Remote MAPping for Children with Cochlear Implants

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School of Health and Rehabilitation Sciences
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No jointly-authored works.
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The Master of Philosophy candidate was primarily responsible for the concept and design of the study, gaining ethical approval, participant recruitment, data collection, analysis and interpretation, and manuscript preparation. However, significant contributions to the thesis as a whole have been made by the following people:

Professor Louise Hickson had substantial input into the concept and project design, the analysis and interpretation of data, revision and critical appraisal of written work and preparation of the manuscript.

Dr. Belinda Henry had input into the concept and design of the project, interpretation and revision and critical appraisal of written work.

Dr. Trevor Russell was primarily responsible for the concept and design of the telerehabilitation system and remote programming setup. He performed initial trials of the telerehabilitation system and remote programming equipment and provided technology support throughout. Dr Russell also had input into the concept and design of the project, interpretation and some revision of the written work.

Dr Gabriella Constantinescu provided input into data analysis and interpretation of data.
Statement of Parts of the Thesis Submitted to Qualify for the Award of Another Degree

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Published Works by the Author Incorporated into the Thesis

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Abstract

Cochlear implants (CIs) are now a widely accepted intervention option for the treatment of deafness in children. The CI is only the first step as the device requires regular programming (MAPping) to ensure the recipient is hearing optimally at all times. CI audiology is very specialized and as such is only usually available in larger cities or via “outreach” services which require a specialist audiologist to travel to different sites. Thus, children with CIs who do not live close to the major cities in Australia, face numerous access barriers to services for programming (MAPping) and assessment of their CIs.

Difficulties with travel and the associated cost, possible time away from work or school for parents and the child and the stress of travelling the large distances to healthcare facilities on a regular basis, raises many challenges for regional and remote families. In addition it is not always time- or cost-effective for the professionals providing the “outreach” services. The use of telehealth technology, specifically the Internet and remote programming software, has the potential to improve equity of access to services for this population and reduce the burden placed on families.

A small number of reports have demonstrated the feasibility of remote MAPping, however there is limited published research which shows the validity of this procedure for any population but, in particular, for children. The aim of this study was to investigate the validity of remote MAPping in children and to measure participant satisfaction with the procedure as operationalized using the custom features of the eHAB® telerehabilitation video conferencing (VC) system. Critical to the project was the determination of whether the ability to build rapport with the child and family, observe behavioural responses in the child and obtain appropriate feedback from the parent was significantly affected by performing the programming using the remote set up instead of the traditional face-to-face (FTF) scenario.

This study was designed to assess the validity of remote MAPping CIs via the Internet for different age groups. There were 45 participants aged from 5 yrs to 23 yrs who were grouped by age (Group 1 > 10 years and Group 2 5-10 years). The inclusion of the two age groups was designed to develop the procedure with the older children and young adults, and then apply it to the younger children. A computer-based eHAB® telerehabilitation system was used for
video and audio communication and Remote Desktop Software was configured to allow remote control of the CI programming software.

Validity was assessed in two ways, firstly by MAPping in both the traditional FTF and remote conditions in a single appointment session and comparing the electrode current level results on a pre-selected subset of electrodes for both Group 1 and Group 2 participants. The MAPping procedure alternated between the remote MAPping setup and the conventional FTF MAPping with an audiologist in both the FTF and remote conditions. Overall results showed that there were no significant differences in electrode threshold and comfort level settings obtained in the two conditions for the different age groups or test conditions ($p > .05$). Participants were also reviewed individually, and whilst three participants had MAP settings that fell outside one of the clinical criterion used for this study, this did not translate to a functional difference and the differences were not specifically related to results obtained in the remote test condition.

Secondly, validity was assessed for both Group 1 and Group 2 by comparing the programs (MAPs) created in the FTF and remote settings using speech perception tests to ascertain if there was any significant difference between the function of the MAPs created in the two conditions. Group analysis of the speech perception data also showed no significant difference between the results obtained in each condition.

A further small implementation trial was conducted with 5 participants (Group 3) to investigate how remote MAPping would be applied in the real world clinical situation. The participants were MAPped using the remote MAPping set up with a therapist on-site with the CI recipient rather than an audiologist. For this group, MAPping levels were only obtained by the remote audiologist and there was no FTF comparison. All recorded responses were reliable and repeatable, the participants were happy with the sound of the MAP created during the sessions and the programming time was essentially the same as it would have been with the conventional FTF approach.

A satisfaction questionnaire was also administered to the participants, parents and professionals involved in the study and results were generally positive and indicated a high level of satisfaction with the remote MAPping procedure and the eHAB® telerehabilitation VC system. Although there were occasional challenges with the audio and video quality in the on-line environment these did not impact on the ability to perform the test procedure.
Overall, the findings presented in this thesis provide evidence for the validity of remote MAPping in children older than 5 years and indicate high levels of satisfaction with this approach. The thesis includes recommendations which may assist clinicians in creating a framework for the delivery of these services. Further research is needed to add to the findings of this project and should include children younger than 5 years.
Key Words

cochlear implants, remote mapping, telehealth, audiology, children
Australian and New Zealand Standard

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List of Abbreviations

ASHA = American Speech and Language Association
ACE = Advanced Combined Encoder
BKB = Bench-Kowal-Bamford sentence test
CI = cochlear implant
C-level = Comfort Level
CL = current level
CNC = Consonant-Nucleus-Consonant
DR = dynamic range
FTF = face to face
KHz = Kilohertz
MJW = Manchester Junior Words
MAD = mean absolute difference
MP = monopolar
OAEs = oto-acoustic emissions
RF = radio frequency
SNHL = sensori-neural hearing loss
SNR = signal to noise ratio
TM = tympanic membrane
T-level = threshold level
VC = video conferencing
VRA = visual response audiometry
CHAPTER ONE

1.1 Introduction

Cochlear implants (CIs) are now a widely accepted intervention option in the treatment of deafness in children. More than 2400 children have received CIs in Australia and this technology has had a significant positive impact on outcomes for children with severe to profound hearing loss.

Children who receive CIs need to meet very strict eligibility criteria and the pre-implant assessment process ascertains that an eligible child should receive more benefit from a CI than from conventional hearing aids. However, the surgical procedure of undergoing cochlear implantation is only the first step of a process which requires a lifelong commitment; the CI needs regular ongoing programming (MAPping) by an audiologist for the rest of the CI recipient’s life in order to ensure the recipient is hearing optimally at all times. Children also require intensive habilitation for the first 3-5 years post CI in order to learn to use the sound information provided by the implant and they will continue to get support at varying levels (depending on need) throughout their school enrollment.

Audiologists who work in the area of CIs have undergone specialist training in this area in order to appropriately assess candidacy, to perform intra-operative assessment of the CI and to program/MAP the device postoperatively. This means that CI audiology is a very specialized field and, as such, it is usually only available in larger cities around Australia or via “outreach” services which require a specialist audiologist to travel to different sites. These geographic barriers create many challenges for children and their families who live in rural and remote locations, as travel to services can impact significantly on education, family and work life and in addition may be a financial strain. (Constantinesu, 2010; Darkins & Cary, 2000; Sevean, Dampier, Spadoni, Strickland & Pilatzke, 2009). Alternately, the provision of services via an outreach visit may not be time or cost efficient for the hospital or clinic providing the service (Krumm, Ribera & Schmiedge, 2005). A telehealth service delivery model may allow a more productive use of health care specialist’s time as the reduction in travel time may allow more patients to be seen (Loane & Wootton, 2001). The cost effectiveness of the telehealth approach
is an important element to successful implementation; however in depth analysis of this issue is beyond the scope of this current thesis and thus not reviewed in this chapter.

Whilst patient/client care in the area of health-related services has traditionally involved direct person-to-person interaction, not every specialty can be represented in every community (Craig, 1999; Fried, 2001). This fact leads to inequity issues related to the delivery of healthcare services in regional and remote areas (Constantinescu, 2010). Given the size and population spread of people in Australia, the potential that this technology has to improve access to health services, for people living in rural and remote locations is very high. The continent of Australia is approximately 7.7 million square kilometres in size and a population of 22.8 million people (Australian Bureau of Statistics, 2012) with approximately 32% living in regional and remote areas (Australian Bureau of Statistics, 2008). In Queensland (Australia’s second largest state) where this research was based the majority of specialist services are located in the south eastern corner and some people have to travel up to 2500km to see specialists (Smith, Scuffham & Wootton, 2007).

In general, there is a lack of hearing healthcare professionals around the world and this dilemma means that people with hearing loss cannot always easily access the services they need (Fagan and Jacobs, 2001; Swanepoel et al., 2010). This is even more so for CI recipients due to the additional specialization of professional skills required. Information and communication technology has been used in the provision of many health-related services (telehealth) to help address the health care needs of specific populations (Givens & Elangovan, 2003). Telehealth procedures have the potential to improve access to health services, increase the efficiency of these services and distribute specialty care more evenly across all communities and help to address some of the current inequity issues (Banjoko, Banjoko & Omoleke, 2008; Bashshur, Mandil, & Shannon, 2002; Constantinescu, 2010; Craig, 1999; Loane & Wootton, 2000; Scalfani, Heheghan, Ginsburg, Sabini, Stern & Dolitsky, 1999).

Audiologists are already using some forms of telehealth practice on a regular basis (e.g., telephone, email, video-conferencing). The internet and the ability to use software that remotely controls existing diagnostic and rehabilitative systems has led to many new opportunities for clinical practice (Givens & Elangovan, 2003; Krumm, Huffman, Dick & Klich, 2008; Krumm et al., 2005). In general, research which validates and describes audiological services provided via the internet is limited and this is especially with regards to
distance services for infants and young children (Krumm et al., 2005; Swanepoel et al., 2010). The ability to remotely program CIs (remote MAPping) using this type of technology has been shown to be possible in a small number of anecdotal reports or small pilot projects (Franck, Pengelly & Zerfoss, 2006; Polovoy, 2008; Ricks, 2008). However, there is limited published research which validates remote CI programming via the internet.

Remote MAPping for CIs needs further development and validation, both in terms of evaluating the accuracy of the test procedures as well as determining child, parent and professional satisfaction with this practice. The overall aim of this study, therefore, was to develop and validate the use of telehealth practices to remotely MAP CIs via the internet in children.

1.2 Hearing Loss and Cochlear Implants in Children

This section describes the auditory system, hearing loss and its prevalence in paediatric populations, as well as CI device function and programming and CIs in children.

1.2.1 Hearing Loss

Hearing can be defined as the transduction of sound (mechanical energy) into neural impulses and the interpretation of those impulses by the central nervous system (Rappaport & Provencal, 2002). Our hearing sense allows us to listen, understand speech, communicate and interpret sounds in the environment. It is also essential for the development of spoken language. The auditory or hearing system can be divided into two portions, the peripheral portion and central portion (Rappaport & Provencal, 2002). The peripheral auditory system is made up of a number of different areas which include the outer ear, middle ear, inner ear or cochlea and the auditory nerve (as shown in Figure 1). These areas work together to transmit sound waves from the environment through the air-filled spaces of the outer and middle ear to the fluid-filled spaces of the inner ear. The mechanical energy of this wave is converted into electrical impulses in the cochlea which are transmitted by the auditory nerve to the brain for the perception of sound (Clark & Ohlemiller, 2008). The central portion of the hearing system includes all the auditory structures beyond the auditory nerve (Rappaport & Provencal, 2002).
In the normal hearing system, sound waves enter the outer ear and travel along the external auditory canal (ear canal) until they reach the tympanic membrane (ear drum) causing it to vibrate. The tympanic membrane (TM) vibrations are transmitted through the middle ear by three small bones called ossicles. These three bones are named the malleus, incus and stapes and transmit the TM vibrations to the oval window (one of two membrane-covered openings in the cochlea; the other is the round window). The footplate of the stapes bone is embedded in the oval window (Kramer, 2008) and it is at this point that the sound wave energy enters the inner ear.
The inner ear is a complex structure that houses the sensory organs for balance (the vestibular system) and the cochlea, which contains the sensory organs for hearing (Bess & Humes, 2003). As shown in Figure 1.1, the cochlea is a snail shaped bony cavity which contains a series of fluid filled canals or scala.

As shown in the Figure 1.2 cross section of the cochlea, there are two bony canals (the scala vestibuli and the scala tympani) and a third membranous canal which lies between the two bony canals called the scala media (Kramer, 2008). The scala media contains the sensory organ for hearing called the organ of Corti. This organ lies on one side of the scala media’s membranous surface called the basilar membrane. The organ of Corti houses sensory receptor cells called hair cells, which are of two types, outer and inner hair cells. The tops of the outer and inner hair cells are bundles of hairs called stereocilia and above these is another membrane, the tectorial membrane, in which the stereocilia of the outer hair cells are embedded (Kramer, 2008).

The outer and inner hair cells are responsible for converting the mechanical waves into electrical activity that is transmitted to the auditory centre in the brain and interpreted as sound (Clark & Ohlemiller, 2008). This occurs as a result of the mechanical sound wave energy entering the cochlea at the level of the oval window. As this compression wave travels through the system, the basilar membrane is displaced and the hair cells are moved back and forth. This shearing motion causes tiny channels in the hair bundle or stereocilia of the IHC to open, resulting in an influx of ions (primarily calcium and potassium) that signal the IHC to release a chemical substance (neurotransmitter) to stimulate the nerve. These electrical potentials are then transmitted along the hearing nerve to the auditory cortex in the brain. The role of the OHCs is less well defined, however it is thought that the OHC makes mechanical changes to its cell shape, increasing the motion of the basilar membrane at the frequency of stimulation, adding to the deflection of hair bundles on the IHC and thus amplifying the signal.

It is important to note that the sensory cells of the cochlea are tonotopically arranged. This means that the hair cells in the organ of Corti are tuned to certain sound frequencies, responding to higher frequencies at the basal end or base of the cochlea (near the oval window) and to lower frequencies at the apical end of the cochlea. This is related to the physical characteristics of the basilar membrane which is narrower (and thus stiffer) at the base of the cochlea and widens towards the apex (Kramer, 2008). The tonotopic arrangement found in the cochlea is preserved in
the auditory nerve and continues throughout the hearing system to the level of the auditory cortex in the brain (Rappaport & Provencal, 2002).

Hearing losses are either congenital or acquired. A congenital hearing loss is defined as present at birth (Alexiades & Hoffman, 2008) and an acquired hearing loss is one that occurs at some point after birth. Hearing loss can be defined in many ways and can result from a defect at one or many different areas in the hearing system. Hearing loss caused by a defect in the peripheral hearing system can be defined as conductive, sensori-neural or mixed. Hearing loss is further defined by the site within the hearing system which is damaged, malformed or blocked. A hearing loss that is caused by blockage or damage in the outer and/or middle ear is called a conductive hearing loss. Whilst some conductive hearing losses are permanent many can be resolved with medical intervention.

A hearing loss which is caused by damage to, or malfunction of, the cochlea (sensory part) or the hearing nerve (neural part) of the hearing system is called a sensori-neural hearing loss (SNHL). SNHL hearing loss is permanent and the level of hearing loss can vary from what is described as mild, moderate, severe or profound. The cause of congenital SNHL may be hereditary or due to some other environmental factor such as maternal infection (e.g., rubella, cytomegalovirus), prematurity, hypoxia, other birth traumas or significant jaundice. A mixed hearing loss means that the cause of hearing loss is due to a combination of conductive and sensori-neural factors.

Studies of the prevalence of significant permanent congenital hearing impairment show that the rate varies greatly from 1-6 per 1000 births (Finitzo, Albright & O’Neal 1998; Mehl & Thompson, 1998; Vohr, et al., 2001). It is the most common disability in neonates when compared to other conditions which are regularly screened (Mehl & Thomson, 1998). Without good access to a full range of sounds from birth, hearing loss will have profound effects on speech, language and cognitive development and also emotional and social well being (Cole & Flexer, 2007; Erenberg, Lemons, Sia, Trunkel & Ziring 1999). As this project relates to CIs and this technology is only one treatment option for people with severe to profound SNHL, this paper will discuss intervention options for people with SNHL.

The intervention strategy employed for many persons with a permanent SNHL is usually with the application of conventional hearing aid amplification in both children and adults. Although the physical characteristics (size and shape) of hearing aids may differ, the internal features are essentially the same. Hearing aids convert sound into an electrical signal which is then
manipulated or processed and amplified, and converted back into an acoustic signal which is
delivered via the ear canal of the hearing aid wearer (Bess & Humes, 2003). Conventional hearing
aids give the greatest benefit to those persons with hearing losses in the mild-severe range.
Unfortunately, conventional hearing aid technology is of minimal benefit to the majority of people
with a severe to profound hearing loss (Hornsby & Ricketts, 2005; Turner, 2006), probably due to
the loss of functioning receptor/ hair cells in the cochlea (Turner, Reiss & Gantz, 2008). The
cochlear implant is an option for people with severe to profound hearing loss because the cochlear
implant directly stimulates the auditory nerve, bypassing the need for functioning hair cells
(Turner, 2006). If the cause of hearing loss is due to the auditory nerve itself, then intervention
using either hearing aids or cochlear implants may not be an option.

1.2.2 Cochlear Implant Device Function

A cochlear implant is a biomedical electronic device which provides access to auditory input for
children and adults with severe to profound SNHL. As illustrated in Figure 3, the device is
surgically implanted into the scala tympani of the cochlea via the round window and acts to
convert sound into electrical currents which directly stimulate the remaining the auditory neural
elements in the cochlea (Balkany et al., 2002). The aim of this stimulation is to produce hearing
sensations in people with severe to profound permanent hearing loss who cannot get sufficient
access to sound with conventional hearing aids (ASHA, 2004; Beiter & Brimacombe, 1999).

Figure 1.3 Cochlear implant insertion into the scala tympani via the round window

Produced courtesy of Cochlear Ltd © 2011

CI technology has been characterised by a fast evolution since the first development of clinical
devices in the early 1980s (Balkany et al., 2002). The first devices were designed using a single
channel which meant that sound was distributed to the hearing nerve as a whole, rather than to specific regions of the cochlea (Alexiades, De Le Ascuncion, Hoffman et al., 2008). Whilst the single channel devices provided sound awareness and cues that helped with lip reading they have now been replaced by multichannel devices (Rubinstein, 2004). The multichannel CI systems were first used in children in 1990 in the USA. All contemporary devices are multichannel which means that the electrode array is separated into different bands or channels, rather than a single electrode. The multichannel arrays are inserted into the cochlea so that different hearing nerve fibres can be stimulated at different regions of the cochlea and thus take advantage of the tonotopic arrangement of the cochlea (Dowell, 2005; Rance & Dowell, 1997; Rouiha, Djedou & Bouchaala, 2008). The incoming speech signal is filtered to a number of frequency bands which correspond to an electrode in the array (ASHA, 2004). Different electrodes are stimulated depending on the frequency components of the signal. Electrodes near the base of the cochlea are stimulated with high frequency signals, while electrodes near the apex are stimulated with low frequency signals (Rouiha et al., 2008). Higher levels of speech perception are achieved by exploiting this “place-pitch” or tonotopic arrangement (Rubenstein, 2004). These implant systems use place coding to transfer spectral information in the speech signal. They also encode timing and intensity cues (ASHA, 2004). Advances in technology have led to a continuous improvement in cochlear implant performance and outcomes for recipients. A cochlear implant does not provide normal hearing, “but rather a representation of sound”, which, through intensive listening and language therapy can be interpreted as speech (Alexiades, De Le Ascuncion, Hoffman et al., 2008). While there is a range in outcomes of cochlear implantation, many CI recipients are able to function at levels comparable to successful, less hearing impaired hearing aid users (Balkany et al., 2001). Many recipients can discriminate and recognize spoken language by hearing alone (without lip-reading) and some can use the telephone and enjoy music (Anderson, Baumgarter, Boheim, Nahler, Arnolder & D’Haese, 2006).

The CI is made up of an internal (surgically implanted) component and an external speech processor and transmitting coil. There are three CIs commercially available worldwide (Cochlear Nucleus, Med-El, and Advanced Bionics). While the devices differ in the exact structure and function, all work on the same basic principles and have some features in common: a microphone that picks up the sound, a signal processor that converts acoustic vibrations (i.e., sound) into electrical signals, a transmission system that transmits the electrical signals to the implanted electrodes and an electrode array electrically stimulates the hearing nerve (Alexiades, De Le Ascuncion, Hoffman, et al., 2008; Rouiha et al., 2008; Rubinstein, 2004). The Cochlear Ltd Nucleus device is used almost exclusively in Australia, and therefore all participants in this study were
recipients of this device (either the Nucleus 22, Nucleus24, Freedom or the Nucleus 5). Therefore, Figure 4 and the description of components below depict the internal and external components of a Cochlear Nucleus device. Whilst participants in this research have different device models (depending on what year they were implanted) the description of components is very similar except that the earlier model (Nucleus 22) does not have the 2 external electrodes only the internal array of 22 electrodes.

**Figure 1.4 Internal and External Components of the Nucleus ® Cochlear Implant**

The external components Cochlear Nucleus devices are made up of a speech processor (which is powered by batteries), and a transmitting coil which contains a magnet. Microphones on the speech processor pick up sounds from the environment and transmit the signal to the speech processor which is typically worn as an ear level device that looks similar to a conventional hearing aid. The speech processor implements speech coding strategies (described in more detail below) to process and analyze the sound information it receives via a processing chip. It then sends the resulting digital code with electrical stimulation parameters to the internal cochlear implant via the transmitting coil (Nucleus Technical Reference Manual, 2000). The transmitting coil sits on the outside of the head behind the ear and uses a radio frequency (RF) signal to transmit information from the speech processor to the internal implant. The implant is powered via the RF signal from the coil. The transmitting coil contains the magnet which couples with the internal magnet.

The internal components of the Cochlear Nucleus device comprise an intra-cochlear electrode array, two external electrodes (extra-cochlear), a receiver/stimulator and a coupling magnet. The intra-cochlear electrode array consists of 22 platinum electrodes. The most basal electrode (closest
to the round window) is electrode 1 and the most apical electrode is electrode 22. All 22 electrodes are connected independently to a receiver/stimulator by insulated platinum-iridium wires.

The receiver/stimulator includes an integrated circuit that decodes the digital information sent across the skin by the speech processor and then activates selected electrodes and also contains a platinum plate (called MP2) which is an extra-cochlear electrode (see below). The receiver-stimulator is placed by the surgeon in a space created on the mastoid bone behind the ear. The receiver stimulator contains the antenna that receives the RF signal from the external coil and it consists of two turns of platinum wire and is connected to the receiver/stimulator and secured by flexible silicone moulding. A coupling magnet is located in the middle of the silicone moulding which houses the antenna and it attracts the external magnet in the external transmitting coil (Nucleus Technical Reference Manual, 2000). The coupling of the magnets allows the signal transmission from the external components to the internal components.

The two extra-cochlear electrodes are components of the newer Nucleus cochlear implant devices. One electrode (MP1) is a small platinum ball which is placed by the surgeon under the temporalis muscle behind the ear and the second is the plate electrode (MP2) which is integrated into the receiver/stimulator. These extra-cochlear electrodes are used as the indifferent or reference electrodes when stimulating using a particular mode called monopolar. Electrical stimulation produces current flow between an active (stimulated) and indifferent (reference) electrodes which together form a channel. The stimulation mode defines the location of the indifferent electrode relative to the active electrode (Nucleus Technical Reference Manual, 2000). The cochlear implant audiologist can choose the stimulation mode, however most CI recipients are programmed using default parameters as recommended by the cochlear implant manufacturer.

As noted above, the speech processor implements speech coding strategies to process and analyze the sound information. The Cochlear Nucleus device has a number of speech processing strategies and different speech processing strategies are selected in order to obtain optimum patient performance (Rouhi, et al., 2008). In this project the participants used either the SPEAK or ACE processing strategies.

Currently the most commonly used strategy is the Advanced Combination Encoder (ACE), and recipients with older devices commonly use the SPEAK strategy. In the SPEAK strategy the energy of the incoming sound signal is analysed by a bank of filters. The analysis (using a speech
processing algorithm) ascertains the bands with the greatest energy (spectral maxima) and these are selected and presented to the corresponding electrodes at a stimulation rate of approximately 250Hz. This means that the outputs of the filters with the largest amplitudes, and the channels which are selected for stimulation vary depending on the spectral makeup of the incoming sound signal (Plant, Whitford, Psarros & Vandali, 2002).

ACE is also a filterbank strategy and uses digital processing to bandpass filter the signal into different frequency bands. As with the SPEAK strategy, each time the speech processor analyses the incoming signal, the speech processing algorithm selects the filters with the highest levels or greatest energy(maxima) and up to 20, but typically 12, maxima can be selected. The electrodes designated to these filters are then stimulated. Stimulation occurs at a rate which is selected for each individual and is typically set to a moderate rate of 900 Hz for most children but can range from 250Hz to 2400Hz. Thus whilst the SPEAK and ACE strategies have some similarities, the major difference between the two strategies is that ACE uses higher stimulation rates than SPEAK (where the stimulation rate is 250Hz per channel) (Plant, et al., 2002; Psarros, et al., 2002) and more maxima can be selected in ACE. The higher stimulation rates of ACE provide more temporal information (i.e. timing and intensity cues) than the slower rate SPEAK strategy.

In summary, the CI microphone picks up sounds from the environment, the speech processor selects and arranges sounds picked up by the microphone and the signals are then transmitted from the speech processor to the internal receiver/stimulator via the RF transmitting coil. The receiver/stimulator then converts these signals into electrical impulses and these impulses are sent to the electrode array which stimulates the auditory nerve.

1.2.3 Cochlear Implant MAPping

The increased auditory access provided by CIs has resulted in improved listening and oral communication outcomes in recipients (Waltzman, Cohen, Green & Roland, 2002). One of the key factors to a successful outcome with a CI is having an optimized program (MAP). Once the CI is switched on, the recipient has to attend for regular programming (MAPping) appointments throughout their lifetime.

MAPping is the name given to the programming of CIs. It is a process by which the electrical current level and other parameters, such as the speech processing strategy, electrodes to be
stimulated etc., are manipulated via a software program and set appropriately. These parameters and levels are unique for each person and need to be fine-tuned on a regular basis to ensure that they are optimal (Alexiades & Hoffman, 2008). MAPping is usually done in a FTF situation and involves setting the electrical stimulation limits necessary for the CI user to perceive a range of sounds from soft to comfortably loud.

The equipment needed for MAPping includes a computer, which has the CI programming software loaded (can be desk top or lap top) and a programming interface which connects to both the speech processor and to the computer. When the speech processor is connected to the interface the cochlear implant recipient does not hear sounds via the microphone, only stimuli presented via the computer. Thus, MAPping can be performed in a normal room or office as it does not need to be sound treated. When adults and older children (> 10 yrs) attend for MAPping the process includes one audiologist and the cochlear recipient. When infants and younger children are being MAPped the process includes an audiologist, MAPping assistant (which may be another audiologist), the child and usually a parent.

MAPping involves manipulating the current level via the computer and setting levels according to feedback provided by the recipient. The T-level corresponds to the softest sound the recipient can hear. The C-level is the level that is loud but comfortable to listen to for a long period of time. With the Cochlear Nucleus device, the amount of electrical stimulation available is between 0 and 255 current levels (CLs). During the MAPping process, the T and C levels of each individual electrode on the CI’s internal electrode array are adjusted in order that the CI recipient can hear a wide range of sounds at different levels.

The difference between the T and C levels is called the electrical dynamic range (DR) and this will be individual for each CI user (Clark, 2003). The incoming DR of the acoustic signal is MAPped to the electrical dynamic range of the recipient so that the range of speech sounds can be heard. It is therefore crucial that the MAPping is accurately performed for each individual so that speech will be perceived optimally. The levels achieved are then downloaded into the CI recipient’s speech processor and incorporated into a speech processing strategy. The processor will not generate electrical currents above these levels.

Adults and older children with cochlear implants can tell the programming audiologist when they perceive a sound or when the sound is too loud (i.e., above C-level). However, measurement in younger children is different. The audiologist sets the T-levels using information obtained by
using the same techniques used for hearing testing of this demographic, that is, either behavioural or subjective test techniques.

For children 6 months to around 2.5 years the behavioural method of choice is usually Visual Reinforcement Audiometry (VRA). Play Audiology would generally be used for children aged around 2.5 to 5 years but is sometimes utilized for slightly older children to make the testing procedure more interesting. VRA involves training the infant or child to make a conditioned head turn to a test stimulus. The sound stimulus is used to cue the child to seek visual reinforcement such as a toy/puppet in a lighted box or a short video clip (Madell, 2008). In between the sound stimulus the testing assistant (or distracter) keeps the child attentive and facing forward using toys or objects. In addition to the conditioned head turn, the testing audiologist and assistant are observing for other behavioural responses (such as facial cues) which may indicate that the child has heard the sound presented.

Once children reach a cognitive age of around 2.5 years they can perform hearing tests by voluntarily cooperating. Around this age a child can be trained to perform play tasks, such as dropping a toy in a bucket or placing a ring on a stick, when they hear a sound (Madell, 2008). The same techniques can be utilized for cochlear implant MAPping. As children get a little older they often require slightly more imaginative games to keep them on task but the theory is still the same in that the child responds using the toy/game when they hear a sound. The testing audiologist needs to be able to clearly see the child’s response to the sound stimulus and as with VRA it is important to be able to observe other behavioural responses. As such, the testing audiologist needs good visualization of the child’s face. Both the tester and assistant need to be involved in decisions relating to the validity of the child’s response (Rance & Dowell, 1997).

The setting of C-levels can sometimes be a difficult task in children. In adults these are set subjectively by the CI recipient to suit their preference. As such they are not ‘psychophysically definable” in the same way that T-levels are (Rance & Dowell, 1997). Young children often cannot make these subjective judgments and the most practical way of obtaining this information is through behavioural observation. This again highlights the importance of being able to clearly observe the child’s facial expressions and in view of this the visual quality of the video-conferencing system used for this project is very important.

Regular MAPping sessions are required for children with cochlear implants. When the device is “switched on” for the first time the DR is initially set quite conservatively as discomfort may
frighten the child and possibly lead to device rejection. Thus the MAP needs to be increased gradually and this is done over a number of sessions. There can also be some post-surgical changes that occur due to the healing mechanisms within the cochlea such as a fibrous sheath growing around the internal electrode array. This sheath can affect the current flow and as such result in changes in both the T and C levels (Rance & Dowell, 1997).

After the initial period of adjustment the MAP usually stabilizes which means that the recipient is obtaining consistent sound input which is essential for listening, speech and language development. The recipient’s MAP still needs to be monitored on a regular basis as MAP fluctuations sometimes occur. If these fluctuations are significant they will affect the quality of the sound input the recipient is receiving. Parents of children who receive CIs agree to attend the multiple appointments required to ensure that their child is hearing optimally all waking hours. The MAP levels need to be checked regularly throughout the recipient’s whole life but slightly more often throughout childhood as middle ear infections, growth and other hormonal changes can sometimes affect the child’s MAPping levels. This is a significant commitment and many families have to travel significant distances to attend these appointments.

1.2.4 Cochlear Implantation in Children

The use of multichannel CIs in hearing impaired children is now well established as a safe and effective means for improving listening and understanding when conventional amplification provides limited benefit (Dowell, Dettman, Blamey, Barker & Clark 2002; Dowell & Cowan, 1997). The definition of limited benefit for children has changed significantly in recent times. Earlier criteria for cochlear implantation in children were generally restricted to children with total hearing loss who derived essentially no benefit from conventional hearing aids. However, as CI technology and documented outcomes have improved, the audiological candidacy boundaries have been widened and resulted in a decrease in the minimum age of implantation in children (Balkany et al., 2002; Fitzpatrick, McCrae & Schramm, 2006).

Children proceed to cochlear implantation after an intensive assessment process. The degree of hearing loss or auditory functioning that determines cochlear implant candidacy varies across clinical programs (Fitzpatrick et al., 2006), and assessment protocols will vary depending on the age of the child. Obtaining accurate audiological information is the core of making appropriate recommendations for cochlear implant candidacy (Nussbaum, 2003). Obtaining a precise
indication of a child's hearing level requires a comprehensive audiological test battery completed by an experienced paediatric audiologist. Most programs use a multi or trans-disciplinary team approach, and the team will differ between individual clinics/programs but usually comprises ENTs, audiologists, speech pathologists, psychologists, social workers and the family.

Part of the assessment process involves the fitting and a trial of conventional hearing aids in order to assess the benefit that the child receives from conventional hearing aids before making recommendations regarding cochlear implantation. If the recommendation is that the child is a medical and audiological candidate, it is then a parental decision as to whether to proceed. Typical criteria are a severe to profound SNHL, limited or no benefit from conventional hearing aids, delayed speech and language, appropriate post implant expectations and parents and family who are dedicated to achieving the best outcome for their child.

After cochlear implantation, recipients need post implant re/habilitation involving regular therapy sessions or lessons which include the child, parents/carers and a listening and spoken language specialist. These lessons occur very regularly initially (weekly or fortnightly) in order to make best use of the CI. Whilst the frequency of these therapy lessons will generally reduce after the first 2 years post implant, the child and family will need to continue attending therapy lessons until the child enters grade one at school, at which time the child will receive support from the education system. Recipients also need to have regular programming (MAPping) sessions in order to ensure their hearing is optimized using the device. A typical CI program requires children to present weekly, monthly and then every 3 months for MAPping sessions in the first 2 years post cochlear implantation and then approximately every 6 months for the rest of the child’s life. This requires an enormous commitment and results in significant travel for those families who do not live in a town or city with local CI services.

Whilst appropriate audiological management and amplification (using current hearing technology) are essential for positive communication outcomes for children with hearing loss (Arehart & Yoshinaga-Itano, 1999; Dornan, 2009), clinical decisions regarding cochlear implantation in children are complicated by the fact that a wide range of performance outcomes have been documented after implantation (Fitzpatrick et al., 2006; O'Donoghue, Nikolopoulos & Archbold, 2000).

There are many factors which impact on the outcomes a child recipient will have with a CI. These have been well documented (Dettman, Pinder, Briggs, Dowell & Leigh, 2007; Dowell, Dettman,
Blamey, Barker, & Clark, 2002; Geers, 2002; Geers, Brenner, Nicholas et al., 2002; Martineau, Lamarche, Marcoux, & Bernard, 2001; Waltzman et al., 2002) and include the age the child’s hearing loss is diagnosed and the age at which amplification is fitted (both hearing aids and cochlear implants) and thus the duration of deafness, the communication mode they have chosen, the type of educational services available, the motivation of both the child recipient and the family, parental and professional expectations, the consistency of device usage appointment attendance, the signal processing strategy and the function of the implant and processor, as optimized listening all waking hours is essential. The presence of other developmental delays is also a factor which may have an effect on outcomes, particularly for those delays involving cognitive deficits (Pyman, Blamey, Lacy, Clark & Dowell, 2000).

The ability to obtain a reliable and optimized MAP will have a direct impact on the degree of auditory access that a child will obtain with a CI. It would follow that as speech and language development is reliant on the ability to be able to access soft sounds across the speech spectrum then obtaining the right MAPping levels as soon as possible post implantation is also a key factor. Mertes and Chinnici (2006) note that infants and children have very special needs and that in order to address these, they require an experienced paediatric clinician. As many children cannot provide accurate feedback to the audiologists who is MAPping their device the experienced clinician needs to take many things into account and these include: Obtaining updated progress information from the child’s parents, teachers and therapist; conducting audiometric tests; observing the child during programming; utilising objective measurements which will provide a guide to appropriate MAPping levels but should not be used in isolation; if age appropriate, the clinician will train the child to participate in programming (using conditioned response or play audiometry, or loudness growth tasks).

Many of the decisions made during CI programming appointments come from the clinician’s knowledge and experience, as well as the child’s behavioural responses (Mertes & Chinnici, 2006). Thus, successful CI MAPping in children is reliant on many factors and the impact that the remote MAPping approach may have on these requires further investigation. The following section provides an overview of telehealth practice and applications in audiology.

1.3 Telehealth Practice and Applications in Audiology

1.3.1 Synopsis
This section contains a review of the literature in the area of telehealth. It provides an overview of telehealth practice and then examines the literature about its use in the field of audiology and, in particular, for remote MAPping.

1.3.2 An Overview of Telehealth Practice

Telehealth is an umbrella term that includes any medically-related activity involving an element of distance and is defined as “the use of information and communication technology to transfer information and/or data in the support of health care” (Givens & Elangovan, 2003). The aim is to deliver health related services to remote locations (Krumm et al., 2005; McCarty & Clancy, 2002). There are many different terms used to describe distance services using communication technology in the related literature. These include telehealth, telepractice or telemedicine (Givens & Elangovan, 2003; Krumm, 2007). Telemedicine relates more to the delivery of remote medical care or curative medicine and this terminology was first introduced in the 1970s whereas telehealth (introduced in the 1990s) describes distance healthcare services which may not necessarily be for persons who are unwell and may encompass preventative health care practices as well as professional education (Constantinescu, 2010; Craig & Patterson, 2006; Pritam, 2011). However, they all refer to the application of this technology to deliver health related services at a distance by linking the health care provider and the patient or linking health professionals when they are located in different places (Loane & Wootton, 2001; Pritam, 2011; Swanepoel et al., 2010).

Services that involve assessment and/or consultation between the health care provider and the patient are described in the literature as either “real-time” (synchronous) or “store-and-forward” (asynchronous) consultations (Craig & Patterson, 2006; Krumm et al, 2005; Loane & Wootton, 2001). The former allow real time interaction between the patient and the health care provider using a variety of technologies such as telephone, video-conferencing, webcam, etc. The latter involves data being collected and stored at a referring site and this information is then forwarded to a consultant for review. Both types of approach have been used successfully in many health related areas such as otolaryngology by using video-otoscopy together with audiogram and tympanometry results (Eikelboom & Atlas, 2004; Eikelboom, Mbao, Coates, Atlas & Gallop, (2005); Scalfani, et al., 1997; Syms & Syms, 2001).
Recently, the internet has become a powerful and more popular medical information resource and offers a “new platform for telehealth” (Elangovan, 2005). Advances in technology, especially in the last decade, have greatly influenced the healthcare industry and provide a bridge between patients and health care providers (Ribera, 2005; Swanepoel et al., 2010). The internet is already being used in a variety of medical/health related applications such as social work, monitoring vital signs, speech pathology, radiology and psychiatry (Bashshur et al., 2002; Bratton, 2001; McCarty & Clancy, 2002; Hill et al., 2006; Whitten & Mair, 2000). In addition, this technology is being utilized to provide a variety of audiology services (see Section 1.3.3 below) and there is much potential for new applications. The purchase cost of equipment may be an issue for many clinical services, however, as the technology advances, the capital costs are becoming less and, as such, should be less of a barrier (Denton, 2005).

In order to achieve the best possible outcome with telehealth real time services, the technology needs to be able to allow the participants to communicate and relate in a way that is similar to a face-to-face (FTF) consultation (Denton, 2005). This is particularly important when working with children and especially when outcomes rely on behavioural responses from the child, as is the case in audiology practice. However, whilst evaluation of the technological aspects (e.g., picture, sound quality etc.) of this type of service provision is essential to achieve high quality outcomes, evaluation of participant satisfaction is also important and the feedback from the participants’ perspective is necessary for continuous improvement of the service (Aoki, Dunn, Johnson-Throop & Turley, 2003). The level of professional and patient satisfaction with telehealth services may also have an impact on the willingness to adopt this approach to clinical practice (Constantinescu, 2010; Craig, Russell, Patterson & Wootton, 1999).

There are several reports of a high acceptance rate and patient satisfaction with telemedicine consultations and a positive attitude toward video-teleconferencing (Eedy & Wootton, 2001; Huston & Burton, 1997; Mair & Whitton, 2000; Marcin, Ellis, Mawis, Nagrampa, Nesbitt & Dimand, 2004). However, a systematic review of studies relating to patient satisfaction with telemedicine by Mair and Whitten (2000) found that, whilst many published papers report that satisfaction is generally positive, many of them fail to provide explanations of the reason for patient satisfaction or dissatisfaction with telemedicine services. They noted that studies generally used surveys, but that results were confounded by methodological difficulties such as small sample sizes, poor return/response rates, lack of formal selection criteria and no information about refusal rate. It has also been noted that very few studies conducted interviews to assess the reason for satisfaction or dissatisfaction (Aoki et al., 2003).
According to Aoki, et al. (2003) qualitative methods may provide more insight into the needs and outcomes of telehealth services, however, in a review of articles that looked at outcomes and methods in telemedicine, they only identified one article using qualitative analysis. This article by Siden (1998) used a qualitative approach to assess community and provider needs in a telehealth project, using a focus group method. Whilst both positive and negative attitudes were reported from this group, “uncertainty” and “trust” were the themes that were highlighted as issues of concern by all participants. Uncertainty related to concerns regarding some aspects of the technology and trust related to “trust of the professionals and the technology”. This again highlights the need of participants to feel the same level of comfort that they would in a FTF situation and to have confidence in the technology.

It is important for professionals to be aware of the potential impact of the technology on the client appointment/consultation. Telehealth systems that are user friendly and promote interactions which are similar to FTF sessions would improve satisfaction as would providing a good explanation regarding the technology prior to the session. It has further been suggested that if professionals delivering the service are able to display an empathetic and warm manner and maintain good eye contact throughout the session, then patient confidence with the service is likely to increase (Constantinescu, 2010; Hill et al., 2006; Hughes, 2001; Miller, 2001; Waite, Cahill, Theodoros, Busuttin & Russell, 2006; Zarate, et al., 1997).

Marcin et al. (2004) assessed the medical needs and satisfaction with a telemedicine program which provided subspecialty care to children with special health care needs in rural underserviced communities. This data was obtained using a survey and, overall, the study reported that satisfaction was very high for both parent/guardians and local providers. It should be noted that the population surveyed had no local access to subspecialist medical services pre- telemedicine, because of their remote location, and 86% of them had to drive more than an hour for appointments. Limitations of the research therefore are that the participants could not compare the telemedicine service delivery to a local FTF service and their positive views were no doubt influenced by concerns over travel time and costs associated with attending a FTF service at a distant location. Whitten and Mair (2000) further state that while some studies suggest high satisfaction, given the choice, patients and providers tend to prefer FTF consultations. However if the choice was between waiting several days or weeks for a FTF consultation and a faster telehealth consultation, then the patient would likely opt for the latter option. Whilst a remote service is unlikely to be equal to FTF provision, telehealth programs need to put systems in place
which will ensure that the quality and outcomes of the remote service are comparable to a FTF consultation. Overall, more pragmatic information which will help in the delivery and development of telehealth services is needed (Whitten & Mair, 2000).

1.3.3 Telehealth and Audiology

As discussed in section 1.3.2, telehealth applications are now used by health professionals to provide a number of health related services. Technology is becoming increasingly available to health professionals serving rural and remote areas but these applications are not yet widely used by audiologists (Krumm et al., 2005), particularly the computer based synchronous (real time) communications. Givens (2004) notes that the American Speech-Language-Hearing Association (ASHA) surveyed audiologists in 2002 and found that only 12% of audiologists were using some form of telehealth practice at that time. Whilst computer based synchronous telehealth communications have significant technology considerations (e.g., bandwidth and the information transmission medium), it is this type of application that may enable a FTF environment which was encouraged in an ASHA position statement (2005) and is the likely means of achieving the best possible outcome for participants (Denton, 2005).

The potential for audiology telehealth applications to offer a solution for service gaps in rural and remote areas is great and there are publications which show the ability to offer sophisticated audiological assessments with reliable outcomes. Remote control software applications enable the clinician to control computers which are located at remote sites. Givens and Elangovan (2003) used such a system to investigate real time diagnostic audiology via the internet and the teleaudiology network demonstrated the first trans-Atlantic hearing test in April of 2009 (Beck, 2009). Elangovan (2005) looked at the real time assessment of oto-acoustic emissions (OAEs). In the diagnostic audiometry project, each participant was tested in a double-blind study of two different systems for assessing auditory pure tone thresholds. One was the conventional on site (local) system and the other the remotely controlled system. Participants had no knowledge of which system was being used in the assessment procedure and both systems were operated by independent audiologists. The audiologists were blind to the results of previous testing for any participant. In the assessment of OAEs, recordings were again under two conditions for each individual ear (i.e., with the conventional system and the tele-OAE system). Both tests were performed by audiologists and the order of testing was counter balanced among test ears (Elangovan, 2005). The results showed good reliability for both systems in that the audiometric
results obtained in local and remote conditions were not statistically different (Elangovan, 2005). The authors did highlight that trained audiologists performed the role of the facilitator at the test site. Thus, while these studies show the feasibility of using this method, validation using trained on-site facilitators who are not audiologists needs further evaluation.

Towers et al. (2005) also examined the reliability of auditory brainstem response testing via the internet by comparing results obtained locally in the conventional manner with those from a remote site. Statistical analysis of the data obtained in the trials showed a strong correlation between data collected at both sites which again showed the potential for this technology to obtain accurate results at a distance. In addition, Wesendahl (2003) has described the potential application of telemedicine in the area of hearing aid fittings: initial fitting, set up, fine tuning and follow-up fitting.

It has been noted in the literature that there is little published research relating to children receiving audiology services via telehealth communications (Krumm et al., 2005). Audiology assessment of children involves a battery of tests that give both subjective and objective information. The research cited above suggests good reliability for automatic test procedures, however, practitioners may have concerns about the quality of care and/or reliability of performing assessments which rely on behavioural responses from the child, due to the fact that facial cues and other behavioural responses may be hard to read in a remote scenario (i.e., on a computer screen).

Audiology telehealth practice can be informed here by studies in the area of psychiatry and social work (Bashshur et al., 2002; Bear, Jacobson, Aaronson & Hanson, 1997; Elford, White, Bowering, et al., 2000; Elford, White, St John, Maddigan, & Ghandi, 2001; McCarty & Clancy, 2002; Ruskin, etal., 2004). Bashshur et al. (2002) reported that telepsychiatry is one of the most commonly used applications involving real time consultations with a high degree of “concordance in diagnostic reliability between telepsychiatric and in-person consults”. Ruskin et al. (2004) conducted a large scale randomized controlled trials and found no significant differences between telepsychiatry and FTF consultations. In addition, Elford et al. (2000) assessed satisfaction amongst 18 children and 23 parents, with a tele-psychiatry program. They reported that overall, children involved in the study were positive about the videoconferencing (VC) system which was used and an equal proportion favoured VC and FTF assessment. The majority of parents reported that their preference would be to use telepsychiatric services as an alternative to traveling to access care and that they were generally happy with their ability to speak with and understand the
child psychiatrist in the session. These findings are significant because psychiatrists need to observe emotional and behavioural responses similar to what would be required for audiological behavioural assessment. Bashshur et al. (2002) also noted that high quality images (requiring higher bandwidth) are essential for these positive outcomes.

1.3.4 Remote MAPping of Cochlear Implants

Telehealth is a broad term and this research project focused on the provision of a specific audiology service, CI programming (MAPping). In view of this, the term ‘remote MAPping’ was used as it more accurately describes the service that was evaluated in this project.

It has been noted in the previous section that audiology telepractice is not yet commonly used. Krumm et al. (2005) has suggested that the low usage of this type of service may be attributed to the fact that very few articles have been published. This lack of published evidence may impede the growth of audiology telepractice and stresses the need for further investigation (Norby, 2008; Polovoy, 2008).

The literature search for publications related to remote MAPping revealed very little published evidence and highlights the need for research in this area. The search found four demonstration and one small pilot (5 adults) projects only. The demonstration projects show that remote MAPping is possible but did not investigate differences between MAPs obtained remotely and those obtained in a FTF condition. The small pilot project did look at comparisons of electrode levels in both conditions but the methodology was different to what has been applied in this project, an issue that is discussed further in this section.

First, the Children’s Hospital of Philadelphia has succeeded in setting up a pilot program which uses videoconferencing and remote access software to do MAPping via host sites (Franck et al., 2006). At the time the article describing the project was published, 10 clients had been MAPped using this procedure. Franck reported that validation studies were performed by initially separating the near and far sites by just a few yards, however results of these studies were not reported. Remote programming software was used to remotely control the Cochlear Ltd. programming software and the possibility of anomalies occurring were investigated by using an “implant in a box” rather than a live patient. The implant in a box was connected to an oscilloscope and, during initial testing, no anomalies were observed even when the connections
were intentionally crashed. Clients were selected carefully (i.e., patients they anticipated would be successful with this process) and Franck noted that remote MAPping had not been used for very young children due to concern about missing the subtle visual cues that provide valuable information when MAPping this population (Franck et al., 2006).

Second, Polovy reported in the ASHA online Leader (2008) that the All Children’s Hospital in Florida began offering remote MAPping of CIs in 2007. The hospital uses video conferencing and remote programming software to deliver this. The article discusses how this has enabled remote families who may not have been considered suitable for cochlear implantation in the past (due to transport issues) to access the CI MAPping services and, therefore, benefit from a CI. Whilst they reported that technical issues such as “time lag” were challenging, again there was no evidence provided that shows that remote MAPping resulted in the same outcomes as a FTF appointment.

Third, it was also reported on the Newsday website in March 2008 that Dr William Shapiro (Chief of Audiology) in New York used remote control software to activate a man’s CI who was located in Uganda (Ricks, 2008).

The articles cited above comment that participants in the remote MAPping service were satisfied, however this information was provided based on client feedback such as testimonials and a more systematic approach, such as a survey questionnaires or interviews, was not used.

Fourth, McElveen et al. (2010) did a restrospective review of CI performance for adult patients who had undergone MAPping of their CI via a remote connection through the internet. The outcome results of seven patients were compared with a similar group of patients who had their MAPping in the traditional FTF scenario. Whilst results were reported as showing no significant difference, comparisons of electrode T and C levels obtained in the FTF verses remote condition were not carried out and as such the project does not provide evidence as to whether the different conditions impact significantly on the MAP created.

Also, a pilot study was conducted by Ramos and others (2009). The study involved five adult participants and testing was spread over 4 separate days and separated by 3 month intervals using an Advanced Bionics CI. CI programming parameters and some electrode levels from across the electrode array were compared and each subject’s auditory progress was also assessed. On days 1, 2 and 3, subjects underwent two separate programming sessions (one in the morning and one in the afternoon). They were programmed according to a schedule assigned randomly. The schedule
comprised: standard (FTF) – remote; remote-standard; remote-remote or standard-standard. The first two combinations offered comparisons of the different conditions and the final two served as controls for normal subject variability. The participants had the program that was performed in the morning session loaded to their CI processors and they went home with this program. After 3 months they returned to the clinic and had their auditory progress measured and were then reprogrammed over 2 sessions in the manner already outlined; and this occurred again 3 months later. On the fourth and last day of the project, auditory progress was assessed on the program that had been taken home 3 months earlier.

No significant differences were found for the electrode parameters or auditory progress and the participants were generally satisfied with the procedure (Ramos, Rodriguez, Martinez-Beneyto, et al., 2009). However, the auditory progress results for a remote versus standard program on the same subject were separated by a minimum of 6 months and using programs that were created on days which were separated by a minimum of 3 months. The subjects chosen were relatively new users of the CI technology in that they had between 7 and 15 weeks experience with the CI. One would expect that their speech perception abilities would still be changing and/or improving at this stage post implant and this fact may represent a confounding factor. That is, one could not definitely state that the remote program had not affected progress for individual participants as it was not possible to compare the progress between the remote and standard MAPs at the same point in time. Ramos et al. (2009) also note that there was large inter subject variability.

Also, whilst the VC equipment used bidirectional audio communication, they only used unidirectional video communication in order to save the “connection resource” (Ramos et al., 2009). This means that the CI recipient could not see the audiologist who was programming the CI remotely. This type of approach may work for some adults with a good support person at the participant end, however this would not be appropriate for a paediatric population (for reasons noted previously) and it would also have the potential to impact on the rapport that the clinician has with the CI recipient and the reassurance that the participant receives from being able to see the testing audiologist (for both adult and paediatric populations). This equipment setup is unlikely to promote interactions which are similar to a FTF session (Denton, 2005).

Finally, Norby (2008) reported on a proposed remote MAPping trial in the Salt Lake valley region. The study planned to have 30 child participants MAPped in a remote location by an audiologist located in the primary medical centre in the Salt Lake valley. Whilst an audiologist
was to be present at the local site, no comparison between remote and FTF MAPs was planned; however, a satisfaction questionnaire was proposed.

1.4 Rationale and Aims of the Study

Regular MAPping of CIs is required to maintain optimal hearing in the recipient. Currently the majority of children who live in regional and remote areas have to travel to larger cities for MAPping. This travel creates many challenges as it can impact significantly on education, family and work life and may be a financial strain. Remote MAPping offers an alternative solution and may allow more equitable access to MAPping services for these families. This project sought to address a clear shortfall in the literature about remote MAPping. To date, there is no research evidence about the validity of this type of MAPping and no data on client or clinician satisfaction with this practice.

In this research, a procedure for remote MAPping of CIs in children was developed and evaluated. The aims were to:

1. Investigate the criterion validity of CI MAPs created using remote MAPping by comparing them to MAPs created in the conventional manner (FTF)
2. Assess participant satisfaction (of children, parents and professionals) with remote MAPping of CIs

Critical to the project was the determination of whether the ability to build rapport with the child and family, observe behavioural responses and obtain appropriate feedback from the children and their parents was significantly affected by performing the programming using the remote set up for teleMAPping instead of the traditional FTF scenario.
CHAPTER TWO: METHODOLOGY

2.1 Research Design

The project was designed to assess the criterion validity of remote CI MAPping of children via the internet. Validity was examined by comparing the MAPping levels obtained from MAPping in the traditional FTF condition (the criterion or standard method of assessment) with those obtained in the remote condition (see description of conditions in Section 2.6) and by assessing speech perception with the MAPs created in FTF and remote conditions. In addition, participant satisfaction with the remote MAPping procedure was investigated using a questionnaire (see Appendix A, B and C). Five sub studies (which made up 3 Groups) were designed to investigate the validity and satisfaction for different age groups and test conditions (as shown in Table 2.1).

2.2 Participants

2.2.1 Children

Forty-five participants (23 aged 10 to 22 years and 22 aged 5 to 10 years) participated in the study (see Table 2.1). The participants all had severe to profound SNHL and had CIs in either one or both ears. Participants were implanted with one of four Cochlear Nucleus devices (Nucleus 22, 24, Freedom or Nucleus 5 CI). Validity was investigated for 40 participants who had MAPs created in both FTF and remote conditions (i.e., Groups 1 and 2). The 5 participants in Group 3 were assessed in a small implementation trial in which MAPs were created remotely in a ‘real life’ scenario with an audiologist in the clinic and the child and therapist at a distance in the same room. The different testing conditions are described in detail in section 2.5 Procedure.

Participants were recruited from the Hear and Say Cochlear Implant Program in Brisbane, Australia. Exclusion criteria were those cochlear implantees who were clinically judged to be unreliable for CI programming by the CI audiology team at Hear and Say or who had significant additional disabilities which prevented them from being able to perform CI programming in a conventional manner.
Table 2.1 Descriptive characteristics of participants in the five research sub studies

<table>
<thead>
<tr>
<th>Study Group</th>
<th>Test Condition</th>
<th>N</th>
<th>Mean Age in Years (SD)</th>
<th>Gender</th>
<th>CI Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>Remote vs FTF room to room</td>
<td>11</td>
<td>14.59 (2.48)</td>
<td>4 (M)</td>
<td>3 Nucleus 22</td>
</tr>
<tr>
<td></td>
<td>7 (F)</td>
<td>6 Nucleus 24</td>
<td>1 Freedom</td>
<td>1 Nucleus 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Audiologist in both conditions</td>
<td></td>
<td></td>
<td></td>
<td>1 Freedom</td>
</tr>
<tr>
<td></td>
<td>Remote vs FTF over distance</td>
<td>9</td>
<td>17.88 (4.22)</td>
<td>2 (M)</td>
<td>2 Nucleus 22</td>
</tr>
<tr>
<td></td>
<td>7 (F)</td>
<td>5 Nucleus 24</td>
<td>1 Freedom</td>
<td>1 Nucleus 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Audiologist in both conditions</td>
<td></td>
<td></td>
<td></td>
<td>1 Nucleus 5</td>
</tr>
<tr>
<td>Group 2</td>
<td>Remote vs FTF room to room</td>
<td>10</td>
<td>7.97 (1.66)</td>
<td>5 (M)</td>
<td>5 Nucleus 24</td>
</tr>
<tr>
<td></td>
<td>5 (F)</td>
<td>4 Freedom</td>
<td>1 Nucleus 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Audiologist in both conditions</td>
<td></td>
<td></td>
<td></td>
<td>1 Nucleus 5</td>
</tr>
<tr>
<td></td>
<td>Remote vs FTF over distance</td>
<td>10</td>
<td>7.97 (1.66)</td>
<td>5 (M)</td>
<td>2 Nucleus 24</td>
</tr>
<tr>
<td></td>
<td>5 (F)</td>
<td>6 Freedom</td>
<td>2 Nucleus 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Audiologist in both conditions</td>
<td></td>
<td></td>
<td></td>
<td>2 Nucleus 5</td>
</tr>
<tr>
<td>Group 3</td>
<td>Implementation Trial: Audiologist in remote location only &amp; Therapist in FTF location</td>
<td>5</td>
<td>13.43(4.8)</td>
<td>2 (M)</td>
<td>1 Nucleus 22</td>
</tr>
<tr>
<td></td>
<td>3 (F)</td>
<td>2 Nucleus 24</td>
<td>1 Freedom</td>
<td>1 Nucleus 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 Freedom</td>
<td>1 Nucleus 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>45</td>
<td>18 (M)</td>
<td>6 Nucleus 22</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>27 (F)</td>
<td>20 Nucleus 24</td>
<td>13 Freedom</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 Nucleus 5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. FTF = face-to-face environment, audiologist or therapist in the same room as the CI recipient; Remote = audiologist in another room or offsite location from CI recipient; (M)=male; (F)=female; (R)=right; (L)=left; SD= standard deviation.
2.2.2 Parents

All parents who attended the remote MAPping research appointments with the CI recipients from Groups 1, 2 and 3 were asked to complete a satisfaction survey at the end of the session. Many of the older children did not have a parent present for the appointment. In total 24 parents agreed to participate and completed the satisfaction survey.

2.2.3 Professionals

Four audiologists with specialist CI programming skills and three Auditory–Verbal Therapists participated in the study. All clinicians involved were employed at the Hear and Say Centre in Brisbane.

2.3 Equipment

Both the remote and FTF sites were equipped with a laptop computer and standard, commercially approved CI programming software (Cochlear Custom Sound versions 3.1 and 3.2) and a Cochlear Ltd CI programming interface (Programming Pod N530). The CI interface was connected to the remote computer and the therapist was able to control the remote CI programming software by establishing a remote desktop session with the client’s laptop. In addition, both sites were equipped with an eHAB® telerehabilitation system for video and audio communication (Hill et al., 2006; Theodoros et al., 2008). The eHAB® telerehabilitation system (see Figure 2.1) is a computer-based videoconferencing (VC) system, developed at The University of Queensland, which enables remote consultations (with 320x240 pixel resolution) between patients and health professionals via a wireless 3G Internet connection (Telstra Next G®) or wide area network. This arrangement enabled full screen two-way interaction with the client via the eHAB® system while the second screen could be used to interact with the remote CI programming software.
The eHAB® system includes echo-cancelling microphones and utilizes video and audio compression and decompression technologies in order to provide high quality video conferencing whilst reducing data requirements. The system allows control of the remote camera and this function was very useful in this project as it allowed the remote audiologist to position the camera in order to have an optimal view of the participant’s head and upper torso. This was of benefit if the child moved during the session and reduced the view of his/her face or the vision of the stimulus response toy/game. In most cases, the remote camera control allowed the remote audiologist to make the necessary adjustments with minimal disruption (i.e., repositioning of the child) to the programming session. The system also has a battery of measurement tools that can objectively quantify the participant’s physical performance and has been used for physiotherapy and speech pathology consultations via the internet (e.g., Constantinescu, Theodoros, Russell et al., 2010; Russell, 2004; Russell, Buttrum, Jull & Wootton, 2011). High resolution and high quality video footage can also be captured and all the tools available in the system have previously undergone extensive calibration and clinical testing (Russell, 2004).

For Group 1 room to room, three participants attended for assessment at the University of Queensland Telerehabilitation Unit and eight at the Hear and Say Centre. At the University of Queensland both eHAB® systems were connected via an 802.11G Wifi Network. At Hear and Say both eHAB® systems were connected via a wired Symmetric High-Bit-Rate Digital Subscriber Line (1.5MBit/s). This line was shared with other wide area network traffic from Hear and Say.

For all other participants The eHAB® system located at the site with the remote testing audiologist was connected via a wired Symmetric High-Bit-Rate Digital Subscriber Line.
(1.5MBit/s). This line was shared with other wide area network traffic from Hear and Say. The eHAB system that was used at the CI participant site was connected using the Telstra 3G wireless network (High-Speed Downlink Packet Access, HSDPA).

Verification of equipment operation was achieved with the equipment initially set up at the University of Queensland Telerehabilitation Research Unit. Testing was performed with an “implant-in-a-box” made by Cochlear Ltd using a Freedom implant. This was connected to the laptop to be located with the client using a Cochlear Ltd CI programming interface and a remote desktop connection to this system was established. Using this connection it was verified that the software could be efficiently manipulated to perform the required operations to program a CI. The “implant in a box” is generally used for research. It is a functioning CI in a plastic “box” which simulates a CI in a recipient’s head. It can be connected and activated in order to perform tests without having a live patient and was ideal for the initial testing to ascertain if we could connect remotely and manipulate the software in order to program the CI.

The test environment also required toys and other resources for those younger children who required play audiometry to assess their T and C levels, and noise makers to check for loudness comfort of the MAP at the end of the session.

A GSI 61 Clinical Audiometer, Sony CD/DVD (model number DVP-NC62K) and speaker were used for the speech perception assessments (when recorded material was used) and these tests were conducted in a sound proof booth. The audiometer and speaker set up were calibrated to ensure accurate output and the sound proof booth met the Australian standards set out in ASI 269. The audiometer is calibrated on an annual basis and output level is checked prior to each appointment.

2.4 Materials

2.4.1 Speech Perception Tests

The participants were assessed using speech perception tests which were presented in either a live voice or recorded format using CDs from the National Acoustics Laboratory at a level of 65 dBA. The decision as to whether the participant was tested using either live voice or recorded material depended on the age of the participant and/or the speech perception abilities of the participant. That is, for some participants the recorded material was too difficult due to their age, stage post
implant or speech perception abilities. Each child was assessed with one or a combination of the following tests:

1. Consonant-Vowel Nucleus-Consonant (CNC) words (Peterson & Lehiste, 1962). The child was asked to repeat back monosyllabic words. Although the original test has 50 words only 25 words were used in the study as this was more appropriate for paediatric testing. Percentage scores for whole words, vowels, consonants and phonemes were obtained.

2. Manchester Junior Words (MJW) list (Watson, 1957). The child was asked to repeat a list of simple monosyllabic words (most appropriate for children 6 years and under). Percentage scores for whole words and phonemes were obtained. This test is only available for live voice presentation.

3. Bench-Kowal-Bamford (BKB) sentence lists (Bench & Bamford, 1979). Each list contains 16 sentences, and the child was asked to repeat back each sentence in the list. Scoring is by the percentage of key words correctly identified. For example, “The clown had a funny face” has 3 key words (maximum points for the sentence is 3). If the child repeated “The clown was funny” he/she would score 2 points. This assessment was presented in both quiet and with speech babble at +10 signal to noise ratio (SNR), as appropriate for the participant's age and stage of development. The SNR means that the signal is 10dB louder than the noise.

2.4.2 Satisfaction Questionnaires

Questionnaires were developed to evaluate child, parent and professional satisfaction with remote MAPping and are included in Appendix A, B and C. It is based on a similar survey developed by Constantinescu et al. (2010) for a telemedicine project. The survey questions had either a 4 or 5 point scale response options and were about picture and sound quality, MAPping time, satisfaction and confidence with the MAP obtained remotely and perceived benefit of introducing this service for children in rural and remote areas. There is also an option for participants to comment on what they liked about the session and what they did not like.

2.5 Procedure

Prior to the commencement of the study, ethical clearance was obtained from the Behavioural and Social Sciences Ethical Review Committee of The University of Queensland, Brisbane. Each
participant attended for one appointment in order to complete the test battery required for this research project. Due to the young age of participants, and occasional issues with cooperation/fatigue of participants, some of the speech perception testing could not be performed on all participants. In addition the number of electrodes that were MAPped was also reduced for some participants.

Before remotely programming CIs at significant distances, pilot testing was performed on site at either the University of Queensland or the Hear and Say Centre. Initially the remote and FTF sites were in separate rooms in the same building. The testing sites were then separated by greater distances. These were either different buildings in the same city or separate town or city locations (e.g., Brisbane to Cairns). The minimum distance was 300m and the maximum distance was 1400km. Four audiologists from the Hear and Say Centre (experienced in the process of CI MAPping and speech perception testing) and three Auditory-Verbal Therapists took part in the series of experiments.

At the beginning of each session the equipment was switched on at both sites and once a connection was established between both the eHAB® systems and the separate programming laptop computers, either the audiologist (for groups 1 and 2) or therapist (for group 3) connected the participant’s CI processor to the CI programming interface.

2.5.1 FTF and Remote Conditions for Groups 1 and 2

In order to validate the remote MAPping procedure, the participants in Groups 1 and 2 were assessed FTF and remotely by two audiologists. The MAPping procedure alternated between the remote and the FTF condition. These two conditions and the speech perception testing environments are explained below:

1) The FTF environment refers to the room set up in which the participant, audiologist and usually a parent were present in a quiet room together (see Figure 2.2). The eHAB® system and MAPping equipment were on a table as well as toys/ resources needed for some of the participants.
Figure 2.2 FTF environment with audiologist, CI participant and parent in the same room

2) The remote environment refers to the room set up where the audiologist performed the CI programming via the internet using the eHAB® system for video and audio communication. The MAPping computer and eHAB® system were on a table in a quiet room and the remote audiologist was able to view the participant via a second eHAB® system placed on a table in the room with the child (see Figures 2.3 and 2.4).

Figure 2.3 Remote audiologist

Figure 2.4 CI participant & remote audiologist on screen
3) Speech perception testing was performed in the free field in a sound proof booth using MAPs created in both the FTF and remote conditions for comparison. All the speech perception testing was done on-site at the Hear and Say Centre and performed by an audiologist. When recorded material was used the participant was seated at a calibrated distance 1 metre from a speaker in the booth. For live voice testing, the speech material was presented auditory alone and with the tester sitting 1 metre from the participant.

Each participant in Groups 1 and 2 underwent a session in which the electrode impedances were checked and a maximum subset of 8 electrodes (22, 19, 16, 13, 10, 7, 4, 3) were MAPped across the CI array using both the remote and FTF test conditions. The order in which the condition (remote or FTF) of MAPping commenced was randomized.

Each audiologist was blind to the MAPping levels obtained by the audiologist in the other condition at the time of testing. This was achieved by the fact that the programming screen was only visible to the testing audiologist at the time they were controlling the software and it was agreed that the testing audiologist would change the electrode level they obtained prior to the alternating audiologist being given control of the software and vision of the programming screen. One or two at a time, each electrode in the subset was MAPped FTF then remotely or vice versa. For some of the younger children 8 electrode pairs were too many to achieve in a single MAPping session and only 4 to 6 electrode pairs from the subset (noted above) were randomly selected across the electrode array. The reason for the reduced number of electrodes MAPped was documented.

T levels were obtained by using pre-agreed step parameters. The T level was recorded at the lowest repeatable point that the participant could detect the sound stimulus produced by electrical stimulation of the hearing nerve via the CI. C levels were obtained by two different methods depending on the age of the child. For the older participants the C level was measured by starting below the pre recorded C level and taking the current level up in steps of 1 or 2 current levels until the participant indicated that it was too loud by telling the testing audiologists to stop or by using a loudness growth chart (see Appendix D). Once the MAPping process is complete a behavioural indication of comfort is obtained from the CI recipient in response to sound presented via noise makers or clapping.
All recorded T and C level results were repeatable (meaning that the participant indicated the same MAPping level twice before it was accepted) and at the end of the sessions the audiologists interpolated the adjacent electrodes and created an individual program or MAP from both the FTF and remote testing situations. Interpolation of the electrodes is an estimation of electrode CLs based on the CLs of the measured T and C levels (Zimmerman-Philips & Murad, 1999).

During the testing procedure, the clinician or therapist and parent could hear and communicate with the remote audiologist at all times, however the child could only hear the remote audiologist when his or her CI processor was in live mode. As mentioned in section 1.2.3, when the CI recipient is connected to the programming interface they only hear the sound stimulus presented, however the CI audiologist has the option of switching on the live mode during the MAPping session which effectively switches on the processor and allows the recipient to hear as they usually would. The “text chat” instant messaging option on the VC system was sometimes utilised for the older children when the remote audiologist or participant wanted to relay some information and the CI was not in live mode. This proved an effective communication tool for the older children.

Speech perception testing was performed after the MAPping was complete and both remote and FTF MAPs were loaded on to the participant’s speech processor, so that they could both be used for the comparative speech perception testing. The two test conditions were randomized. All tests were performed in the audition alone condition and, wherever possible, using recorded material. After the speech perception testing was complete a satisfaction questionnaire was given to participants (child, parents and clinicians as appropriate). Some children were too young to complete the questionnaire and for some of the older children a parent did not attend the MAPping session and as such all questionnaires were not completed.

2.5.2 Group 3 Testing Condition

The five CI recipients who participated in Group 3 were MAPped using the remote condition set up with a therapist on-site with the CI recipient rather than an audiologist. For this group MAPping levels were only obtained by the remote audiologist and there is no FTF comparison and no speech perception testing was performed. This condition reflected how remote MAPping would be applied in the real world clinical situation. Participants in Group 3 (CI recipients, parents and professionals) were asked to complete a satisfaction questionnaire.
2.6 Data Analysis

All data were recorded in a Microsoft Excel spreadsheet and later analysed using Statistical Package for the Social Sciences (SPSS) software, version 17.0. The validity of the FTF and remote MAPs was assessed by comparing the electrode T and C CLs obtained in both conditions for Groups 1 and 2 participants. For each participant there were a maximum of 8 T levels and 8 C levels in each condition. Groups 1 (>10 years) and 2 (5 to 10 years) were analysed separately in order to evaluate if age was a factor which would impact on the reliability of the remote MAPping procedure. However, the subgroups in groups 1 and 2 (i.e., room to room versus greater distance) were analysed and reported together as there was no significant difference between MAPs obtained across these conditions, nor were there any increased technical difficulties as the distance increased.

For each pair of electrodes an absolute difference was calculated irrespective of whether or not they were positive or negative differences. Subsequently, a mean absolute difference (MAD) was calculated for all electrode pairs. The MAD is a descriptive statistic and is the average of all of the differences between the two methods without regard for the direction of the difference (Bland, 2000). The MAD is commonly used in telehealth studies (Hoffman & Russell, 2008; Constantinescu, 2010); when comparing two test environments. In addition, paired t-tests were used to test for statistical difference between the T and C current levels in the FTF versus the remote condition.

In addition, results for each of the 40 children in groups 1 and 2 were examined for clinically relevant differences between FTF and remote MAPs. Clinically, there are no strict guidelines as to what constitutes a significant difference between electrode levels and the perception of difference may vary from person to person on a functional level (i.e., some CI recipients will note a difference in sound quality with only very minimal changes to their T and C levels whilst others appear to be able to tolerate more change without a change to their listening function). Also, the amount of variation in T and C levels which constitutes a significant difference depends to some extent on the dynamic range (DR) of each electrode. Rance and Dowell (1997) note that, as a general rule, changes in T and C levels which are greater than 20% of the DR on individual electrodes should be considered significant. For a CI recipient with an average DR of 40 current levels, a 20% difference would equal 8 current levels. At the Hear and Say Centre where this
research was based, the CI audiologists generally report significant changes to a child’s MAP if there is a greater than 5 current level difference on more than 3 electrodes. In this study, both criteria were applied.

The validity of the procedure was also assessed by comparing speech perception scores obtained using the MAPs created in both conditions. Phoneme, vowel, consonant and word scores on the CNC word lists and the key word scores for the BKB sentence tests were statistically compared across conditions using the non-parametric Wilcoxon Rank Sum Test. In addition, individual subjects results for the CNC, MJW and BKB word scores were reviewed using the Critical Difference Table for Word Recognition Testing (Carney & Schlauch, 2007) to determine if any individual cases had significantly different speech perception with the FTF versus remote MAPs. This table provides a quantitative basis for determining whether two scores are to be judged “significantly different” by using a binomial model to create a table of ranges over which two word recognition scores were likely to range by chance alone using a 95% critical interval.

The satisfaction questionnaires were analysed descriptively and participant comments were also recorded.

Finally, the outcomes of the Group 3 implementation trial were analysed descriptively using results from the satisfaction questionnaires.

CHAPTER 3: RESULTS

3.1 Electrode CL Results

Overall, no significant differences were observed for T and C levels between FTF and remote test conditions for Group 1 and 2 participants. There were some significant differences observed for a small number of individual participants.

3.1.1 Group Data

Descriptive statistics and paired sample t-tests are shown in Tables 3.1 and 3.2 respectively for the group analysis of data for Group 1 and in Tables 3.3 and 3.4 respectively for the group analysis of
data for Group 2. Statistical comparisons of the differences between T and C electrode current levels obtained in the FTF versus remote conditions using paired sample t-tests showed no significant differences between conditions for either Group 1 or Group 2. Very small differences (<5 current levels) were evident on the MAD for both T and C level comparisons.

**Table 3.1** The MAD of T and C current levels obtained in FTF and remote conditions for the >10 years group (n = 20).

<table>
<thead>
<tr>
<th>Condition</th>
<th>N (of electrode pairs)</th>
<th>MAD (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T levels pairs</td>
<td>160</td>
<td>3.48 (2.26)</td>
</tr>
<tr>
<td>C levels pairs</td>
<td>158</td>
<td>2.13 (2.38)</td>
</tr>
</tbody>
</table>

*Note. N = number; SD = standard deviation; MAD = mean absolute difference.*

**Table 3.2** Paired t-test of the T and C current levels obtained in FTF and remote conditions for the >10 years group (n = 20).

<table>
<thead>
<tr>
<th>Condition</th>
<th>N (electrodes)</th>
<th>Mean (SD)</th>
<th>t</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-level FTF</td>
<td>160</td>
<td>120.93 (30.28)</td>
<td>0.08</td>
<td></td>
<td>0.94*</td>
</tr>
<tr>
<td>T-level</td>
<td>160</td>
<td>120.90 (29.57)</td>
<td></td>
<td>159</td>
<td>0.39*</td>
</tr>
<tr>
<td>Remote</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-level FTF</td>
<td>158</td>
<td>193.56 (29.90)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-level</td>
<td>158</td>
<td>193.77 (29.71)</td>
<td>-0.86</td>
<td>157</td>
<td>0.39*</td>
</tr>
</tbody>
</table>

*Note. FTF = face-to-face; N = number of electrodes; CL = current level; SD = standard deviation; df = degrees of freedom; (* level of no significant difference = >0.05).*

**Table 3.3** The MAD of the T and C current levels obtained in FTF and remote conditions in the 5 to 10 years age group (n = 20).

<table>
<thead>
<tr>
<th>Condition</th>
<th>N (of electrode pairs)</th>
<th>MAD (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T levels pairs</td>
<td>142</td>
<td>2.70 (2.32)</td>
</tr>
<tr>
<td>C levels pairs</td>
<td>105</td>
<td>2.57 (2.36)</td>
</tr>
</tbody>
</table>

*Note. N = number of electrodes; SD = standard deviation; MAD = mean absolute difference.*
Table 3.4 Paired t-test of the electrode T and C current levels obtained in FTF and remote conditions in the 5 to 10 years age group.

<table>
<thead>
<tr>
<th>Condition</th>
<th>N (electrodes)</th>
<th>Mean (SD)</th>
<th>t</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-level FTF</td>
<td>142</td>
<td>131.19 (24.31)</td>
<td>-0.26</td>
<td>141</td>
<td>0.79*</td>
</tr>
<tr>
<td>T-level Remote</td>
<td>142</td>
<td>131.27 (24.10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-level FTF</td>
<td>105</td>
<td>184.48 (27.15)</td>
<td>-0.55</td>
<td>104</td>
<td>0.58*</td>
</tr>
<tr>
<td>C-level Remote</td>
<td>105</td>
<td>184.68 (27.40)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. FTF = face to face; N = number of electrodes; CL = current level; SD = standard deviation; df = degrees of freedom; (* level of significant no difference = > 0.05).

3.1.2 Individual Data

Individual participant data was collated and comparisons of the T and C levels of participants in the FTF versus remote conditions were performed using the two criteria described in section 2.7. According to the Hear and Say Centre stricter criteria 95% of T-level comparisons and 95% of C-level comparisons showed no significant clinical difference for the >10 years group. For the children aged 5 to 10 yrs, 95% of T-level comparisons and 100% of C-level comparisons showed no significant difference. Using the 20% criteria suggested by Rance and Dowell (1997) none of the individual participants showed a significant difference between MAPs created in the two conditions.

Tables 3.5, 3.6 and 3.7 show the findings from each participant whose results fell outside the Hear and Say clinical criteria. Two participants showed more than a 5 CL difference on more than 3 electrodes for T levels (Tables 3.5 and 3.6) and one participant demonstrated this for C-levels (Table 3.7).
### Table 3.5 T-level CLs obtained from participant 6 in Group 1 (13yrs, 10mths) and the difference between levels for FTF and remote conditions.

<table>
<thead>
<tr>
<th>Participant 6 (&gt;10yrs)</th>
<th>Electrode number</th>
<th>T-level FTF</th>
<th>T-level Remote</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>E3</td>
<td>128</td>
<td>131</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>E4</td>
<td>129</td>
<td>132</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>E7</td>
<td>136</td>
<td>127</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>E10</td>
<td>128</td>
<td>125</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>E13</td>
<td>133</td>
<td>127</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>E16</td>
<td>137</td>
<td>126</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>E19</td>
<td>131</td>
<td>134</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>E22</td>
<td>121</td>
<td>127</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* FTF = face to face; CL = current level

### Table 3.6 T-level CLs obtained from participant 7 in Group 2 (9yrs, 5mths) and the difference between levels for FTF and remote conditions

<table>
<thead>
<tr>
<th>Participant 7 (9 to 10yrs)</th>
<th>Electrode number</th>
<th>T-level FTF</th>
<th>T-level Remote</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>E3</td>
<td>160</td>
<td>166</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>E4</td>
<td>156</td>
<td>159</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>E7</td>
<td>152</td>
<td>160</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>E10</td>
<td>158</td>
<td>156</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>E13</td>
<td>160</td>
<td>168</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>E16</td>
<td>164</td>
<td>164</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>E19</td>
<td>159</td>
<td>170</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>E22</td>
<td>168</td>
<td>166</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* FTF = face to face; CL = current level
Table 3.7 C-level CLs obtained from participant 17 in Group 1 (19yrs, 7 mths) and the difference between levels for FTF and remote conditions.

<table>
<thead>
<tr>
<th>Participant (&gt;10yrs)</th>
<th>Electrode number</th>
<th>C-level FTF</th>
<th>C-level Remote</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>E3</td>
<td>168</td>
<td>180</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>E4</td>
<td>176</td>
<td>181</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>E7</td>
<td>167</td>
<td>180</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>E10</td>
<td>188</td>
<td>181</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>E13</td>
<td>185</td>
<td>190</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>E16</td>
<td>182</td>
<td>182</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>E19</td>
<td>183</td>
<td>182</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>E22</td>
<td>181</td>
<td>171</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

Note. FTF = face to face; CL = current level

3.2 Speech Perception Results

Speech perception was measured on participants using the MAPS created in the FTF and the remote conditions and scores were compared for both group and individual participant data.

3.2.1 Group Data

Speech perception scores from Groups 1 and 2 were analysed separately. The number of children completing the live voice Manchester Junior Words rather than the more difficult recorded CNC words test was too few for analysis (i.e., one participant). Also the BKB sentences in noise were too difficult for most children in Group 2 and as such the number who completed this test were too few for analysis. Statistical comparisons of the differences between scores on speech perception tests showed no significant differences between conditions for either age group.

3.2.1.1 Group 1 (>10 years)

Descriptive and non-parametric analysis of the speech perception results for group 1 (>10yrs) on CNC words and BKB sentences measured using MAPs obtained in both test conditions are summarized in Table 3.8. Results show that there was no significant difference between conditions.
Table 3.8 Wilcoxon Signed Ranks Test for CNC Words and BKB Sentences for Group 1 (>10 yrs)

<table>
<thead>
<tr>
<th></th>
<th>FTF</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Name of Test</td>
<td>N</td>
<td>Mean Score</td>
<td>SD</td>
<td>Range</td>
<td>Mean Score</td>
<td>SD</td>
<td>Range</td>
<td>Wilcoxon z</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>%</td>
<td></td>
<td></td>
<td>%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNC Words Recorded 65dBA (Quiet)</td>
<td>Phoneme Score</td>
<td>20</td>
<td>77.3</td>
<td>12.11</td>
<td>37-92</td>
<td>20</td>
<td>76.9</td>
<td>11.8</td>
<td>-0.885</td>
</tr>
<tr>
<td></td>
<td>Vowel Score</td>
<td>20</td>
<td>86</td>
<td>13.51</td>
<td>36-100</td>
<td>20</td>
<td>85.8</td>
<td>11.8</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Consonant Score</td>
<td>20</td>
<td>73.3</td>
<td>12.76</td>
<td>38-94</td>
<td>20</td>
<td>73.5</td>
<td>13.3</td>
<td>-0.024</td>
</tr>
<tr>
<td></td>
<td>Word Score</td>
<td>20</td>
<td>54.1</td>
<td>18.02</td>
<td>8-84</td>
<td>20</td>
<td>52.2</td>
<td>18.6</td>
<td>-1.325</td>
</tr>
<tr>
<td>BKB Sentences Recorded 65dBA (Quiet)</td>
<td></td>
<td>18</td>
<td>81</td>
<td>20.02</td>
<td>24-100</td>
<td>18</td>
<td>84.55</td>
<td>20.90</td>
<td>-1.784</td>
</tr>
<tr>
<td>BKB Sentences Recorded 65dBA (+10SNR)</td>
<td></td>
<td>14</td>
<td>80.64</td>
<td>7.37</td>
<td>70-94</td>
<td>14</td>
<td>80.36</td>
<td>8.89</td>
<td>-0.141</td>
</tr>
</tbody>
</table>

3.2.1.2 Group 2 (5-10 years)

Descriptive and non-parametric analysis of the speech perception results for group 2 (5-10 years) on CNC words and BKB sentences measured using MAPs in both test conditions are summarized in Table 3.9. Results show that there was no significant difference between conditions. Only results from BKB sentences in quiet are shown due to the younger age of the participants in this group. Many were not able to perform speech in noise testing and the number of results obtained was insufficient for analysis.
Table 3.9 Wilcoxon Signed Ranks Test for CNC Words and BKB Sentences for Group 2 (5 to 10 yrs)

<table>
<thead>
<tr>
<th>Name of Test</th>
<th>FTF</th>
<th>Remote</th>
<th>Wilcoxon z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNC Words Recorded 65dBA (Quiet)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phoneme Score</td>
<td>13</td>
<td>80.15</td>
<td>12.58</td>
<td>13</td>
</tr>
<tr>
<td>Vowel Score</td>
<td>13</td>
<td>85.38</td>
<td>19.85</td>
<td>28-100</td>
</tr>
<tr>
<td>Consonant Score</td>
<td>13</td>
<td>76.38</td>
<td>13.09</td>
<td>52-96</td>
</tr>
<tr>
<td>Word Score</td>
<td>13</td>
<td>60.76</td>
<td>22.08</td>
<td>24-92</td>
</tr>
<tr>
<td>BKB Sentences Recorded 65dBA (Quiet)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>82.15</td>
<td>14.24</td>
<td>52-100</td>
</tr>
</tbody>
</table>

3.2.2 Individual Data

Speech perception scores from each individual participant were analysed separately using the Critical Difference Table for Word Recognition Testing to determine if any individual differences may have occurred that were not highlighted by the group analysis.

3.2.2.1 Group 1 (>10 years group) CNC Word Lists

Individual comparisons of 20 participants showed that on CNC words, 95% of participants (i.e., 19 participants) had no significant difference between MAPs created in both conditions. Percentage word score results and the percentage differences are shown in table 3.10 and the measured significant difference was obtained from participant 11 whose results have been bolded.
### Table 3.10 CNC Word List, Percentage (%) Words Correct for Group 1 (>10 years) (N=20)

<table>
<thead>
<tr>
<th>Group 1 (&gt;10 years) CNC % Words Correct</th>
<th>Participant Number</th>
<th>FTF MAP % Words Correct</th>
<th>Remote MAP % Words Correct</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>48</td>
<td>44</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>42</td>
<td>48</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>60</td>
<td>44</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>44</td>
<td>36</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>56</td>
<td>64</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>68</td>
<td>64</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>68</td>
<td>64</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>60</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>60</td>
<td>64</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>68</td>
<td>68</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><strong>11</strong></td>
<td><strong>48</strong></td>
<td><strong>80</strong></td>
<td><strong>32</strong></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>48</td>
<td>40</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>84</td>
<td>80</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>40</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>76</td>
<td>72</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>24</td>
<td>28</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>56</td>
<td>44</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>48</td>
<td>44</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>8</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>76</td>
<td>56</td>
<td>20</td>
</tr>
</tbody>
</table>

*Note, FTF MAP= CI program created in face-to-face condition; REM MAP = CI program created in remote condition.*

#### 3.2.2.2 Group 1 (>10 years group) BKB Sentence Lists

On BKB sentences in quiet, individual comparisons of 18 participants showed that 94.5% of participants had no significant difference between MAPs created in both conditions. Percentage
word score results and the percentage difference are shown in Table 3.11; a significant difference was obtained from one participant (i.e., participant 8). On BKB sentence lists in noise, individual comparisons of 14 participants showed no significant differences between the MAPs created in both conditions for 100% of participants.

**Table 3.11 BKB Sentence List, Percentage (%) Words Correct for Group 1 (>10 years) (N=18)**

<table>
<thead>
<tr>
<th>Participant Number</th>
<th>FTF MAP % Words Correct</th>
<th>REM MAP % Words Correct</th>
<th>% Difference Words Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>94</td>
<td>82</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>94</td>
<td>84</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>82</td>
<td>84</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>96</td>
<td>86</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>84</td>
<td>74</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>94</td>
<td>96</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>98</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td><strong>8</strong></td>
<td><strong>100</strong></td>
<td><strong>80</strong></td>
<td><strong>20</strong></td>
</tr>
<tr>
<td>9</td>
<td>80</td>
<td>90</td>
<td>10</td>
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<tr>
<td>10</td>
<td>100</td>
<td>100</td>
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<td>88</td>
<td>96</td>
<td>8</td>
</tr>
<tr>
<td>12</td>
<td>74</td>
<td>76</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>98</td>
<td>94</td>
<td>4</td>
</tr>
<tr>
<td>14</td>
<td>82</td>
<td>78</td>
<td>4</td>
</tr>
<tr>
<td>15</td>
<td>DNT</td>
<td>DNT</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>DNT</td>
<td>DNT</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>98</td>
<td>94</td>
<td>4</td>
</tr>
<tr>
<td>18</td>
<td>94</td>
<td>82</td>
<td>12</td>
</tr>
<tr>
<td>19</td>
<td>18</td>
<td>24</td>
<td>6</td>
</tr>
<tr>
<td>20</td>
<td>48</td>
<td>38</td>
<td>10</td>
</tr>
</tbody>
</table>

*Note, FTF MAP= CI program created in face-to-face condition; REM MAP = CI program created in remote condition; DNT=did not test*

**3.2.2.3 Group 2 (5 to 10years) CNC Words and BKB Sentences**

Individual comparisons of results from 13 participants showed that on CNC words and BKB sentences in quiet no significant difference was evident between conditions for all participants.
3.3 Satisfaction Survey Results

Participant (child, parent and professional) satisfaction with the remote MAPping procedure was assessed by administering a satisfaction survey.

3.3.1 Groups 1 and 2

Tables 3.12 and 3.13 show responses from children in Group 1 and 2 respectively to the satisfaction survey. Overall results indicate generally high satisfaction with the remote MAPping procedure for these two groups.

<table>
<thead>
<tr>
<th>Question</th>
<th>Excellent</th>
<th>Very Good</th>
<th>Good</th>
<th>Not so good</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What was the sound of the audiologist’s voice like?</td>
<td>3 (18.75%)</td>
<td>4 (25%)</td>
<td>6 (37.5%)</td>
<td>1 (6.25%)</td>
<td>2 (12.5%)</td>
</tr>
<tr>
<td>2. What was the picture of the audiologist on the computer screen like?</td>
<td>4 (25%)</td>
<td>3 (18.75%)</td>
<td>7 (43.75%)</td>
<td>1 (6.25%)</td>
<td>1 (6.25%)</td>
</tr>
<tr>
<td>3. How fast was your MAPping session?</td>
<td>3 (18.75%)</td>
<td>2 (12.5%)</td>
<td>8 (50%)</td>
<td>3 (18.75%)</td>
<td>0</td>
</tr>
<tr>
<td>4. Are you happy with the sound of the MAP made in this session?</td>
<td>7 (43.75%)</td>
<td>6 (37.5%)</td>
<td>2 (12.5%)</td>
<td>1 (6.25%)</td>
<td>0</td>
</tr>
</tbody>
</table>
Many of the participants in Group 1 commented that they enjoyed the remote MAPping experience and that they liked the instant messaging function available with the VC system. Some also commented on the reduced travel time that this procedure could offer. One participant noted that the picture quality was quite pixilated during the session and another noted that sound through the VC system speaker was distorted at times. One participant also said that there was a time delay sometimes between the sound presentations in the remote condition.

**Table 3.13** Child Satisfaction Questionnaire for Group 2, 5 to 10 years ; N= 10

<table>
<thead>
<tr>
<th>Question</th>
<th>Excellent</th>
<th>Very Good</th>
<th>Good</th>
<th>Not so good</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What was the sound of the audiologist’s voice like?</td>
<td>3 (30%)</td>
<td>6 (60%)</td>
<td>1 (10%)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2. What was the picture of the audiologist on the computer screen like?</td>
<td>1 (10)</td>
<td>2 (20%)</td>
<td>6 (60%)</td>
<td>1 (10%)</td>
<td>0</td>
</tr>
<tr>
<td>3. How fast was your MAPping session?</td>
<td>2 (20%)</td>
<td>7 (70%)</td>
<td>1 (10%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Completely happy</td>
<td>Very happy</td>
<td>Happy</td>
<td>Not completely happy</td>
<td>Not happy at all</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>------------------</td>
<td>------------</td>
<td>-------</td>
<td>----------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>4. Are you happy with the sound of the MAP made in this session?</td>
<td>1(10%)</td>
<td>4(40%)</td>
<td>5(50%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>A big help</th>
<th>Some help</th>
<th>Not much help</th>
<th>No help at all</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Do you think that Mapping in this way would be of help to you or your family?</td>
<td>2(20%)</td>
<td>7(70%)</td>
<td>1(10%)</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.14 shows satisfaction survey responses from the parents of CI recipients in Groups 1 and 2 which were collated and reported on together. Many of the parents noted that they found the remote MAPpings procedure interesting and one commented that it was very “interactive” and another “engaging”. One parent stated that they felt their child enjoyed using the VC technology and another noted that the procedure “maintained the personal touch”. Parents commented that the instant messaging function would be useful and that they could see the potential for the remote MAPpings procedure and technology.

Table 3.14 Parent Questionnaire for Groups 1 and 2 (N= 20)

<table>
<thead>
<tr>
<th>Question</th>
<th>Excellent</th>
<th>Very Good</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What was the general sound quality during the session</td>
<td>4(20%)</td>
<td>10(50%)</td>
<td>5(25%)</td>
<td>1(5%)</td>
<td>0</td>
</tr>
<tr>
<td>2. What was the visual quality during this session?</td>
<td>7(35%)</td>
<td>6(30%)</td>
<td>7(35%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Question</td>
<td>Very fast</td>
<td>Less time than expected</td>
<td>As expected</td>
<td>More time than expected</td>
<td>A very long time</td>
</tr>
<tr>
<td>----------</td>
<td>-----------</td>
<td>-------------------------</td>
<td>-------------</td>
<td>-------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>3. How fast was your MAPping session?</td>
<td>2 (10%)</td>
<td>3 (15%)</td>
<td>13 (65%)</td>
<td>2 (10%)</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Completely confident</th>
<th>Very confident</th>
<th>Confident</th>
<th>Somewhat confident</th>
<th>Not confident</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Are you confident with the results obtained in this session?</td>
<td>9 (45%)</td>
<td>8 (40%)</td>
<td>3 (15%)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Completely satisfied</th>
<th>Very satisfied</th>
<th>Satisfied</th>
<th>Somewhat satisfied</th>
<th>Not satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Are you satisfied with the sound of the MAP made via the internet?</td>
<td>9 (45%)</td>
<td>7 (35%)</td>
<td>4 (20%)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Significant benefit</th>
<th>Some benefit</th>
<th>Sl. benefit</th>
<th>No Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Would the introduction of internet Mapping benefit your family?</td>
<td>11 (55%)</td>
<td>7 (35%)</td>
<td>2 (10%)</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Very satisfied</th>
<th>More than satisfied</th>
<th>Satisfied</th>
<th>Less than satisfied</th>
<th>Not satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Rate your overall satisfaction with internet remote MAPping.</td>
<td>15 (75%)</td>
<td>1 (5%)</td>
<td>4 (20%)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 3.15 shows satisfaction survey responses from professionals (audiologists) involved the testing of children in Groups 1 and 2. Clinicians involved in the study reported that the equipment was easy to use. Some noted that the picture quality was pixilated for some sessions and they felt that the VC system could be improved if the picture and instant messaging screens were slightly larger. They also noted that this procedure could be of significant benefit with regards reduced travel time and improved ease of access to services.

Table 3.15 Professional Questionnaire for Groups 1 and 2; N = 4

<table>
<thead>
<tr>
<th>Question</th>
<th>Excellent</th>
<th>Very Good</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What was the general sound quality during the session?</td>
<td>2(50%)</td>
<td>2(50%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. What was the visual quality during this session?</td>
<td>1(25%)</td>
<td>1(25%)</td>
<td>2(50%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Time taken to complete the session?</td>
<td>2(50%)</td>
<td>2(50%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4. Are you confident with the results obtained in this session?</td>
<td>3(75%)</td>
<td>1(25%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5. Would the introduction of Internet Mapping benefit families?</td>
<td>4(100%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6. Rate your overall satisfaction with Internet remote MAPping.</td>
<td>4(100%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
3.3.2 Group 3 Implementation Trial

Participants in this group were MAPped in the remote condition only with a therapist (not an audiologist) as the support person assisting with the session. A satisfaction questionnaire was administered to the child participants (Table 3.16), parents (Table 3.17) and professionals (Table 3.18). Participants provided some comments and feedback which are also presented below.

Table 3.16 Child Questionnaire for Group 3; N= 4

<table>
<thead>
<tr>
<th>Question</th>
<th>Excellent</th>
<th>Very Good</th>
<th>Good</th>
<th>Not so good</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What was the sound of the audiologist’s voice like?</td>
<td>1(25%)</td>
<td>3(75%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. What was the picture of the audiologist on the computer screen like?</td>
<td>2(50%)</td>
<td>2(50%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. How fast was your MAPping session?</td>
<td>1(25%)</td>
<td>1(25%)</td>
<td>2(50%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Completely happy</th>
<th>Very happy</th>
<th>Happy</th>
<th>Not completely happy</th>
<th>Not happy at all</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Are you happy with the sound of the MAP made in this session?</td>
<td>1(25%)</td>
<td>2(50%)</td>
<td>1(25%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. Do you think that Mapping in this way would be of help to you or your family?

Feedback from one participant in this group was that she thought this procedure would significantly help isolated children but this participant did express some concern that it may be difficult for the family and clinician to build a good rapport using this method alone.

**Table 3.17 Parent Questionnaire for Group 3; N= 4**

<table>
<thead>
<tr>
<th>Question</th>
<th>Excellent</th>
<th>Very Good</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What was the general sound quality during the session</td>
<td>2(50%)</td>
<td>1(25%)</td>
<td>1(25%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2. What was the visual quality during this session?</td>
<td>1(25%)</td>
<td>2(50%)</td>
<td>1(25%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3. How fast was your MAPping session?</td>
<td>0</td>
<td>2(50%)</td>
<td>1(25%)</td>
<td>1(25%)</td>
<td>0</td>
</tr>
<tr>
<td>4. Are you confident with the results obtained in this session?</td>
<td>0</td>
<td>4(100%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
5. Are you satisfied with the sound of the MAP made via the Internet?

<table>
<thead>
<tr>
<th>Question</th>
<th>Completely satisfied</th>
<th>Very satisfied</th>
<th>Satisfied</th>
<th>Somewhat satisfied</th>
<th>Not satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.</td>
<td>1(25%)</td>
<td>2(50%)</td>
<td>1(25%)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

6. Would the introduction of Internet Mapping benefit your family?

<table>
<thead>
<tr>
<th>Question</th>
<th>Significant benefit</th>
<th>Some benefit</th>
<th>Sl. benefit</th>
<th>No Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.</td>
<td>3(75%)</td>
<td>1(25%)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

7. Rate your overall satisfaction with internet remote MAPping.

<table>
<thead>
<tr>
<th>Question</th>
<th>Very satisfied</th>
<th>More than satisfied</th>
<th>Satisfied</th>
<th>Less than satisfied</th>
<th>Not satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td>4(100%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Feedback from one parent participant in Group 3 related to the positive effect of reduced travel time that the remote MAPping procedure could offer. This parent also noted that whilst the instant messaging function was useful, the display could be larger on the VC screen to enable easier use.

**Table 3.18** Professional Questionnaire for Group 3; N = 2

<table>
<thead>
<tr>
<th>Question</th>
<th>Excellent</th>
<th>Very Good</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What was the general sound quality during the session?</td>
<td>0</td>
<td>2(100%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2. What was the visual quality during this session?</td>
<td>0</td>
<td>1(50%)</td>
<td>1(50%)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Very fast</th>
<th>Less time than expected</th>
<th>As expected</th>
<th>More time than expected</th>
<th>A very long time</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Time taken to complete the session?</td>
<td>1(50%)</td>
<td>1(50%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Question</td>
<td>Completely confident</td>
<td>Very confident</td>
<td>Confident</td>
<td>Somewhat confident</td>
<td>Not confident</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>----------------------</td>
<td>----------------</td>
<td>-----------</td>
<td>--------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>4. Are you confident with the results obtained in this session?</td>
<td>1(50%)</td>
<td>1(50%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Significant benefit</th>
<th>Some benefit</th>
<th>Sl. benefit</th>
<th>No Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Would the introduction of Internet Mapping benefit families?</td>
<td>2(100%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Very satisfied</th>
<th>More than satisfied</th>
<th>Satisfied</th>
<th>Less than satisfied</th>
<th>Not satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Rate your overall satisfaction with Internet remote MAPping.</td>
<td>2(100%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Was the equipment easy to use?</td>
<td>2(100%)</td>
<td>0</td>
</tr>
</tbody>
</table>

Clinician feedback was positive with regards to the ease of connection, MAPping time, confidence with the results and the potential cost saving to families. One clinician noted that the instant messaging screen would be improved if it was larger.
CHAPTER 4: DISCUSSION

This study was designed to investigate the validity of using a remote MAPping procedure to program the CIs of children (of different ages) through the internet and to investigate satisfaction with this procedure. As described in Chapter 1, there is very little published research in the area of audiology telepractice, particularly regarding services for children (Krumm et al., 2005). Whilst a small number of proof-of-concept publications were found (e.g., Franck et al., 2006; McElveen et al., 2010; Polovy, 2008; Ricks, 2008) none compared results obtained for both the FTF and remote conditions on the same CI recipient and in the same testing session. It has been suggested that the lack of published evidence in this area may impede the growth and acceptance of audiology telehealth services and in addition may contribute to the current low usage of this type of service (Krumm, 2007; Norby, 2008; Polovoy, 2008). This research project goes some way towards addressing this gap and has demonstrated a model to assess the criterion validity of the remote MAPping procedure.

T and C CLs of the MAPs created in the conventional FTF manner were compared to those created in the remote condition for the same CI recipient and speech perception tests were performed using both the MAPs created in the FTF and remote conditions to ascertain if there was any functional difference between the comparative MAPs, in order to assess the validity of the procedure. The participants were also divided into two different age groups in order to investigate if there were any particular problems validating the procedure for the younger children in the study.

In addition to the quantitative data, a satisfaction questionnaire was administered to the CI recipients, parents (if applicable) and professionals involved. The importance of performing some qualitative analysis when assessing telehealth services has been reported (Aoki et al., 2003; Mair & Whitton, 2000) and is essential for continuous improvement of this type of approach. As part of the satisfaction questionnaire, feedback on technical aspects including the visual and audio quality of the eHAB® VC system was obtained in order to ascertain if subtle behavioural responses could be observed sufficiently by the remote audiologist, as this has been previously noted as particularly important when assessing children (Mertes & Chinnici, 2006). The quality of audio and visual communication was considered vital for successful communication with participants (CI recipients, parents and professionals) in the remote setting. The feedback from
participants regarding these technical aspects was generally positive and may help to address reported concerns about potential changes in the “patient-professional dynamic” (Constantinescu, 2010) and the ability to maintain an appropriate level of rapport with participants in an on-line session (Denton, 2005; Hicks et al., 2000). This feedback is discussed further in section 4.3.

4.1 T and C Current Level Comparisons

Overall results showed excellent agreement between T and C CLs on the FTF and remote MAPs indicating that, for children in this study, MAPping remotely produced essentially the same results as the conventional FTF approach. Thus the findings indicate that remote MAPping is a valid option for children aged 5 years and above.

Whilst these findings are very encouraging, they cannot be generalized across all children for a number of reasons. Firstly, only children 5 years and above were assessed and secondly, due to the exclusion criteria, those children who were clinically judged to be unreliable or who had significant additional disabilities (which prevented them from being MAPped in a conventional manner) were not included. As such we cannot assume that the same results would follow for children under 5 years of age or those who are not MAPped in a conventional manner and further research for these groups is needed.

4.1.1 Group 1 (> 10 years)

Statistical analysis of the electrode CL data revealed that there were no significant differences between MAPs created in both conditions for this group. Comparisons of individual participant CL data (using the Hear and Say Centre clinical criteria) showed that for 95% of T and C level comparisons no significant difference was observed. Moreover, using the Rance and Dowell (1997) criteria of 20% of the DR, none of the comparisons showed no significant differences. Results for participants 6 and 17 fell outside the stated Hear and Say Centre clinical criteria for T level and C level results respectively, with both having a greater that 5 CL difference between conditions on four electrodes. Subjectively, both CI recipients reported that the created MAPs from each condition sounded essentially the same and speech perception testing did not show any significant difference between the two MAPs for either participant. The results obtained in the assessment of functional performance (i.e., speech perception testing) and using the Rance and Dowell (1997) criteria for significant MAP differences suggest that the measured difference
between electrode CLs using the Hear and Say criteria was not a significant finding. Both participants remained on task throughout the testing, however occasionally concentration/attention can vary and this may be the reason for the different CLs obtained (even though they were tested almost simultaneously), rather than the remote MAPping procedure itself.

### 4.1.2 Group 2 (5 to 10 years)

As for the older group, statistical analysis of the electrode CL data for the younger group revealed that there were no significant differences between MAPs created in the two conditions. Comparisons of individual participant CL data (using the Hear and Say Centre clinical criteria) showed that for 95% of T level and 100% of C-level comparisons no significant differences were observed. Using the Rance and Dowell (1997) criteria no significant differences were found for either T or C level individual participant comparisons.

The T level results for participant 7 fell outside the stated Hear and Say Centre clinical criteria, with a greater than 5 CL difference on four electrodes. Subjectively, the CI recipient reported that the created MAPs from each condition sounded essentially the same and speech perception testing revealed no significant difference. Overall, the group and individual data indicate that the validity of the procedure was not compromised for younger children.

### 4.2 Speech Perception Testing

Overall, the results of the speech perception testing also established good validity for the remote MAPping procedure with no significant differences between scores for FTF and remote MAPs observed on statistical analysis of the group data. Whilst age and/or speech perception abilities prevented all speech perception tests from being performed on some of the children, word list results were obtained for all children in the study and as such allowed some statistical comparisons of functional performance on all participants. The results are discussed further in sections 4.2.1 and 4.2.2.
4.2.1 Group 1 (>10 years)

Statistical analysis of the speech perception tests performed using the MAPs created in both conditions showed no significant difference for this group on CNC words or BKB sentences. Individual comparisons, using the Carney and Schlauch,(2007) Critical difference Table, showed that participant 11 had a significant difference in scores between conditions using CNC words (i.e., whole words correct). However, the reduced score was actually obtained from the MAP that was set in the FTF condition not the remote. The FTF condition was assessed first for this participant. Sometimes CI recipients improve on the speech perception tasks part way into the administration (a practice effect) and this may account for the higher score on the test list for the remote MAP, which was administered second. Subjectively, the recipient did not report a difference between the MAPs and the fact that this participant’s T and C MAPping levels showed no significant difference between conditions suggests that the CNC word score obtained from the MAP created in the FTF condition may not be a true reflection of the participant’s listening function with that particular program.

Individual recipient comparisons of BKB sentences in both quiet and noise showed no significant differences on scores obtained from MAPs in both conditions.

4.2.2 Group 2 (5 to 10 years)

Statistical analysis of the speech perception tests performed using the MAPs created in the two conditions showed no significant difference for this group for CNC words or BKB sentences and no individual differences were observed. These findings, together with the T and C CL data, further support the finding that outcomes were not affected by age for the children in this study.

4.3 Satisfaction with Remote MAPping

Overall, feedback obtained on the satisfaction questionnaires suggests that all participants (CI recipients, parents, professionals) were generally satisfied with the remote MAPping procedure and these results are discussed in more detail below for the different participant groups. It has been reported that the level of patient and professional satisfaction is reliant on the extent to which the technology allows the participants to develop a good rapport and communicate in a way that is similar to a FTF consultation. Also, the level of satisfaction may impact on the willingness of patients and professionals to adopt telehealth services (Denton, 2005; Constantinescu, 2010 and
Craig et al., 1999). Whilst a small percentage of participants reported dissatisfaction with the audio and visual quality of the eHAB® VC system, the generally high level of satisfaction achieved in this project is very promising and in agreement with other reports of high acceptance and patient satisfaction with telehealth consultations (Holtman, 1998; Marci et al., 2004). These results may assist in encouraging more audiologists in the field to consider a computer based, real time VC communications approach to their clinical practice.

4.3.1 Groups 1 and 2

On the participant satisfaction questionnaire, the majority of participants in Group 1 were happy, very happy or completely happy with the sound of the MAPs created in the session (94%). The one participant (6%) who was not completely happy commented that the sound of the MAP had changed and when this occurs it will often take a few days for the CI recipient to get used to the new program that has been created. As such this feedback was not related to one particular MAP (i.e., FTF versus remote) or the remote modality but instead an overall change to the sound of the new MAP.

The majority of participants in Group 1 (67%) felt that the sound quality of the audiologist’s voice through the VC system was good, very good or excellent. The remainder (36%) felt that the sound quality was not so good or poor. The older children were the first tested and, early in the research, a problem with some distortion in the speakers on the eHAB® VC system at the participant end was noted. This was subsequently corrected; however, this problem is likely to have impacted on the participant’s ability to discriminate speech coming through the speakers and true satisfaction levels with the audio quality may be higher for this group. Also, individual participant speech perception abilities are likely to have an impact, and this is a limitation that needs to be considered for each individual as live voice speech is easier to understand than voice through a speaker system.

All participants in Group 2 were happy, very happy or completely happy with the sound of the MAPs created in the remote session. The majority of participants (90%) reported that the sound quality of the audiologist’s voice through the eHAB® system was good, very good or excellent. One participant responded that the sound quality was not so good. However, the participant was able to understand what was being said via the VC system using his speech processor before and after the MAPping session as he responded appropriately. When asked about this, the participant’s
feedback was that the sound through the speaker was different to a live voice conversation. The extra information obtained from the two participants in groups 1 and 2 regarding their feedback on the sound quality highlights the importance of qualifying responses and or comments obtained on satisfaction questionnaires and assessing the reason for satisfaction or dissatisfaction (as noted by Mair & Whitten, 2000) in order to interpret the feedback correctly and obtain a true understanding of the participant’s perspective.

On the whole, no significant audio delays for speech were experienced or reported through the VC system. The instant messaging function was well received and a great help for the older group, particularly during MAPping when the CI recipient is unable to hear anything other than the sound stimulus being presented unless the audiologists switches their processor to “live mode” (which can be time consuming and affect the flow of the appointment). Also, the support person who was with the CI recipient played an important role in relaying information which may not have been understood via the speakers of the VC system. Thus, whilst the sound quality was reported to be not at an acceptable level for all participants, it did not impact on the outcome of the MAPping session and the appropriateness of the sound quality for the remote MAPping procedure was reflected by the fact that the majority of recipients in Groups 1 and 2 (67% and 90% respectively) rated it as good, very good or excellent. However, prior discussion with the CI recipient about the possible sound quality limitations is recommended as part of the preparation for the procedure, in order to reduce anxiety and get the best outcome.

One participant in Group 1 also commented that there was a delay (of 2 to 3 seconds) between stimulus presentations when using the remote programming software to operate the MAPping program and this was likely due to the internet connection (on the day of testing) and was also noted by the remote audiologist in a number of the sessions. Whilst this was not optimal, it did not impact on the reliability of the procedure as the remote audiologist communicated to the FTF audiologist or support person that this was occurring and allowances were made. However, this issue may need to be considered when assessing very young children as the testing audiologist needs to wait for the optimal time or state of awareness in the child before presenting the stimulus to get a conditioned head turn response (Madell, 2008; Rance & Dowell, 1997) and, as such, requires the stimulus to occur immediately in order to get the best response from the child.

The quality of the picture was largely reported by Group 1 as excellent (25%), very good (19%) or good (44%). Twelve per cent reported it as not so good or poor and commented that the picture quality on the day of assessment was very pixilated making it hard for the participant to always clearly view the remote audiologist. For Group 2, the quality of the picture was largely reported as
very good or good (80%). Twenty percent reported it as not so good or poor and, as for Group 1, commented that the picture quality on the day of assessment was very pixilated.

The reduced picture quality for both groups in some testing sessions was likely due to the bandwidth and possible local area network congestion or high usage at the time of testing. However, increased distance between testing sites was not found to be a confounding factor with regards to picture quality. Difficulties in visual quality have also been identified in other studies utilising low-bandwidth VC (Constantinescu, 2010; Hill, et al., 2006 and Sclafani et al., 1999). However the generally high satisfaction with picture quality for the majority of participants in this study indicates that it was adequate. These findings together with the generally positive feedback on audio quality are in agreement with the reports of participant satisfaction from tele-psychiatry and social work reports on real time consultations cited in Chapter one (Bear et al.,1997; McCarty, 2002; Rashid et al., 2002). The visual quality and the possibility of obtaining higher bandwidth in order to improve picture quality is something that needs to be considered by clinics when setting up a remote MAPping service.

Participants in Group 1 reported that the testing time was very fast (19%), took less time than expected (13%) or was as expected (50%); 19% reported that it took more time than expected. The MAPping sessions in total (i.e., performing both the remote and FTF MAP) took between 50 and 60 minutes on average for this group. The vast majority of participants in Group 2 reported that the testing time was less time than expected or as expected and only one participant reported that it took more time than expected; this participant generally did not like the amount of time it takes to do a MAP in a conventional FTF manner and as such the feedback was not specifically related to the remote MAPping procedure. MAPping sessions (i.e., performing both the remote and FTF MAP) took 60 minutes on average for this group which was very similar to Group 1. Taking into account that these children are younger, this is a good outcome with regards to practical service delivery in relation to telehealth services for children. Also, considering that the procedure alternated between the FTF and remote conditions and that each of the 8 electrodes selected in the subset were programmed twice, the testing time was reasonable and quite similar to the time it would take to program a similar number of electrodes FTF. As previously noted, this is an important factor for both CI recipient and clinician satisfaction as the more similar a session is to a FTF consultation the more likely that this technology will be accepted by professionals in the field and by patients.
All participants in Group 1 felt that remote MAPping would be a big help (70%) or some help (30%) to them or their family and 90% of participants in group 2 felt that it would be a big help to them or their family. This is an important finding as the majority of participants in this research (83%) were not from outreach locations and as such they had a FTF service to compare the procedure to. It was noted in Chapter 1 that the inability to be able to compare services was one of the limitations of some of the reports of high satisfaction with telehealth services. These results go further to suggest that a remote consultation can be comparable to a FTF one.

4.4 Parent Satisfaction with Remote MAPping

Survey results showed that parents from both groups were generally happy with the sound and picture quality provided by the eHAB® system and only 10% thought that the session took more time than expected. All parents surveyed stated that they were confident, very confident or completely confident with the results obtained in the session which is very positive as the majority of these parents are very experienced with the MAPping process and have a good understanding the importance of obtaining accurate results and how a conventional MAPping session is performed.

The majority of parents thought that remote MAPping would be of some or a significant benefit and 100% were either satisfied, more than satisfied or very satisfied with the procedure. As stated above, many of the families in this study actually live in a metropolitan area where they can access a CI clinical service and, as such, distance is not an issue for them. However, many did state that if this technology was available in the home, they feel it would be of significant benefit to their child, particularly when they are older and have the demands of study or work or if they just needed some quick trouble shooting. This feedback demonstrates that the time demands of attending appointments have impacts for local families as well as those in regional and remote areas and there are potential benefits of remote MAPping for all CI recipients.

4.5 Professional Satisfaction Questionnaire

All professionals surveyed reported that the sound quality through the videoconferencing system was very good or excellent. They were generally happy with the visual quality with 50% stating that it was very good or excellent and 50% stating that it was good. There were some sessions
where the picture was more pixilated than would be preferred but this did not affect the outcomes of the session.

It should also be noted that when we initially started remote MAPping using a wireless equipment setup there were significant connection problems. It was discovered that one of the aerials was not connected correctly and once this was corrected there was no recurrence of connection problems. However, this scenario highlighted the importance of having good technology support and regular equipment checks in order to alleviate any concerns with equipment reliability.

The feedback obtained from the professionals indicates that the clinicians involved were generally happy with the appointment time and 100% were very confident or completely confident with the results obtained and were very satisfied with the remote MAPping procedure. This group reported that the equipment was easy to use and they felt that the approach would be of significant benefit to families. Concerns have been reported regarding confidence in the technology and equipment use and the importance of these factors in the successful integration of telehealth services into clinical practice (Bashshur et al., 2000; Constantinescu, 2010; Siden et al., 1998). This feedback shows that clinicians can feel the same level of confidence and satisfaction with remote MAPping as with a FTF session.

4.6 Implementation Trial

No electrode comparisons or speech perception assessments were performed for this group as the support person on the recipient end was not an audiologist and as such a comparative MAP could not be completed. Whilst the results from groups 1 and 2 showed the feasibility of using the remote MAPping procedure it was necessary to show that the procedure could be performed successfully without a specialist audiologist facilitating the procedure at the FTF site. This point was highlighted by Elangovan (2005) in an audiology study looking at an automatic diagnostic hearing assessment (OAEs) being delivered via telepractice and using an audiologist at both the FTF and remote sites. Elangovan noted that further evaluation using trained on-site facilitators who were not audiologists is something that is needed for validation.

The CI recipient and parent feedback on the satisfaction surveys for these pilot participants was very positive, with 100% of the parents reporting that they were very confident with the results obtained. The majority of recipients (75%) were very happy or completely happy with the MAP
created and 25% were happy. These results support the findings from Groups 1 and 2 that the MAPping levels obtained were appropriate.

As for Groups 1 and 2, parents and CI recipients reported positively about the sound and picture quality and also the majority were happy with the time taken to complete the session. One participant did note concern that it may take longer to build up a relationship with the audiologist initially using the remote MAPping procedure. However, two of the parents surveyed reported that they thought the ease of communication was good and one even commented that it was “just like a face-to-face session”.

All parents reported that they were very satisfied with the remote MAPping procedure.

The support persons (Hear and Say therapist) involved with the pilot study also gave positive feedback regarding the remote MAPping procedure (as shown in Table 3.18) and 100% found the equipment easy to use which further supports the feedback regarding equipment use from the professionals in Groups 1 and 2 and suggests that a non-audiologist with the correct instruction can successfully facilitate the session at the CI participant site.

Whilst the pilot project is limited because of its small sample size (n = 5 child participants), the results, when considered alongside the results from Groups 1 and 2, indicate that clinicians can have confidence that the remote MAPping procedure used here will yield valid and reliable MAPs in children aged over 5 years and that stakeholders involved in the procedure are satisfied with it.

4.7 Limitations of the Research

The present study had a number of limitations. First, since this study focused on children over 5 years of age, the results obtained cannot be generalized to younger children. Secondly, as children who were clinically judged to be unreliable at performing MAPping, or who had significant additional disabilities (which prevented them from being MAPped in a conventional manner), were not included in the study, the results cannot be generalized to these groups of children. The third limitation relates to the fact that the support person at the remote site for Groups 1 and 2 was an audiologist. Elangovan (2005) has noted this limitation previously in relation to a teleaudiology project looking at remote audiometry and OAE testing. Elangovan (2005) stated that in the ideal telepractice setup, an appropriately trained individual (e.g., teacher or health professional) will
serve as facilitator. Whilst the project demonstrated the feasibility of a telehealth model, further evaluation is required using a support person who does not have prior CI experience. This research project endeavored to address this issue in a small way with the implementation trial project using a therapist from the Hear and Say Centre at the remote site for a small group of participants. However, the final limitation relates to the small sample size of the pilot project. Whilst the project demonstrated that remote MAPping could be performed successfully using a “real world” set up and a “non-audiologist” at the CI recipient end, further evaluation using a larger sample size is needed to fully validate the procedure.

4.8 Clinical Implications

Current audiology practice requires that CI recipients have CI programming performed in a FTF session. CI audiology is a very specialized field and usually only available in the cities and some larger towns in Australia. Remote MAPping has the potential to distribute this specialty care across more communities and the results obtained in this research project show that it is both a reliable and valid option. Importantly, it has the potential to reduce the stress and financial burden placed on families from regional and remote locations.

One of the key factors in the successful outcomes of this project was the support person at the recipient end. Selecting a support person who relates well to children and who is able to build a good rapport with the parent is essential. Training in the equipment set up, play audiometry and also behavioural observation would be required. At the Hear and Say Centre, many parents have become skilled in assisting the audiology staff with the MAPping of their own child (in the FTF situation) and a number of administration staff and volunteers (from a variety of backgrounds) have also been trained to assist. This experience highlights the possibility that with the correct selection criteria and training a non-clinician could assist at the recipient end and this has the potential to increases the scope for this technology significantly.

4.9 Future Directions

As stated above in section 4.7, further research with this procedure using non-audiologists at the CI recipient location is needed. In addition, future research should expand the study (using the same research model) to children under 5 years of age and also those with additional disabilities.
or who are not reliable at MAPping in order to ascertain if this procedure can be generalized to these populations.

There is also a need to assess the cost effectiveness of the telehealth approach. There is generally limited knowledge of the cost effectiveness of telehealth services compared to conventional methods of delivery. The lack of quantitative evidence may impact on the willingness of health care professionals to consider a telehealth approach and also the ability to get long term funding for these types of programs (Smith et al., 2007).

### 4.10 Conclusions

The findings of this research indicate that remote MAPping of children with CIs is valid for those aged 5 years and above. No significant differences between MAPping CLs or speech perception results were obtained from the FTF and remote conditions for different age groups. Participant satisfaction with the procedure and technology used was generally positive and helps to support the telehealth modality as a viable option for children with CIs.

Given the size, population distribution and limited spread of specialist health care services in Australia, the potential for remote MAPping applications to offer a solution for service gaps in rural and remote areas is great. By demonstrating that the outcomes from this approach are essentially the same as those obtained in the traditional FTF manner this project has shown that this model is a feasible alternative. Therefore, it has the potential to reduce the tyranny of distance by reducing the burden of travel and cost and also the impacts on family and work life. This project shows that the telehealth approach can be positive and effective for those involved and good outcomes can be achieved. More research which compares the results obtained in the traditional FTF versus the remote scenario is required, however it is hoped that the outcomes data obtained in this project, will encourage clinicians in the field to consider remote programming of CIs.
REFERENCES


Appendices

A. Remote MAPping for Children with Cochlear Implants - Child Satisfaction Questionnaire
B. Remote MAPping for Children with Cochlear Implants - Parent Satisfaction Questionnaire
C. Remote MAPping for Children with Cochlear Implants – Professional Satisfaction Questionnaire
D. Loudness Growth Chart
Remote MAPping for Children with Cochlear Implants

Child Satisfaction Questionnaire

Participant ID number: _____________________________

Date: _____________________________

This questionnaire has been developed to work out how happy you were with the MAPping we did using the internet. Please circle the answers that you feel shows what you thought of the MAPping session.

1. What was the sound of the audiologist’s voice coming through the internet like?
   a) Excellent
   b) Very good
   c) Good
   d) Not so good
   e) Poor

2. What was the picture of the audiologist on the computer screen like?
   a) Excellent
   b) Very Good
   c) Good
   d) Not so good
   e) Poor
3. How fast was your MAPping session?
   a) Very Fast
   b) Less time than expected
   c) As expected
   d) More time than expected
   e) A very long time

4. Are you happy with the sound of the MAP made in this session?
   a) Completely happy
   b) Very happy
   c) Happy
   d) Not completely happy
   e) Not happy at all

5. Do you think that MAPping in this way would be of any help to you or your family?
   a) A big help
   b) Some help
   c) Not much help
   d) No help at all

6. What did you like about the session?
   Comment:
   
   
   
   

7. What did you NOT like about the session?
   Comment:
   
   
   
   

Remote MAPping for Children with Cochlear Implants

Parent Satisfaction Questionnaire

Participant ID number: _____________________________

Date: _____________________________

This questionnaire has been developed to determine your satisfaction with the remote MAPping procedure over the internet. Please circle the answer that you feel is most appropriate based on your experience.

1. What is your opinion of the general sound quality (your ability to hear the audiologist via the internet) during the session?
   a) Excellent
   b) Very Good
   c) Good
   d) Fair
   e) Poor

2. What is your opinion of the visual quality (what you were able to see) during the session?
   a) Excellent
   b) Very Good
   c) Good
   d) Fair
   e) Poor
3. In your opinion was the time taken to complete the MAPping session:
   a) Very Fast
   b) Less time than expected
   c) As expected
   d) More time than expected
   e) A very long time

4. Are you confident with the results obtained in this session?
   a) Completely confident
   b) Very confident
   c) Confident
   d) Somewhat confident
   e) Not confident

5. In your opinion would the introduction of internet MAPping benefit your child and/or your family?
   a) Significant benefit
   b) Some benefit
   c) Slight benefit
   d) No benefit

6. Please rate your overall satisfaction with the internet (remote MAPping) session:
   a) Very satisfied
   b) More than satisfied
   c) Satisfied
   d) Less than satisfied
   e) Not at all satisfied

7. What did you like about the session?

   Comment:

   

8. What did you NOT like about the session?

   Comment:

    
Remote MAPping for Children with Cochlear Implants

Professional Satisfaction Questionnaire

Name:____________________________________

Participant ID number: _______________________

Date: _____________

This questionnaire has been developed to determine your satisfaction with the remote MAPping procedure over the internet. Please circle the answer that you feel is most appropriate based on your experience.

4. What is your opinion of the general sound quality (your ability to hear the remote audiologist via the eHAB VC system) during the session?

   a) Excellent
   b) Very Good
   c) Good
   d) Fair
   e) Poor
5. What is your opinion of the visual quality (what you were able to see) during the session?
   a) Excellent
   b) Very Good
   c) Good
   d) Fair
   e) Poor

6. In your opinion was the time taken to complete the MAPping session:
   a) Very Fast
   b) Less time than expected
   c) As expected
   d) More time than expected
   e) A very long time

4. Are you confident with the results obtained in this session?
   f) Completely confident
   g) Very confident
   h) Confident
   i) Somewhat confident
   j) Not confident

6. In your opinion would the introduction of internet MAPping benefit children and families in your cochlear implant clinic?
   a) Significant benefit
   b) Some benefit
   c) Slight benefit
   d) No benefit

Comment:

7. Please rate your overall satisfaction with the internet (remote MAPping) session:
   a) Very satisfied
   b) More than satisfied
   c) Satisfied
   d) Less than satisfied
   e) Not at all satisfied
8. **What did you like about the session?**
Comment: 

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9. **What did you NOT like about the session?**
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10. **Was the equipment easy to use?**

    YES / NO

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LOUDNESS SCALE: CHILDREN

TOO LOUD

JUST RIGHT

TOO QUIET