledged that the SF12v2 may have not been the most appropriate HRQOL measure for construct validation due to its limited relation to hearing-related difficulties. Either way, the findings show that the MRQOL questionnaire can predict some aspects of general HRQOL and this way they offer some support for construct validity. The findings also support previously reported correlations between music enjoyment or sound quality and QOL (Zhao et al., 2008; Lassaletta et al., 2008a).

The lack of strong evidence for an impact of music on the QOL and the lack of any other association between the MRQOL subscale scores and SF12v2 domain scores can be explained in two ways. First, the SF12v2 may cover aspects of CI users' health that are not related to music. Although the SF12v2 is an established and validated HRQOL measure suitable to provide utility scores, its validity with CI users had not been proven. It has been reported that the SF12v2 may not be the most sensitive measure of the effects of CIs (Arnoldner et al., 2014). It was chosen mainly because it tapped the three QOL dimensions more accurately than the other two common HRQOL measures. The second reason for the lack of correlations between music and HRQOL could be that, although music has an impact on the HRQOL when it is rated as important, still other component of HRQOL are more important than MRQOL and affect HRQOL more. Given the effects of age on the frequency scores, it is likely that this is more true for older than younger adults. Music has been reported to be more important than other activities for teenagers (13-14 years old) or undergraduate students [M_{age}=20 years old] (Lonsdale & North, 2011; North et al., 2000). In addition to age, it is likely that the impact of music on the QOL is affected by other individual differences such as degree of music training and preferences (Bartel et al., 2011). Overall, it is unclear to what extent the findings of the study support the impact of music on the QOL given the lack of strong correlations and also the choice of QOL measure. It is likely that correlations are not appropriate for studying the impact of music on the QOL; an alternative way to measure this impact is proposed in the next chapter.

Chapter 8. Measuring the impact of music on QOL

One of the aims of this thesis was to investigate the impact of music on the QOL and how it can be measured (Aim 4, section 1.1). Directly measuring the impact of music on the QOL of CI users (and hearing-impaired adults in general) could support music-related research and provision of music rehabilitation. It could also highlight aspects of music experience that affect the QOL and need to be targeted by music interventions such as auditory music training. Towards the development of an instrument that can measure this impact, the MRQOL concept was proposed, according to which the impact of music on QOL is a function of music perception/engagement and their importance. Based on this concept, two sets of 18 items were developed, one assessing music experiences and one assessing importance. Items were selected with the use of psychometric techniques and the 'frequency' items were further validated. This chapter investigates how the 'importance' scores can be used for the measurement of the impact of music on QOL.

8.1 Is it worth assessing 'importance'?

Before using importance ratings to weigh frequency scores, the range of importance scores was looked at to understand if it is worth using them to predict the impact of music on QOL. Figure 8.1 below shows the distribution of responses per response option for the final 18 importance items (responses collected at the item selection study, Chapter 1.). CI users rated importance of music positively overall since in 71% of the responses music was at least 'Somewhat important'. However, all the response options were used and scores were relatively spread across the scale, which shows that the importance of music was different across participants/items. This suggested that importance ratings can help to discriminate among items and participants. The high percentage for the higher response options is not surprising because items with low importance had already been removed during item selection. It is rather the relative importance of each item compared to other items and the relative importance among individuals that is of interest for the measurement of the impact of music on the QOL. The high overall importance of music may also be related to bias from the sample tested; although special interest in music was not necessary to participate in the study, it is likely that people for whom music played a big role in life were more interested in participating.

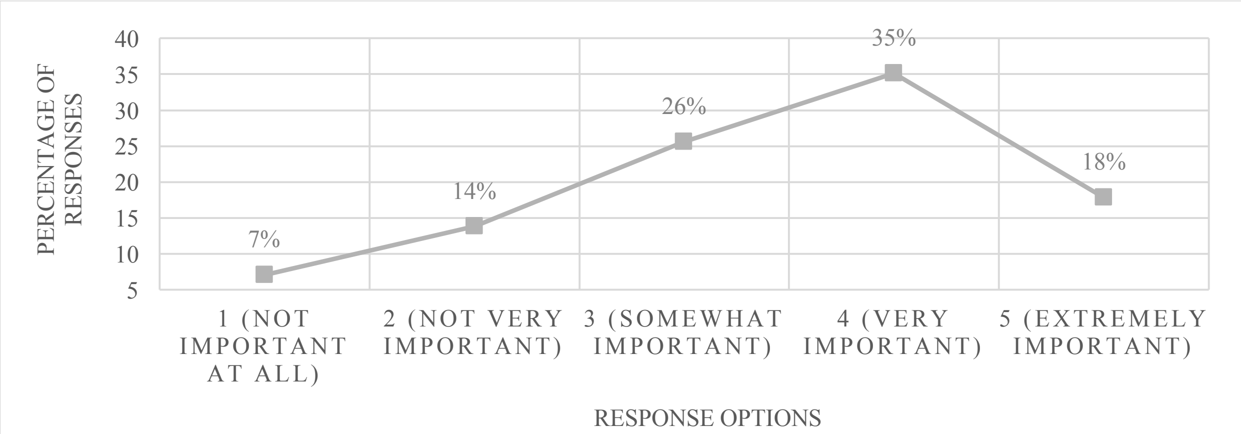


Figure 8.1 *Distribution of importance scores (percentage out of the total number of scores) per response option overall for the final 18-item MRQOL questionnaire (N=147). Scores are aggregated across all respondents and items. The distribution of responses shows a prevalence of high importance ratings but also a spread of responses.*

8.2 Relationship between 'frequency' and 'importance' scores

Correlations between frequency and importance were examined to find out if one can predict the other. Moderate (>.3) positive Pearson correlations were found in the CI sample (N=147) between the frequency and importance total (18 items) scales ($r=0.281$, $p<0.001$) and in the engagement subscales ($r=0.488$, $p<0.001$). The correlation was strongest for the 'engagement' subdomain (Figure 7.2 below), which suggests that CI users consider music enjoyment, activity and participation more important when they can actually enjoy music more, perform and participate in musical activities more frequently (or vice versa). In the perception subscale, the correlation was weak ($r=0.203$, $p<0.05$).

Figure 8.3 below illustrates this relationship by showing how importance increases (i.e. higher percentage of responses for higher scale points and lower for lower scale points) together with the frequency level (up to level 4). Although high levels of frequency (4 or 5) correspond to at least an importance of 3 and never to low importance (no data at the bottom-right side of the graph), high importance can correspond to low frequency (1 or 2) as can be seen from the cases at the top-left of the chart. For CI users who rate music as important but report low frequency (for perception or engagement), MRQOL is poor and music is assumed to have a strong but "negative" impact in their QOL.

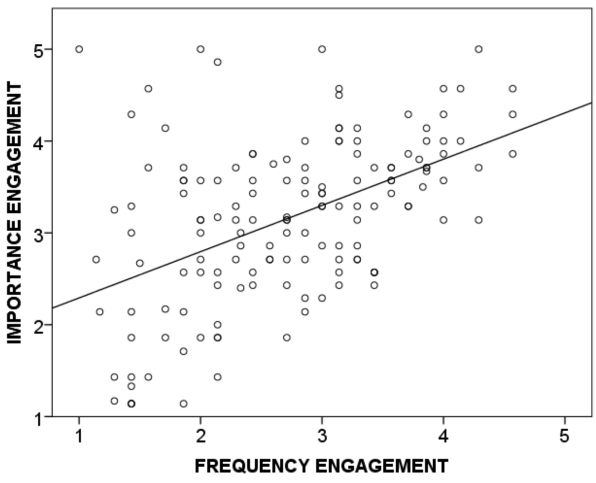


Figure 8.2 *Scatterplot showing a moderate positive correlation (Pearson' r=.488, p<0.001) between frequency and importance in the MRQOL engagement subscale. The significance criterion was set at p<0.01.*

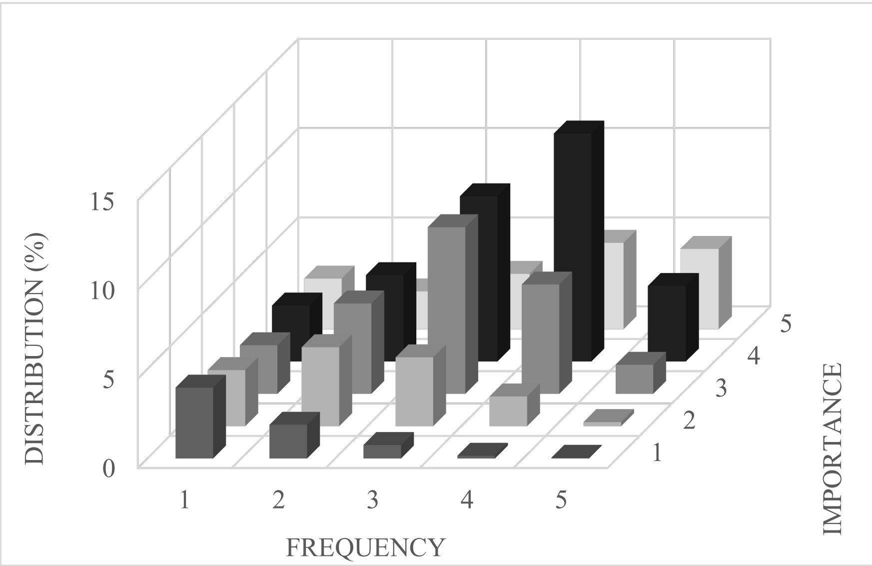


Figure 8.3 *3-D plot of the distribution (percentage of responses out of total number of responses) of frequency and importance scores combined.*

Correlations were also tested for the matched NH and CI groups (n=68) to find out if this relationship between frequency and importance is characteristic to CI users only or it extends to NH adults too. Given the mixed evidence for normality in those groups (section 7.1.3), non-parametric Spearman correlations were used. The matched CI group, showed moderate positive correlations for the whole scale and 'Engagement' subscale and an almost moderate correlation for 'Perception', in agreement with the full sample. In the NH sub-group, strong positive correlations were found between frequency and importance in the total scale and the Engagement subscale and moderate correlation for Perception. This suggests that the relationship between frequency and importance found in CI users may not be specific to the CI population but may reflect the way people assign importance to the different aspects of music experience. All correlations were stronger for NH than CI, suggesting the more important music is, the more a person engages with it if they have the hearing ability to do so.

Table 8.1 *Correlations between frequency and importance in the CI and NH matched groups (N=68).*

Overall	**Perception**	**Engagement**
NH group Spearman's rho: .467** (.000)	NH group Spearman's rho: .430** (.000)	NH group Spearman's rho: .619** (.000)
CI group Spearman's rho: .340** (.005)	CI group Spearman's rho: .266* (.029)	CI group Spearman's rho: .528 (.000)

All in all, it can be concluded that CI users tend to value more those aspects of music that they can perceive or engage with more and that this effect is not specific to the CI population but extends to NH adults too. This result could be examined in combination with the poorer frequency scores of CI users as opposed to NH adults overall: if frequency and importance correlate for both CI users and NH adults, and CI users have poorer frequency than NH adults (results of Study 4, section 7.1), CI users would also be expected to have low importance. However, this was not confirmed by the data and comparison between the CI and NH group showed that CI users overall may find music more important than NH peers despite poorer perception and engagement (Table 8.1 above and Figure 7.1 in section 7.1). Two possible explanations can be given: frequency and importance correlate within each group despite overall difference between the groups or CI users scoring low in frequency still consider music important.

8.3 Combination of frequency and importance scores

Throughout the development and validation of the MRQOL questionnaire, the frequency and importance scales were analysed, refined and validated separately. This was because no assumptions could be made regarding the relationship between combinations of frequency and importance scores. For example, it was unknown if a frequency score of 4 and an importance score of 5 reflect a stronger impact of music on the QOL than a frequency of 5 and an importance of 4. It was necessary to determine linear relationships between the combined scores because non-linear scores could not be used with the traditional statistical techniques of the classical test theory that were employed in this project.

However, it was intended that frequency and importance scores are combined to assess the impact of music on the QOL; this was in line with the MRQOL concept and was the main purpose of the construction of the importance questions (sections 4.1 and 5.3). The combination of the frequency and importance scores was supported by:

1. The one-to-one correspondence between frequency and importance items
2. The evidence for reliability and validity of the frequency scale
3. The fact that certain measurement properties (acceptability, repeatability, discriminability) were also ensured for the importance scale

The use of importance scores to produce QOL scores is not new. Two alternative versions of a formula were used to convert satisfaction scores into QOL scores in the Quality of Life Profile (Renwick et al., 2003; Raphael et al., 1996). However, these formulas were inappropriate for the MRQOL concept for a number of reasons. First, because they generate the same scores more than once which makes interpretation difficult. This is actually a typical problem with weighting questionnaire scores (Streiner et al. 2015:131-134; Skevington et al. 2004). Second, because they would give unweighted MRQOL scores for an importance of 3 and not weigh scores based on importance at all which is not in agreement with the MRQOL concept according to which low importance should result in neutral MRQOL scores.

An alternative code for generating 25 unique scores for all the possible combinations was designed. For the calculation of combined scores, the 1-5 frequency and importance scores were transformed using the following codes:

Frequency: [-3 -1 1 3 5]

Importance: [1 4 7 10 13]

Simple multiplication of frequency and importance using these codes would then generate a MRQOL or ‘impact’ (i.e. impact of music on the QOL) matrix as in Table 8.2 below. In this matrix, least important is at the top of the matrix, most important is at the bottom, least frequent is to the left and most frequent is to the right. According to the matrix, an individual scoring 5 in frequency and 5 in importance (i.e. music is extremely important, highest perception/engagement) would get a MRQOL score of 65 (bottom right) reflecting the highest MRQOL possible, whereas a 5 in importance but 1 in frequency (i.e. music is extremely important but poorest music perception/engagement) would give a score of -39 (bottom left of the matrix). The actual MRQOL scores are meaningless and only represent levels of impact of music on the QOL.

To the extent that the importance of music is an indicator of its impact on the QOL, impact scores could be interpreted as follows:

- High importance (4 or 5) indicates a strong impact of music on the QOL
- Low importance (1 or 2) indicates a weak impact of music on the QOL and gives lower scores overall compared to high importance, regardless of frequency
- For any importance (high or low), higher frequency means higher impact, e.g. between two individuals who find an aspect of music or music overall ‘Not very important’ (2), one who perceives music/enjoys music/participates in musical activities ‘Sometimes’ (3) has higher MRQOL than one with a frequency of 2.
- High frequency (4 or 5) indicates a positive impact of music on QOL, i.e. music benefits the QOL, and the higher the importance the higher the impact. For positive frequency scores (e.g. 4, ‘Frequently’), an importance of 5 (‘Extremely Important’) gives a higher MRQOL than an importance of 4 because more important aspects of music contribute more to the QOL than less important
- Low frequency (1 or 2) results in a ‘negative’ impact of music on the QOL, e.g. negative feelings or activity limitations as a result of poor perception or enjoyment of music. Higher importance gives lower (i.e. more negative) MRQOL scores because poor perception of or engagement with important aspects of music has a more negative effect on the QOL than non-important aspects. For frequencies of 1 or 2, going from the top to the bottom of the matrix (higher importance), combined scores decrease.

Table 8.2 *Scoring matrix generated after combining frequency and importance scores. The magnitudes of the scores are meaningless and only represent the 25 different comibinations of frequency and importance. The shaded area indicates scores that could be interpreted as 'critical' for clinical rehabilitative purposes.*

		FREQUENCY (LOW-HIGH)					
		1 (NEVER)	2 (RARELY)	3 (OCCASIONALLY)	4 (FREQUENTLY)	5 (ALWAYS)	
IMPORTANCE (HIGH-LOW)	1 (NOT IMPORTANT AT ALL)	-3	-1	1	3	5	POOR IMPORTANCE – LOW IMPPACT
	2 (NOT VERY IMPORTANT)	-12	-4	4	12	20	
	3 (SOMEWHAT IMPORTANT)	-21	-7	7	21	35	HIGH IMPORTANCE – HIGH IMPACT
	4 (VERY IMPORTANT)	-30	-10	10	30	50	
	5 (EXTREMELY IMPORTANT)	-39	-13	13	39	65	
		POOR FREQUENCY – NEGATIVE IMPACT			HIGH FREQUENCY – POSITIVE IMPACT		

In order to interpret neutral scores for both scales using the present data, normative data could be used. The score distributions of the NH and CI matched groups (N=68) for frequency and importance (Figure 7.1 in section 7.1.3) showed that almost 100% of the NH mean scores for frequency were >3 ['Occasionally'] and for importance >2 ('Not very important'). These findings were taken to suggest that to the extent that this NH sub-sample was representative of the NH population, a score of 3 for frequency should be regarded as a poor score because it is outside the NH range and an importance of 3 should still indicate high importance as it falls within the NH range. Therefore, scores indicating individuals who find music important but perceive and/or engage with it poorly result in a strong-negative impact on their QOL. Such scores could be interpreted as 'critical' from a rehabilitative point of view. The grey-shaded area in Table 8.2 above shows which MRQOL scores would fall in a critical block, in this example matrix. It is suggested that, in future studies, neutral scores of 3 are interpreted in the context of the population examined. It is also acknowledged that importance is only a crude indicator of impact on QOL. The extent to which importance reflects the impact should be considered.

Chapter 9. General discussion and conclusions

9.1 How the aims of the project were addressed

New CI technologies and auditory music training programmes have the potential to benefit CI users' music perception and appreciation, despite limitations such as the poor transmission of pitch information through the implant (van Besouw et al., 2015; Limb & Roy, 2013). However, more evidence for the effectiveness of these interventions is necessary to convince patients, clinicians and budget holders to invest time and money in music rehabilitation. Previous music questionnaires designed for CI users can capture real-life benefits more accurately than formal music perception tests used in the lab, but have limitations, such as that they do not cover the whole range of music experiences and that they have not been psychometrically validated (section 2.3). This PhD project was driven by the need for a new self-report measure that would be more appropriate to evaluate music rehabilitation for CI users than previous music questionnaires.

In this context, the aims of this thesis as these were stated in Chapter 1. , were to:

1. Develop a new instrument that overcomes limitations of previous music questionnaires designed for CI users (primary aim)
2. Assess the reliability and construct validity of the new questionnaire (primary aim)
3. Investigate the whole range of music experiences and introduce a new concept that will link music and QOL for CI users
4. Investigate the impact of music on the QOL of adult CI users and the measurement of this impact

How this PhD project met these aims and filled knowledge gaps and the novel contributions of the project are discussed below.

9.1.1 MRQOL concept and novel aspects of music experience (Aim 3)

The organisation of music experiences according to the NCIQ HRQOL model and the strong involvement of CI users allowed a more holistic investigation and identification of issues poorly addressed or not addressed at all previously, e.g. embarrassment with singing or avoidance of social activities where music is played such as dinner at a restaurant (Table 4.3 in section 4.6). This broadens understanding of CI users' relationship with music. The range of CI users recruited in both the focus groups and the item selection and validation supports the generalisability of the findings. The MRQOL of CI users (section 4.1 and Table 6.11) is a function of music perception &

music engagement and their importance. The study arrived at the two dimensions of the concept, i.e. music perception and engagement, after a long, systematic and psychometric process (including focus groups and factor analysis), which is an advantage over previous studies. The new concept not only covers CI users' relationship with music in a broader way than previous concepts, e.g. music appreciation or music listening habits, but also directly addresses the impact of music experiences on the QOL, which is novel in the literature. The MRQOL framework (Table 6.11, section 6.6) can guide and structure music-related research and measurements in the future. It can be used as a reference for both self-report measures and music tests. For example, researchers could decide to assess Basic Music Perception using music tests and Advanced Music Perception with asking patients the relevant MRQOL questions or through interviews. They could also decide to train Music Perception aspects using auditory music training and then assess their impact on Music Engagement. From a theoretical perspective, the MRQOL framework addresses the limitation of inconsistent terminology and classifications in previous music-CI studies (section 4.1).

9.1.2 Development and validation of the MRQOL measure (Aims 1 and 2)

The main contribution of this PhD project is the MRQOL measure. The new questionnaire overcomes limitations of previous music questionnaires developed for CI users (discussed in section 2.3.5). The MRQOL covers music experiences holistically; novel issues were included in the final MRQOL questionnaire, namely the perception of lyrics, the perception of the meaning of music, the ability to judge music quality, the confidence with hearing music and listening to music whilst travelling. The use of one uniform rating scale (one for 'frequency' and one for 'importance') facilitates calculation of average scores for the total scale or the perception and engagement subscales. The face validity of the items (assessed with professionals and patients) as well as their high overall applicability and importance, the minimal floor/ceiling effects and high sensitivity were also advantages over previous questionnarires.

The content validity of the MRQOL questionnaire was ensured by the strong involvemement of CI users in many stages of the questionnaire development (item generation, selection) and validation. To the knowledge of the author, the samples employed are some of the largest that have been reported in the CI literature overall, not only questionnaire development studies (Drennan et al., 2014; Looi & She, 2010). The size and diversity of the CI users recruited also had advantages for the generalisability of the findings and the applicability of questionnaire items to a range of adult CI users. Finally, due to the range of CI users recruited, the MRQOL has potential to be used with both the prelingually and the postlingually deaf, CI users with and without music training and with unilateral, bilateral, bimodal CI users or users of EAS.

The use of psychometric techniques for item selection and the assessment of the reliability and construct validity of the MRQOL questionnaire overcomes a major weakness of previous music questionnaires designed for CI users, i.e. that they had not been fully validated. The overall *frequency* and *importance* scales and *perception* and *engagement* subscales had test-retest reliability and internal consistency of > 0.8, which is appropriate for group assessments (Table 6.10). Furthermore, the test-retest reliability for all the *frequency* measures and the Cronbach's α for the overall *frequency* and *importance* scales and *perception* domain subscales exceeded the 0.90 criterion that has been recommended for individual level measurements (McHorney & Tarlov, 1995). Although the high values of α should be interpreted with caution, the lower bounds of the confidence intervals of α were also > 0.8 for all measures (except for frequency engagement), giving a high degree of certainty that internal consistency is sufficiently high to justify the use of these scores at the group level but also at the individual level for the overall frequency scale and perception subscale where the lower bound was > 0.9 (Table 6.10).

The frequency items clustered together in two meaningful subscales (music perception and music engagement). Despite the fact that the engagement subscale was correlated with perception, the weak correlations between engagement and SF12v2 scores and the weaker reliabilities for engagement than for perception (the latter may also be related to limitations with the use of Cronbach's α), the role of the engagement component/subscale within the MRQOL construct and questionnaire is particularly important: it ensures that the degree of music enjoyment, activity and participation, their importance and impact on the QOL of CI users are captured. This is important not only for the evaluation of music rehabilitation programmes but also for clinical assessments at the individual level.

The construct validity of the MRQOL questionnaire was supported to some extent by two findings: the statistically significantly higher overall frequency score for NH adults compared to CI users and the statistically significant moderate positive correlation between the MRQOL frequency engagement score and SF12v2 RP domain, covering activity limitations. Despite statistical significance, it is unclear a) how large the 1-point difference between the CI group and the NH group is and b) how the correlation between music engagement and general activity can be interpreted. The latter may be related to the choice of the SF12v2 as a QOL measure but it may also imply that correlations are not the optimal method to assess the impact of music on the QOL. Yet, these findings were taken to suggest that a) the difference in frequency scores between CI users and NH adults demonstrate that the questionnaire measures a concept relevant to the hearing-impaired and b) the correlation with the SF12v2 showed that the MRQOL questionnaire can predict some aspects of general HRQOL. Despite the methodological limitations highlighted, the findings were preliminary evidence for the construct validity of the MRQOL measure and show that the MRQOL measure has the potential to fill the gap for a new reliable and valid measue that can be used for the evaluation of music interventions for CI users. However, further work is needed to fully assess construct validity.

9.1.3 Impact of music on the QOL of CI users: is the MRQOL a QOL measure? (Aim 4)

The correlation between the average frequency MRQOL scores in the Music Engagement subscales and the Role Physical (RP) score showed a relationship between music and the QOL and confirmed previously reported positive correlations between changes in music enjoyment or self-perceived sound quality and changes in the QOL post-implantation measured with different instruments (Calvino et al., 2015; Lassaletta et al., 2008a; Zhao et al., 2008). Despite the lack of strong correlations between MRQOL and SF12v2 scores and the limitations of the choice of the SF12v2, the findings may also suggest that correlations may not be the optimal method to explore the effects of music on the QOL (section 7.2). It was unclear if the correlations found could be taken to suggest an impact of music on the QOL or vice versa. It is likely that they could reflect an impact of general physical functioning on music participation than the other way around. The MRQOL construct and measure offers an alternative method to directly measure of the impact of music on the QOL through the assessment of importance.

The MRQOL measure was intended to incorporate music and QOL in order to address limitations of previous music questionnaires that were not designed to assess the impact of music on the QOL. This aim was not fully achieved in the present thesis; although a frequency and an importance scale were developed and a method for combining the scores to arrive at QOL scores was proposed, the two scales were validated in parallel and no combined scores were actually used for analysis. Therefore it is unknown what combined mean and how exactly they can be used. However, this was certainly a first step towards an instrument that can directly measure the impact of music on QOL, thus addressing previous limitations.

In the same context, the finding that the CI group rated music as important as the NH group on average, despite lower scores for frequency perception and engagement, supports the need to improve the music perception and enjoyment of CI users, with potential subsequent benefits for their QOL.

9.2 Limitations and bias

Limitations of this PhD project have already been acknowledged throughout the thesis; the main limitations are also summarised here. First, the traditional psychometric techniques of CTT that were employed in the MRQOL questionnaire development have been critised mainly due to the assumptions about the interval-level properties of the Likert-scale data. The potential limitations of the use of CTT techniques and their implications for the validity of the results have been acknolwegded and discussed throughout this thesis (e.g. sections 3.3 and 6.2.5). A second limitation that has to be acknowledged is that the assessment of the reliability and validity of the items and the final scale was done using the responses to the final items collected at the item selection stage when CI users completed the 46-item version. It is likely that a separate administration of only the selected 18 items would produce different answers to those items with consequences for the test-retest reliability and sensitivity of the items, the factor structure, the internal consistency and the construct validity of the scale and subscales. Another limitation is that the constuct validity of the questionnaire was not fully assessed. It was assumed that the importance of music experiences reflects the extent to which they affect the QOL, i.e. aspects of music rated important contribute to the QOL more than non-important ones. This assumption was based on previous QOL assessments whereby satisfaction from different aspects of life was combined with their importance to arrive at QOL scores (Renwick et al., 2003; Skevington et al., 2004). However, to what extent the use of importance ratings to measure impact is realistic, was not tested. The impact of music on the QOL may be more complex than a combination of perception/engagement and importance and importance ratings may be a crude way to measure effects on the QOL.

There are many potential sources of bias in this work. It is likely that the participants of the study had a particular interest or background in music and therefore cannot be seen as representative of the general population. This may have affected the generalisability of the findings. Different types of bias may have also been involved in completing the questionnaire, especially for the importance questions, e.g. it is commonly reported that questionnaire respondents tend to give positive responses to questions about their health or quality of life to show that they perform well [social desirability bias] (Bowling, 2014; Streiner et al., 2015). The removal of all negatively phrased items from the final questionnaire version may have increased this. Respondents may also have avoided extreme answers and preferred moderate response options (end-aversion bias). Cognitive bias may have affected the importance ratings: the way different people interpret and rate the importance of different aspects of their life is subjective. There is also a potential for researcher bias in the project, where interpretation of the data and judgement was involved, particularly with regard to the qualitative data analysis in Study 1, 4.2

9.3 Appropriateness for group and individual-level measurements

The test-retest reliability (indicated by ICC) for all the frequency measures and the Cronbach's α for the overall frequency and importance scales and perception domain subscales exceed the 0.90 criterion that has been recommended for individual level measurements (McHorney & Tarlov, 1995). This, in addition to the evidence for validity and the measurement properties of the individual items, suggests that the MRQOL could be a useful measure not only for the assessment of music experiences at the group level but also for diagnosing and monitoring the difficulties of individual patients with music in clinic. However, which changes in music experiences are clinically important has to be assessed with the use of clinical anchors at the individual level (Revicki et al., 2008). Given the lack of a validated clinical music perception test, clinician ratings post-intervention could be used to identify individuals who have changed; MURQOL change scores in these individuals could be interpreted as clinically important change.

The < 0.90 Cronbach's α and wider confidence intervals for the frequency and importance engagement subscales may be related to the fewer number of items (seven) in this subscale and could increase by increasing the number of items. However, item selection was based on other criteria that ensured the measurement properties of the individual items. Yet, the internal consistency was very high and appropriate for group measurements. For individual measurements in clinic, the overall scores can be used to maximise internal consistency. The other psychometric properties of the engagement subscale (repeatability, statistically significant difference between the CI and NH group, correlation with the SF12v2) and its importance for content validity support its usefulness. The < 0.90 test-retest reliability for all importance scores suggests that the importance scores may not be appropriate to reliably assess individual patients in clinic. The lower repeatability for the importance scale and subscales suggests that participants found these items difficult to answer; this is further supported by participants' anecdotal comments (e.g. 'How important is it for me to hear the beat, rhythm or instruments, voices etc.? My answer is 'Extremely important'. But as I can't hear any of these things it also has to be N/A'). Despite these limitations, the repeatability of the importance measures (> .80) is suitable for group assessments (Nunnally & Bernstein, 1994: 264-265).

9.4 How to use the MRQOL questionnaire

The ambition of this PhD project was to develop a measure that would be appropriate to assess outcomes of music rehabilitation for adult CI users. Based on the evidence presented in this thesis, the MRQOL 'frequency' and 'importance' scales can be used independently and average scores can be calculated for each subscale (music perception/engagement) or for the overall scales as in studies 3, 4 and 5 (chapters 6 and 7). For group comparisons it is recommended that the overall frequency and importance scores and/or the perception and engagement subscale scores are used depending on the aims of the study. For example, if one is assessing the effects of musical instrument recognition training on music engagement in particular, the average frequency scores of the engagement subscale could be used. If the interest is in the effects of a CI on the importance of music, the average overall frequency score could be used. The NH range and average scores from study 4 (section 4.1) can be used to interpret CI scores but the size and sociodemographic characteristics of the NH sample should be considered in relation with the CI sample recruited. The MRQOL measure was found to be appropriate for and can be used with adult CI users of a wide age range, postlingually or prelingually deaf and with various degrees of music experience but its use with other hearing-impaired groups needs to be studied.

There is potential for the frequency and importance scales to be combined to measure the impact of music on the QOL (as in section 8.3). To identify rehabilitation needs in clinic, the scores for the 18 final frequency and importance items can be plotted on a matrix, as shown in Table 8.2. The number of items falling in the critical block of the matrix for an individual patient can highlight areas of concern and can help forming a profile for that individual. For individual patients it is recommended that only the frequency scores are used because only these exceeded the 0.90 test-retest reliability criterion for individual measurements. However, until the meaning of the combined scores is better understood, it is suggested that the scores are also qualitatively analysed for each item and that responses are discussed with the patient for a full understanding of music experiences and their effect on QOL. Calculation or interpretation of combined frequency and importance scores could detect patients who perceive or engage poorly with aspects of music that are important and the apsects of music perception/engagement that are important and are poorly perceived or engaged with. This way, the MRQOL questionnaire could be used to identify music rehabilitation needs in clinic or monitor progress with music. The MRQOL questionnaire can also be used to measure changes in music experiences post-intervention.

Most of the questionnaire responses were collected from the online version of the MRQOL questionnaire which shows potential that the questionnaire can be used as an online self-assessment tool in the future. Online implementation would facilitate scoring and would quickly produce an impact matrix.

The MRQOL questionnaire intends to become a standardised instrument for the assessment of music outcomes or the impact of music on the QOL. However, limitations of self-report measures such as bias and subjectivity, have to be acknowledged. Both music perception tests and self-report evidence are required for a complete music assessment (Drennan et al., 2014). Therefore, it is envisaged that the MRQOL questionnaire will be combined with perceptual measures, such as music test batteries developed for CI users (Kang et al., 2009).

9.5 Future directions

Future research could focus on (a) the use of the MRQOL questionnaire to detect changes, with a view to the evaluation of music rehabilitation and (b) the meaning of combined frequency & importance scores and their use to assess the impact of music on the QOL. The responsiveness of the items of the MRQOL questionnaire to changes after music interventions should be assessed in a future longitudinal study. For instance, patients in the waiting list for an implant could be asked to complete the questionnaire before and after implantation or existing CI users before and after they participate in music training in a randomised clinical trial. Minimally important differences (the smallest difference that is perceived by patients as beneficial and meaningful) could be established at least for ‘frequency’ scores. However, it is important that clinically meaningful changes are determined with the use of clinical anchors or individual interviews with the patients to confirm that detected changes are associated with a true change in music experience. Interviews with the patients could be used as a clinical anchor to determine these differences. The ability of the MRQOL measure to detect changes, the kind of changes it can detect and the time intervals it should be used with should be further studied. Test-retest data from this study could be used in the future to determine what percentage of change is significant. It is recommended that clinical changes on the individual level are measured only using the overall frequency score and frequency subscale scores, which fulfilled the recommended 0.90 reliability criterion for individual measurements. A follow-up study could also examine correlations between CI users’ MRQOL frequency-perception scores and their scores in music perception tests. This would help professionals gain a better understanding of the relationship between the patient’s self-perception and perceptual accuracy. The measurement of the impact and specifically the meaning of the different combinations of frequency and importance on the matrix also have to be further explored. Better understanding of the relationship between the different scores will aid scoring and interpretation of the MRQOL questionnaire. Adult CI users could complete the MRQOL questionnaire and then interviewed to discuss their answers and compare with their responses. Whether meaningful average combined scores for the scale/subscales can be calculated, should also be further explored. Impact scores could also be used to monitor progress and measure music-specific CI outcomes post-intervention but how combinations of frequency and importance can be compared and what change is clinically meaningful should all be further studied. For instance, although same importance scores may be straightforward when frequency increases or decreases, it is not clear what changes in importance mean or scores of different importance and different frequency. This will also provide further evidence for the construct validity of the MRQOL measure.

Other areas of future research coud be:

- The potential use of the MRQOL measure in clinic for the assessment of individual differences. This could include assessment of efficiency (i.e. time required to complete, ease of completion), reliability and validity for individual patients. It should be ensured that psychometric properties meet the criteria for measurement of individual differences (McHorney & Tarlov, 1995). Patient monintoring could help to assess validity of the MRQOL scores for individual patients.
- The assessment of the appropriateness, reliability and validity of the MRQOL questionnaire for age groups not included in the present studies, e.g. teenagers, for other hearing-impaired groups than adult CI users or for the general population.

9.6 Conclusions

The following conclusions can be drawn from this PhD thesis:

1. The MRQOL of CI users was found to be a function of music perception & engagement and their importance. The concept covers music experiences more broadly than previous concepts, it allowed novel aspects to be discovered and it links music with the QOL of CI users.
2. The MRQOL measure is a new music self-report measure for adult CI users, developed with the aim to fill the gap for a reliable and valid outcome measure for the evaluation of music rehabilitation for CI users. With its content and face validity, uniform response scale, item properties, test-retest reliability, high internal consistency and some evidence for construct validity, the MRQOL measure may be more appropriate than previous questionnaires to measure music rehabilitation outcomes.
3. Average MRQOL ‘importance’ score for Scale Total was correlated with the corresponding ‘frequency’ score (music perception & engagement), for both the adult CI user and NH adult group selected. However, overall, average MRQOL ‘importance’ score for Scale Total for the CI group was comparable to that of the NH group, despite poorer ‘frequency’ score for music perception & engagement for CI users.
4. Average MRQOL frequency score for the Music Engagement subscale was moderately correlated with the Role Physical (RP) subdomain of the SF12v2, but it is unclear if this

suggests an impact of music on the QOL or vice versa; despite methodological limitations, this may suggest that correlations may not be the optimal method for the assessment of the effects of music on the QOL. The MRQOL measure may enable the direct measurement of the impact of music on the QOL of CI users with the combination of frequency and importance scores of the final 18 items.

5. At least some measures of the MRQOL questionnaire are reliable for individual-level measurements, suggesting that the questionnaire can be clinically useful. However, clinical utility will be fully assessed after actual use of the questionnaire in clinic and use of clinical anchors.
6. Future work should focus on further assessing construct validity, on how the MRQOL measure can be used to assess the effects of music rehabilitation for CI users and on the meaning of individual 'impact', i.e. combinations of frequency and importance, scores.

Appendix A. Background and ethics

Appendix A.1 NRES ethical approval

Page 1 of the letter of the National Research Ethics Service (NRES) confirming approval of Studies 1-6 of the project.

Health Research Authority

NRES Committee East Midlands - Northampton
The Old Chapel
Royal Standard Place
Nottingham
NG1 6FS

Telephone: 0115 883 9440

26 March 2014

Mr Giorgos Dritsakis
Auditory Implant Centre Building 19
University of Southampton
Southampton
SO17 1BJ

Dear Mr Dritsakis,

Study title:	**Music questionnaire development with the involvement of adult cochlear implant (CI) users, normally hearing (NH) adults and professionals.**
REC reference:	**14/EM/0140**
Protocol number:	**RGO 8264**
IRAS project ID:	**143058**

Thank you for your letter of 24 March 2014, responding to the Proportionate Review Sub-Committee's request for changes to the documentation for the above study.

The revised documentation has been reviewed and approved by the sub-committee.

We plan to publish your research summary wording for the above study on the NRES website, together with your contact details, unless you expressly withhold permission to do so. Publication will be no earlier than three months from the date of this favourable opinion letter. Should you wish to provide a substitute contact point, require further information, or wish to withhold permission to publish, please contact the REC Manager Rebecca Morledge, NRESCommittee.EastMidlands-Northampton@nhs.net.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised.

Appendix A.2 The SF12v2 questionnaire

Your Health and Well-Being

This survey asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities. ***Thank you for completing this survey!***

For each of the following questions, please tick the one box that best describes your answer.

1. In general, would you say your health is:

Excellent	Very good	Good	Fair	Poor
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

2. The following questions are about activities you might do during a typical day. Does <u>your health now limit you</u> in these activities? If so, how much?

	Yes, limited a lot	Yes, limited a little	No, not limited at all
a <u>Moderate activities</u>, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	☐ 1	☐ 2	☐ 3
b Climbing <u>several</u> flights of stairs	☐ 1	☐ 2	☐ 3

3. During the <u>past 4 weeks</u>, how much of the time have you had any of the following problems with your work or other regular daily activities <u>as a result of your physical health</u>?

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a Accomplished less than you would like	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b Were limited in the kind of work or other activities	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

4. During the <u>past 4 weeks</u>, how much of the time have you had any of the following problems with your work or other regular daily activities <u>as a result of any emotional problems</u> (such as feeling depressed or anxious)?

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a Accomplished less than you would like	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b Did work or other activities less carefully than usual	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

5. During the <u>past 4 weeks</u>, how much did pain interfere with your normal work (including both work outside the home and housework)?

Not at all	A little bit	Moderately	Quite a bit	Extremely
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

6. These questions are about how you feel and how things have been with you __during the past 4 weeks__. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the __past 4 weeks__...

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a Have you felt calm and peaceful?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b Did you have a lot of energy?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c Have you felt downhearted and low?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

7. During the __past 4 weeks__, how much of the time has your __physical health or emotional problems__ interfered with your social activities (like visiting with friends, relatives, etc.)?

All of the time	Most of the time	Some of the time	A little of the time	None of the time
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Thank you for completing these questions!

Page 3

Appendix B. Item generation

Appendix B.1 Demographics of focus groups participant*s*

N$_o$	Age	Gender	Implant type	Type of deafness	Duration of CI use (years, months)	Implant manufacturer	Music training	Participated in music focus group before
1	75	Female	Bimodal	Post-lingual	1 year	AB	Yes	Yes
2	60	Female	Unilateral	Post-lingual	1 year	AB	Yes	No
3	66	Male	Bimodal	Undefined	15 months	Med-El	No	Yes
4	80	Female	Bimodal	Post-lingual	1 year	AB	No	Yes
5	37	Female	Bimodal	Pre-lingual	1 year	AB	No	No
6	53	Female	Unilateral	Pre-lingual	4 years	AB	No	Yes
7	42	Female	Unilateral	Post-lingual	4 years	Cochlear	No	Yes
8	64	Male	Unilateral	Post-lingual	8 years	AB	Yes	No
9	63	Male	Unilateral	Post-lingual	2 years	Med-El	No	No
10	68	Female	Unilateral	Post-lingual	2 years	AB	No	No
11	71	Female	Unilateral	Post-lingual	6 years	Cochlear	Yes	Yes
12	67	Male	Bimodal	Post-lingual	2 years	Med-El	Yes	Yes
13	64	Female	Unilateral	Post-lingual	18 years	Not reported	No	No
14	57	Male	Bimodal	Post-lingual	1 year	AB	No	No
15	81	Male	Bilateral	Post-lingual	4 years	Cochlear	No	Yes
16	81	Male	Bimodal	Post-lingual	1 year	AB	No	No
17	66	Male	Bimodal	Post-lingual	1 year	AB	No	No
18	26	Male	Unilateral	Pre-lingual	13 years	Cochlear	No	No
19	68	Female	Unilateral	Post-lingual	2 years	Med-El	No	No
20	67	Female	Unilateral	Post-lingual	2 years	Med-El	Yes	Yes
21	80	Female	Unilateral	Post-lingual	1 year	AB	No	No
22	67	Female	Bimodal	Post-lingual	2 years	Med-El	No	No
23	62	Female	Unilateral	Pre-lingual	1 year	Cochlear	No	No
24	18	Male	Bimodal	Pre-lingual	7 years	Cochlear	Yes	No
25	68	Male	Unilateral	Post-lingual	3 year	Med-El	No	No
26	77	Male	Unilateral	Post-lingual	2 years	Neurelec	Yes	No
27	67	Female	Bimodal	Post-lingual	1 year	Med-El	Yes	No
28	43	Female	Unilateral	Post-lingual	5 years	Med-El	No	Yes
29	76	Female	Bilateral	Post-lingual	3 years	Neurelec	No	No

Appendix B

No	Age	Gender	Implant type	Type of deafness	Duration of CI use (years, months)	Implant manufacturer	Music training	Participated in music focus group before
30	48	Female	Unilateral	Post-lingual	7 years	AB	No	Yes

Appendix B.2 Focus group questions

1. Where and why do you listen to music? For example, do you listen to music at home, in the car, at work? Do you listen to music to relax, to improve your mood, to dance?

2. What are your everyday activities that are related to music? For example, do you go to concerts, do you watch videos on YouTube, do you play a musical instrument, do you buy CDs? Tell us about activities that you do not do at the moment but you would like to do.

3. What is important for you to get from music? For instance, to recognise songs you know, to distinguish between notes when playing a musical instrument or just listening to music to relax

4. How satisfied are you with the music you hear? Is there something that you can perceive from music and you are happy about it? Is there something that you find difficult or you don't like in the music you hear and it bothers you?

5. How do you feel about music in general? You might say for instance: 'I feel confident when I listen to music', 'I like it' or 'I avoid listening to music'.

Appendix B.3 Existing items' evaluation

	How important is it for you to…	Origin of item	Very important/ Extremely important	Most important comments
1	…be able to distinguish whether one or more instruments are playing simultaneously	*HISQUI$_{19*}$	20/30	Be able to recognise the different instruments when they play together To understand the piece of music As this gives the music value and understanding
2	…be able to identify musical instruments in familiar pieces of music	UCMLQ	22/30	Like to know what instrument is playing to recognise the sound

	How important is it for you to…	Origin of item	Very important/ Extremely important	Most important comments
				I can recognise some instruments in music I enjoy
3	…be able to recognise your favourite song/singer	UCMLQ	27/30	Feel quite disappointed if I cannot recognise a piece I used to like This gives identity to the music and also emotion
4	…be able to recognise the ringing of your phone	*HISQUI$_{19*}$	27/30	
5	…be able to hear the difference between notes when you listen to music or when play your favourite instrument	MUMU	23/30	Once again it helps me recognise the music being played Because this will give the music identity also
6	…be able to distinguish between different rhythms	*NCIQ*	27/30	To give the music meaning
7	…be able to recognise a movie's dialogue when music is playing in the background	*HISQUI$_{19*}$	24/30	Have to use subtitles
8	…be able to play your favourite instrument	Mirza 2003, MUMU	8/30	Is the question about the physical act of playing an instrument or is it about being able to hear myself playing my favourite instrument?
9	…hear music that sounds natural	MUMU, UCMLQ, IMBQ	26/30	Not sure what is natural to me
10	…hear music that sounds clear		29/30	
11	…hear music that sounds pleasant		27/30	So I can recognise which sound is bad or good
12	…be able to sing your favourite song	Mirza 2003, MUMU,	19/30	I can sing my favourite song but is the question about sing my favourite song in tune and time? I cannot sing!
13	…be able to dance to the music that you hear	*Music Engagement Questionnaire (MEQ)*	16/30	Is this question about dancing in time to the music? Would be nice to understand music in a club Lot of music that I can enjoy that I know it would be impossible with my dancing skills!
14	…be able to enjoy music at a religious gathering, e.g. a church service	Anecdotal patients' reports, MUMU	23/30	Not necessarily enjoy but to be able to hear / understand what is being played
15	…feel comfortable in a place where music is played	*NCIQ*	27/30	
16	…talk to other people about music	*NCIQ*	22/30	
17	…be patient when trying to understand a song	*NCIQ*	25/30	Understanding a song can be very frustrating and takes a long time to understand I like to explore and the meaning of the song I would like to understand my music Do you mean 'do you understand that you need to be patient' or 'do you personally need to be patient in order to understand?'

Appendix B

	How important is it for you to…	Origin of item	Very important/ Extremely important	Most important comments
18	…be going to concerts or music shows	MUMU, IMBQ	21/30	
19	…be going to social events (e.g. parties) where music is played	MUMU	19/30	Would not attend a function where music was played as background to conversation Would love to be able to but know that would struggle to socialise etc so often will not go I don't go to these events any more due to the difficult of hearing

Appendix B.4 Initial template of the focus group data analysis

Music-related Quality of Life (MRQoL)

Domain: MUSIC-RELATED PHYSICAL FUNCTIONING

A. Basic music perception

1. Perception of the musical beat
2. Perception of the words in music
3. Perception of the loudness of the music
4. Recognition of musical instruments
5. Ability to follow the melody (tune)
6. Ability to follow/understand/recognise familiar music
7. Ability to hear differences in pitch

B. Advanced music perception

1. Ability to understand music in the car
2. Ability to distinguish between musical instruments
3. Ability to hear good/bad singers
4. Ability to hear differences between singers
5. Ability to understand new music
6. Ability to understand a musical play at the theatre
7. Ability to perceive the beat correctly to dance (in tune)
8. Ability to understand music on TV/DVD
   - 8.1. With headphones
   - 8.2. With subtitles
9. Ability to understand classical music
10. Perception of emotion in music
11. Ability to follow music at the church

C. Music production

1. Ability to sing in tune

Domain: MUSIC-RELATED PSYCHOLOGICAL FUNCTIONING

D. Music-related self-esteem

1. Feeling at ease (comfortable) with music
2. Feeling confident with music
3. Avoidance of music
4. Perseverance with music

E. Feelings about music

1. Positive feelings
   - 1.1. Enjoyment of (getting pleasure from) music
     - 1.1.1. Enjoyment of birds singing
     - 1.1.2. Enjoyment of music at the theatre
     - 1.1.3. Enjoyment of public music shows
     - 1.1.4. Enjoyment of music in the car
     - 1.1.5. Enjoyment of music while exercising
     - 1.1.6. Enjoyment of music (shows) on TV/DVD
     - 1.1.7. Enjoyment of familiar/favourite music
     - 1.1.8. Enjoyment of music at home
2. Negative feelings
   - 2.1. Frustration with music

F. Music appraisal

1. Annoyance by music sounds
   - 1.1. Annoyance by bird singing
   - 1.2. Annoyance by background music at the shop
   - 1.3. Annoyance by high pitch
2. Appraisal of musical instruments
   - 2.1. Violin sounds beautiful
3. Music sound quality
   - 3.1. Clarity of the music
   - 3.2. Music sounds "substantial" ("rich")
   - 3.3. Music sounds different than before
   - 3.4. Music sounds "like noise"
   - 3.5. Music sounds pleasant
   - 3.6. Music sounds harmonious

Domain: MUSIC-RELATED SOCIAL FUNCTIONING

G. Musical activity

1. Music listening
   - 1.1. Listening to music at home
     - 1.1.1. Listening to music on the iPod
     - 1.1.2. Listening to music on DVD/CD/computer
     - 1.1.3. Listening to music on a tablet
     - 1.1.4. Listening to music while exercising
     - 1.1.5. Listening to records
   - 1.2. Listening to music in the car
   - 1.3. Listening to new music
2. Dancing
3. Participation
   - 3.1. Participation in music workshops
   - 3.2. Going to public musical shows
     - 3.2.1. Opera
     - 3.2.2. Musical theatre
     - 3.2.3. Concerts
4. Music making
   - 4.1. Singing

H. Music-related social interaction

1. Taking part in musical activities in the family

Uncategorised themes

- Music is relaxing
- Concentration - listening effort
- Ability to listen to music casually while doing other things / listening to music casually while doing other things

Appendix B

Appendix B.5 Final template of the focus group data analysis

Music-related Quality of Life (MRQoL)

Domain: MUSIC LISTENING ABILITY

A. Perception of elements of music

1. Ability to hear the musical beat
2. Ability to hear the words in music
3. Ability to determine the loudness of music
4. Ability to recognise musical instruments
5. Ability to follow the melody of music
6. Ability to hear differences in musical pitch
   - 6.1. When listening to music
   - 6.2. Ability to hear yourself singing in tune
   - 6.3. Ability to hear yourself playing a musical instrument in tune
7. Ability to perceive the emotion of music
8. Ability to understand the meaning of music
9. Ability to distinguish between different musical instruments in a mixture

B. Music perception in particular listening scenarios

1. Ability to understand music using audio-only media in noise
2. Ability to understand familiar music
3. Ability to understand new music
4. Ability to understand music in public music events
5. Ability to understand music using audio-visual media
6. Ability to hear music casually with little effort or concentration
7. Ability to recognise music-like every-day sounds
8. Ability to tell if a musical performance is good or bad
9. Ability to understand audio-only music in quiet

Domain: ATTITUDE TOWARDS MUSIC

C. Music-related self-esteem

1. Confidence with music (with music listening and making)
2. Embarrassment with music

D. General attitude towards music

1. Avoidance of music
2. Perseverance with music

E. Feelings about music

1. Positive feelings
   - 1.1. Enjoyment of music
     - 1.1.1. Enjoyment of music listening
     - 1.1.2. Enjoyment of going to public music shows
     - 1.1.3. Enjoyment of music making
   - 1.2. Feeling at ease with music
2. Negative feelings
   - 2.1. Frustration with music
   - 2.2. Disappointment with music

F. Music appraisal

1. Annoyance by music sounds
   - 1.1. Annoyance by music-like every-day sounds
   - 1.2. Annoyance by background music in public places
   - 1.3. Annoyance by high-pitched music
2. Music sound quality
   - 2.1. Music sounds/does not sound clear
   - 2.2. Music sounds/does not sound pleasant
   - 2.3. Music sounds/does not sound discordant
   - 2.4. Music sounds/ does not sound "as it should"
   - 2.5. Music sounds/does not sound "like noise"
3. Music sounds comfortable/uncomfortable

Domain: MUSICAL ACTIVITY

G. Music listening activity

1. Listening to music actively
2. Having music in the background while doing something else
3. Listening to music whilst travelling
4. Listening to new music

H. Participation & Social interaction

1. Participation in music interest groups
2. Going to public musical events
3. Taking part in social events where music is potentially played
4. Talking about music to others
5. Participating in dances and fitness classes

I. Music making activity

1. Singing (alone or with others)
2. Playing a musical instrument (alone or with others)
3. Music lessons

Appendix B.6 The prototype MRQOL questionnaire (Version 1)

MUSIC LISTENING ABILITY

A. Perception of elements of music

1. Can you hear the beat in music?
2. Can you hear the words in music?
3. Can you tell how loud or quiet music is?
4. Can you recognise the sounds of musical instruments?
5. Can you follow the melody in music (e.g. follow the melody of a song or a familiar tune)?
6. Can you hear differences in musical pitch?
7. Can you hear whether you are singing or playing a musical instrument in tune (in tune with the music or with others)?
8. Can you hear the emotion in music (e.g. when a piece of music is happy or sad)?
9. Can you understand the meaning of music (i.e. why it was created or what message it is trying to get across)?
10. Can you distinguish between different musical instruments when they play together?
11. Can you distinguish between different rhythmic patterns in music?

B. Music perception in particular listening scenarios

12. Can you understand music using audio-only media (without visual cues) in noisy environments (e.g. in the car over the engine/road noise or at a party)?
13. Can you understand music that you know (e.g. a familiar song, singer, tune or musical play)?
14. Can you understand music that you have never heard before?
15. Can you understand music at public music events (e.g. at a theatre, cinema, concert, music festival or church service)?
16. Can you understand music using audio-visual media (e.g. music on TV, DVD or on the computer) with subtitles?
17. Can you understand music using audio-visual media (e.g. on TV, DVD or on the computer) without subtitles?
18. Can you hear music casually without effort or having to concentrate?
19. Can you recognise music-like every-day sounds such as the ringing of your phone, the doorbell or different bird songs?
20. Can you tell when a musical performance (singing, musical instrument playing) is good or bad?
21. Can you understand music using audio-only media in quiet environments, e.g. music on the radio or CD player at home?

ATTITUDE TOWARDS MUSIC

C. Music-related self-esteem

22. Do you feel confident about your ability to hear music that you listen to (e.g. confident that you hear it correctly and understand it)?
23. Do you feel confident about your ability to sing, play a musical instrument or dance to music?
24. Do you feel embarrassed with music, (e.g. when you cannot sing in tune with others)?

D. General attitude towards music

25. Do you avoid music (e.g. avoid listening to music, avoid public music shows or social events where music is played)?
26. Do you persevere with music (e.g. continue to attempt to listen when music is hard to recognise, follow or understand)?

E. Feelings about music

27. Do you feel at ease in places where music is playing?
28. Do you enjoy listening to music?
29. Do you enjoy going to public/live music events (e.g. theatre, concert, opera, church service, cinema, recital, gig)?
30. Do you enjoy making music (e.g. singing, whistling or playing a musical instrument)?
31. Do you feel frustrated with music (e.g. when music is hard to recognise or understand, when music does not sound as it should or when there is background music in a restaurant or pub)?
32. Do you feel disappointed with music (e.g. when you cannot understand music, when it does not sound as before, when you cannot sing in tune)?

F. Music appraisal

33. Do you find music-like every-day sounds (e.g. bird songs or church bells) annoying?
34. Do you find background music in public places (e.g. background music in a shop, restaurant or pub) annoying?
35. Do you find high-pitched music (e.g. soprano singing, whistling or flute playing) annoying?
36. Does music sound uncomfortable?
37. Does music sound clear?
38. Does music sound pleasant?
39. Does music sound discordant?
40. Does music sound 'like noise'?
41. Does music sound as you think it should sound?

ACTIVITY & PARTICIPATION

G. Music listening activity

42. Do you put music on to listen to (e.g. watch a musical show on TV or DVD, listen to a CD or to music on the radio)?
43. Do you have music on in the background while doing something else (e.g. while reading, painting, doing gardening, exercising or just relaxing)?
44. Do you listen to music whilst travelling (e.g. in the car)?
45. Do you listen to music that you have never heard before?

H. Participation & social interaction

46. Do you participate in 'music interest' groups (e.g. music workshops or music clubs)?
47. Do you participate in public music events (e.g. musicals, concerts or music festivals)?
48. Do you participate in social events or activities where music is played (e.g. parties or getting together with the family)?
49. Do you talk about music to others?
50. Do you dance or participate in music fitness classes?

I. Music making activity

51. Do you sing, whistle or play a musical instrument when you are alone?
52. Do you sing or play a musical instrument when others are singing /playing at the same time?
53. Do you participate in music classes (e.g. singing lessons)?

Appendix C. Refinement and item selection

Appendix C.1 Expert review results

The percentage of domain allocation agreement and the professionals' comments for each item of the prototype questionnaire. In bold, items that reached the 65% domain allocation agreement. The questionanaire items are grouped here under the domains and subdomains where they were initially allocated (see the Prototype MRQOL questionnaire in the previous section). Please note that subdomains A, B, E and F were made available to the participants with different subdomain labels (see 8.3.2).

Prototype item	***Domain allocation agreement***	***Experts' comments***
Domain: MUSIC LISTENING ABILITY Subdomain A. Perception of elements of music		
1. Can you hear the beat in music?	80% Music listening ability 16% Appraisal of music sounds 4% Music perception in particular listening settings	• Is this different than the question about rhythm? • Perception - no listening setting • Perfect
2. Can you hear the words in music?	80% Music listening ability 12% Appraisal of music sounds 4% Music listening activity 4% Music perception in particular settings	• Can you understand the words in music? Is it more difficult than understanding spoken words? • Hear or understand or follow the lyrics? • I would say 'distinguish' instead of 'hear' because if you know there are words then you are hearing them but you probably mean if you can recognize the words. • It is clear here. please compare comments comments on all items including the word "understanding". imo these items might be confounded with this question here. • This may be a bit too general There are many pieces of music where normally hearing people can't make out the words either it very much depends on the type of music.
3. Can you tell how loud or quiet music is?	68% Music listening ability 28% Appraisal of music sounds	• Again I would get rid of 'regularly'

Appendix C

Prototype item	***Domain allocation agreement***	***Experts' comments***
	4% Music perception on particular listening settings	• Often CI users I have spoken with respond with "I think I can" but are not sure whether they are hearing differences or not. I think it would be difficult for them to answer this question. • Perception only • Clear
4. Can you recognise the sounds of musical instruments?	78.3% Music listening ability 21.7% Appraisal of music sounds	• Also could fall in the category of music listening ability • "Different musical instruments" • Can you recognise the sounds that different musical instruments make? • Perhaps add 'different' musical instruments • Do you mean can you recognise the difference between the sounds of different instruments? • What does this question mean? Can you recognise a particular instrument or would you know there's an instrument playing vs. nothing playing (detection) or would you know it's a musical instrument vs. another aural stimuli (e.g.noise)? • Sound identification • Ok
5. Can you follow the melody in music (e.g. follow the melody of a song or a familiar tune)?	91.7% Music listening ability 8.3% Music perception in particular listening settings	• "Eg. the tune of a song" (to remove the use of melody twice and add clarity) • Will vary depending on how familiar the song is • Again is a perception task but has no setting information • perfect
6. Can you hear differences in musical pitch?	80% Music listening ability 16% Appraisal of music sounds 4% Music perception in particular listening scenarios	• It might help to give an example - not everyone will understand "pitch". Alternatives to use as an example might be: "How high or low the music is" "How high or deep the music is" "Pitch means how high or low a sound is. For example men tend to have low pitched voices and women and children tend to have high pitched voices". • beware of the fact that pitch and volume are commonly confused in the English language • Include a simple definition of pitch • Very difficult for CI users to answer • I would put this an a few of the previous questions in the 'Musical Perception' category if it did not specify 'in a particular listening setting'. • Good question. • Perception only • ok
7. Can you hear whether you are singing or playing a musical instrument in tune (in tune with the music or with others)?	68% Music listening ability 12% Music making activity 12% Appraisal of music sounds 4% Music perception in particular listening settings	• Perfect • nice questions particularly for those patients who were active in a choir translates into satisfaction with outcome in terms of social participation and so much more

Prototype item	*Domain allocation agreement*	*Experts' comments*
	4% Participation and social interaction	
8. Can you hear the emotion in music (e.g. when a piece of music is happy or sad)?	50% Music listening ability 30.8% Music-related feelings 19.2% Appraisal of music sounds	• Impossible to codify this? happy and sad seems too simplistic to me • Good question. By the way this question is not one in the category of 'music-related feelings' because it is not about the emotion of the listener.
9. Can you understand the meaning of music (i.e. why it was created or what message it is trying to get across)?	54.2% Music listening ability 20.8% Appraisal of music sounds 8.3% General attitude towards music 8.3% Music perception in particular listening scenarios 4.2% Participation and social interaction 4.2% Music-related feelings	• You are assuming there *is* a meaning ... • this is likely to be a tricky question to answer. The meaning of music varies between pieces and genres and is sometimes much more obvious than others. • I'm not sure a non-CI user always can! • i find this a question that can not be answered with a Likert-scale; this is different per person • ok
10. Can you distinguish between different musical instruments when they play together?	75% Music listening ability 25% Appraisal of music sounds	• There should then also be the question 'when they play separately' (don't know if that question will come). • good. maybe distinguish / make clearer if i see the musicians or not. • Overlap between listening ability and appraisal of music sounds - could fit into either category good question
11. Can you distinguish between different rhythmic patterns in music?	72% Music listening ability 24% Appraisal of music sounds 4% Music perception in particular listening settings	• or more simply 'between different rhythms?' • 'distinguish' not 'distinguish between'. • perfect
Subdomain B. Music perception in particular listening scenarios		
12. Can you understand music using audio-only media (without visual cues) in noisy environments (e.g. in the car over the engine/road noise or at a party)?	76% Music perception in particular listening settings 20% Music listening ability 4% Music listening activity	• words melody or both? • Not sure whether "audio only media" would be confusing. Maybe remove this and keep "without visual cues". • What do you mean by "understand" • too many brackets (I think)...! • what do you mean by 'understand music'? • It is not clear what 'understand' means. Do you refer to lyrics? Also 'visual cues' could be clearer? Do you mean any video or the aid of a score or a text? • what is meant by "understanding"? "understand lyrics" etc. please see comment on question refering to audiovisual counterpart. • good to have examples which explain the question well • As previously

Appendix C

Prototype item	*Domain allocation agreement*	*Experts' comments*
13. Can you understand music that you know (e.g. a familiar song, singer, tune or musical play)?	79.2% Music listening ability 8.3% Music perception in particular listening settings 8.3% Appraisal of music sounds 4.2% Music listening activity	• replace "understand" with "recognize"? • I don't like the word 'understand' in this context. Also 'musical play' is not a commonly used expression. • that you know? From when? before implantation? • id. about 'understand'. • again not sure what is meant by "understanding" (compare other items including this term)? recognise? enjoy? understand the words?
14. Can you understand music that you have never heard before?	84% Music listening ability 8% Appraisal of music sounds 4% General attitude towards music 4% Music perception in particular listening settings	• words melody or both? • See previous comment on "never heard before" • Not sure what you mean by understand • recognise rather than understand? • id. about 'understand'. • please see comments on other items including the term "understand"
15. Can you understand music at public music events (e.g. at a theatre, cinema, concert, music festival or church service)?	65.4% Music perception in particular listening settings 15.4% Music listening ability 15.4% Participation and social interaction 3.8% Appraisal of music sounds	• words or melody or both? • Again I don't like the word 'understand' • The answer may be different for different settings. What do you mean by "understand" • Same remark as before about the word 'understand'. Perhaps 'hear well/correctly hear/appreciate/do you like music when it is played...' • I'm not sure you 'understand' music but I can't think of a more appropriate word! 'Identify' perhaps or 'hear'? • not clear: what is menat by understanding "understand lyrics in music"? or "identify songs you know"? or "identify instruments"? • Would you use the word 'understand'? Are you talking about following the tune or lyrics? • Again I think 'understand music' is a difficult concept - maybe specify whether you are interested in their ability to make out words make out a tune recognise a piece or style etc.
16. Can you understand music using audio-visual media (e.g. music on TV, DVD or on the computer) with subtitles?	50% Music perception in particular listening settings 41.7% Music listening ability 4.2% Appraisal of music sounds 4.2% Music listening activity	• this sounds similar to another question I already read words melody or both? • avoid 'understand' and 'audio-visual media' • I feel that the phrase 'understand music' needs some elaboration as it it not clear what is meant at least to me • 'songs' rather than 'music' again • what do you mean by 'understand'? What are the subtitles? is it of the lyrics? But what if it's an instrumental song? • Do you mean understand music or understand the lyrics? • for some other question as well: maybe say what is 'sometimes'. 1 out of 3 times? 1 out of 10 1 out of 100? • again compare other comments using the term "understand" which imo is not so clear.

Prototype item	*Domain allocation agreement*	*Experts' comments*
		• 'Understand music' is maybe a little unclear. Maybe specify 'Understand the lyrics in music' if that is what the question is trying to ask or 'make out the tune of music' etc • music listening activity --is also suitable
17. Can you understand music using audio-visual media (e.g. on TV, DVD or on the computer) without subtitles?	54.2% Music listening ability 41.7% Music perception in particular listening settings 4.2% Appraisal of music sounds	• Do you mean music with lyrics? There is quite a bit of music without lyrics. • I don't think that the word understand works very well in this question. I think that you may need to use hear appreciate enjoy or something else • What do you mean by "understand" • What does understanding music mean? being able to follow the music? Or do you mean to ask about the lyrics of music? Understanding music is very difficult cause I think I understand music but do I understand it as you do? • Music without lyrics is excluded here. say "can you understand songs..." instead? • What do you mean by understand? • hm.. "understand LYRICS in audiovisual music" 'd make it a bit more clear since not all music has lyrics. • Because of the mention of subtitles I presume this question refers to understanding lyrics if so perhaps it would be helpful to ask 'understand lyrics' explicitly?
18. Can you hear music casually without effort or having to concentrate?	95.8% for 'Music listening ability' 4.2% Appraisal of music sounds	• Does it take effort/concentration to listen to music? • In which environment? • ". . . without effort or without having to concentrate". • I would take out the word 'casually' • Not sure what you mean - being able to hear music is a detection task - i.e. whether there's music playing or not? Is that what you mean? • Ok • Perhaps simplify to something like 'Can you hear music clearly without having to concentrate?'
19. Can you recognise music-like every-day sounds such as the ringing of your phone, the doorbell or different bird songs?	52.2% Music listening ability 39.1% Appraisal of music sounds 8.7% Music perception in particular listening settings	• Consider using the same examples across questions related to music-like everyday sounds (previous question included church bells). • doorbell isn't necessarily musical sound? • Clear. • Sound identification • I'm not sure whether ringing of the phone doorbell can be described as music-like. • clear
20. Can you tell when a musical performance (singing, musical instrument playing) is good or bad?	52% Appraisal of music sounds 36% Music listening ability 8% Music perception in particular listening settings 4% General attitude towards music	• Does your opinion tend to match the opinions of others? • What is good and what is bad? • Wording much too general. Good/bad technical performance - or just don't like the genre of music?

Appendix C

Prototype item	*Domain allocation agreement*	*Experts' comments*
		• Or 'do you have an opinion about the quality of a musical performance' because now it sounds as if it is objective. CI users might not be so aware that it is subjective. • ok
21. Can you understand music using audio-only media in quiet environments, e.g. music on the radio or CD player at home?	56% Music perception in particular listening settings 40% Music listening ability 4% Music listening activity	• words melody or both? • Maybe use "without visual cues" instead of "audio-only media". • I am not sure that everyone will understand the term 'audio-only media'. You could use something like 'recorded music'. I don't think that the word understand is quite right here either. • see remark about understand before • please see comments on other items including the term "understand" • I would make the same suggestions as with the previous question regarding audio-visual media i.e. 'Understand music' might not be specific enough.
	Domain: ATTITUDE TOWARDS MUSIC Subdomain C. Music-related self-esteem	
22. Do you feel confident about your ability to hear music that you listen to (e.g. confident that you hear it correctly and understand it)?	65.2% Music-related self-esteem 21.7% Music listening ability 8.7% General attitude towards music 4.3% Music-related feelings	• Understand? • ?? • The phrase within parentheses is needed to understand the question (so keep it). • I still struggle with the concept of 'understanding' music • i think i get the point. if important maybe point out if the rated music was chosen by the listener or not. • hard to say. Can hearing people answer this question with confidence? If a hearing person has so-so experience with music but cannot be a professional then the answer could be sometimes.
23. Do you feel confident about your ability to sing, play a musical instrument or dance to music?	70.8% Music-related self-esteem 12.5% Music making activity 8.3% Music-related feelings 8.3% Participation and social interaction	• Dance??? Thats movement not listening • there seem to be three different questions here! • perhaps too many items in one question If I am sonfident with singing but not with dancing what do you expect me to answer? • You could add something like 'in as much as it is related to the CI' because people could also be uncomfortable with this because of the way they are or play in general. • ok
24. Do you feel embarrassed with music, (e.g. when you cannot sing in tune with others)?	58.3% Music-related self-esteem 25% Music-related feelings 8.3% Music making activity 4.2% General attitude towards music	• very similar to the question about confidence • do you feel embarrassed by ... I think that you need to be a bit more specific here • "embarrassed because of music" • Strange question. How can you feel embarrassed with music?

Prototype item	*Domain allocation agreement*	*Experts' comments*
	4.2% Participation and social interaction	• rogue comma. many ci users wouldn't know they were out if tune?I this question is unclear. I don't think we feel embarrassed with music but rather about our relationship with music? • Question doesn't really make sense - Do you feel embarrassed when singing with others may be a better phrasing • emarrassed when making music? • ok
Subdomain D. General attitude towards music		
25. Do you avoid music (e.g. avoid listening to music, avoid public music shows or social events where music is played)?	52% General attitude towards music 20% Participation and social interaction 16% Music-related feelings 8% Music listening activity 4% Music-related self-esteem	• Is it avoid *loud* music or avoid all music? • public music shows is not a commonly used expression. • Perhaps concerts and music festivals would be better • varied examples - may be different answers to these • ok
26. Do you persevere with music (e.g. continue to attempt to listen when music is hard to recognise, follow or understand)?	54.2% General attitude towards music 20.8% Music listening activity 16.7% Music listening ability 4.2% Music-related self-esteem 4.2.% Music-related feelings	• If music perception is difficult is it important to you to make the effort to listen? • Don't really get the question here • good
Subdomain E. Feelings about music		
27. Do you feel at ease in places where music is playing?	58.3% Music-related feelings 25% General attitude towards music 8.3% Music perception in particular listening settings 4.2% Music listening ability 4.2% Participation and social interaction	• It might depend on the environment or the type of music they are listening to so the answer 'sometimes' might not give you the exact answer you are looking for • some people may want to qualify this by saying that it depends on the type of music level what they are doing etc. • 'feeling at ease' needs elaboration. Do you imply annoyance? • ok
28. Do you enjoy listening to music?	50% General attitude towards music 37.5% Music-related feelings 4.2% Appraisal of music sounds 4.2% Music listening activity 4.2% Music-related self-esteem	• I think that it might be better to suggest an amount of time per day or week e.g. less than 15 mins 15 - 29 mins etc • ok

Prototype item	*Domain allocation agreement*	*Experts' comments*
29. Do you enjoy going to public/live music events (e.g. theatre, concert, opera, church service, cinema, recital, gig)?	50% Participation and social interaction 16.7% Music listening activity 12.5% General attitude towards music 12.5% Music-related feelings 4.2% Music-related self-esteem 4.2% Appraisal of music sounds	• Not sure the answer is always the same for each example given • Sounds like a question that has already been asked but if you ask them consecutively the difference could be clear enough. Detail: some of the examples you mention are not really music events but events which usually feature music (but are about other things). • good
30. Do you enjoy making music (e.g. singing, whistling or playing a musical instrument)?	40.7% Music making activity 25.9% Music-related feelings 22.2% General attitude towards music 3.7% Music listening activity 3.7% Music-related self-esteem 3.7% Participation and social interaction	• This question in particular could fit in to several sub-domains • Could be attitude or feelings • Perfect • Would you combine whistl
31. Do you feel frustrated with music (e.g. when music is hard to recognise or understand, when music does not sound as it should or when there is background music in a restaurant or pub)?	83.3% Music-related feelings 8.3% Music perception in particular listening settings 4.2% Music listening ability 4.2% General attitude towards music	• Might have a different answer for the different examples you gave • Frustrated with the volume of the music or with the content (eg someone who dislikes jazz being frustrated with there being jazz in the background)? • again there is more than one question here • I would consider frustrations with background music a different issue to not being able to recognise music. Therefore it is difficult to answer this question when you have a different answer to these two examples. • The description of the situation "background music in a restaurant or pub" makes this question difficult to answer because a pub is a very special situation with much background noise. I would propose to specify an "easy-listening" situation such as at home or during a concert in which no additional background noise is present • Ok • this is a multi-layered question - may be better to separate the background music question out as a separate question
32. Do you feel disappointed with music (e.g. when you cannot understand music, when it does not sound as before, when you cannot sing in tune)?	70.8% Music-related feelings 25% General attitude towards music 4.2% Music-related self-esteem	• "when it does not sound as before"--do you mean prior to the CI? • the examples suggest that the individual won't be able to understand music that it doesn't sound as before and that the CI user cannot sing in tune • Perhaps "Do you feel disappointed about the quality of music" • perfect
Subdomain F. Music appraisal		
33. Do you find music-like every-day sounds (e.g. bird songs or church bells) annoying?	40.9% Music-related feelings 31.8% Appraisal of music sounds 27.3% General attitude towards music	• Not sure how to categorise this one • There was a similar question before. The same comment applies also here

Prototype item	*Domain allocation agreement*	*Experts' comments*
		• not sure this question is appropriate since in my opinion ci recipients might find it hard to distinguish music-like every-day sounds from noise. will you also aks something like "do you find music you have not chosen (e.g. in a restaurant or department store) annoying"? maybe i don´t get the point here.
34. Do you find background music in public places (e.g. background music in a shop, restaurant or pub) annoying?	32% Music perception in particular listening settings 32% Music-related feelings 24% General attitude towards music 8% Music listening ability 4% Appraisal of music sounds	• Put the example after the whole question. • I think the word 'annoying' might not be the appropriate word • And was that always the case if the hearing loss is acquired? • perfect. i wondered if you´d ask that in another comment =)
35. Do you find high-pitched music (e.g. soprano singing, whistling or flute playing) annoying?	60.9% Appraisal of music sounds 21.7% Music-related feelings 8.7% Music listening ability 8.7% General attitude towards music	• see former comment • annoying is a very loaded word... • Clear. • very good.
36. Does music sound uncomfortable?	44% Appraisal of music sounds 28% Music-related feelings 20% General attitude towards music 4% Music listening ability 4% Music perception in particular listening settings	• what do you mean by uncomfortable? Do you mean does music sound too loud? • Not sure here whether you mean painful (eg when it's too loud?) or not pleasant/awkward? • Better: 'make you feel uncomfortable' (which makes the category 'music-related feelings'). • ok
37. Does music sound clear?	50% Appraisal of music sounds 45.8% Music listening ability 4.2% Music-related feelings	• Again I don't think that regularly quite fits with this question. • Perception only • Ok • or self-esteem or appraisal
38. Does music sound pleasant?	43.5% Appraisal of music sounds 26.1% Music-related feelings 17.4% General attitude towards music 8.7% Music listening ability 4.3% Music-related self-esteem	• good • or --appraisal of music sound
39. Does music sound discordant?	60% Appraisal of music sounds 16% Music listening ability 16% General attitude towards music 8% Music perception in particular listening settings	• Need to define discordant as some people won't understand it. Maybe use "out of tune" "unpleasant". • What does "discordant" mean? • I think that this is a reasonable question but requires a certain amount of musical training to understand the word 'discordant'. It might be necessary to have 'don't know' or similar as an answer. • Define discordant for the participant • Discordant - need less complicated vocabulary - maybe a descriptive phrase?

Prototype item	*Domain allocation agreement*	*Experts' comments*
		• It could be my English (I'm not a native) but I suppose that the word 'discordant' might be unclear or unknown to some recipients. Is there an easier more frequent synonym or a paraphrase for this? Perhaps 'inappropriate in tone or harmony' • Good • Perhaps follow up with a brief definition of 'discordant' because I think it may be unfamiliar to some members of the public who don't have much musical experience.
40. Does music sound 'like noise'?	54.2% Appraisal of music sounds 29.2% Music listening ability 8.3% General attitude towards music 4.2% Music-related feelings 4.2% Music perception in particular listening settings	• Maybe "just like noise" • Depends what style it is ... • Difficult question. What is noise? White noise traffic noise? The word 'noise' is not clear • Good • I think it would be helpful to specify a type of music here. Mozart or heavy rock? Could strongly affect the answer.
41. Does music sound as you think it should sound?	66.7% Appraisal of music sounds 12.5% Music listening ability 12.5% General attitude towards music 4.2% Music perception in particular listening settings 4.2% Music-related feelings	• Interesting. • Music perception [no information about setting] • I'm worried everybody will say 'never' • puh tough one. this depends on so many things.
Domain: MUSICAL ACTIVITY Subdomain G. Music listening activity		
42. Do you put music on to listen to (e.g. watch a musical show on TV or DVD, listen to a CD or to music on the radio)?	72% Music listening activity 8% Music making activity 8% General attitude towards music 4% Music listening ability 4% Participation and social interaction 4% Appraisal of music sounds	• The first eg is not an example: a "musical show" is the X-Factor but clearly thats not in the usual definition of "Do you put music on to listen to?" • Perhaps the question needs to be a bit rephrased? • internet? • perfect
43. Do you have music on in the background while doing something else (e.g. while reading, painting, doing gardening, exercising or just relaxing)?	54.2% Music listening activity 20.8% General attitude towards music 8.3% Appraisal of music sounds 8.3% Music perception in particular listening settings 4.2% Music listening ability 4.2% Music-related feelings	• this sounds similar to a previous question • good

Prototype item	*Domain allocation agreement*	*Experts' comments*
44. Do you listen to music whilst travelling (e.g. in the car)?	52% Music listening activity 36% Music perception in particular listening settings 8% Music listening ability 4% Music-related self-esteem	• Experience of listening in the car and train/coach may differ. • You could add an open question asking in what travelling circumstances they listen to music (car train plane ... otherwise). • Ok • could include (if you haven't) a question about listening to music while excercising
45. Do you listen to music that you have never heard before?	54.2% Music listening activity 20.8% General attitude towards music 16.7% Music listening ability 4.2% Appraisal of music sounds 4.2% Music perception in particular listening settings	• Need to clarify. I presume this means "music you had never heard before you had the implant". Could also include an example "e.g. new songs that have been written since you had the implant". • Does anyone listen to music that they have "never" heard before? • Sounds like a question that has already been asked (?). • I would make it clear if with 'hear before' you mean before with CI or before you went deaf or before with hearing aid? • perfect
Subdomain H. Participation & social interaction		
46. Do you participate in 'music interest' groups (e.g. music workshops or music clubs)?	70.8% Participation and social interaction 20.8% Music making acitivity 4.2% General attitude towards music 4.2% Music listening ability	• I think that some people won't understand this question • Good • tough one as so much overlap of categories
47. Do you participate in public music events (e.g. musicals, concerts or music festivals)?	60.9% Participation and social interaction 21.7% Music making activity 13% Music listening activity 4.3% Music perception in particular listening settings	• Particiapte means "be in". Or do you mean "go to" • people might not quite understand what is meant by participation in this context i.e. do you mean attendance or actually performing? • Participation could be making music or selling tickets - need to be more specific • unclear whether as performer or listener? • Sounds very similar to a previous about music in public events. Just make sure the difference is very clear. • Could be either music making activity or participation • Ok • instead of participate use "attend"? • I found 'participate' unclear because I wasn't sure whether it referred to attending and listening to public music events or whether participation meant creating the music. Maybe this could be re-phrased to say either 'Do you attend public music events' or 'Do you perform at public music events'?
48. Do you participate in social events or activities where music is played (e.g. parties or getting together with the family)?	92% Participation and social interaction 4% Music making activity 4% Music perception in particular listening settings	• It is not clear whether this questions asks whether the person likes to go to this form of event or how much they participate/engage. • It should be clear if live music or a recording or both is meant.

Prototype item	*Domain allocation agreement*	*Experts' comments*
		• ok maybe ask "do you enjoy participating...". it might be i have to participate for other reasons..
49. Do you talk about music to others?	70.8% Participation and social interactiov 20.8% General attitude towards music 8.3% Music-related self-esteem	• I think it should be 'with' others • "music with others" not to • What is the purpose of this question? • ok maybe specify do you "..talk about problems with music.." or "..talk ybout music you like.." on the other hand.. if you want to ask if music is important for an individual it might be appropriate just the way it is.
50. Do you dance or participate in music fitness classes?	79.2% Participation and social interaction 8.3% Music making activiry 8.3% Music listening acitivity 4.2% Music perception in particular listening settings	• Does the music contribute positively toward the experience? • "Do you dance or participate in fitness classes that use music?" • "in fitness classes that use music" • what is music fitness? • ok
Subdomain I. Music making activity		
51. Do you sing, whistle or play a musical instrument when you are alone?	76% Music making activity 8% Music listening activity 8% General attitude towards music 4% Music-related self-esteem 4% Participation and social interaction	• Interesting one. • ok
52. Do you sing or play a musical instrument when others are singing /playing at the same time?	60% Music making activity 40% Participation and social interaction	• is this in a band or casually at home? • Why not just ask "Do you sing or play a musical instrument?" • I think that regularly and usually are not quite the same but similar enough that people might have difficulty choosing between them. I don't think that regularly really fits well with this question. • isn't it first relevant to ask if they do and then later ask whether they do it with other present? • this doesn't make sense to me. • hm. you might not get the extent how much a pro does music because he/she might tick "sometimes" (instead of always) because singing along at the classical concert he regulary visits is not considered appropriate. please check asking "would or do you enjoy to sing or play along a musical instrument when..." or maybe ask "how often do you.." -->or simply "Do you sing / play with others" • or listening ability

Prototype item	*Domain allocation agreement*	*Experts' comments*
53. Do you participate in music classes (e.g. singing lessons)?	48% Participation and social interaction 48% Music making activity 4% Music listening activity	• Do you want to distinguish between private lessons and music classes that are part of the school curriculum? • Again could be participation or music making activity • Perfect • depends on whether one participated the class willingly or under compulsion

Appendix C.2 The second draft MRQOL questionnaire (Version 2)

<table>
<tr><td>MUSIC-RELATED PHYSICAL FUNCTIONING – MUSIC LISTENING ABILITY</td><td rowspan="11">Never
Rarely
Occasionally
Frequently
Always</td></tr>
<tr><td>A. Basic music listening ability</td></tr>
<tr><td>1. Can you hear the beat in music?
2. Can you distinguish different rhythmic patterns in music?
3. Can you tell how loud or quiet music is?
4. Can you follow the melody in music i.e. follow the melody of a song or a familiar tune?
5. Can you hear differences in musical tone, i.e. how high or low music is?
6. Can you recognise the words in songs?
7. Can you recognise the sounds of different musical instruments when they play separately (‘solo’)?</td></tr>
<tr><td>B. Advanced music listening ability</td></tr>
<tr><td>8. Can you distinguish different musical instruments when they play together?
9. Can you hear the emotion of music (e.g. whether a piece of music is happy or sad)?
10. Can you hear the meaning of music, i.e. why it was created or what message it is trying to get across?
11. Can you hear music without effort or without having to concentrate?
12. Can you recognise familiar music (e.g. a song, singer or tune)?
13. Can you recognise music-like every-day sounds such as the ringing of your phone, the doorbell, different bird songs or church bells?
14. Can you judge the quality of a musical performance (e.g. singing or musical instrument playing)?
15. Can you hear whether you are singing or playing a musical instrument in tune (in tune with the music or with others)?
16. Can you recognise music that you have not heard before?</td></tr>
<tr><td>MUSIC-RELATED PSYCHOLOGICAL FUNCTIONING - ATTITUDE TOWARDS MUSIC</td></tr>
<tr><td>E. Music-related self-esteem</td></tr>
<tr><td>17. Do you feel confident that you hear music like other people do?
18. Do you feel embarrassed when whistling, singing or playing a musical instrument with others present?</td></tr>
<tr><td>F. Music enjoyment</td></tr>
<tr><td>19. Do you enjoy music in noisy environments when no visual cues are available (e.g. at a party, at the pub or in the car over the engine/road noise)?
20. Do you enjoy music in quiet environments when visual cues are not available (e.g. music on the radio or on a CD player at home?</td></tr>
</table>

21. Do you enjoy music at public music events (e.g. music at a theatre, cinema, concert, music festival or church service)? 22. Do you enjoy music on TV, DVD or on the computer when visual cues are available? 23. Do you enjoy music that you hear for the first time, i.e. music that you have not heard before?	**Never** **Rarely** **Occasionally** **Frequently** **Always**
G. Negative music-related feelings	
24. Does music make you feel uncomfortable? 25. Do you feel disappointed with the quality of the music or if it is difficult to enjoy, recognise or follow music? 26. Do you feel frustrated with background music at a shop, restaurant or pub?	
H. Appraisal of music sound quality	
27. Does music sound out of tune? 28. Does music sound 'just like noise'? 29. Does music sound clear? 30. Does music sound pleasant? 31. Does music sound 'as you think it should sound'? 32. Do you find music-like every-day sounds (e.g. the ringing of your phone, the doorbell, bird songs or church bells) annoying? 33. Do you find high-pitched music (e.g. soprano singing, flute playing or whistling) annoying?	
MUSIC-RELATED SOCIAL FUNCTIONING – ACTIVITY & PARTICIPATION	
I. Music listening activity	
33. Do you put music on to listen to (e.g. do you listen to a CD, to music on the radio/internet or watch a musical show on TV/DVD)? 34. Do you choose to have music on in the background while doing something else (e.g. while reading, painting, doing gardening, exercising or just relaxing)? 35. Do you listen to music whilst travelling (e.g. in the car)? 36. Do you choose to listen to new music, i.e. music that you have not heard before? 37. Do you make the effort to listen if the music is hard to recognise or follow?	
J. Participation & social interaction	
40. Do you participate in 'music interest' groups (e.g. music workshops or music clubs)? 41. Do you attend public music events (e.g. musicals, concerts or music festivals)? 42. Do you avoid social events or activities where music is played (e.g. parties or getting together with the family)? 43. Do you talk about music with others (e.g. about music that you like or about problems that you have with music)? 44. Do you dance or participate in fitness classes that use music?	**Never** **Rarely** **Occasionally** **Frequently** **Always**
K. Music making activity	
44. Do you sing, play a musical instrument or whistle ***when you are alone***?	

45. Do you sing, play a musical instrument or whistle ***when others are present***? 46. Do you choose to participate in music classes (e.g. singing lessons)?	

Appendix C.3 The importance scale

MUSIC LISTENING ABILITY		
1.	How important is it for you to be able to hear the **beat** in music?	*Not important at all* *Not very important* *Somewhat important* *Very important* *Extremely important*
2.	How important is it for you to be able to distinguish **different rhythmic patterns** in music?	
3.	How important is it for you to be able to tell how loud or quiet music is?	
4.	How important is it for you to be able to follow the melody in music (i.e. follow the melody of a song or a familiar tune)?	
5.	How important is it for you to be able to hear differences in musical tone (i.e. how high or low music is)?	
6.	How important is it for you to be able to recognise the words in songs?	
7.	How important is it for you to be able to recognise the sounds of different musical instruments **when they play separately ('solo')**?	
8.	How important is it for you to be able to distinguish different musical instruments **when they play together**?	
9.	How important is it for you to be able to hear the emotion of music (e.g. whether a piece of music is happy or sad)?	
10.	How important is it for you to be able to hear the meaning of music (i.e. why it was created or what message it is trying to get across)?	
11.	How important is it for you to be able to hear music without effort or without having to concentrate?	
12.	How important is it for you to be able to recognise familiar music (e.g. a song, singer or tune)?	
13.	How important is it for you to be able to recognise music-like every-day sounds (e.g. the ringing of your phone, the doorbell, different bird songs or church bells)?	
14.	How important is it for you to be able to judge the quality of a musical performance (e.g. singing or musical instrument playing)?	
15.	How important is it for you to be able to hear whether you are singing or playing a musical instrument in tune (in tune with the music or with others)?	
16.	How important is it for you to be able to recognise music that you have not heard before?	
ATTITUDE TOWARDS MUSIC		

17.	How important is it for you to feel confident that you hear music like other people do?	*Not important at all* *Not very important* *Somewhat important* *Very important* *Extremely important*
18.	How important is it for you not to feel embarrassed when whistling, singing or playing a musical instrument with others present?	
19.	How important is it for you to enjoy music **in noisy environments** when no visual cues are available (e.g. at a party, at a restaurant or in the car over the engine/road noise)?	
20.	How important is it for you to enjoy music **in quiet environments** when visual cues are not available (e.g. music on the radio or on a CD player at home)?	
21.	How important is it for you to enjoy music at public music events (e.g. music at a theatre, cinema, concert, music festival or church service)?	
22.	How important is it for you to enjoy music on TV, DVD or on the computer when visual cues are available?	
23.	How important is it for you to enjoy music that you hear for the first time (i.e. music that you have not heard before)?	
24.	How important is it for you **not** to feel uncomfortable because of music?	
25.	How important is it for you **not** to feel disappointed with music (e.g. with the quality of the music, or if it is difficult to enjoy, recognise or follow music)?	
26.	How important is it for you **not** to feel frustrated with background music at a shop, restaurant or pub?	
27.	How important is it for you to hear music that sounds in tune?	
28.	How important is it for you to hear music that does not sound 'just like noise'?	
29.	How important is it for you to hear music that sounds clear?	
30.	How important is it for you to hear music that sounds pleasant?	
31.	How important is it for you to hear music that sounds 'as you think it should sound'?	
32.	How important is it for you **not** to be annoyed by music-like every-day sounds (e.g. the ringing of your phone, the doorbell, bird songs or church bells)?	
33.	How important is it for you **not** to be annoyed by high-pitched music (e.g. soprano singing, flute playing or whistling)?	
	ACTIVITY & PARTICIPATION	
34.	How important is it for you to put music on to listen to (e.g. CDs, music on the radio/internet or musical shows on TV/DVD)?	
35.	How important is it for you to have music on in the background while doing something else (e.g. while reading, painting, doing gardening, exercising or just relaxing)?	
36.	How important is it for you to listen to music whilst travelling (e.g. in the car)?	
37.	How important is it for you to listen to new music (i.e. music that you have not heard before)?	

38.	How important is it for you to make the effort to listen if the music is hard to recognise or follow?	*Not important at all* *Not very important* *Somewhat important* *Very important* *Extremely important*
39.	How important is it for you to participate in 'music interest' groups (e.g. music workshops or music clubs)?	
40.	How important is it for you to attend public music events (e.g. musicals, concerts or music festivals)?	
41.	How important is it for you **not** to have to avoid social events or activities where music is played (e.g. parties or getting together with the family)?	
42.	How important is it for you to talk about music with others (e.g. about music that you like or about problems that you have with music)?	
43.	How important is it for you to dance or participate in fitness classes that use music?	
44.	How important is it for you to sing, play a musical instrument or whistle **when you are alone**?	
45.	How important is it for you to sing, play a musical instrument or whistle **when others are present**?	
46.	How important is it for you to participate in music classes (e.g. singing lessons)?	

Appendix C.4 Demographics of CI participants in item selection (study 3)

N_o	Age	Gender	Type of deafness	Duration of CI use (years,months)	Implant type	Implant manufacturer	Music training
1*	43	F	Postlingual	18 months	Unilateral	Cochlear	No
2*	81	F	Postlingual	2 years	Bimodal	AB	No
3	78	M	Postlingual	3	Hybrid	Neurelec	No
4*	44	F	Postlingual	nearly 8 years	Unilateral	MED-EL	No
5*	44	F	Postlingual	5 years	Unilateral	Cochlear	No
6*	69	M	Postlingual	3	Unilateral	MED-EL	No
7*	55	F	Prelingual	5	Bimodal	AB	No
8*	77	F	Postlingual	3 Years 8 months	Bilateral	Neurelec	No
9*	72	F	Postlingual	7 years	Unilateral	Cochlear	Yes
10*	49	F	Postlingual	3 years 8 months	Bimodal	AB	No
11*	67	M	Postlingual	20 months	Unilateral	MED-EL	No
12*	67	M	Postlingual	1 year 10 months	Bimodal	AB	No
13*	83	M	Postlingual	16 yrs	Bilateral	Cochlear	No
14*	50	F	Postlingual	8 yeras	Unilateral	AB	No
15*	64	M	Postlingual	3 years	Unilateral	MED-EL	No
16*	68	F	Postlingual	2 years 8 months	Unilateral	MED-EL	No
17*	81	F	Postlingual	2 1/2 years	Unilateral	AB	No
18*	61	M	Postlingual	18 Years	Unilateral	Cochlear	No

Nₒ	Age	Gender	Type of deafness	Duration of CI use (years,months)	Implant type	Implant manufacturer	Music training
19*	34	M	Postlingual	5	Bimodal	AB	No
20*	24	F	Prelingual	8 Years	Bimodal	Cochlear	No
21*	68	M	Postlingual	7 months	Unilateral	Cochlear	No
22*	50	M	Prelingual	2 years	Bimodal	AB	No
23*	57	F	Postlingual	7years	Bimodal	MED-EL	No
24*	19	F	Postlingual	14 years	Bilateral	Cochlear	No
25*	40	F	Prelingual	2 years	Bimodal	AB	No
26*	39	F	Postlingual	3 years 11 mths	Unilateral	MED-EL	No
27*	83	M	Postlingual	5 years	Unilateral	Cochlear	No
28*	59	M	Postlingual	Six months	Bimodal	Cochlear	No
29*	38	F	Prelingual	7 years	Unilateral	Cochlear	No
30*	80	M	Postlingual	Nearly 3 years	Unilateral	MedEl	No
31*	19	F	Prelingual	Since the age of 2 years old	Bimodal	Cochlear	No
32 [P] *	69	F	Postlingual	7 years, 1 month	unilateral	med-el	no
33*	63	M	Prelingual	5 years	Bimodal	med-el	No
34*	34	M	Prelingual	since 2013	Bimodal	AB	No
35*	51	F	Postlingual	1 year	Bimodal	Med-el	No
36*	70	F	Prelingual	1 year	Unilateral	Cichlear	No
37*	65	F	Postlingual	10 months	Bimodal	Cochlear	No
38*	64	M	Postlingual	Since December 2008	Undefined	AB	No
39*	69	F	Postlingual	2 years	Bimodal	Med-el	No
40*	18	F	Prelingual	Since the age of 17. 1 year.	Bilateral	Cochlear	No
41*	56	M	Prelingual	5 years	Unilateral	AB	No
42*	49	F	Prelingual	2 years	Bimodal	Cochlear	No
43*	58	F	Postlingual	11 years	Unilateral	Cochlear	No
44 [P] *	84	M	Postlingual	3 years	bimodal	AB	no
45*	49	M	Prelingual	7 years 11 months	Bimodal	Cochlear	No
46 [P] *	67	F	Postlingual	23 years	Unilateral	Undefined	no
47*	62	F	Postlingual	5 years	Unilateral	AB	No
48*	39	F	Postlingual	one year	Unilateral	Cochlear	No
49*	57	M	Prelingual	17 months	Bimodal	AB	No
50 [P] *	66	F	Postlingual	3 years 4 months	Unilateral	Undefined	Yes
51 [P]	83	M	Postlingual	2 years 6 months	bimodal	AB	no
52*	39	F	Prelingual	4 years	Bilateral	cochlear	Yes
53*	66	F	Prelingual	3 years	Unilateral	AB	No
54	51	F	Postlingual	3yrs	Unilateral	medel	No
55 [P] *	45	F	Postlingual	14 years	Unilateral	cochlear	no
56 [P] *	77	F	Postlingual	13 years	Unilateral	cochlear	no

Appendix C

N_o	Age	Gender	Type of deafness	Duration of CI use (years,months)	Implant type	Implant manufacturer	Music training
57*	56	M	Postlingual	since 1997	Unilateral	Cochlear	No
58*	47	F	Postlingual	4years	Unilateral	AB	No
59 P *	68	M	Postlingual	23 years, 8 months	Unilateral	cochlear	no
60 P *	63	F	Prelingual	12 years	Unilateral	Undefined	no
61 P *	56	F	Postlingual	4 years 4 months	bimodal	medel	no
62 P	67	M	Postlingual	18 years	Unilateral	cochlear	no
63 P *	78	F	Postlingual	1 year 2 months	Bimodal	AB	no
64 P *	70	M	Postlingual	11 years 6 months	Unilateral	cochlear	no
65 P *	65	M	Postlingual	8 years, 8 months	Unilateral	cochlear	no
66*	55	F	Postlingual	10 years	Unilateral	cochlear	No
67*	57	F	Postlingual	1 year	Unilateral	AB	No
68*	66	M	Postlingual	9 years	Unilateral	AB	Yes
69*	66	M	Postlingual	3	Bimodal	Medel	No
70 P *	78	F	Postlingual	15 years, reimplanted 6 months	Unilateral	medel	no
71*	29	M	Prelingual	4 years and 5 months.	Unilateral	Cochlear	No
72*	26	F	Prelingual	Left ear since April 2015	Bimodal	Cocklea	No
73	59	M	Postlingual	12 years	Unilateral	Cochlear	No
74*	73	F	Postlingual	23 years	Unilateral	Cochlear	No
75*	29	F	Prelingual	15 years	Unilateral		No
76	64	M	Postlingual	10 years 5 months	Unilateral	Cochlear	No
77*	43	F	Postlingual	15 years	Unilateral	Cochlear	No
78*	41	M	Prelingual	14 years	Unilateral	Cochlear	No
79*	31	F	Prelingual	9 years	Bimodal	Cochlear	No
80*	83	M	Postlingual	Undefined	Unilateral	Medel	No
81*	76	F	Postlingual	two years	Bimodal	AB	No
82*	40	F	Postlingual	8years	Bimodal	Cochlear	No
83	52	M	Postlingual	One year	Unilateral	Cochlear	No
84*	50	F	Postlingual	6 years 5 months	Unilateral	Medel	No
85	38	F	Prelingual	2 years	Bimodal	AB	No
86*	23	F	Prelingual	11.5 years	Bimodal	Cochlear	No
87*	66	F	Prelingual	Three and a half years	Bimodal	Med-EL	No
88*	65	F	Postlingual	from 3rd June 2015	Unilateral	Cochlear	No
89	67	M	Prelingual	3.5 years	Bimodal	Med-el	No
90*	72	M	Postlingual	3 years	Unilateral	AB	No
91	25	F	Prelingual	Since 25 February 2000	Unilateral	Cochlear	No
92*	70	F	Postlingual	10 years	Bimodal	Cochlear	No
93	42	M	Postlingual	19 years	Unilateral	Cochlear	No
94*	68	F	Postlingual	13 years	Unilateral	cochlear	No
95*	69	F	Postlingual	5 years	Bimodal	Cochlear	No

N_o	Age	Gender	Type of deafness	Duration of CI use (years,months)	Implant type	Implant manufacturer	Music training
96*	70	F	Postlingual	three years	Unilateral	MED-EL	No
97*	70	F	Postlingual	11 years	Bimodal	Med El	No
98*	62	F	Postlingual	Since 2010	Unilateral	Med-el	No
99	50	F	Postlingual	10 years	Bilateral	AB	Yes
100*	51	M	Postlingual	10 years	Unilateral	Medel	No
101*	52	M	Prelingual	3 years	Unilateral	MED-EL	No
102*	46	F	Prelingual	10 years	Bilateral	AB	No
103*	35	F	Postlingual	19 months	Bimodal	Cochlear	Yes
104*	55	F	Postlingual	14.5 years	Unilateral	Cochlear	No
105*	59	M	Postlingual	21 years	Unilateral	Cochlear	No
106*	23	F	Prelingual	19	Unilateral	Cochlear	No
107*	30	F	Prelingual	6 years	Unilateral	Cochlear	No
108*	68	M	Postlingual	10 years	Unilateral	Cochlear	No
109*	50	F	Prelingual	7 years	Bimodal	AB	No
110	77	M	Postlingual	6 years	Unilateral	MED-EL	No
111*	59	M	Postlingual	7 years	Unilateral	AB	No
112*	58	F	Postlingual	Implanted June 1998.	Unilateral	Cochlear	No
113*	68	M	Postlingual	2.5years	Bimodal	AB	No
114*	76	F	Postlingual	19	Unilateral	Cochlear	No
115*	53	F	Postlingual	9 months	Bimodal	MED-EL	No
116*	57	M	Postlingual	4 years	Unilateral	Cochlear	No
117*	50	F	Postlingual	23 years	Unilateral	Cochlear	No
118*	80	M	Postlingual	13 yrs	Unilateral	AB	No
119*	75	F	Postlingual	10 years, 6 months	bilateral	Cochlear	Yes
120*	63	F	Prelingual	2yrs	Hybrid	Cochlear	No
121*	66	F	Postlingual	Since 2002	bimodal	AB	No
122*	48	F	Postlingual	Now 3yrs	unilateral	Cochlear	No
123*	40	F	Prelingual	2 years	bimodal	AB	No
124*	61	F	Postlingual	1.5 years	Unilateral	AB	No
125*	68	F	Postlingual	16 months	bimodal	AB	No
126*	60	F	Postlingual	2 1/2 years	bimodal	Cochlear	No
127*	71	F	Postlingual	11 months	Unilateral	Cochlear	No
128	52	F	Postlingual	5 years	Unilateral	AB	No
129*	70	F	Postlingual	11 1/2 years (April 2004)	bimodal	MED-EL	No
130*	38	F	Postlingual	12 years	Unilateral	Cochlear	Yes
131*	52	F	Postlingual	2 years	bimodal	Cochlear	No
132*	53	M	Postlingual	Right ear approx 15 years. (switched off approx 8 years ago) Left ear 8 years.	Bilateral	Cochlear	No

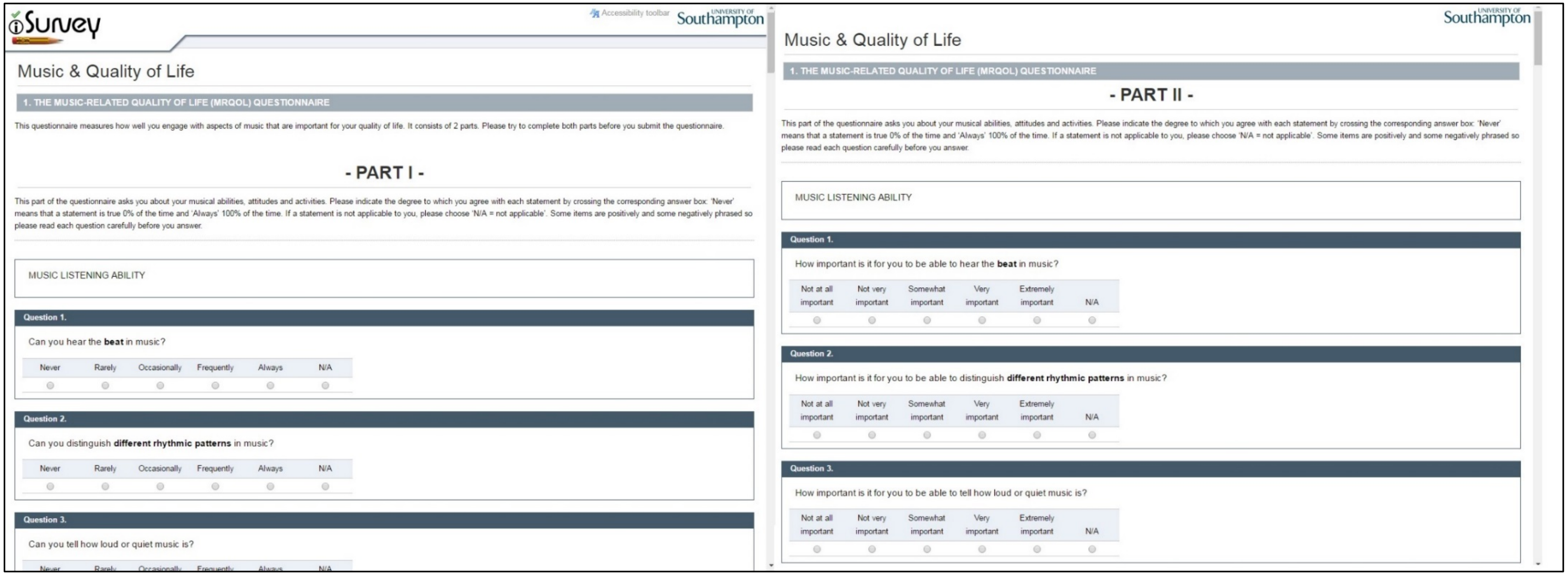
Appendix C

N_o	Age	Gender	Type of deafness	Duration of CI use (years,months)	Implant type	Implant manufacturer	Music training
133*	43	M	Undefined	3 YEARS	Unilateral	MED-EL	No
134*	74	M	Postlingual	Operation Feb 2000, switched on May 2000	Unilateral	Cochlear	No
135*	63	M	Postlingual	18 months	Unilateral	cochlear	No
136*	29	M	Postlingual	4 months	Unilateral	Cochlear	No
137*	54	F	Prelingual	6 months	Bimodal	Medel	No
138*	59	F	Postlingual	7-8 years	Unilateral	cochlear	No
139*	80	M	Postlingual	9 months	Unilateral	Cochlear	No
140*	65	M	Postlingual	6	Unilateral	cochlear	No
141*	53	M	Prelingual	12 months	Unilateral	Cochlear	No
142	28	Female	Postlingual	2 years	unilateral	Cochlear	No
143*	66	Male	Postlingual	5 years	unilateral	Cochlear	Yes
144*	66	Male	Postlingual	Four and a half years	bimodal	AB	No
145 [P]	26	male	Prelingual	16 years	Unilateral	cochlear	no
146*	64	Male	Postlingual	15 months	Unilateral	Cochlea	Classically trained
147	55	Female	Postlingual	26 years	Unilateral	Cochlear	No
148	57	Female	Postlingual	6 months	Unilateral	Cochlear	No
149 [P]	72	post	Postlingual	1 year	hybrid	cochlear	no

* Repeated the questionnaire 2 weeks after the first completion

[P] Completed the questionnaire by post

Appendix C.5 Screenshot of the online version of the questionnaire



Appendix C.6 The questionnaire sheet

Respondent ID: *CONFIDENTIAL

Music-related Quality of Life (MRQoL) questionnaire

This questionnaire measures how well you engage with aspects of music that are important for your quality of life. It consists of 2 parts. Please try to complete both parts before you post back the questionnaire. Before you begin, please give us som important personal information.

Personal information (write or circle)

Date of questionnaire completion: __ / __ / ______

Age: ______

Gender: Female / Male

Duration of hearing loss: ______ years / From birth

Duration of implant use: ______ years ______ months

Implant type: One ear | Both ears | Hearing aid in the other ear | Hybrid implant*

* i.e. a cochlear implant and a hearing-aid in the same ear

Implant manufacturer:

Professional music training: Yes / No

(if yes please specify:)

Page 1 of 3

Respondent ID: *CONFIDENTIAL*

PART I

This part of the questionnaire asks you about your musical abilities, attitudes and activities. Please indicate the degree to which you agree with each statement by crossing the corresponding answer box: 'Never' means that a statement is true 0% of the time and 'Always' 100% of the time. If a statement is not applicable to you, please choose 'N/A = not applicable'. Some items are positively and some negatively phrased so please read each question carefully before you answer.

	Never	Rarely	Occasionally	Frequently	Always	N/A
MUSIC LISTENING ABILITY						
1. Can you hear the **beat** in music?						
2. Can you distinguish **different rhythmic patterns** in music?						
3. Can you tell how loud or quiet music is?						
4. Can you follow the melody in music (i.e. follow the melody of a song or a familiar tune)?						
5. Can you hear differences in musical tone (i.e. how high or low music is)?						
6. Can you recognise the words in songs?						
7. Can you recognise the sounds of different musical instruments **when they play separately ('solo')**?						
8. Can you distinguish different musical instruments **when they play together**?						
9. Can you hear the emotion of music (e.g. whether a piece of music is happy or sad)?						
10. Can you hear the meaning of music (i.e. why it was created or what message it is trying to get across)?						
11. Can you hear music without effort or without having to concentrate?						
12. Can you recognise familiar music (e.g. a song, singer or tune)?						
13. Can you recognise music-like every-day sounds (e.g. the ringing of your phone, the doorbell, different bird songs or church bells)?						
14. Can you judge the quality of a musical performance (e.g. singing or musical instrument playing)?						

Page 2 of 3

Respondent ID: *CONFIDENTIAL*

PART II

This part of the questionnaire asks you how important the above music listening abilities, attitudes towards music and musical activities are for you. Please indicate the importance of each statement by putting a cross in the corresponding answer box. If a statement is not applicable to you, please choose 'N/A = not applicable'. Some items are positively and some negatively phrased so please read each question carefully before you answer.

	Not at all important	Not very important	Somewhat important	Very important	Extremely important	N/A
MUSIC LISTENING ABILITY						
1. How important is it for you to be able to hear the **beat** in music?						
2. How important is it for you to be able to distinguish **different rhythmic patterns** in music?						
3. How important is it for you to be able to tell how loud or quiet music is?						
4. How important is it for you to be able to follow the melody in music (i.e. follow the melody of a song or a familiar tune)?						
5. How important is it for you to be able to hear differences in musical tone (i.e. how high or low music is)?						
6. How important is it for you to be able to recognise the words in songs?						
7. How important is it for you to be able to recognise the sounds of different musical instruments **when they play separately ('solo')**?						
8. How important is it for you to be able to distinguish different musical instruments **when they play together**?						
9. How important is it for you to be able to hear the emotion of music (e.g. whether a piece of music is happy or sad)?						

Page 3 of 3

Appendix C.7 Descriptive statistics of the prototype items

Desciptive statistics of the 46 ‘frequency’ items and the 46 ‘importance’ items.

	Range	Mean		Std. Deviation	Skewness		Kurtosis		Intra-class correlation coefficient (ICC)
	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic	Std. Error	
FREQUENCY ITEMS									
1	3	4.31	.069	.841	-1.121	.200	.639	.397	.779
2	4	3.86	.077	.925	-.664	.201	.205	.399	.675
3	4	4.18	.071	.860	-1.085	.200	1.421	.397	.643
4	4	3.46	.085	1.027	-.501	.201	-.285	.400	.774
5	4	3.48	.089	1.081	-.449	.200	-.557	.397	.802
6	4	2.82	.076	.927	.047	.200	-.372	.397	.806
7	4	3.19	.081	.975	-.156	.202	-.195	.401	.776
8	4	2.47	.083	.998	.288	.201	-.490	.399	.773
9	4	3.44	.096	1.154	-.542	.201	-.290	.400	.779
10	4	2.73	.091	1.092	.133	.202	-.725	.401	.791
11	4	2.95	.109	1.312	.009	.201	-1.155	.399	.789
12	4	3.49	.089	1.072	-.545	.201	-.209	.399	.753
13	3	4.12	.071	.859	-.699	.200	-.241	.397	.661
14	4	2.58	.095	1.152	.119	.200	-.808	.397	.812
15	4	2.49	.104	1.206	.270	.209	-.914	.416	.786
16	4	2.21	.090	1.083	.546	.202	-.581	.401	.789
17	4	2.27	.101	1.213	.608	.202	-.688	.401	.846
18	3	1.88	.076	.832	.401	.221	-.977	.438	-.059
19	4	2.12	.094	1.133	.637	.201	-.686	.400	.738
20	4	3.63	.099	1.201	-.590	.200	-.592	.397	.835
21	4	3.09	.100	1.178	-.061	.205	-.734	.407	.818
22	4	3.64	.094	1.128	-.637	.201	-.261	.400	.831
23	4	2.76	.096	1.164	-.025	.201	-.907	.399	.847
24	4	2.24	.095	1.140	.808	.203	.063	.403	-.087
25	4	2.18	.077	.915	.646	.204	.760	.406	.102
26	3	1.95	.067	.809	.257	.200	-1.021	.397	-.010
27	4	3.28	.100	1.188	-.400	.205	-.707	.407	.830
28	3	2.26	.070	.847	.300	.201	-.445	.399	-.025
29	4	3.01	.089	1.080	-.180	.201	-.831	.399	.793
30	4	3.36	.081	.981	-.368	.201	-.172	.399	.758
31	4	2.86	.109	1.272	-.041	.208	-1.087	.413	.841
32	4	2.39	.100	1.208	.712	.200	-.208	.397	-.061
33	4	2.31	.078	.933	.451	.202	.317	.401	.022
34	4	3.18	.106	1.282	-.251	.200	-.971	.397	.826
35	4	2.53	.109	1.319	.269	.201	-1.217	.399	.895
36	4	3.21	.117	1.415	-.354	.201	-1.164	.399	.886
37	4	2.40	.097	1.172	.286	.201	-.954	.399	.801
38	4	2.97	.100	1.203	-.079	.202	-.851	.401	.627
39	4	1.36	.070	.827	2.559	.206	6.358	.410	.726
40	4	2.42	.089	1.075	.284	.201	-.538	.399	.836
41	4	2.26	.096	1.157	.746	.202	-.018	.401	-.081
42	4	2.82	.082	.984	.058	.201	-.353	.400	.594
43	4	1.99	.106	1.240	.837	.207	-.688	.411	.745
44	4	2.77	.108	1.285	.018	.204	-1.133	.406	.821
45	4	1.85	.081	.959	.852	.205	-.123	.407	.731
46	4	1.15	.048	.567	4.427	.207	21.722	.411	.667
IMPORTANCE ITEMS									
1	4	3.82	.081	.973	-.772	.201	.262	.399	.668
2	4	3.67	.083	1.000	-.729	.201	.394	.400	694
3	4	3.50	.075	.912	-.720	.201	.716	.399	.585
4	4	3.94	.080	.955	-1.095	.202	1.444	.401	.617
5	4	3.65	.084	1.019	-.660	.200	.005	.397	.598
6	4	3.63	.084	1.013	-.333	.201	-.478	.400	.709
7	4	3.34	.083	1.005	-.262	.201	-.324	.399	.582

Appendix C

	Range	Mean		Std. Deviation	Skewness		Kurtosis		Intra-class correlation coefficient (ICC)
	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic	Std. Error	
8	4	2.96	.084	1.009	.042	.201	-.297	.399	.612
9	4	3.50	.080	.966	-.718	.201	.442	.400	.663
10	4	3.09	.089	1.068	-.219	.203	-.550	.403	.633
11	4	3.82	.081	.973	-.999	.201	.956	.399	.489
12	4	3.97	.069	.828	-.901	.201	1.429	.400	.548
13	4	4.23	.066	.797	-1.101	.201	1.640	.400	.485
14	4	3.21	.084	1.017	-.264	.201	-.435	.399	.677
15	4	3.35	.113	1.269	-.412	.215	-.854	.427	.763
16	4	3.10	.096	1.146	-.223	.203	-.650	.403	.623
17	4	3.49	.090	1.084	-.283	.202	-.646	.401	.761
18	4	3.31	.109	1.244	-.238	.212	-.913	.422	.625
19	4	3.09	.097	1.154	-.097	.203	-.733	.404	.599
20	4	3.87	.084	1.019	-.885	.201	.352	.399	.712
21	4	3.81	.087	1.049	-.774	.201	.125	.400	.714
22	4	3.84	.081	.984	-.773	.200	.390	.397	.678
23	4	3.35	.090	1.084	-.308	.201	-.387	.400	.682
24	4	3.82	.097	1.165	-.820	.201	-.207	.400	.482
25	4	3.73	.091	1.105	-.650	.201	-.257	.399	.667
26	4	3.48	.093	1.119	-.288	.201	-.822	.400	.557
27	4	3.77	.086	1.044	-.920	.201	.557	.399	.629
28	4	4.12	.086	1.028	-1.299	.202	1.372	.401	.656
29	4	4.10	.072	.872	-1.223	.201	2.145	.400	.651
30	4	4.19	.073	.882	-1.361	.201	2.399	.400	.679
31	4	4.05	.075	.895	-.926	.202	.879	.401	.645
32	4	3.54	.100	1.202	-.594	.201	-.457	.400	.634
33	4	3.45	.101	1.213	-.422	.201	-.764	.400	.542
34	4	3.68	.099	1.186	-.706	.202	-.287	.401	.681
35	4	3.01	.106	1.271	-.013	.202	-1.077	.401	.760
36	4	3.29	.107	1.269	-.286	.203	-.903	.404	.777
37	4	3.06	.098	1.174	-.242	.203	-.738	.403	.648
38	4	3.13	.101	1.210	-.221	.203	-.793	.403	.696
39	4	1.90	.099	1.148	1.348	.209	.988	.414	.743
40	4	3.00	.107	1.291	.000	.201	-1.062	.400	.762
41	4	3.77	.104	1.249	-.807	.203	-.408	.403	.592
42	4	2.82	.100	1.193	.245	.203	-.812	.404	.719
43	4	2.39	.118	1.365	.491	.209	-1.105	.416	.703
44	4	2.86	.116	1.365	.196	.206	-1.217	.410	.830
45	4	2.24	.113	1.312	.832	.208	-.501	.413	.748
46	4	1.66	.092	1.050	1.630	.213	1.920	.423	.783

Appendix C.8 Structure matrix of factor analysis

Frequency Item	Component	
	1 Eigenvalue: 8.9 % of Variance: 49	2 Eigenvalue: 5.6 % of Variance: 31
4	.842	.470
5	.842	.413
11	.820	.526
12	.800	.459
17	.796	.515
14	.796	.439
10	.794	.535
27	.794	.483
7	.764	.304
6	.731	.379
22	.698	.638
2	.668	.355
19	.654	.563
35	.542	.829
37	.642	.814
36	.534	.797
40	.474	.707
44		.436

Appendix C.9 The final MRQOL questionnaire (Version 3)

Item numbers were retained here as in Version 2 to facilitate references between the two versions.

MUSIC-RELATED QUALITY OF LIFE (MRQOL)										
MUSIC PERCEPTION (ABILITY)										
	Never (1)	*Rarely (2)*	*Occasionnaly (3)*	*Frequently (4)*	*Always (5)*	*Not important at all (1)*	*Not very important (2)*	*Somewhat important (3)*	*Very important (4)*	*Extremely important (5)*
2.	Can you distinguish different rhythmic patterns in music?					How important is it for you to be able to distinguish different rhythmic patterns in music?				
4	Can you follow the melody in music (i.e. follow the melody of a song or a familiar tune)?					How important is it for you to be able to follow the melody in music (i.e. follow the melody of a song or a familiar tune)?				
5	Can you hear differences in musical tone (i.e. how high or low music is)?					How important is it for you to be able to hear differences in musical tone (i.e. how high or low music is)?				
6	Can you recognise the words in songs?					How important is it for you to be able to recognise the words in songs?				
7	Can you recognise the sounds of different musical instruments when they play separately ('solo')?					How important is it for you to be able to recognise the sounds of different musical instruments when they play separately ('solo')?				
10	Can you hear the meaning of music (i.e. why it was created or what message it is trying to get across)?					How important is it for you to be able to hear the meaning of music (i.e. why it was created or what message it is trying to get across)?				
12	Can you recognise familiar music (e.g. a song, singer or tune)?					How important is it for you to be able to recognise familiar music (e.g. a song, singer or tune)?				
14	Can you judge the quality of a musical performance (e.g. singing or musical instrument playing)?					How important is it for you to be able to judge the quality of a musical performance (e.g. singing or musical instrument playing)?				
27	Does music sound in tune?					How important is it for you to hear music that sounds in tune?				
MUSIC ENGAGEMENT (ATTITUTE, ACTIVITY & PARTICIPATION)										
	Never (1)	*Rarely (2)*	*Occasionnaly (3)*	*Frequently (4)*	*Always (5)*	*Not important at all (1)*	*Not very important (2)*	*Somewhat important (3)*	*Very important (4)*	*Extremely important (5)*
17	Do you feel confident that you hear music like other people do?					How important is it for you to feel confident that you hear music like other people do?				

19	Do you enjoy music in noisy environments when no visual cues are available (e.g. at a party, at a restaurant or in the car over the engine/road noise)?	How important is it for you to enjoy music in noisy environments when no visual cues are available (e.g. at a party, at a restaurant or in the car over the engine/road noise)?
22	Do you enjoy music on TV, DVD or on the computer when visual cues are available?	How important is it for you to enjoy music on TV, DVD or on the computer when visual cues are available?
35	Do you choose to have music on in the background while doing something else (e.g. while reading, painting, doing gardening, exercising or just relaxing)?	How important is it for you to have music on in the background while doing something else (e.g. while reading, painting, doing gardening, exercising or just relaxing)?
36	Do you listen to music whilst travelling (e.g. in the car)?	How important is it for you to listen to music whilst travelling (e.g. in the car)?
37	Do you choose to listen to new music (i.e. music that you have not heard before)?	How important is it for you to listen to new music (i.e. music that you have not heard before)?
38	Do you make the effort to listen if the music is hard to recognise or follow?	How important is it for you to make the effort to listen if the music is hard to recognise or follow?
40.	Do you attend public music events (e.g. musicals, concerts or music festivals)?	How important is it for you to attend public music events (e.g. musicals, concerts or music festivals)?
44	Do you sing, play a musical instrument or whistle when you are alone?	How important is it for you to sing, play a musical instrument or whistle when you are alone?

Appendix D. Validation

Appendix D.1 Demographics of NH participants

Participant	Age	Gender	Educational level	Occupation	Music training
1	30	Male	A-Level	Administration - Auditory Implant Service, University of Southampton	No
2	35	Male	BSc (Hons)	Project Manager	No
3	23	Female	Degree	Communications and Marketing Assistant	No
4	53	Female	Further Education	Clinic Secretary	No
5	42	Female	University degree	Childminder	No
6	61	Female	Degree	Retired	No
7	60	Female	RN RM	retired midwife	No
8	45	Female	Degree	Exam invigilator and housewife	No
9	46	Female	Btech/college	Purchasing Administrator	No
10	40	Female	University Degree	Group Administrator	No
11	25	Male	Undergraduate Study	Administrator	No
12	25	Male	MSc	PhD student	No
13	27	Female	MSc Engineering	PGR student	No
14	29	Male	Msc	Student	No
15	45	Female	phd	consultant engineer	No
16	28	Female	BSc	Administration	No
17	61	Female	Degree	Trainer	No
18	35	Female	Higher education	Financing Marketing Manager	No
19	27	Female	PhD	Engineering Consultant	No
20	20	Female	Undergraduate	Student	Yes
21	43	Male	A Level	Human Resources Middle Management	No
22	40	Female	MA	Project Manager	No
23	30	Male	Graduate	Learning Consultant	No
24	54	Male	Masters	Carer	No
25	51	Female	Fellowship	Medical Research Standards Officer	No
26	42	Female	Hons Degree	Research Manager	No
27	29	Male	Degree	Marketing Officer	No
28	18	Female	Undergraduate	Student	No
29	56	Female	post-graduate	database administrator	No
30	32	Female	1st degree	Administrator	No
31	27	Male	PHD	student	No
32	27	Female	Post-graduate	Administrative officer	No
33	25	Male	Degree	student nurse	No
34	27	Female	Degree	Data Manager	No
35	26	Female	Postgraduate (Masters)	WP Coordinator (outreach)	No
36	27	Male	A levels	PCD Laboratory Technician	No
37	38	Male	Degree	HR Manager	No

Appendix D

Participant	Age	Gender	Educational level	Occupation	Music training
38	28	Female	Undergraduate Degree	Executive Assistant FBLA	No
39	19	Male	Undergraduate	Student	No
40	29	Male	Masters	Administrator	No
41	31	Female	Degree	Assistant Research Manager	No
42	28	Female	Undergraduate	Student	No
43	37	Female	PhD	Researcher	No
44	59	Female	'A' Level	Residential Services Coordinator	No
45	65	Female	GCE	Customer Enquiries Assistant	No
46	27	Male	BSc	Accountant	No
47	55	Female	Higher Education	Assistant Research Manager	No
48	56	Male	MASTERS DEGREE	SENIOR EXPERIMENTAL OFFICER	No
49	29	Female	First degree	Manager	No
50	18	Male	A Levels	Part Time student	yes
51	27	Female	BA	Administrator	No
52	39	Female	Undergraduate degree	Library Assistant	No
53	31	Female	Msc	Assistant Librarian	No
54	30	Female	Degree	Administraitive officer	No
55	34	Male	A level	faculty rosource assistant	No
56	38	Female	Degree	Lab Manager	No
57	25	Female	PhD	Lecturer	yes
58	25	Male	Undergraduate MEng	Student	No
59	38	Female	first degree	research technician	No
60	28	Female	MA English Studies	Administrator	No
61	33	Male	Postgraduate diploma	Digital Marketing	No
62	48	Male	Phd	experimental officer	No
63	21	Male	BSc Physics	Student	yes.
64	29	Female	Degree	Clinical Trial Coordinator	No
65	34	Female	Bsc	trainee teacher	No
66	19	Female	Undergraduate	Student	yes
67	28	Female	Undergraduate	University administrator	No
68	57	Female	Sixth form	Helpdesk Advisor	No
69	22	Female	First Degree	Customer Services Advisor	No
70	18	Female	Undergraduate	Student	No
71	26	Female	Graduate	Client Service Advisor	No
72	45	Male	Masters	Teacher	yes
73	43	Female	MA	Marketier	yes
74	25	Male	Master's degree	Scientist	No
75	49	Female	Degree	Administrator	No
76	24	Female	Masters student	student	yes
77	47	Female	Level 4	Finance	No
78	49	Female	HND	Laboratory supervisor	No
79	22	Male	Matriculation / Foundation	Student	No

Participant	Age	Gender	Educational level	Occupation	Music training
80	32	Female	PGCE	Service Analysis and Improvement Officer	yes
81	23	Female	MSc	Research Fellow	No
82	28	Female	Degree	Administrative Officer	No
83	34	Female	BSc	Administrator	No
84	19	Male	2nd year uni	Medicine student	No
85	44	Female	A level	Research Manager	No
86	30	Female	Masters	Regional Director	No
87	30	Female	B.A.	Accountant	yes
88	54	Male	HNC	System manager	No
89	21	Female	Undergraduate	Student	No
90	42	Female	doctorate	academic staff	No
91	26	Female	MSc	Business Analyst	No
92	46	Male	BTEC	Design Techniciam	No
93	19	Male	First Year	Student	No
94	28	Male	Masters degree	Data analyst	No
95	33	Female	PGCE	Senior Administrative Officer	No
96	27	Male	Degree	Administrator	No
97	53	Female	PhD	Senior Research Advisor	No
98	18	Female	degree	Full time student	No
99	31	Male	MA	Strategic Planning Officer	No
100	40	Female	MA in Applied Linguistics	Secondary Professor	No
101	18	Female	A-levels	Student	No
102	41	Female	Masters	Personal Assistant	yes
103	26	Male	Bachelors Degree	Software Engineer	No
104	30	Female	MSc	Research institute coordinator	yes
105	57	Female	Postgraduate (MSc)	Database Officer	No
106	46	Female	BA (Hons)	Education Administration	No
107	27	Male	MPhil	PhD student	yes
108	24	Male	Degree	PhD Student	yes
109	41	Female	Degree	technician	No
110	38	Male	MSc	Tissue bank technician	No
111	36	Female	Masters	market research	No
112	28	Female	Undergraduate	Administrator	No
113	54	Female	post granduate	arts administrator	No
114	59	Female	ordinary degree level	Library Assistant	No
115	32	Female	postgraduate degree	Research manager	No
116	41	Female	MPhil	Technician	No
117	22	Female	Undergraduate Degree	Fundraiser	No
118	37	Female	MA	administrator	No
119	30	Female	PhD	University employee	No
120	24	Male	MSc	Student	No
121	63	Female	M.Sc	retired	No

Appendix D

Participant	Age	Gender	Educational level	Occupation	Music training
122	48	Female	MSc	Research assistamt	No
123	40	Female	PhD	lecturer	No
124	18	Male	3	Student	yes
125	33	Female	Degree	Admin manager	No
126	38	Female	A levels	Business Change Manager	No
127	34	Male	Degree	Transport Manager	No
128	36	Male	Postgraduate	student	yes
129	20	Female	Polish New-Matura exam	Student	yes
130	46	Female	1st year Bs Hons	student	No
131	21	Male	School/college	Student	No
132	61	Female	Professional accountancy qualification	Accountant	No
133	18	Male	undergraduate level.	Student	No
134	64	Female	degree	now retired, previously school teacher	No
135	58	Male	Masters degree	Librarian	No
136	80	Male	HNC	Retired Computer engineer	No
137	77	Male	B Sc. PhD	Retired	No
138	74	Male	GCE 'A' level	Semi-retired computer programmer	No
139	73	Female	Technical College	Retired	No
140	27	Female	BA HOnours Degree	Project Management in Financial Services	No
141	69	Male	A Level	Retired	No
142	69	Female	'O' level,	retired	No

Appendix D.2 Normality tests of the matched CI and NH groups

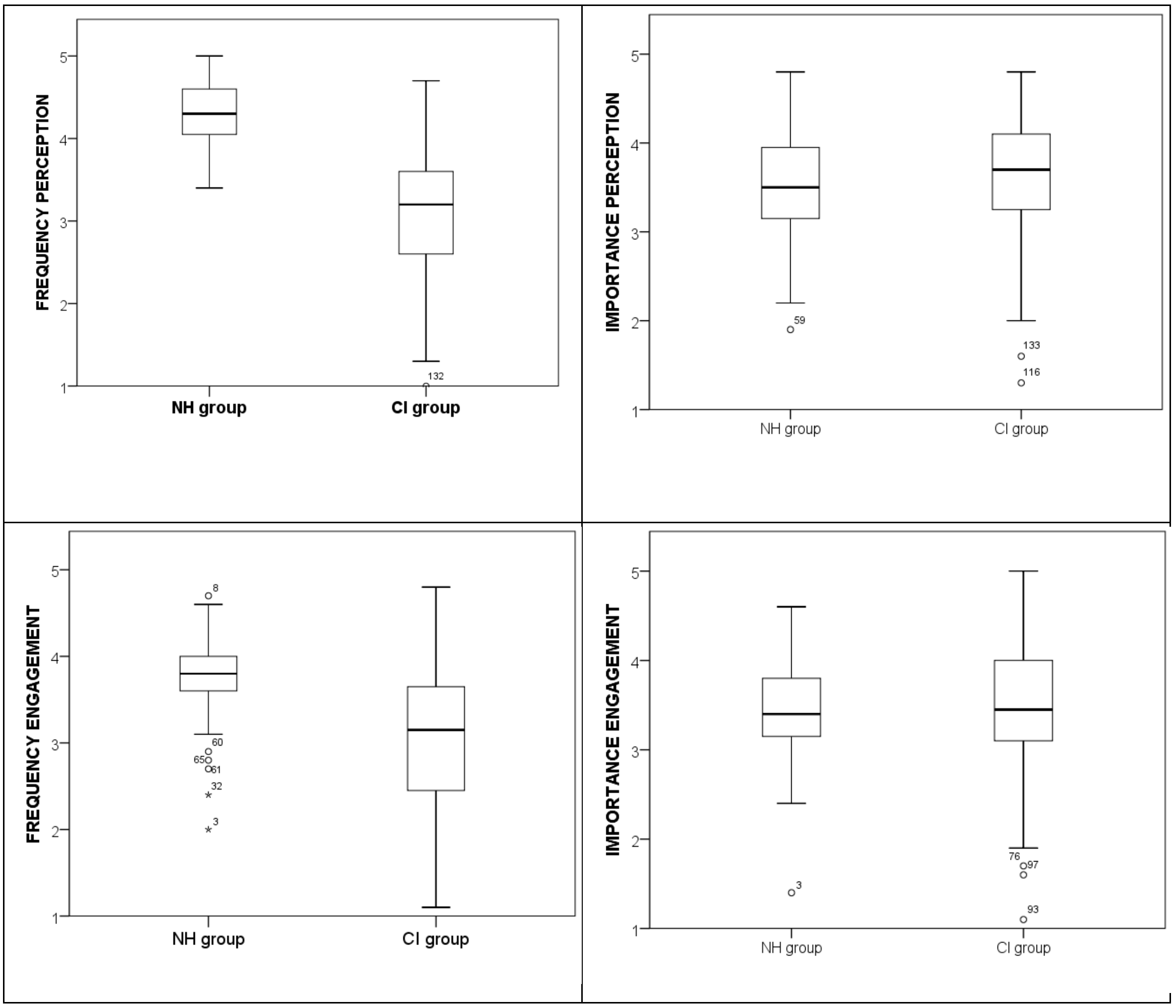
	CI group (N=68)	NH group (N=68)
Frequency overall	Skewness: -.206 Kurtosis: -.206 Kolmogorov-Smirnov: .020 Shapiro-Wilk: .355	Skewness: -.873 Kurtosis: 1.116 Kolmogorov-Smirnov: .000 Shapiro-Wilk: .006
Frequency perception	Skewness: -.111 Kurtosis: -.090 Kolmogorov-Smirnov: .200* Shapiro-Wilk: .308	Skewness: -.186 Kurtosis: -.695 Kolmogorov-Smirnov: .033 Shapiro-Wilk: .171
Frequency engagement	Skewness: -.292 Kurtosis: -.412	Skewness: -1.186 Kurtosis: 2.460

	Kolmogorov-Smirnov: .200* Shapiro-Wilk: .319	Kolmogorov-Smirnov: .000 Shapiro-Wilk: .000
Importance overall	Skewness: -.873 Kurtosis: 1.704 Kolmogorov-Smirnov: .062 Shapiro-Wilk: .008	Skewness: -.494 Kurtosis: .760 Kolmogorov-Smirnov: .014 Shapiro-Wilk: .095
Importance perception	Skewness: -.864 Kurtosis: 1.406 Kolmogorov-Smirnov: .035 Shapiro-Wilk: .006	Skewness: -.161 Kurtosis: .072 Kolmogorov-Smirnov: .200* Shapiro-Wilk: .830
Importance engagement	Skewness: -.636 Kurtosis: .746 Kolmogorov-Smirnov: .200* Shapiro-Wilk: .062	Skewness: -.767 Kurtosis: 1.581 Kolmogorov-Smirnov: .018 Shapiro-Wilk: .031

Appendix D.3 Boxplots for CI and NH group comparison

The boxes represent the interquartile range, i.e. the middle 50% of the observations, the whiskers are the top and bottom 25% of the scores, the horizontal bars are the medians and the circles show the outliers.

Appendix D


FREQUENCY PERCEPTION
NH group
CI group
132
IMPORTANCE PERCEPTION
NH group
CI group
59
133
116
FREQUENCY ENGAGEMENT
NH group
CI group
8
60
65
61
32
3
IMPORTANCE ENGAGEMENT
NH group
CI group
3
76
97
93
1
2
3
4
5

Bibliography

Adams, D., Ajimsha, K.M., Barberá, M.T., Gazibegovic, D., Gisbert, J., Gómez, J., Raveh, E., Rocca, C., Romanet, P., Seebens, Y. & Zarowski, A. (2014). Multicentre evaluation of music perception in adult users of Advanced Bionics cochlear implants. *Cochlear implants international*. 15 (1). p.pp. 20–6.

Amann, E. & Anderson, I. (2014). Development and validation of a questionnaire for hearing implant users to self-assess their auditory abilities in everyday communication situations: the Hearing Implant Sound Quality Index (HISQUI19). *Acta oto-laryngologica*. 134 (9). p.pp. 915–23.

Ambert-Dahan, E., Giraud, A.-L., Sterkers, O. & Samson, S. (2015). Judgment of musical emotions after cochlear implantation in adults with progressive deafness. *Frontiers in Psychology*. 6 (March). p.pp. 1–11.

Arnoldner, C., Lin, V.Y., Bresler, R., Kaider, A., Kuthubutheen, J., Shipp, D. & Chen, J.M. (2014). Quality of life in cochlear implantees: Comparing utility values obtained through the Medical Outcome Study Short-Form Survey-6D and the Health Utility Index Mark 3. *Laryngoscope*. 124 (11). p.pp. 2586–2590.

Arnoldner, C., Riss, D., Brunner, M., Durisin, M., Baumgartner, W.-D. & Hamzavi, J.-S. (2007). Speech and music perception with the new fine structure speech coding strategy: preliminary results. *Acta oto-laryngologica*. 127 (12). p.pp. 1298–303.

Arranz, P., Remor, E., Quintana, M., Villar, a, Díaz, J.L., Moreno, M., Monteagudo, J., Ugarriza, a, Soto, I., Pérez, R., Chacón, J., García-Luaces, M., Cid, a, Balda, I., López, M.F., Gutíerrez, M.J., Martínez, E., Marrero, C., Prieto, M., Sedano, C., Vaca, R., Altisent, C. & Hernández-Navarro, F. (2004). Development of a new disease-specific quality-of-life questionnaire to adults living with haemophilia. *Haemophilia : the official journal of the World Federation of Hemophilia*. 10. p.pp. 376–382.

Barry, J.G., Tomlin, D., Moore, D.R. & Dillon, H. (2015). Use of Questionnaire-Based Measures in the Assessment of Listening Difficulties in School-Aged Children. *Ear and Hearing*. p.pp. 1–14.

Bartel, L.R., Greenberg, S., Friesen, L.M., Ostroff, J., Bodmer, D., Shipp, D. & Chen, J.M. (2011). Qualitative case studies of five cochlear implant recipients' experience with music. *Cochlear implants international*. 12 (1). p.pp. 27–33.

Baumgartner, W.-D., Jappel, A., Morera, C., Gstöttner, W., Müller, J., Kiefer, J., Van De Heyning, P., Anderson, I. & Nielsen, S.B. (2007). Outcomes in adults implanted with the FLEXsoft electrode. *Acta oto-laryngologica*. 127 (6). p.pp. 579–86.

van Besouw, R.M., Grasmeder, M.L., Hamilton, M.E. & Baumann, S.E. (2011). Music activities and responses of young cochlear implant recipients. *International journal of audiology*. 50 (5). p.pp. 340–8.

van Besouw, R.M., Oliver, B.R., Grasmeder, M.L., Hodkinson, S.M. & Solheim, H. (2015). Evaluation of an interactive music awareness program for cochlear implant recipients. *Music Perception*. p.pp. 2255479–2255483.

Boltz, M., Schulkind, M. & Kantra, S. (1991). Effects of background music on the remembering of filmed events. *Memory & cognition*. 19 (6). p.pp. 593–606.

Bowling, A. (2001). Health-related quality of life: conceptual meaning, use and measurement. In: *Measuring disease. A review of disease-specific qualiy of life measurement scales*.

Bowling, A. (2014). *Research methods in health. Investigating health and health services.* 4th Ed. New York, NY: Open University Press.

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*. 3. p.pp. 77–101.

Brazier, J. & Deverill, M. (1999). A Checklist for Judging Preference-Based Measures of Health Related Quality of Life: Learning from Psychometrics. *Health Econ.* 8. p.pp. 41–51.

Brazier, J., Roberts, J. & Deverill, M. (2002). The estimation of a preference-based measure of health from the SF-36. *Journal of health economics*. 21 (2). p.pp. 271–92.

British Cochlear Implant Group (2012). *BCIG Annual Update on UK Cochlear Implant Provision (2011-2012)*.

Brockmeier, S.J., Fitzgerald, D., Searle, O., Fitzgerald, H., Grasmeder, M., Hilbig, S., Vermiere, K., Peterreins, M., Heydner, S. & Arnold, W. (2011). The MuSIC perception test: a novel battery for testing music perception of cochlear implant users. *Cochlear implants international*. 12 (1). p.pp. 10–20.

Brockmeier, S.J., Grasmeder, M., Passow, S., Mawmann, D., Vischer, M., Jappel, A., Baumgartner, W., Stark, T., Müller, J., Brill, S., Steffens, T., Strutz, J., Kiefer, J., Baumann, U. & Arnold, W. (2007). Comparison of musical activities of cochlear implant users with different speech-coding strategies. *Ear and hearing*. 28 (2 Suppl). p.p. 49S–51S.

Brockmeier, S.J., Nopp, P., Vischer, M., Baumgartner, W., Stark, T., Schon, F., Muller, J., Braunschweig, T., Busch, R., Getto, M., Arnold, W. & Allum, D.J. (2002). Correlation of speech and music perception in postlingually deaf Combi 40/40 users. In: *Cochlear Implants: An Update*. pp. 459–464.

Bryman, A. (2012). The nature of qualitative research. In: *Social research methods*. Oxford University Press.

Buechner, A., Brendel, M., Krüeger, B., Frohne-Büchner, C., Nogueira, W., Edler, B. & Lenarz, T. (2008). Current steering and results from novel speech coding strategies. *Otology & neurotology : official publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology*. 29 (2). p.pp. 203–7.

Buhagiar, R. (2012). *Development of a quality of life measure for adults with bilateral cochlear implants*. University of Southampton.

Buhagiar, R. & Lutman, M. (2011). Development of a quality-of-life measure for adult patients with sequential bilateral cochlear implants. *Cochlear implants international*. 12 Suppl 2. p.pp. S44-6.

Burack, O.R., Jefferson, P. and & Libow, L.S. (2002). Individualized Music Individualized Music : A Route to Improving the Quality of Life for Long-Term Care Residents. *The Hawthorn Press*. 27 (1). p.pp. 37–41.

Calvino, M., Gavilán, J., Sánchez-Cuadrado, I., Pérez-Mora, R.M., Muñoz, E., Díez-Sebastián, J. & Lassaletta, L. (2015). Using the HISQUI29 to assess the sound quality levels of Spanish adults with unilateral cochlear implants and no contralateral hearing. *European Archives of Oto-Rhino-Laryngology*.

Chan, M.F., Wong, Z.Y., Onishi, H. & Thayala, N.V. (2012). Effects of music on depression in older people: a randomised controlled trial. *Journal of clinical nursing*. 21 (5–6). p.pp. 776–83.

Chin, T. & Rickard, N.S. (2012). THE MUSIC USE (MUSE) QUESTIONNAIRE: AN INSTRUMENT TO MEASURE ENGAGEMENT IN MUSIC. *Music Perception*. 29 (4). p.pp. 429–446.

Clark, G. (2003). *Cochlear implants: fundamentals and applications*. Springer New York.

Coelho, D.H., Hammerschlag, P.E., Bat-chava, Y. & Kohan, D. (2009). *Psychometric validity of the Cochlear Implant Function Index (CIFI): a quality of life assessment tool for adult cochlear implant users*. 10 (January). p.pp. 70–83.

Coffman, D. (2002). Music and Quality of life in older adults. *Psychomusicoloogy*. 18. p.pp. 76–88.

Cohen, S.M., Labadie, R.F., Dietrich, M.S. and & Haynes, D.S. (2004). Quality of Life in Hearing-Impaired Adults: The Role of Cochlear Implants and Hearing Aids. *Otolaryngol Head Neck Surg*. 131 (4). p.pp. 413–422.

Cooke, M., Moyle, W., Shum, D., Harrison, S. & Murfield, J. (2010). A randomized controlled trial exploring the effect of music on quality of life and depression in older people with dementia. *Journal of health psychology*. 15 (5). p.pp. 765–76.

Cott, C. a, Teare, G., McGilton, K.S. & Lineker, S. (2006). Reliability and construct validity of the client-centred rehabilitation questionnaire. *Disability and rehabilitation*. 28 (22). p.pp. 1387–1397.

Cox, R.M. & Alexander, G.C. (1995). The Abbreviated Profile of Hearing Aid Benefit. *Ear and Hearing*. 16 (2). p.pp. 176–186.

Crew, J.D., Galvin III, J.J., Landsberger, D.M. & Fu, Q.-J. (2015). Contributions of Electric and Acoustic Hearing to Bimodal Speech and Music Perception. *Plos One*. [Online]. 10 (3). p.p. e0120279. Available from: http://dx.plos.org/10.1371/journal.pone.0120279.

Dalla Bella, S., Peretz, I., Rousseau, L., Gosselin, N., Ayotte, J. & Lavoie, A. (2001). Development of the happy-sad distinction in music appreciation. Does tempo emerge earlier than mode? *Annals of the New York Academy of Sciences*. 930. p.pp. 436–8.

Damen, G.W.J.A., Beynon, A.J., Krabbe, P.F.M., Mulder, J.J.S. & Mylanus, E.A.M. (2007). Cochlear implantation and quality of life in postlingually deaf adults : Long-term follow-up. *Otolaryngology–Head and Neck Surgery*. 136. p.pp. 597–604.

Damen, G.W.J. a, Pennings, R.J.E., Snik, A.F.M. & Mylanus, E. a M. (2006). Quality of life and cochlear implantation in Usher syndrome type I. *The Laryngoscope*. 116 (5). p.pp. 723–8.

Demers, L., Weiss-Lambrou, R. & Ska, B. (2000). Item analysis of the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST). *Assistive Technology*. 12 (2). p.pp. 96–105.

DeNora, T. (2000). *Music in Everyday Life*. Cambridge: Cambridge University Press.

Deyo, R.A., Diehr, P. & Patrick, D.L. (1991). Reproducibility and responsiveness of health status measures statistics and strategies for evaluation. *Controlled clinical trials*. 12 (4). p.pp. S142–S158.

Donaldson, G.S., Dawson, P.K. & Borden, L.Z. (2011). Within-subjects comparison of the HiRes and Fidelity120 speech processing strategies: Speech perception and its relation to place-pitch sensitivity. *Ear Hear*. 32 (2). p.pp. 238–250.

Drennan, W.R., Oleson, J.J., Gfeller, K., Crosson, J., Driscoll, V.D., Won, J.H., Anderson, E.S. &

Rubinstein, J.T. (2014). Clinical evaluation of music perception, appraisal and experience in cochlear implant users. *International journal of audiology*. (October 2013). p.pp. 1–10.

Drennan, W.R. & Rubinstein, J.T. (2008). Music perception in cochlear implant users and its relationship with psychophysical capabilities. *The Journal of Rehabilitation Research and Development*. 45 (5). p.pp. 779–790.

de Dreu, M.J., van der Wilk, a S.D., Poppe, E., Kwakkel, G. & van Wegen, E.E.H. (2012). Rehabilitation, exercise therapy and music in patients with Parkinson's disease: a meta-analysis of the effects of music-based movement therapy on walking ability, balance and quality of life. *Parkinsonism & related disorders*. 18 Suppl 1. p.pp. S114-9.

Driscoll, V.D., Oleson, J., Jiang, D. & Gfeller, K. (2009). Effects of Training on Recognition of Musical Instruments Presented through Cochlear Implant Simulations. *J Am Acad Audiol*. 20 (1). p.pp. 71–82.

Driscoll, V.D., Welhaven, A.E., Gfeller, K., Oleson, J. & Olszewski, C.P. (2016). Music Perception of Adolescents Using Electroacoustic Hearing. *Otology & Neurotology*. 37 (2). p.pp. e141–e147.

Edwards, S.L. (2014). *Pitch perception, production and musical development of hearing impaired children*. UCL (University College London).

Eisenberg, L.S. (1982). Use of the cochlear implant by the prelingually deaf. *Annals of Otology, Rhinology & Laryngology, Supplement*. 91 (92 Pt 3)). p.pp. 62–66.

Ekström, S.R. & Borg, E. (2011). Hearing speech in music. *Noise & Health*. 13 (53). p.pp. 277–285.

Erkkilä, J., Punkanen, M., Fachner, J., Ala-Ruona, E., Pöntiö, I., Tervaniemi, M., Vanhala, M. & Gold, C. (2011). Individual music therapy for depression: randomised controlled trial. *The British journal of psychiatry : the journal of mental science*. 199 (2). p.pp. 132–9.

Feeny, D. (2005). The Health Utilities Index: A tool for assessing health benefits. *PRO Newsletter*. 34. p.pp. 2–6.

Field, A. (2014). *Discovering statistics using IBM SPSS Statistics*. 4th Ed. Sage Publications.

Forsblom, A., Laitinen, S., Särkämö, T. & Tervaniemi, M. (2009). Therapeutic role of music listening in stroke rehabilitation. *Annals of the New York Academy of Sciences*. 1169. p.pp. 426–30.

Francis, H.W., Chee, N., Yeagle, J., Cheng, A. & Niparko, J.K. (2002). Impact of cochlear implants on the functional health status of older adults. *The Laryngoscope*. 112 (8 Pt 1). p.pp.

1482–8.

Frederigue-Lopes, N.B., Bevilacqua, M.C. & Costa, O.A. (2015). Munich Music Questionnaire: adaptation into Brazilian Portuguese and application in cochlear implant users. *CoDAS*. 27 (1). p.pp. 13–20.

Fuller, C., Mallinckrodt, L., Maat, B., Başkent, D. & Free, R. (2013). Music and quality of life in early-deafened late-implanted adult cochlear implant users. *Otology & neurotology*. 34 (6). p.pp. 1041–7.

Galloway, S., Bell, D., Hamilton, C. & Scullion, A.C. (2006). Quality of life and well-being: measuring the benefits of culture and sport: literature review and thinkpiece. *Scottish Government. Edinburgh, UK*.

Galvin, J.J., Fu, Q.-J. & Nogaki, G. (2007). Melodic contour identification by cochlear implant listeners. *Ear and hearing*. 28 (3). p.pp. 302–19.

Galvin III, J.J., Fu, Q.-J. & Oba, S.I. (2009). Effect of a competing instrument on melodic contour identification by cochlear implant users. *The Journal of the Acoustical Society of America*. 125 (3). p.p. EL98-103.

Gantz, B.J. & Turner, C.W. (2003). Combining acoustic and electrical hearing. *The Laryngoscope*. 113 (10). p.pp. 1726–30.

Gatehouse, S. (1999). Glasgow Hearing Aid Benefit Profile: derivation and validation of a client-centered outcome measure for hearing aid services. *J Am Acad Audiol*. 10. p.pp. 80–103.

Gatehouse, S. (1997). *Outcome measures for the evaluation of adult hearing aid fittings and services: scientific and technical report*. Glasgow, Scotland.

Gatehouse, S., Browning, G.G. & Robinson, K. (1998). *The Glasgow health status questionnaires manual*.

Gatehouse, S. & Noble, W. (2004). The Speech , Spatial and Qualities of Hearing Scale (SSQ). *International Journal of Audiology*. 43. p.pp. 85–99.

Gfeller, Kate & Lansing, Charissa, P. (1992). Musical Perception of Cochlear Implant Users as Measured by the Primary Measures of Music Audiation: An Item Analysis. *Journal of music therapy*. 29 (1). p.pp. 18–39.

Gfeller, K. (2009). Music and Cochlear Implants: Not in Perfect Harmony. *ASHA Lead.* p.pp. 2009–2011.

Gfeller, K., Buzzell, A., Driscoll, V., Kinnaird, B. & Oleson, J. (2009). The Impact of Voice Range and Instrumental Background Accompaniment on Recognition of Song Lyrics. In: *7th Asia Pacific Symposium on Cochlear Implants and Related Sciences*. 2009, pp. 35–40.

Gfeller, K., Christ, A., Knutson, J.F., Witt, S. & Mehr, M. (2003). The effects of familiarity and complexity on appraisal of complex songs by cochlear implant recipients and normal hearing adults. *Journal of music therapy*. 40 (2). p.pp. 78–112.

Gfeller, K., Christ, A., Knutson, J.F., Witt, S., Murray, K.T. & Tyler, R.S. (2000a). Musical Backgrounds, Listening Habits, and Aesthetic Enjoyment of Adult Cochlear Implant Recipients. *Journal of the American Academy of Audiology*. 11. p.pp. 390–406.

Gfeller, K., Driscoll, V., Smith, R.S. & Scheperle, C. (2012a). The music experiences and attitutes of a first cohort of prelingually-deaf adolescents and young adults CI recipients. *Seminars in Hearing*. 33 (4). p.pp. 346–360.

Gfeller, K., Jiang, D., Oleson, J., Driscoll, V. & Knutson, J.F. (2010). Temporal Stability of Music Perception and Appraisal Scores of Adult Cochlear Implant Recipients. *J Am Acad Audiol.* 21 (1). p.pp. 28–34.

Gfeller, K., Knutson, J.F., Woodworth, G., Witt, S. & DeBus, B. (1998a). Timbral Recognition and Appraisal by Adult Cochlear Implant Users and Normal-Hearing Adults. *Journal of the American Academy of Audiology*. 9. p.pp. 1–19.

Gfeller, K., Oleson, J., Driscoll, V., Olszewski, C., Knutson, J.F., Turner, C. & Gantz, B. (2012b). The Effects of Musical and Linguistic Components in Recognition of Real-World Musical Excerpts by Cochlear Implant Recipients and Normal-Hearing Adults. *Journal of music therapy*. 49 (1). p.pp. 68–101.

Gfeller, K., Oleson, J., Knutson, J.F., Breheny, P., Driscoll, V. & Olszewski, C. (2008). *Multivariate Predictors of Music Perception and Appraisal by Adult Cochlear Implant Users*. 19 (2). p.pp. 120–134.

Gfeller, K., Turner, C., Mehr, M., Woodworth, G., Fearn, R., Knutson, J.F., Witt, S. & Stordahl, J. (2002a). Recognition of familair melodies by adult cochlear implant recipients and normal-hearing adults. *Cochlear implants international*. 3 (1). p.pp. 29–53.

Gfeller, K., Turner, C., Oleson, J., Kliethermes, S. & Driscoll, V. (2012c). *Accuracy of Cochlear Implant Recipients on Speech Reception in Background Music*. 121 (12). p.pp. 782–791.

Gfeller, K., Turner, C., Oleson, J., Zhang, X., Gantz, B., Froman, R. & Olszewski, C. (2007). Accuracy of cochlear implant recipients on pitch perception, melody recognition, and speech reception in noise. *Ear and hearing*. 28 (3). p.pp. 412–23.

Gfeller, K., Witt, S.A., Spencer, L.J., Stordahl, J. & Tomblin, B. (1998b). Musical Involvement and Enjoyment of Children Who Use Cochlear Implants. *The Volta Review*. 100 (4). p.pp. 213–233.

Gfeller, K., Witt, S.A., Stordahl, J., Mehr, M. & Woodworth, G. (2000b). The Effects of Training on Melody Recognition and Appraisal by Adult Cochlear Implant Recipients. *Journal Academy of Rehabilitative Audiology*. 33. p.pp. 115–138.

Gfeller, K., Witt, S., Adamek, M., Mehr, M.A., Rogers, J., Stordahl, J. & Ringgenberg, S. (2002b). Effects of Training on Timbre Recognition and Appraisal by Postilingually Deafened Cochlear Implant Recipients. *J Am Acad Audiol*. 13. p.pp. 132–145.

Gfeller, K., Witt, S., Mehr, M.A., Woodworth, G. & Knutson, J.F. (2002c). Effects of Frequency, Instrumental Family, and Cochlear Implant Type on Timbre Recognition and Appraisal. *Annals of Otology and Laryngology*. 111 (4). p.pp. 349–356.

Gfeller, K., Woodworth, G., Robin, D.A.., Witt, S. & Knutson, J.F. (1997). Perception of Rhythmic and Sequential Pitch Patterns by Normally Hearing Adults and Adult Cochlear Implant Users. *Ear & Hearing*. 18 (3). p.pp. 252–260.

Gfeller, K.E., Olszewski, C., Turner, C., Gantz, B. & Oleson, J. (2006). Music perception with cochlear implants and residual hearing. *Audiology & neuro-otology*. 11 Suppl 1 (suppl 1). p.pp. 12–5.

Gifford, R.H., Dorman, M.F. & Brown, C.A. (2010). Psychophysical Properties of Low-Frequency Hearing: Implications for Perceiving Speech and Music via Electric and Acoustic Stimulation. *Adv Otorhinolaryngol.* 67. p.pp. 51–60.

Gifford, R.H., Dorman, M.F., Skarzynski, H., Lorens, A., Polak, M., Driscoll, C.L.W., Roland, P. & Buchman, C.A. (2013). Cochlear implantation with hearing preservation yields significant benefit for speech recognition in complex listening environments. *Ear & Hearing*. 34 (4). p.pp. 413–425.

Glaser, B. & Strauss, A.L. (1976). *The Discovery of Grounded Theory*. New York: Aldine Publications.

Gordon-Hickey, S. & Moore, R.E. (2007). Influence of Music and Music Preference on Acceptable Noise Levels in Listeners with Normal Hearing. *J Am Acad Audiol*. 427. p.pp. 417–427.

Grasmeder, M.L. & Lutman, M.E. (2006). The Identification of Musical Instruments through Nucelus Cochlear Implants. *Cochlear implants international*. 7 (3). p.pp. 148–158.

Grasmeder, M.L. & Verschuur, C.A. (2015). Perception of the pitch and naturalness of popular music by cochlear implant users. *Cochlear Implants International*. 16 (Ci). p.pp. 79–90.

Guetin, S., Portet, F., Picot, M.C., Pommie, C., Messaoudi, M., Djabelkir, L., Olsen, A.L., Cano, M.M., Lecourt, E. & Touchon, J. (2009). Effect of music therapy on anxiety and depression in patients with Alzheimer's type dementia: Randomised, controlled study. *Dementia and Geriatric Cognitive Disorders*. 28 (1). p.pp. 36–46.

Härkönen, K., Kivekäs, I., Rautiainen, M., Kotti, V., Sivonen, V. & Vasama, J.-P. (2015). Sequential bilateral cochlear implantation improves working performance, quality of life, and quality of hearing. *Acta oto-laryngologica*. 6489 (October 2014). p.pp. 1–7.

Harris, F., Fields, S., Frewin, B., Speech, S. & Therapists, L. (2013). Beyond BKB : Painting a fuller picture of CI benefit. In: *British Cochlear Implant Group Conference*. 2013, p. 4.

Harris, J.P., Anderson, J.P. & Novak, R. (1995). An Outcomes Study of Cochlear Implants in Deaf Patients Audiologic, Economic, and Quality-of-Life Changes. *Arch Otolaryngol Head Neck Surg*. 121 (4). p.pp. 398–404.

Hawthorne, G., Hogan, A., Giles, E., Stewart, M., Kethel, L., White, K., Plaith, B., Pedley, K. & Taylor, A. (2004). Evaluating the health-related quality of life effects of cochlear implants : a prospective study of an adult cochlear implant program. *International Journal of Audiology*. 43. p.pp. 183–192.

Hays, R. & Revicki, D. (2005). Reliability and validity (including responsiveness). In: *Assessing quality of life in clinical trials*. pp. 25–40.

Hays, T. & Minichiello, V. (2005). The contribution of music to quality of life in older people: an Australian qualitative study. *Ageing and Society*. 25 (2). p.pp. 261–278.

Henshaw, H. & Ferguson, M. a (2013). Efficacy of individual computer-based auditory training for people with hearing loss: a systematic review of the evidence. *PloS one*. 8 (5). p.p. e62836.

Herdman, M., Gudex, C., Lloyd, A., Janssen, M., Kind, P., Parkin, D., Bonsel, G. & Badia, X. (2011). Development and preliminary testing of the new five-level version of EQ-5D (EQ-5D-5L). *Quality of life research*. 20 (10). p.pp. 1727–36.

Heydebrand, G., Hale, S., Potts, L., Gotter, B. & Skinner, M. (2007). Cognitive predictors of improvements in adults' spoken word recognition six months after cochlear implant activation. *Audiology and Neurotology*. 12 (4). p.pp. 254–264.

Hilliard, R.E. (2003). The Effects of Music Therapy on the Quality and Length of Life of People Diagnosed with Terminal Cancer. *Journal of music therapy*. 2. p.pp. 113–137.

Hinderink, J.B., Krabbe, P.F. & Van Den Broek, P. (2000). Development and application of a health-related quality-of-life instrument for adults with cochlear implants: the Nijmegen cochlear implant questionnaire. *Otolaryngology-Head and Neck Surgery*. 123 (6). p.pp. 756–65.

Hirschfelder, A., Gräbel, S. & Olze, H. (2008). The impact of cochlear implantation on quality of life: The role of audiologic performance and variables. *Otolaryngology - Head and Neck Surgery*. 138 (3). p.pp. 357–362.

Hochmair, I., Nopp, P., Jolly, C., Schmidt, M., Schösser, H., Garnham, C. & Anderson, I. (2006). MED-EL Cochlear implants: state of the art and a glimpse into the future. *Trends in amplification*. 10 (4). p.pp. 201–19.

Hossain, S. & Assmann, P. (2012). *Music masking speech in hybrid cochlear implant simulations*. 14 (November). p.pp. 060005–060005.

Hyrkäs, K., Appelqvist-Schmidlechner, K. & Oksa, L. (2003). Validating an instrument for clinical supervision using an expert panel. *International Journal of Nursing Studies*. 40 (6). p.pp. 619–625.

Johnston, J.M., Leung, G.M., Fielding, R., Tin, K.Y.K. & Ho, L.-M. (2003). The development and validation of a knowledge, attitude and behaviour questionnaire to assess undergraduate evidence-based practice teaching and learning. *Medical education*. 37 (11). p.pp. 992–1000.

Kang, R., Nimmons, G.L., Drennan, W., Longnion, J., Ruffin, C., Nie, K., Won, J.H., Worman, T., Yueh, B. & Rubinstein, J. (2009). Development and validation of the University of Washington Clinical Assessment of Music Perception test. *Ear and hearing*. 30 (4). p.pp. 411–8.

Kaplan, D.M., Shipp, D.B., Chen, J.M., Ng, A.H.C. & Nedzelski, J.M. (2003). Early-deafened adult cochlear implant users: Assessment of outcomes. *Journal of Otolaryngology*. 32 (4). p.pp. 245–249.

Kim, I., Yang, E., Donnelly, P.J. & Limb, C.J. (2010). Preservation of rhythmic clocking in cochlear implant users: a study of isochronous versus anisochronous beat detection. *Trends in amplification*. 14 (3). p.pp. 164–9.

King, N. (2012). Doing Template Analysis. In: Symon & Casell (eds.). *Qualitative organisational reserch. Core methods and current challenges.*

King, N., Nahm, E.A., Liberatos, P., Shi, Q. & Kim, A.H. (2014). A new comprehensive cochlear implant questionnaire for measuring quality of life after sequential bilateral cochlear implantation. *Otology & neurotology : official publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and*

Neurotology. 35 (3). p.pp. 407–13.

Kitzinger, J. (2006). Focus groups. In: C. Pope & N. Mays (eds.). *Qualitative research in health care*. pp. 21–31.

Kobosko, J., Jedrzejczak, W.W., Pilka, E. & Pankowska, A. (2015). *Satisfaction With Cochlear Implants in Postlingually Deaf Adults and Its Nonaudiological Predictors : Psychological Distress , Coping Strategies , and Self-Esteem*.

Kong, Y.-Y. & Carlyon, R.P. (2007). Improved speech recognition in noise in simulated binaurally combined acoustic and electric stimulation. *The Journal of the Acoustical Society of America*. 121 (6). p.pp. 3717–27.

Kong, Y.-Y., Cruz, R., Jones, J.A. & Zeng, F.-G. (2004). Music Perception with Temporal Cues in Acoustic and Electric Hearing. *Ear and Hearing*. 25 (2). p.pp. 173–185.

Kong, Y.-Y., Stickney, G.S. & Zeng, F.-G. (2005). Speech and melody recognition in binaurally combined acoustic and electric hearing. *The Journal of the Acoustical Society of America*. 117 (3). p.p. 1351.

Krabbe, P.F., Hinderink, J.B. & van den Broek, P. (2000). The effect of cochlear implant use in postlingually deaf adults. *International journal of technology assessment in health care*. 16 (3). p.pp. 864–73.

Kraus, N. & Chandrasekaran, B. (2010). Music training for the development of auditory skills. *Nature reviews. Neuroscience*. 11 (8). p.pp. 599–605.

Krueger, R.A. & Casey, M.A. (2009). *Focus groups: A practical guide for applied research*. Sage.

Laiho, S. (2004). The Psychological Functions of Music in Adolescence. *Nordic Journal of Music Therapy*. 13 (1). p.pp. 47–63.

Landis, J.R. & Koch, G.G. (1977). The Measurement of Observer Agreement for Categorical Data. *Biometrics*. 33. p.pp. 159–174.

Lantz, M.E. & Cuddy, L.L. (2002). *Michael E. Lantz 1 and Lola L. Cuddy 2*. 30 (3). p.pp. 164–165.

Lassaletta, L., Castro, A., Bastarrica, M., Perez-Mora, R., Herrán, B., Sanz, L., De Sarriá, J.M. & Gavilán, J. (2008a). Changes in listening habits and quality of musical sound after cochlear implantation. *Otolaryngology - Head and Neck Surgery*. 138 (3). p.pp. 363–367.

Lassaletta, L., Castro, A., Bastarrica, M., Pérez-Mora, R., Herrán, B., Sanz, L., de Sarriá, M.J. & Gavilán, J. (2008b). Musical perception and enjoyment in post-lingual patients with cochlear implants. *Acta otorrinolaringológica española*. 59 (5). p.pp. 228–34.

Lassaletta, L., Castro, A., Bastarrica, M., Pérez-Mora, R., Madero, R., De Sarriá, J. & Gavilán, J. (2007). Does music perception have an impact on quality of life following cochlear implantation? *Acta Oto-Laryngologica*. 127 (7). p.pp. 682–6.

Lassaletta, L., Castro, A., Bastarrica, M., de Sarriá, M.J. & Gavilán, J. (2006). Quality of life in postlingually deaf patients following cochlear implantation. *European archives of oto-rhino-laryngology*. 263 (3). p.pp. 267–70.

Laukka, P. (2007). Uses of music and psychological well-being among the elderly. *Journal of Happiness Studies*. 8 (2). p.pp. 215–241.

Leal, M.C., Shin, Y.J., Laborde, M., Calmels, M., Verges, S., Lugardon, S., Andrieu, S., Deguine, O. & Fraysse, B. (2003). Music Perception in Adult Cochlear Implant Recipients. *Acta Oto-laryngologica*. 123 (7). p.pp. 826–835.

Lee, Y.Y., Chan, M.F. & Mok, E. (2010). Effectiveness of music intervention on the quality of life of older people. *Journal of advanced nursing*. 66 (12). p.pp. 2677–87.

Lewis, K. (2014). Pupils' and teachers' experiences of school-based physical education: a qualitative study. *BMJ Open*. 4 (9). p.pp. 1–7.

Li, X., Nie, K., Imennov, N.S., Rubinstein, J.T. & Atlas, L.E. (2013). Improved perception of music with a harmonic based algorithm for cochlear implants. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*. 21 (4). p.pp. 684–694.

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology*. 22 (140).

Limb, C.J. & Roy, A.T. (2013). Technological, biological, and acoustical constraints to music perception in cochlear implant users. *Hearing research*. p.pp. 1–14.

Loeffler, C., Aschendorff, A., Burger, T., Kroeger, S., Laszig, R. & Arndt, S. (2010). Quality of Life Measurements after Cochlear Implantation. *The Open Otorhinolaryngology Journal*. 4. p.pp. 47–54.

Loizou, P.C. (2006). Speech processing in vocoder-centric cochlear implants. *Advances in oto-rhino-laryngology*. 64. p.pp. 109–43.

Lonsdale, A.J. & North, A.C. (2011). Why do we listen to music? A uses and gratifications analysis. *British journal of psychology (London, England : 1953)*. 102 (1). p.pp. 108–134.

Looi, V., Gfeller, K. & Driscoll, V. (2012). Music appreciation and training for cochlear implant recipients: A review. *Seminars in Hearing*. 33 (4). p.pp. 307–334.

Looi, V., Lee, Z.Z. & Loo, J.H.Y. (2016). Hearing-related quality of life outcomes for Singaporean children using hearing aids or cochlear implants. *European Annals of Otorhinolaryngology, Head and Neck Diseases*. 133. p.pp. S25–S30.

Looi, V., McDermott, H., McKay, C. & Hickson, L. (2007). Comparisons of quality ratings for music by cochlear implant and hearing aid users. *Ear and hearing*. 28 (2 Suppl). p.p. 59S–61S.

Looi, V., McDermott, H., McKay, C. & Hickson, L. (2008a). Music perception of cochlear implant users compared with that of hearing aid users. *Ear and hearing*. 29 (3). p.pp. 421–34.

Looi, V., McDermott, H., McKay, C. & Hickson, L. (2004). Pitch discrimination and melody recognition by cochlear implant users. *International Congress Series*. 1273. p.pp. 197–200.

Looi, V., McDermott, H., McKay, C. & Hickson, L. (2008b). The effect of cochlear implantation on music perception by adults with usable pre-operative acoustic hearing. *International journal of audiology*. 47 (5). p.pp. 257–68.

Looi, V. & She, J. (2010). Music perception of cochlear implant users: a questionnaire, and its implications for a music training program. *International journal of audiology*. 49 (2). p.pp. 116–28.

Looi, V., Teo, E.-R. & Loo, J. (2015). Pitch and lexical tone perception of bilingual English-Mandarin-speaking cochlear implant recipients, hearing aid users, and normally hearing listeners. *Cochlear implants international*. 16 Suppl 3. p.pp. S91–S104.

Looi, V., Winter, P., Anderson, I. & Sucher, C. (2011). A music quality rating test battery for cochlear implant users to compare the FSP and HDCIS strategies for music appreciation. *International journal of audiology*. 50 (8). p.pp. 503–18.

Maarefvand, M., Marozeau, J. & Blamey, P.J. (2013). A cochlear implant user with exceptional musical hearing ability. *International journal of audiology*. 52 (6). p.pp. 424–32.

Maglione, A.G., Vecchiato, G., Leone, C.A., Grassia, R., Mosca, F., Colosimo, A., Malerba, P. & Babiloni, F. (2014). *Different Perception of Musical Stimuli in Patients with Monolateral and Bilateral Cochlear Implants*. 2014.

Maillet, C., Tyler, R. & Jordan, H. (1995). Change in the quality of life of adult cochlear implant patients. *Ann Otol Rhinol Laryngol Suppl.* 165. p.pp. 31–48.

Maruish, M.E. (2012). *User's manual for the SF-12v2 Health Survey*.

McColl, E. (2005). Developing questionnaires. In: P. Fayers & R. Hays (eds.). *Assessing quality of life in clinical trials*. pp. 9–23.

McDermott, H.J. (2004). Music Perception with Cochlear Implants: A Review. *Trends in amplification*. 8 (2). p.pp. 49–82.

McHorney, C. a & Tarlov, a R. (1995). Individual-patient monitoring in clinica practice: are available health status survey adequate? *Qual Life Res*. 4 (93). p.pp. 293–307.

Migirov, L., Kronenberg, J. & Henkin, Y. (2009). Self-reported listening habits and enjoyment of music among adult cochlear implant recipients. *The Annals of otology, rhinology, and laryngology*. 118 (5). p.pp. 350–5.

Mirza, S., Douglas, S., Lindsey, P., Hildreth, T. & Hawthorne, M. (2003). Appreciation of music in adult patients with cochlear implants: a patient questionnaire. *Cochlear implants international*. 4 (2). p.pp. 85–95.

Mo, B., Harris, S. & Lindbaek, M. (2004). Cochlear implants and health status: a comparison with other hearing-impaired patients. *The Annals of otology, rhinology, and laryngology*. 113 (11). p.pp. 914–21.

Mo, B., Lindbaek, M. & Harris, S. (2005). Cochlear implants and quality of life: a prospective study. *Ear and hearing*. 26 (2). p.pp. 186–94.

Moran, M., Rousset, A. & Looi, V. (2016). Music appreciation and music listening in prelingual and postlingually deaf adult cochlear implant recipients. *International Journal of Audiology*. 2027 (April). p.pp. 1–7.

Morris, A.E., Lutman, M.E. & Yardley, L. (2009). Measuring outcome from vestibular rehabilitation, part II: refinement and validation of a new self-report measure. *International journal of audiology*. 48 (1). p.pp. 24–37.

Müllensiefen, D., Gingras, B., Musil, J. & Stewart, L. (2014). The musicality of non-musicians: an index for assessing musical sophistication in the general population. *PloS one*. 9 (2). p.p. e89642.

Nabelek, A.K., Tucker, F.M. & Letowski, T.R. (1991). Toleration of background noises: Relationship with patterns of hearing aid use by elderly persons. *Journal of Speech and Hearing Research*. 3. p.pp. 679–685.

Di Nardo, W., Scorpecci, A., Giannantonio, S., Cianfrone, F. & Paludetti, G. (2011). Improving melody recognition in cochlear implant recipients through individualized frequency map fitting. *European Archives of Oto-Rhino-Laryngology*. 268 (1). p.pp. 27–39.

Nilsson, U. (2008). The anxiety- and pain-reducing effects of music interventions: a systematic review. *AORN Journal*. 87 (4). p.pp. 780–807.

Nimmons, G.L., Kang, R.S., Drennan, W.R., Longnion, J., Ruffin, C., Yueh, B. & Rubinstein, J.T. (2008). Clinical Assessment of Music Perception in Cochlear Implant Listeners. *Otol Neurotol.* 29 (2). p.pp. 149–155.

North, a C., Hargreaves, D.J. & O'Neill, S. a (2000). The importance of music to adolescents. *The British journal of educational psychology*. 70 (Pt 2). p.pp. 255–272.

Nunnally, J.C. & Bernstein, I.H. (1994). *Psychometric theory*. Third. McGraw-Hill.

Papadogianni-Kouranti, M. (2014). *Auditive and Audiotactile Music Perception of Cochlear Implant Users*. Technical University of Berlin.

Peterson, N. & Bergeson, T.R. (2015). Contribution of hearing aids to music perception by cochlear implant users. *Cochlear implants international*. 16 Suppl 3. p.pp. S71-8.

Philips, B., Vinck, B., De Vel, E., Maes, L., D'Haenens, W., Keppler, H. & Dhooge, I. (2012). Characteristics and determinants of music appreciation in adult CI users. *European archives of oto-rhino-laryngology*. 269 (3). p.pp. 813–21.

Plant, G. (2012). *Reintroducing Music to Adults with Cochlear Implants*. 1 (212). p.pp. 419–424.

Pope, C., Ziebland, S. & Mays, N. (2006). Analysing qualitative data. In: *Qualitative research in health care*.

QSR International Pty Ltd. (2012). *NVivo qualitative data analysis software (Version 10)*.

Rader, T., Fastl, H. & Baumann, U. (2013). Speech perception with combined electric-acoustic stimulation and bilateral cochlear implants in a multisource noise field. *Ear and hearing*. 34 (3). p.pp. 324–32.

Raphael, D., Brown, I., Renwick, R., Cava, M., Weir, N. & Heathcote, K. (1997). Measuring the quality of life of older persons: a model with implications for community and public health nursing. *International journal of nursing studies*. 34 (3). p.pp. 231–9.

Raphael, D., Rukholm, E., Brown, I., Hill-Bailey, P. & Donato, E. (1996). The Quality of Life Profile--Adolescent Version: background, description, and initial validation. *The Journal of adolescent health : official publication of the Society for Adolescent Medicine*. 19 (5). p.pp. 366–75.

Reeve, B.B. & Fayers, P. (2005). Applying item response theory modelling for evaluating questionnaire item and scale properties. In: *Assessing quality of life in clinical trials*. pp. 55–73.

Renwick, R., Nourhaghighi, N., Manns, P.J. & Rudman, D.L. (2003). Quality of life for people with physical disabilities: a new instrument. *International journal of rehabilitation research. Internationale Zeitschrift für Rehabilitationsforschung. Revue internationale de recherches de réadaptation*. 26 (4). p.pp. 279–87.

Revicki, D., Hays, R.D., Cella, D. & Sloan, J. (2008). Recommended methods for determining responsiveness and minimally important differences for patient-reported outcomes. *Journal of Clinical Epidemiology*. 61 (2). p.pp. 102–109.

Riss, D., Hamzavi, J., Blineder, M., Honeder, C., Ehrenreich, I., Kaider, A., Baumgartner, W., Gstoettner, W. & Arnoldner, C. (2014). *FS4 , FS4-p , and FSP : A 4-Month Crossover Study of 3 Fine Structure Sound-Coding Strategies*. p.pp. 272–281.

Rosslau, K., Spreckelmeyer, K.N., Saalfeld, H. & Westhofen, M. (2012). Emotional and analytic music perception in cochlear implant users after optimizing the speech processor. *Acta Oto-laryngologica*. 132 (1). p.pp. 64–71.

Roy, A.T., Carver, C., Jiradejvong, P. & Limb, C.J. (2015). *Musical Sound Quality in Cochlear Implant Users : A Comparison in Bass Frequency Perception Between Fine Structure Processing and High-Definition Continuous Interleaved Sampling Strategies*. p.pp. 1–9.

Russo, F. a & Pichora-Fuller, M.K. (2008). Tune in or tune out: age-related differences in listening to speech in music. *Ear and hearing*. 29 (5). p.pp. 746–60.

Ruud, E. (1997). Music and the Quality of Life. *Nordic Journal of Music Therapy*. 6 (2). p.pp. 86–97.

Salimpoor, V.N., Benovoy, M., Larcher, K., Dagher, A. & Zatorre, R.J. (2011). Anatomically distinct dopamine release during anticipation and experience of peak emotion to music. *Nature neuroscience*. 14 (2). p.pp. 257–62.

Sarkamo, T. & Soto, D. (2012). Music listening after stroke: Beneficial effects and potential neural mechanisms. *Annals of the New York Academy of Sciences*. 1252 (1). p.pp. 266–281.

Saxena, S., Carlson, D. & Billington, R. (2001). The WHO quality of life assessment instrument (WHOQOL-Bref): the importance of its items for cross-cultural research. *Quality of life research : an international journal of quality of life aspects of treatment, care and rehabilitation*. 10 (8). p.pp. 711–21.

Schäfer, T., Sedlmeier, P., Städtler, C. & Huron, D. (2013). The psychological functions of music listening. *Frontiers in psychology*. 4 (August). p.p. 511.

Schalock, R.L. (2004). The concept of quality of life: what we know and do not know. *Journal of intellectual disability research : JIDR*. 48 (Pt 3). p.pp. 203–16.

Schulz, E. & Kerber, M. (1994). Music Perception with the MED-EL implants. In: *Advances in Cochlear Implants*. pp. 326–332.

Skevington, S.M., O'Connell, K.A. & the WHOQOL Group (2004). Can we identify the poorest quality of life? Assessing the importance of quality of life using the WHOQOL-100. *Quality of life research : an international journal of quality of life aspects of treatment, care and rehabilitation*. 13 (1). p.pp. 23–34.

Sladen, D.P. & Zappler, A. (2015). Older and Younger Adult Cochlear Implant Users: Speech Recognition in Quiet and Noise, Quality of Life, and Music Perception. *American journal of audiology*. 24. p.pp. 31–39.

Smith, Z.M., Delgutte, B. & Oxenham, A.J. (2002). Chimaeric sounds reveal dichotomies in auditory perception. *Nature*. 416 (6876). p.pp. 87–90.

Streiner, D.L., Norman, G.R. & Cairney, J. (2015). *Health Measurement Scales. A practical guide to their development and use.* 5th Ed. Oxford University Press.

Sucher, C.M. & Mcdermott, H.J. (2009). *Bimodal stimulation : benefi ts for music perception and sound quality*. 10. p.pp. 96–99.

Sucher, C.M. & McDermott, H.J. (2007). Pitch ranking of complex tones by normally hearing subjects and cochlear implant users. *Hearing research*. 230 (1–2). p.pp. 80–7.

Sung, H.-C., Lee, W.-L., Chang, S.-M. & Smith, G.D. (2011). Exploring nursing staff's attitudes and use of music for older people with dementia in long-term care facilities. *Journal of clinical nursing*. 20 (11–12). p.pp. 1776–1783.

Swanepoel, D.W. & Hall, J.W. (2010). A systematic review of telehealth applications in audiology. *Telemedicine journal and e-health : the official journal of the American Telemedicine Association*. 16 (2). p.pp. 181–200.

Swanson, B.A. (2008). *Pitch Perception with Cochlear Implants*. PhD thesis. The University of Melbourne.

Teoh, S.W., Pisoni, D.B. & Miyamoto, R.T. (2004). Cochlear Implantation in Adults with Prelingual Deafness. Part I. Clinical Results. *Laryngoscope*. 114 (9). p.pp. 1536–1540.

Turner, C.W., Gantz, B.J., Vidal, C., Behrens, A. & Henry, B. a. (2004). Speech recognition in noise for cochlear implant listeners: Benefits of residual acoustic hearing. *The Journal of the Acoustical Society of America*. 115 (4). p.p. 1729.

Veekmans, K., Ressel, L., Mueller, J., Vischer, M. & Brockmeier, S.J. (2009). Comparison of music perception in bilateral and unilateral cochlear implant users and normal-hearing subjects. *Audiology & neuro-otology*. 14 (5). p.pp. 315–26.

Vickers, D., Dincer, H., Boyle, P., Olgun, L., Incesulu, A., Yucel, E., Onder, S. & Aygener, N. (2007). Development of Musical Behavior in Children with Cochlear Implants. *Advanced Bionics ® Auditory Research Bulletin*. p.pp. 146–148.

Wall, M. & Duffy, A. (2010). The effects of music therapy for older people with dementia. *British Journal of Nursing*. 19 (2). p.pp. 108–114.

von Wallenberg, E. & Briggs, R. (2014). Cochlear's unique electrode portfolio now and in the future. *Cochlear implants international*. 15 Suppl 1. p.pp. S59-61.

Ware, J.E. (2000). SF-36 health survey update. *Spine*. [Online]. 25 (24). p.pp. 3130–9. Available from: http://www.ncbi.nlm.nih.gov/pubmed/11124729.

Ware, J.E., Kosinski, M. & Keller, S.D. (1996). A 12-Item Short-Form Health Survey: Construction of Scales and Preliminary Tests of Reliability and Validity. *Medical Care*. 34 (3). p.pp. 220–233.

Warner-Czyz, a. D., Loy, B. a., Evans, C., Wetsel, A. & Tobey, E. a. (2015). Self-Esteem in Children and Adolescents With Hearing Loss. *Trends in Hearing*. 19 (0). p.pp. 1–12.

Weller, C.M. & Baker, F. a. (2011). The role of music therapy in physical rehabilitation: a systematic literature review. *Nordic Journal of Music Therapy*. 20 (1). p.pp. 43–61.

WHOQOL (1998). Development of the World Health Organization WHOQOL-BREF quality of life assessment. The WHOQOL Group. *Psychological medicine*. 28 (3). p.pp. 551–8.

WHOQOL (1993). Study protocol for the World Health Organization project to develop a Quality of Life assessment instrument (WHOQOL). *Quality of life research*. 2 (2). p.pp. 153–9.

Wilson, B.S. & Dorman, M.F. (2008a). Cochlear implants: a remarkable past and a brilliant future. *Hearing research*. 242. p.pp. 3–21.

Wilson, B.S. & Dorman, M.F. (2008b). Cochlear implants: Current designs and future possibilities. *The Journal of Rehabilitation Research and Development*. 45 (5). p.pp. 695–730.

Wilson, B.S. & Dorman, M.F. (2007). The surprising performance of present-day cochlear implants. *IEEE transactions on bio-medical engineering*. 54 (6 Pt 1). p.pp. 969–72.

Wood, N. & Smith, S.J. (2004). Instrumental routes to emotional geographies. *Social & Cultural Geography*. 5 (4). p.pp. 533–548.

Wright, R. & Uchanski, R.M. (2012). Music Perception and Appraisal: Cochlear Implant Users and Simulated CI Listening. *J Am Acad Audiol*. 23 (5). p.pp. 350–379.

Wyatt, R.J., Niparko, J.K., Rothman, M.L. & DeLissovoy, G. (1995). Cost Effectiveness of the Multichannel Cochlear Implant. *The American Journal of Otology*. 16 (1).

Yang, Y., Longworth, L. & Brazier, J. (2013). An assessment of validity and responsiveness of generic measures of health-related quality of life in hearing impairment. *Quality of life research*.

Yardley, L. (2000). Dilemmas in qualitative health research. *Psychology & Health*. 15 (2). p.pp. 215–228.

Zhao, F., Bai, Z. & Stephens, D. (2008). The relationship between changes in self-rated quality of life after cochlear implantation and changes in individual complaints. *Clinical otolaryngology*. 33 (5). p.pp. 427–34.

Zhao, F., Stephens, S.D., Sim, S.W. & Meredith, R. (1997). The use of qualitative questionnaires in patients having and being considered for cochlear implants. *Clinical otolaryngology*. 22 (3). p.pp. 254–9.