TELEPHONE USE AND PERFORMANCE IN COCHLEAR IMPLANT CANDIDATES

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Abstract

Telephones are an integral part of everyday life in today's society. It is well known that hearing impaired people have difficulty understanding speech on the telephone. The ability to use the telephone is commonly reported as one of the many benefits of cochlear implantation. Assessment for a cochlear implant (CI) includes a variety of aspects related to communication and hearing ability. Included in the case history, mention is made whether the person can use the telephone. The purpose of the present study was firstly to identify if the inability to use the telephone could be used a predictor for suitability for a cochlear implant. It was also purposed to determine if telephone ability could be assessed by self-reported measures. The participants were 13 severe to profoundly hearing impaired people who had previously undergone candidacy assessment for a cochlear implant. Each participant was evaluated on their use and understanding of speech on the telephone. Participants were separated into two groups: those who were candidates for a cochlear implant and those who were not. Speech perception testing was evaluated using a recording of CUNY sentences on the telephone. Results indicated that cochlear implant candidates correctly perceived a significantly lower number of words on the telephone than non-candidates. Use of the telephone was evaluated using a 51-item questionnaire. Results indicated that there was no significant difference in self-reported use of the telephone between cochlear implant candidates and non-candidates. The differences in speech perception understanding on the telephone were most likely due to the overall better hearing levels of the non-candidates. The clinical implications of the present study are considered.

Introduction

The Nature of Hearing Loss

Hearing loss affects people of all ages. Hearing loss can result from a number of factors, including noise damage, illness and disease, drugs, aging, hereditary or other factors (Martin & Clark, 2003). Hearing loss can be categorised in terms of type, frequencies, and degree. There are three types of hearing loss: conductive, sensorineural and mixed hearing loss, the latter being the combination of the preceding two. Hearing loss is also classified according to the affected frequencies (low, mid or high), the number of ears effected (either monaural or binaural), and the degree of hearing loss (from slight to profound). Labelling the degree of hearing loss allows the audiologist to categorise the hearing loss into its severity, which generally reflects the extent of difficulty that the person will have listening and understanding speech (Martin & Clark, 2003).

A common and successful form of rehabilitation for hearing loss is a hearing aid. The function of a hearing aid is to amplify sounds to the extent that the wearer of the aid can hear and understand incoming information (Dillon, 2000). There are many types and styles of hearing aids, each suited to a particular hearing loss. Generally, the less severe the hearing loss the more rehabilitation options are available (Dillon, 2000). Those with severe to profound hearing losses are the most difficult to successfully fit with a hearing aid that provides enough amplification to enable adequate perception and interpretation of speech. As sensorineural hearing loss results from damage to the cochlear or auditory nerve, which in turn results in distorted perception of speech, fitting some people with a hearing aid may only intensify the distortion (Lim, 2005). Tactile aids, that use vibration as the stimulus, can provide environmental and speech information that can supplement a lip-reader (Dillon, 2000).

A consequence of severe to profound hearing loss is a reduced ability to communicate with other people. This can lead to social isolation. Maillet et al. (1995) as cited in Lassaletta et al. (2005), categorises individuals with profound hearing loss to have fewer relationships, decreased social activities, feelings of isolation and are more likely to experience depression or irritability. These experiences may be linked with the reduced ability to communicate, maintain friendships and participate in social gatherings, and may be compounded by difficulty in maintaining contact via the telephone.

Telephones and Speech Perception

Telephones are an integral part of business, social and personal life. Telephones enable communication that does not rely on mobility or sight. The telephone uses a speech coder to compress speech signals into a compact form to reduce the frequency bandwidth, resulting in an economical and efficient transfer of information (Donald, 2002). There are a number of possible speech coders that remove different acoustical aspects of the speech signal. The typical telephone signal in New Zealand is a low-pass filtered (300-3400 Hz) transmitted signal (TelstraClear, 2006).

A telephone adapter may be used by a hearing impaired person to reduce the difficulties associated with listening to the telephone signal. Telephone adapters consist of a parallel resonant circuit that covers the telephone frequency band and then attenuates that band by up to 20dB at both edges of the pass band; thus acting to eliminate approximately half of the noise power without disrupting the speech components (Veekmans, 2004). Many hearing impaired people are fit with a hearing aid that contains a telecoil “T Switch” to enable listening on the telephone. A telecoil is a small coil of wire that produces a voltage when an alternating magnetic field flows through it. The magnetic field picked up by the telecoil is generated by an electrical current. The new signal has the same current as the original audio signal, but a larger voltage, meaning that the audio signal is made louder (Dillon, 2000). A telecoil becomes more essential in order to hear the telephone as hearing loss increases.

Studies of telephone use among the hearing impaired show the difficultly in using this form of communication. Kepler, Terry and Sweetman (1992) found that over two thirds of the hearing impaired people questioned frequently avoid using the telephone. These difficulties are more pronounced for listeners with a profound hearing loss (Terry, 1992). There are three main explanations for this difficulty (Terry, 1992). Firstly, the telephone line transmits a limited frequency range of the speech signal, typically between 300 and 3500 Hz, which eliminates high frequency information that is required to understand speech. Secondly, communicating via the telephone requires total reliance on auditory information and provides no additional visual information. Visual cues become increasingly important, as hearing loss increases, to fill in any information that listeners have missed with other sensory modalities. Visual cues also provide complementary cues to enhance overall word recognition performance (Kaiser, 2003). Thirdly, the amplitude of the signal transmitted through the telephone line is insufficient due to the decreased hearing sensitivity of the listener.

Little research has assessed actual speech perception tasks over the telephone in the severe to profoundly hearing impaired population. Of the research available in this area, most has assessed telephone performance and usage by means of a survey. For example, Kepler et al. (1992) studied telephone use of 104 hearing impaired people, of whom 87.5% had a moderate or severe hearing loss and 8.7% had a profound hearing loss. They found that 69% of the surveyed people were discouraged from using the telephone due to their hearing impairment. More so, 81% reported that their hearing impairment had a moderate to great effect on their use of the telephone. "Talker variables" affect the ability to accurately listen and perceive speech. It has been found that familiar voices, talking on familiar topics, are much easier to understand than a stranger (unfamiliar voice) talking on either a familiar or unfamiliar topic. The study showed that 70% of people responded to a questionnaire stating that strangers' voices are more difficult to hear than familiar voices (Kepler, 1992).

A limitation of self-reported abilities via a survey is the possibility that responders exaggerate their telephone ability. In one particular study it was found that two out of 10 respondents falsely claimed they could use the telephone competently, which was made clear when testing begun (Cohen, 1989).

Holmes and Frank (1984) examined speech perception of a simulated telephone signal among three groups of hearing impaired listeners. The signal was presented at 86dB SPL (which simulated the output of a standard telephone handset at 1000 Hz) and up to 103dB SPL (which simulated the output range of an amplified telephone handset). The groups were organized according to the severity of their hearing loss. Speech perception abilities were evaluated using the Northwestern University Auditory Test No. 6 (NU-6) speech perception test (Tillman, 1966) in three different conditions: (1) unaided, through a TDH-39 earphone, (2) unaided, using a telephone handset and (3) aided, acoustically coupled to the telephone handset. Little difference was found between the three conditions within each group.

It was speculated that the three conditions resulted in similar scores because each condition provided the critical frequency range of 500 to 3000 Hz that is necessary for understanding speech. However, there was a significant difference between groups. The group with the most severe hearing loss performed significantly poorer in all three conditions. The researchers concluded that individuals with moderate to severe flat hearing losses had similar word discrimination scores between listening through a TDH-39 earphone and through a simulated telephone setting, and that overall performance increased as the listening level was increased (Holmes, 1984).

Terry et al. (1992) assessed telephone abilities in 16 participants, whose hearing loss ranged from mild in the low frequencies to severe in the high frequencies. In an effort to replicate the telephone signal, speech was presented via headphones as a 300 to 3000 Hz bandpass filtered signal. When the signal was presented at 20dB above the pure tone average, the average score of 42.9% (SD 3.8) was obtained on the Californian Consonant Test (CCT) (Owens, 1977). Terry et al. found that listeners with a moderate hearing loss encountered difficulty accurately perceiving fricative consonants (e.g. f, s, z, v). Fricative consonants contain spectral information above 3000 Hz, which are necessary to distinguish one fricative from the next. The reduced bandwidth of a telephone essentially eliminated the important spectral information, thereby reducing overall clarity of speech.

Simpson, McDermott and Dowell (2005) studied consonant recognition in ten hearing impaired listeners as the bandwidth of the speech signal of interest was increased. As the bandwidth of the signal increased, which added additional high frequency information, the scores for consonant recognition improved significantly in all ten participants. They concluded that the availability of high frequency speech cues increases speech perception in listeners with a severe high frequency hearing loss, suggesting that increasing the bandwidth of the signal will increase speech perception abilities.

Contrary to Simpson, McDermott and Dowell's findings, it has been proposed that for people with hearing loss greater than 55dB, providing audible speech to high frequency regions (>3000 Hz) will make no difference in overall speech perception (Ching, 1998; Hogan, 1998; Turner, 1999; Hornsby, 2006; Turner, 2006). Hornsby and Ricketts (2006) suggested that speech perception on a limited bandwidth signal (of up to 3000 Hz) will not improve significantly as the bandwidth is increased. Therefore, speech perception scores on the telephone would be equal to that as for a signal with a wider frequency band.

Supporting these findings, van Schijndel, Houtgast and Festen (2001) proposed that performance of hearing impaired listeners on degraded signals can be explained using the distortion-sensitivity model. This model suggests that when cues that are not normally perceived are removed from a particular signal, hearing performance for hearing impaired listeners will not change. It is thought that the hearing impaired listeners simply do not hear the cues in the first place, so removing them does not differ the signal, and therefore the speech perception (van Schijndel, 2001).

Summary of Telephones and Speech Perception

Perceiving speech via a telephone limits the audibility of speech sounds because of the limited bandwidth, reduced signal, and lack of visual cues. Not surprisingly, individuals with any degree of hearing loss report considerable difficulty effectively using the telephone (Holmes, 1984; Kepler, 1992; Terry, 1992). While there is limited research on telephone use and performance in the severe to profoundly hearing impaired population, it is clear that this group experience difficulty perceiving speech accurately. While Simpson, McDermott and Dowell (2005) found that increasing the bandwidth of a signal to make more frequencies audible can improve speech perception abilities for hearing impaired listeners, other research suggests that it adds no additional benefit for listeners with a hearing loss greater than 55dB (Ching, 1998; Hogan, 1998; Turner, 1999, 2006). Therefore, there may be no difference between speech perception in general and on a reduced frequency bandwidth such as the telephone (van Schijndel, 2001). Evaluating telephone ability on both a questionnaire and a formal speech perception test would provide an accurate guide of a person's telephone ability and help avoid over-rating on self-reported ability.

Cochlear Implants

Between 11 and 15 percent of those with a hearing loss fit into the severe to profound severity category (puretone thresholds greater than 70 db HL) (Flynn, 1998). Furthermore, it has been estimated that ten percent of individuals with a sensorineural hearing loss do not benefit from conventional hearing aids (Palmer, 1999); most of which have puretone thresholds above 90 dB HL (Hnath-Chisolm, 1994). When a hearing loss becomes so pronounced that no further benefit can be achieved with a hearing aid, due to either inaudibility or distortion, a cochlear implant (CI) is a possible option to restore sensory information and assist with re-entering the hearing world (Ginsberg, 1994). A CI involves the surgical insertion of an electrode array into the cochlea that provides direct stimulation to the auditory nerve, bypassing the defective outer and middle ear. Cochlear implants function on the assumption that there are a sufficient number of auditory nerve fibres left intact in the inner ear so that stimulation can occur via the inserted electrodes (Loizou, 1998). It is thought that early deafness, coupled with long-term auditory deprivation results in poor auditory performance with a CI, due to loss of neural plasticity of the auditory system (Peasgood, 2003).

Cochlear Implant Candidate Selection

Referral for consideration for a CI is typically made by an audiologist, otolaryngologist, or advisor for deaf children. The Southern Cochlear Implant Programme (SCIP) co-ordinates cochlear implantation and rehabilitation for the lower half of the North Island and the whole of the South Island of New Zealand. The SCIP team is comprised of a range of specialists who are dedicated to the identification and rehabilitation of children and adults with moderate to profound sensorineural hearing loss who derive minimal benefit from conventional hearing aids. The SCIP is supported by the Southern Hearing Charitable Trust, the Ministry of Health, and the Ministry of Education to fund and provide CI's to adults and children who reside in the lower half of New Zealand.

The current evaluation for a CI in New Zealand includes a thorough assessment from a number of health professionals including an audiologist, otolaryngologist, and psychologist or counsellor. The audiologist's role is to perform an assessment that includes an extensive case history including whether the person can currently use the telephone, hearing aid check, free field audiometry, tympanometry, pure tone audiometry, otoacoustic emissions, and aided speech perception testing. Evaluating speech perception at the sentence level is assumed to provide the most information about a person's higher level processing. Such high level processing is required to fill-in missed information and is relied upon during the initial period when the CI is switched-on (Loizou, 1998). The audiologist also ascertains the extent of benefit the person is currently obtaining from their existing hearing aid. The audiologist assesses communication needs, expectations of benefit from a CI, and provides information on the implant technology, benefits and limitations.

The otolaryngologist assess whether the person's general health is suitable for surgery. During this assessment, the functionality of the auditory nerve is evaluated when its integrity is in doubt, as it is required to be intact for successful stimulation via the CI (Hnath-Chisolm, 1994). A CT scan checks for the feasibility of cochlear implantation. Counselling involving both the candidate and their families purports to instil realistic expectations to both parties in order to maximise positive outcomes after surgery. Family support at the time of surgery and the initial stages of the CI 'switch on' (activation) has been found to be critical for the patient in their long-term success with the implant (Larky, 2000). Part of the candidacy evaluation also involves the candidate and their family meeting an implant user.

The criteria for CI candidates aims to identify and select people who are likely to obtain maximum benefit from implantation of the device (Gantz, 1993; Waltzman, 1995; Kaiser, 2003; Peasgood, 2003). It is important to distinguish between benefits associated with wearing hearing aids compared to benefits associated with having a CI. In the past, eligibility for a CI was mainly based on having a profound hearing loss (i.e., greater than 90dB) and sentence recognition of less than 30% (Loizou, 1998; Mok, 2006). Current selection criteria in New Zealand is now less stringent and includes consideration of the following for adults (age 18 years and over): (1) severe to profound hearing loss in both ears and must have previously had sufficient hearing to have satisfactorily spoken language, (2) demonstrate little or no benefit from carefully selected and well fitted hearing aids, worn on a daily basis, and (3) aided responses and speech perception measures should suggest the person is likely to gain greater benefit from a CI. The score of open-set HINT sentences in a quiet situation in the best aided conditions must be less than 70% for bilateral speech perception, and less than 40% for speech perception in the implant ear.

Cochlear Implant Preoperative Predictors

Much research has focused on identifying factors that can predict success with a CI (Gantz, 1989; Pyman, 1992; Summerfield, 1995; Waltzman, 1995; Larky, 2000). Those people who are likely to have high success with a CI will be those who make likely candidates based on pre-implant measures and predictors. Rubinstein et al. (1999) studied a variety of preoperative variables for CI success and found two predictors. The first preoperative predictor for CI success was sentence recognition (Rubinstein, 1999). This finding was also supported by Dowell, Hollow and Winton (2003). In regards to preoperative sentence recognition, Dowell et al. found that people with a CI, on average, achieved similar postoperative scores in quiet as a person with a 66dB hearing loss.

The second preoperative predictor for CI success identified by Rubinstein et al. (1999) was the duration of deafness, which was supported by previous research (Gantz, 1993; Waltzman, 1995). Gantz et al. (1993) proposed that people with a short duration of deafness, regardless of their pre-operative audiological assessment scores, will have high speech perception scores post implantation. Short duration of deafness was defined as a brief period of time when the auditory nerve received little or no stimulation (Rubinstein, 1999). Furthermore, duration of deafness was taken to be based on the length of time from when a person ceased using the telephone in their implantable ear. Rubinstein et al.'s inclusion of time since the telephone was able to be used as a predictor of CI success presupposes a relationship between deafness and telephone ability. That is, they suggest that a telltale sign of deafness commences when the telephone can no longer be used.

Summary of Cochlear Implants

The processes involved in CI candidacy are complex and incorporate the skills of many professionals. From an audiological standpoint, the two major predictors for CI success are preoperative sentence recognition ability and duration of deafness (Rubinstein, 1999). Therefore, there is a suggestion that a short period of time from when a person no longer feels capable of speaking on the telephone will correlate with good post-implantation speech perception (Rubinstein, 1999). To date there have been no direct attempts to determine whether telephone use is a preoperative predictor of CI candidacy and success.

Post-Implantation Outcome Measures and Telephone Use

The determination of CI success is typically based on performance measures of speech perception and other audiological measures. These measures include the ability to discriminate, detect, identify or recognize speech (Loizou, 1998). Many authors (Hirshorn, 1986; Pyman, 1992; Ito, 1995; Dorman, 2000; Hamzavi, 2001; Propps, 2001; Sanderson, 2004; Mok, 2006) report scores of speech perception tests, comparing pre- and post-implantation scores that show a large increase in percentage of words perceived correctly since implantation. However, tangible benefits provided by a CI in daily life have been found to be equally as important as increases in speech perception in overall CI evaluation (Peasgood, 2003; Hawthorne, 2004; Lassaletta, 2005; Vermeire, 2005). Current research now commonly reports post-implantation outcomes of not only auditory performance but also of psychosocial benefits and increased quality of life (Faber, 2000; Lassaletta, 2005; Vermeire, 2005). These benefits often include independent use of the telephone.

Many authors report an increase in speech perception via the telephone after cochlear implantation (Hirshorn, 1986; Pyman, 1992; Ito, 1995; Dorman, 2000; Mawman, 2000; Hamzavi, 2001; Propps, 2001; Sanderson, 2004; Mok, 2006). A comprehensive study by Ito, Nakatake and Fujita (1999) evaluated ten people implanted with the Nucleus multichannel CI. Each participant performed three speech perception tests under the following three conditions: (1) listening to a natural voice (no lipreading), (2) listening to a voice through a telephone, and (3) listening through a telephone adapter. The participants were scored on correct number of phrases perceived in a five-minute interval. Although the results indicated similar scores for listening to a natural voice and listening with a telephone adapter, there was a significant difference between natural voice and voice on the telephone. The results of Ito et al. (1999) indicate that there is a disadvantage to listening to a voice on the telephone compared with a natural voice and that speech perception can increase by the addition of a telephone adapter. Telephone adapters are used to reduce noise level, and given the observed increase in scores, one can assume that the telephone condition in the Ito et al. study had a considerable amount of noise present.

Milchard and Cullington (2004) studied the effect of a limited bandwidth signal (300-3400 Hz) for speech recognition in normal hearing adults and adults with cochlear implants. They found, like Holmes and Frank (1984), there was no difference in speech perception abilities between the limited bandwidth signal and the normal signal for normal hearing listeners. However, they found there was a significant difference in the cochlear implant wearers in speech recognition scores between the limited bandwidth signal and a normal, unfiltered signal, with a decrease in speech perception scores by 17.7% when listening to the limited bandwidth signal.

Everyday telephone use by CI users was examined by Mawman et al. (2000). In this study, 83 CI users completed a questionnaire on their telephone use, which attempted to identify aspects of day to day communication on the telephone. The results indicated that 83% of the respondents reported to use the telephone. Most (71%) were comfortable with answering the telephone. A little over half of the respondents (52%) were able to understand familiar voices on the telephone, however only a third (35%) were able to understand unfamiliar voices. When questioned about their expectations of using the telephone, 55% of people reported to be experiencing benefit using the telephone. Only 14% of respondents reported to be performing worse than expected.

Adams et al. (2004) examined speech perception over a telephone in 34 CI users. In this study, a researcher telephoned a participant who was situated in another room (within a hospital). The researcher spoke into the telephone two lists of the Central Institute for the Deaf (CID) Telephone Sentences Test (Davis & Silverman, 1978) and the CI participant was asked to repeat the sentences presented to them. Although it is unclear whether the same environmental controls were used for all participants, the study found that the mean score for speech perception for the group of independent telephone users was 67%, which they classified as *fair*. The researchers concluded by characterizing the “good” performer on the telephone as being:

> An adult male who was relatively older when he lost his hearing but who had already experienced a relatively longer duration of hearing loss; he had previously worn a high-quality hearing aid, and he received a MED-EL Combi 40+ implant a relatively short time ago. pp102 (Adams, 2004).

Cray et al. (2004) evaluated telephone use in CI users by way of a questionnaire. The researchers surveyed 478 respondents who had a CI, approximately 70% of whom classified themselves as telephone users. Cray et al. showed that within five months after implantation, 85% of people were able to interact with strangers on the telephone and two thirds of users could differentiate between the voices of men, women and children. They found that over 95% of users could differentiate between a dial tone, a busy signal, and voices. Most people could also understand unfamiliar voices on an unfamiliar topic. This is a substantial increase compared with studies by Kepler et al. (1992) of the hearing impaired population which found that 70% of people found strangers (unfamiliar) voices most difficult to understand.

Finally, Lasaletta et al. (2005) used a questionnaire to evaluate telephone use pre- and post-implantation. A significant improvement in telephone use following implantation was the recognition of both signals and voices. The ability to use the telephone was scaled from 0 (impossible) to 100 (easy). Lassaletta et al. found that the participants mean scores increased from 4/100 to a score of 73/100 after implantation. Similarly, recognizing a busy signal and a voice rose from 4/100 to 86/100 and 4/100 to 71/100, respectively. The study provides clear evidence of self-reported difficulty to use the telephone prior to implantation of a CI, with noticeable improvements post implantation.

Whereas the aforementioned studies all assessed adults, either pre- or post-implant, a study by Tait, Nikolopoulos, Archbold and O'Donoghue (2001) assessed telephone use in prelingually deafened children with a cochlear implant. This particular study scored the children against a profile of telephone use, which included items such as 'identifies hello', 'identifies own name', and 'discriminates days of the week'. Scores on the telephone profile rose from 0 (pre-implant) to a median of 27 (out of a maximum of 34), five years after implantation. To determine whether the telephone profile accurately assessed the auditory skill for these children, and to determine how they compared with understanding live voice, scores were correlated against the IOWA sentence test and in connected discourse tracking (CDT). Results indicated that there was a high correlation between the telephone profile ratings and the scores on the sentence tests, despite results on the telephone profile being more difficult than the sentence tests (Tait, 2001).

Summary of Telephone use and Cochlear Implants

Telephone use and performance is often recorded as a positive outcome of receiving a CI, along with increased quality of life and speech perception abilities. However, reported use and performance on the telephone is varied between past studies. Adams et al. (2004) summarised prior research (Brown 1985; Kelsall 1995; Facer 1994; Cohen 1989; & Ito 1999) and found that successful telephone use by way of average speech perception scores ranged anywhere between 21% and 87%. As there are no set criteria between these studies of what it means to 'successfully use the telephone' and given that the speech perception tests differed, it is difficult to make comparisons between studies. While these studies report significant findings post implantation, they fail to document the pre-implantation scores and abilities on a variety of measures that are vital for full evaluation of the change due to the cochlear implant.

Statement of the Problem

Communication on the telephone is an integral part of everyday living that is used in many areas of business, social and personal life. Due to the acoustic characteristics of the telephone signal, many severely hearing impaired individuals experience difficulty communicating via the telephone (Holmes, 1984; Kepler, 1992; Adams, 2004). While some suggest that the telephone is a more trying form of communication than everyday speech, some authors suggest that decreasing the bandwidth (such as in the telephone situation) will not decrease speech perception scores, as the cues that are taken away were not perceived in the first instance, when they were made available (Ching, 1998; Hogan, 1998; Turner, 1999, 2006).

Cochlear implants are becoming a common rehabilitation option for severe to profound hearing impaired people, who are thought to make up between 11 and 15 percent of people with a hearing loss (Flynn, 1998). Cochlear implant candidate selection is initially based on a severe to profound hearing loss with speech perception scores in the best aided condition of less than 70% for bilateral speech perception and less than 40% for speech perception in the ear to be implanted (Mears, 2005). There are a number of preoperative predictors for CI success, one of which is a short period of time from when a person ceases to use the telephone (Rubinstein, 1999). In most cases, a CI results in good auditory performance post-implantation. Another measure to show the success of a CI is quality of life (Faber, 2000; Hawthorne, 2004; Lassaletta, 2005; Vermeire, 2005). One feature of improved quality of life is the ability to independently use the telephone as one factor that increases overall quality of life. However, the significance of reporting post-implant telephone ability depends on pre-implant abilities for a complete comparison. At present, no data are available showing pre-implant telephone performance scores.

The purpose of this study was to determine if a person’s performance on the telephone is predictive of their candidacy for a CI. An aim of the present study was 1) to examine if there was a difference in telephone use and performance between CI candidates and non-candidates, and 2) to determine if there were any specific behaviours regarding telephone use that could separate candidates from non-candidates.

Two groups of participants were sampled in the present study. All participants were initially referred for assessment to determine their suitability for a CI. On the basis of the assessment, participants were judged to either be a candidate for a CI or a non-candidate for a CI. Those individuals judged to be candidates for a CI were ultimately compared to those judged to be non-candidates. On the basis of this comparison, the following hypotheses were posed:

1. *Compared to non-candidates, CI candidates will have significantly lower aided speech perception scores via the telephone (Conditions 2 and 3)*
2. *Both CI candidate and non-candidate groups will show no significant difference in speech perception between the three Conditions*
3. *Both CI candidates and non-candidates will show a significant correlation between aided speech perception scores (Condition 1) and speech perception on the two telephone conditions (Conditions 2 and 3)*
4. *Self reported telephone use will be poorer in the CI candidate group compared to the non-candidate group*
5. *Both CI candidate and non-candidate groups self reported use of the telephone should correlate with the results obtained for speech perception on the two telephone conditions (Condition 2 and 3)*

Method

Participants

The participants for this study consisted of 13 adults ranging in age from 21 to 76 years with a mean age of 57 years. Each participant was referred to the Southern Cochlear Implant Programme (SCIP) for an initial assessment of candidacy for a cochlear implant (CI).

Eligibility for participation in the present study was based on the initial criteria established by the SCIP for CI candidates. The specific eligibility criteria included:

1. Severe to profound bilateral hearing loss, or aided thresholds above 2000 Hz that fall outside of the speech range
2. A current user of hearing aids or had trialled hearing aids for a minimum of two months
3. Receiving no further benefit from using a hearing aid

The participants for the study were obtained from two sources. The first source was from a pool of people who were referred to the SCIP by an Audiologist, Otolaryngologist, or an Advisor on Deaf Children. Those participants had yet to be formally tested in regards to their eligibility for an implant by the SCIP. The second source of participants was those who had already been evaluated in 2006 by the SCIP for CI assessment. All people who were evaluated for a CI in 2006 were possible participants for the current study, except those who had since been implanted. The general characteristics of the thirteen participants used in the present study are listed in Table 1 and Table 2. Informed consent was obtained from each participant before testing commenced. The methods used in this study were approved by the University of Canterbury Committee on Human Ethics (see Appendix 1).

Cochlear Implant Candidacy Outcome

The initial assessment for CI candidacy involves full audiometric testing, including case history, hearing aid check, free field audiometry, tympanometry, pure tone audiometry, oto-acoustic emissions, and aided speech perception testing. Selection criteria include: hearing loss should be either severe to profound or profound in both ears, and/or aided thresholds above 2000 Hz should fall outside of the speech range. Aided responses and speech perception measures should lead to the suggestion that the client will get greater benefit from a CI than hearing aids. Speech perception scores for open-set sentences in quiet in the best aided condition should be less than 70%, and less than 40% in the ear to be implanted. The audiologist's role is to also make an appraisal of communication needs, and discussion of the expectations, benefits, and limitations of a CI. Following this initial assessment, the candidate meets with the Otolaryngologist, and, when requested, a Psychologist or Family Counsellor (SCIP). Once the initial assessment for CI candidacy was completed, a decision was made regarding whether the person was deemed a suitable candidate for a CI. This decision was made by the team of professionals comprising the SCIP. The researcher was informed as to the decision reached for each of the participants. On the basis of the decision, each participant was assigned to either the CI candidate group or non-CI candidate group.

Speech Stimuli

The stimuli used for the speech perception testing were a modified version of the City University of New York (CUNY) sentence list (Boothroyd, 1985) as produced by HearWorks Pty Limited, Australia, referred to as the 'CUNY sentences'.

Table 1: General characteristics of the eight cochlear implant candidate (CI) participants who were used in the present study, including age, gender, length and etiology of hearing loss, pure tone average and speech audiometry score for HINT sentences (auditory alone).

	Age (yrs)	**Gender**	**Length of Hearing Loss (years)**	**Etiology**	**Pure Tone Average (dB HL)**	**Speech Discrimination (HINT sentences)** auditory alone
CI1	76	Male	46	Hereditary	90	19%
CI2	24	Male	23	Hereditary	110	30%
CI3	76	Female	10	Unknown	100	0%
CI4	62	Male	42	Noise exposure	90	11%
CI5	57	Female	50	Unknown	80	0%
CI6	65	Male	63	Maternal Rubella	105	0%
CI7	63	Female	62	Meningitis	90	10%
CI8	48	Male	48	Hereditary and Ototoxicity	90	0%

Table 2: General characteristics of the five cochlear implant non-candidate (NCI) participants who were used in the present study, including age, gender, length and etiology of hearing loss, pure tone average and speech audiometry score for HINT sentences (auditory alone).

	Age (yrs)	**Gender**	**Length of Hearing Loss (years)**	**Etiology**	**Pure Tone Average (dB HL)**	**Speech Discrimination (HINT sentences)** auditory alone
NCI1	58	Male	25	Hereditary	80	10%
NCI2	62	Male	32	Accident	100	53%
NCI3	62	Male	12	Noise	85	40%
NCI4	70	Male	56	Unknown	55	60%
NCI5	21	Female	21	Pendreds Syndrome	85	100%

The CUNY sentences consist of 60 lists of sentences. Each list consists of 12 sentences, ranging in length from 3 to 14 words, with 102 words per list. The CUNY sentences are commonly used to assess speech perception abilities in hearing-impaired adults. Three of the sentence lists (31-33) were arbitrarily selected to be used in the present study. A list of these sentences is provided in Appendix 2. The three sentence lists were modified to represent three different listening conditions and subsequently transferred to a CD. The specific conditions were defined as follows:

Condition 1: CUNY sentence List 32 was used for condition 1. In this condition, there was no filtering or alteration to the original sentence list. This condition is referred to as the unfiltered condition.

Condition 2: CUNY sentence List 33 was used for condition 2. In this condition, the list was played through a telephone line. To create this condition, the original signal was routed through the phone system and digitally recorded at the other end. The materials were routed through a Telephone Recorder AD0145 (Dictation Distributors Ltd., Auckland, NZ) to replicate the digitising and bit-rate specifications of the telephone, giving a consistent and accurate representation of the effect of the phone system on the speech signal of interest. The materials were played via a battery-powered CD player (SONY MP3 CD Walkman D-CJ01) to avoid earth loops. The materials received through the telephone line were digitally recorded via a computer programme. The sentence list was played through a telephone handset to ensure a representative frequency response of the telephone. This condition is referred to as the telephone condition.

Condition 3: CUNY sentence List 31 was used for condition 3. In this condition, the list was filtered to simulate the frequency response of the telephone, according to specifications given by the national telephone company. This condition was chosen to evaluate the whether speech perception via a filter that matched the stated characteristics of the frequency response of a telephone was equal to speech perception on a real recording of the telephone (condition 2). To perform this filtering, it was first necessary to obtain the frequency characteristics from the national telephone company, TelstraClear. The characteristics were reported to be the following:

> A telephone microphone and earpiece, based on legacy technology and on their construction, respond at their best between 200Hz and 4000Hz. To this end, derived voice circuits have filters that will roll on at 300 Hz and roll off at 3400Hz. The analogue voice input is sampled 8000 times per second at a chunk size of 8000Hz (64K Timeslot) for PCM30. Ballpark figures for a given piece of equipment, from a given manufacturer, have: Bandwidth = 3100Hz, High Pass <=3400Hz, Low Pass = >=300Hz, with the peak level obtained at 1600Hz, rolling up from 300Hz and dying horribly after around 3400Hz (TelstraClear, 2006).

Once this information was obtained, the sentence list, along with white noise were routed through the phone system and subsequently digitally recorded. The frequency response of the white noise was analyzed, and filters were set up to match the response for the telephone. Two 2nd-order Butterworth high-pass filters at 44 and 145 Hz were used to shape the low frequency slope of the filter, followed by a Butterworth low-pass filter at 440 Hz. To enable the steep slope between 440 Hz and 3345 Hz, a 14th-order Butterworth low-pass filter at 3345 Hz was created. A full description of the filters used is found in Appendix 3. This condition is shown in Figure 1. This track was administered through a telephone handset to complete the frequency response of the telephone, to the aided participant. This condition is referred to as the filtered telephone condition.

<u>Instrumentation</u>

A block diagram of the instrumentation used to evaluate telephone speech perception abilities is displayed in Figure 2. The main pieces of equipment consisted of an audiometer (Interacoustics Audiometer (calibrated 12/2005) model AC33), a compact disc player (SONY MP3 CD Walkman D-CJ01), and a telephone (Oricom Amplified Big Button Phone, TP100), which was attached to a telephone adapter (Walker, Amplifying Life) presented at 100dB peak level. The volume level for the speech stimuli was controlled by the participant, who was able to adjust the volume of the telephone, in addition to adjusting the volume through the telephone adapter (maximum of 20dB).

The three CUNY sentences recorded on the CD were played through an audiometer. The output cable from the audiometer was connected to a telephone recorder, which was subsequently connected to a telephone handset. The telephone adapter was attached to a telephone recorder, which was connected to the base of the telephone. Prior to undertaking the speech perception testing, the audiometer was calibrated for each sentence list so that the peak volume unit (VU) meter deflected to zero when a 1000 Hz calibration tone was played.

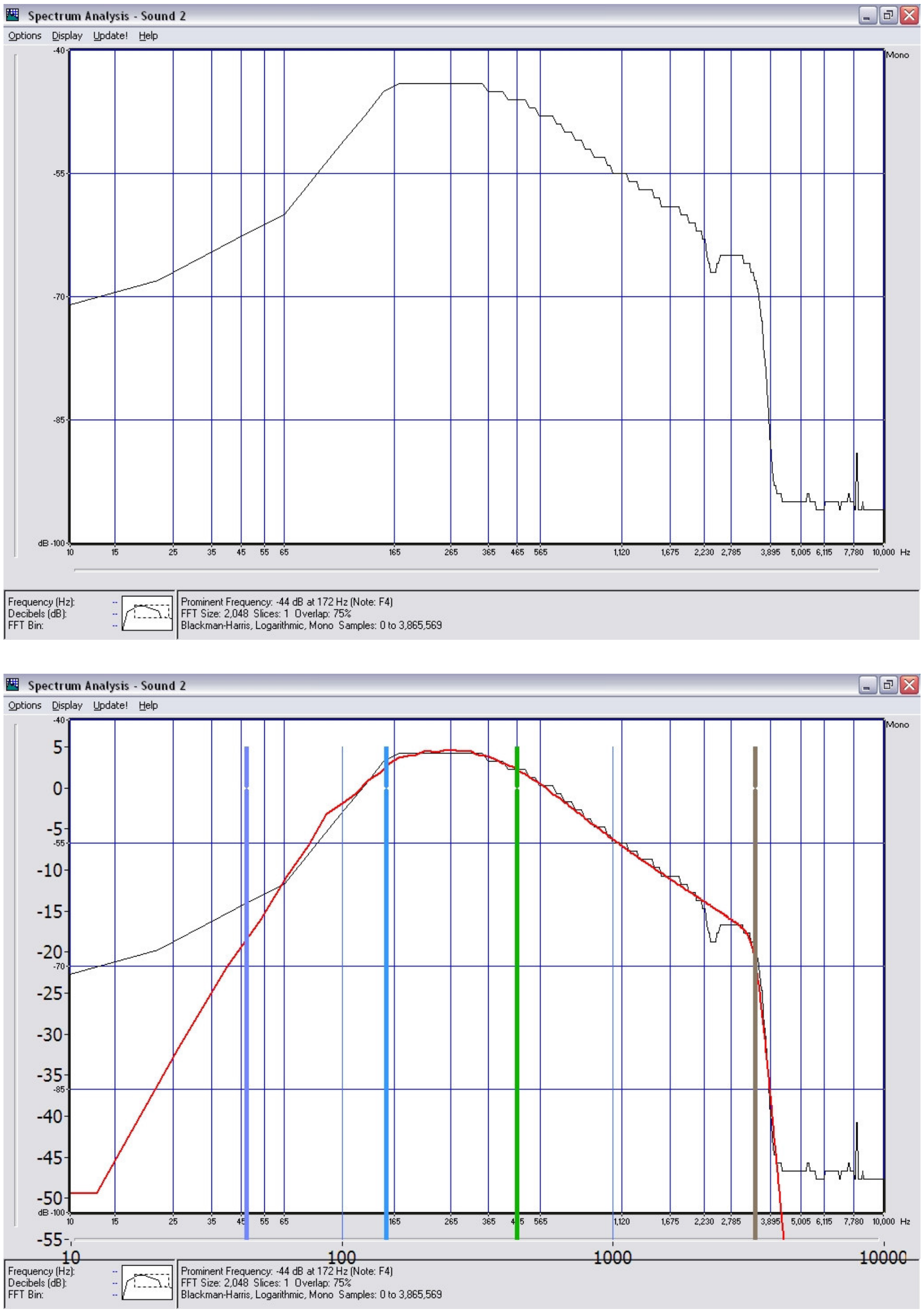


Figure 1: Frequency response of white noise recorded through an external telephone line is presented in the top display. The bottom display shows the resulting frequency response obtained via filters. The filter output (red line) is superimposed over the original frequency response of the white noise, via a telephone.

Speech Perception Tests

Prior to performing the speech perception tasks, each participant took part in a full audiometric assessment to ensure they matched the criteria for participation in the current research. In addition, each participant's hearing aid was evaluated during this appointment to ensure it was working adequately.

Written instructions were supplied to each participant and they were encouraged to seek clarification on the procedures. Each participant was seated facing the researcher, who was seated behind the audiometer. The three listening conditions were presented to the participants in random order. For condition 1, the participant sat at a distance of one meter from the loud speaker and the sentence list was presented in a soundfield at 70dBA. The 70dBA level was chosen as it is the level used within the SCIP audiometric test battery for CI candidacy assessment. Conditions 2 and 3 were presented through the telephone handset. The audiometer was set to 100dB, which was the limits of the audiometer, to allow the participants to hear the signal of interest.

The participant had access to the volume controls on the telephone adapter, as well as on the base of the telephone. He/She was instructed to listen to the sentence lists as they were presented through the telephone. They could choose to adjust the volume controls on the telephone to assist with the audibility of the sentence lists. The participants all wore their hearing aids to complete the speech perception tasks, and had the option of using T-coil for Conditions 2 and 3 to optimise listening on the telephone. The participants were instructed to repeat back all or part of the sentence they perceived. During the presentation of each sentence list, they were encouraged to guess at the words if they were uncertain. No sentences were repeated. The entire procedure (three listening conditions) took approximately 20 minutes to complete.

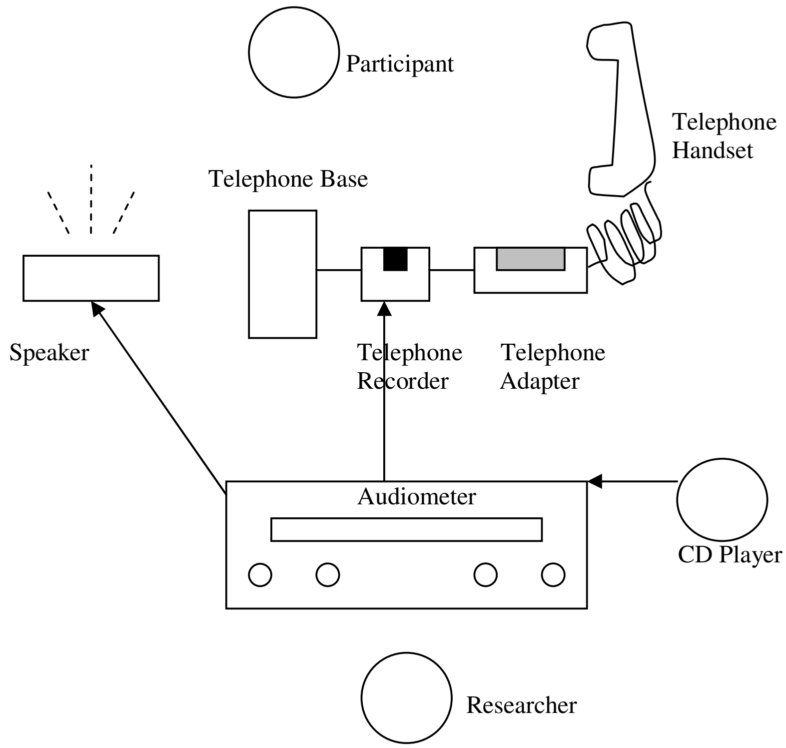


Figure 2: Telephone setup for Speech Perception testing in the sound-booth

Telephone Questionnaire

Participants were required to complete a 51-item questionnaire on their ability to use and converse on the telephone. The questionnaire was based on previous questionnaires developed by Kepler et al. (1992) and Cray et al. (2004). The questionnaire involved a collection of short answer, multiple choice, and yes/no questions. Questions included ability to listen and understand familiar and unfamiliar people, confidence on asking about products or services, number of phone calls made and received per day, and general feelings regarding their ability to use the telephone. Participants were given the option to either complete the questionnaire on the same day as the speech perception testing or to complete the questionnaire at a later date. They were provided with a postage-paid addressed envelope in order for them to return the questionnaire to the researcher at a later date. Questionnaires needed to be returned to the researcher within one week of the speech perception tests. A copy of the questionnaire can be found in Appendix 4.

Data Analysis

Analysis of the results of the speech perception testing and the questionnaire on telephone use and ability was undertaken. The speech perception tasks were scored on the number of key words correct per sentence. There were between 3 and 14 key words per sentence and a total of 102 words per sentence list. The raw score was then converted into a percentage correct score. A score was obtained for each participant and an overall group score was calculated for the candidate and non-candidate groups.

The questionnaire was organized into five major themes (1) understanding a signal on the telephone (2) initiating telephone calls, (3) answering telephone calls (4) sound quality over the telephone and (5) quality of life issues. The questionnaire was scored in the following way. Where the question had a forced choice answer of either; a) yes most the time, b) yes some of the time, or c) no, answers were scored as a) 2 points, b) 1 point, and c) scored as 0 points. When the question had a yes/no answer, an answer ‘yes’ was scored as 2 points, and an answer ‘no’ was scored as 0 points. Score were summed to result in a figure representing telephone ability. The results obtained for each participant were evaluated according to each of the five themes. The responses from each participant were evaluated in regard to these five themes. In addition, the collective results obtained from the candidate and non- candidate groups were evaluated in regards to the five themes.

Results

Speech Perception Tests

The results are presented in three sections. The first section contains the scores for the CI and NCI participants for the speech perception testing. The second section contains the results of the questionnaire completed by the CI and NCI participants. The third section provides a correlational analysis of the speech perception testing and the questionnaire results.

Condition 1: CI vs NCI. The results for the 13 participants in Condition 1 are displayed in Tables 3 and 4, and Figure 4. The scores for the CI participants ranged from 2 to 31 words correct (out of 102) with a mean of 11.76. The score for the NCI participants ranged from 48 to 100 words correct (out of 102) with a mean of 68.6. A two-tailed *t*-test was performed to determine whether the two groups differed significantly. The test was significant [$t(11) = -6.70$, $p<0.001$], indicating that the NCI group perceived a significantly greater number of words in the aided unfiltered speech condition than the CI group.

Condition 2: CI vs NCI. The results for the 13 participants in Condition 2 are displayed on Tables 3 and 4, and Figure 5. The scores for the CI participants ranged from 0 to 12 words correct (out of 102) with a mean of 4.66. The scores for the NCI participants ranged from 8 to 86 words correct (out of 102) with a mean of 40.2. Due to the lack of homogeneity variance between the two groups, a Mann-Whitney Rank Sum test was performed to determine whether speech perception on a telephone differed between CI candidates and non-candidates. The test was significant [$T(11) =53$, $p<0.05$], indicating that the NCI group perceived a significantly greater number of words in the telephone condition than the CI group.

Table 3: Raw score (out of 102) and percentage correct for speech perception testing using the three Conditions for cochlear implant candidates (CI). Standard deviations are shown in parentheses.

Participant	**Condition**		
	1	**2**	**3**
CI 1	31 / 30.39%	10 / 9.80%	34 / 33.33%
CI 2	16 / 15.69%	7 / 6.86%	7 / 6.86%
CI 3	14 / 13.73%	2 / 1.96%	0 / 0.00%
CI 4	9 / 8.22%	2 / 1.96%	15 / 14.71%
CI 5	7 / 6.86%	12 / 11.76%	8 / 7.84%
CI 6	2 / 1.96%	2 / 1.96%	0 / 0.00%
CI 7	10 / 9.80%	0 / 0.00%	0 / 0.00%
CI 8	7 / 6.86%	3 / 2.94%	3 / 2.94%
Median	**10**	**2.5**	**5**
Mean	**11.76 (8.64)**	**4.66 (4.28)**	**8.21 (11.37)**

Table 4: Raw score (out of 102) and percentage correct for speech perception testing using the three Conditions for cochlear implant non-candidates (NCI). Standard deviations are shown in parentheses.

Participant	**Condition**		
	1	**2**	**3**
NCI 1	50 / 49.02%	8 / 7.84%	20 / 19.61%
NCI 2	79 / 77.45%	59 / 57.84%	89 / 87.25%
NCI 3	48 / 47.06%	21 / 20.59%	31 / 30.39%
NCI 4	66 / 64.71%	27 / 26.47%	64 / 62.75%
NCI 5	100 / 98.04%	86 / 84.31%	98 / 96.80%
Median	**66**	**27**	**64**
Mean	**68.60 (21.62)**	**40.20 (31.74)**	**60.40 (34.42)**

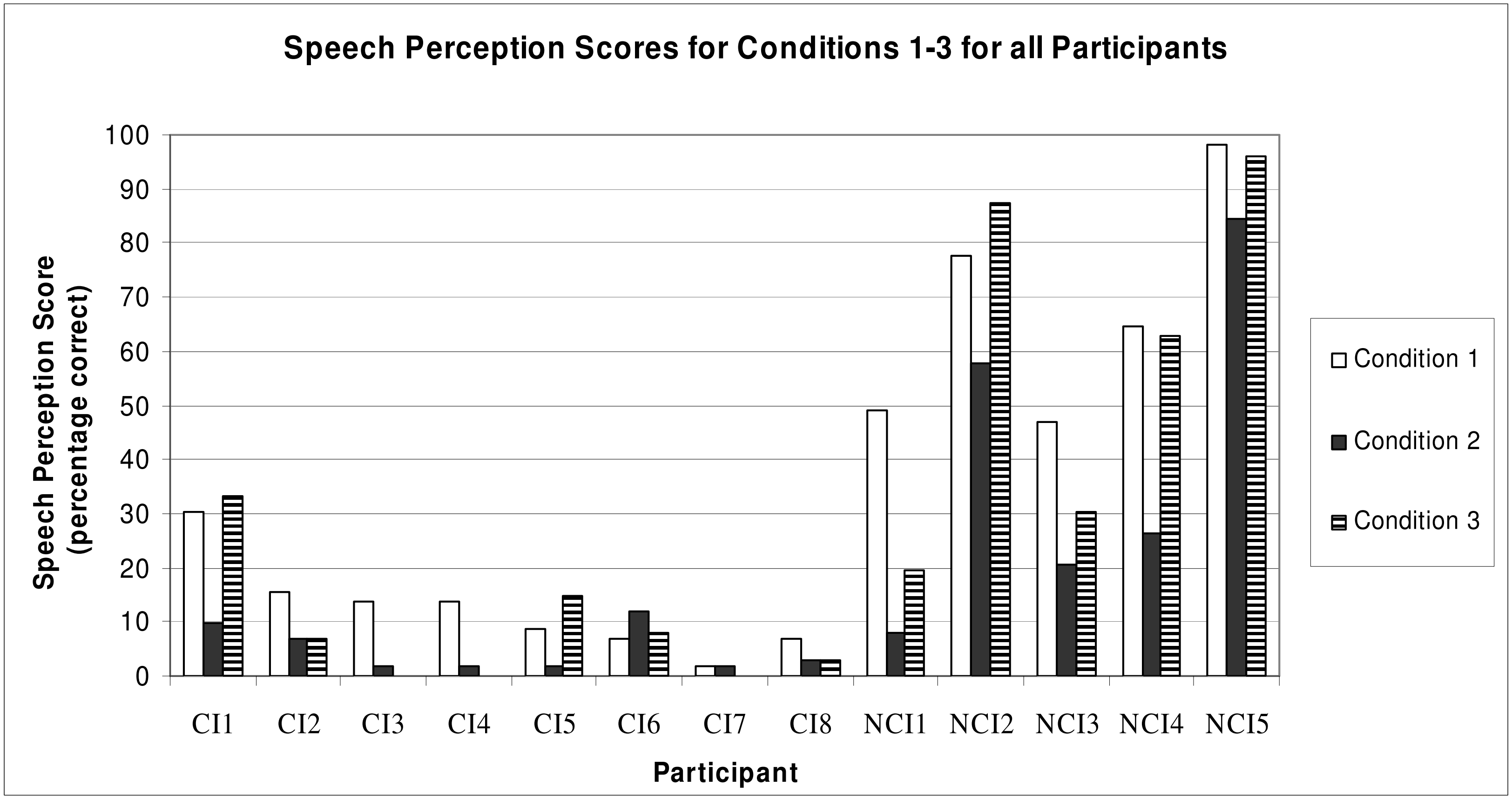


Figure 3: Speech perception scores (in percentage correct) for three listening Conditions. The individual results for the cochlear implant candidates (CI) and non-candidates (NCI) are shown.

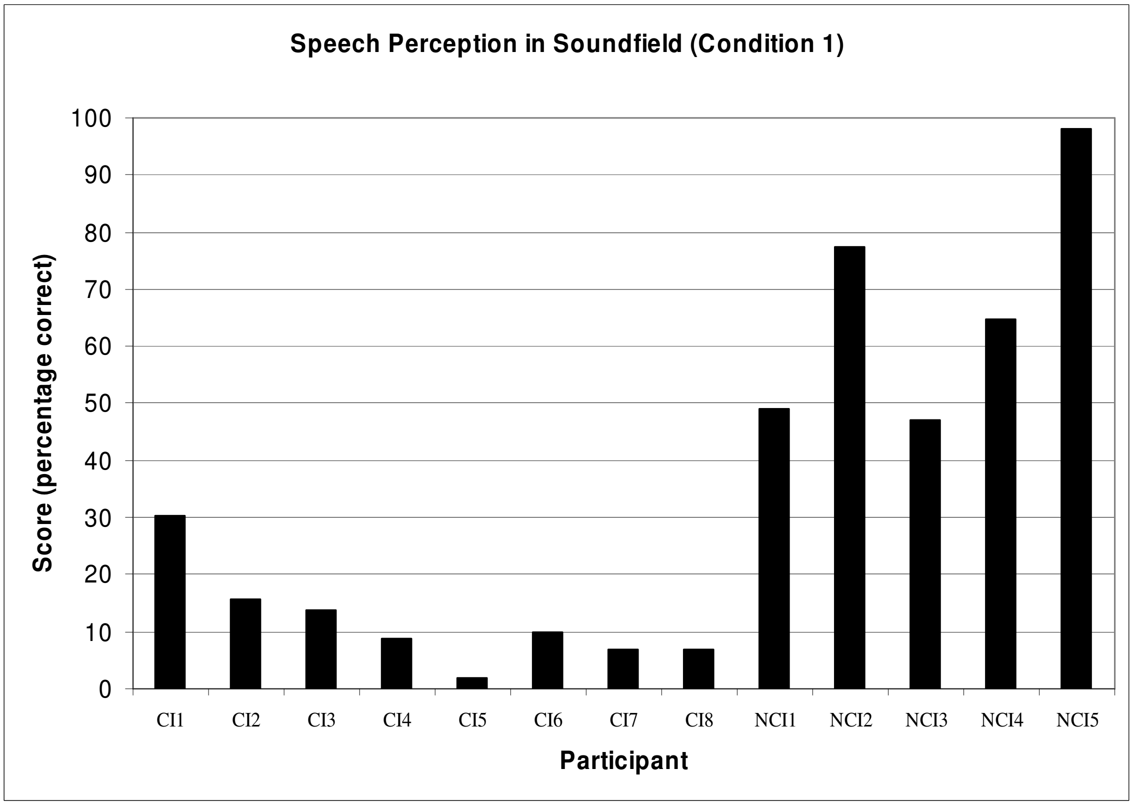


Figure 4: Speech perception scores (in percentage correct) for Condition 1. The individual results for cochlear implant candidates (CI) and non-candidates (NCI) are shown.

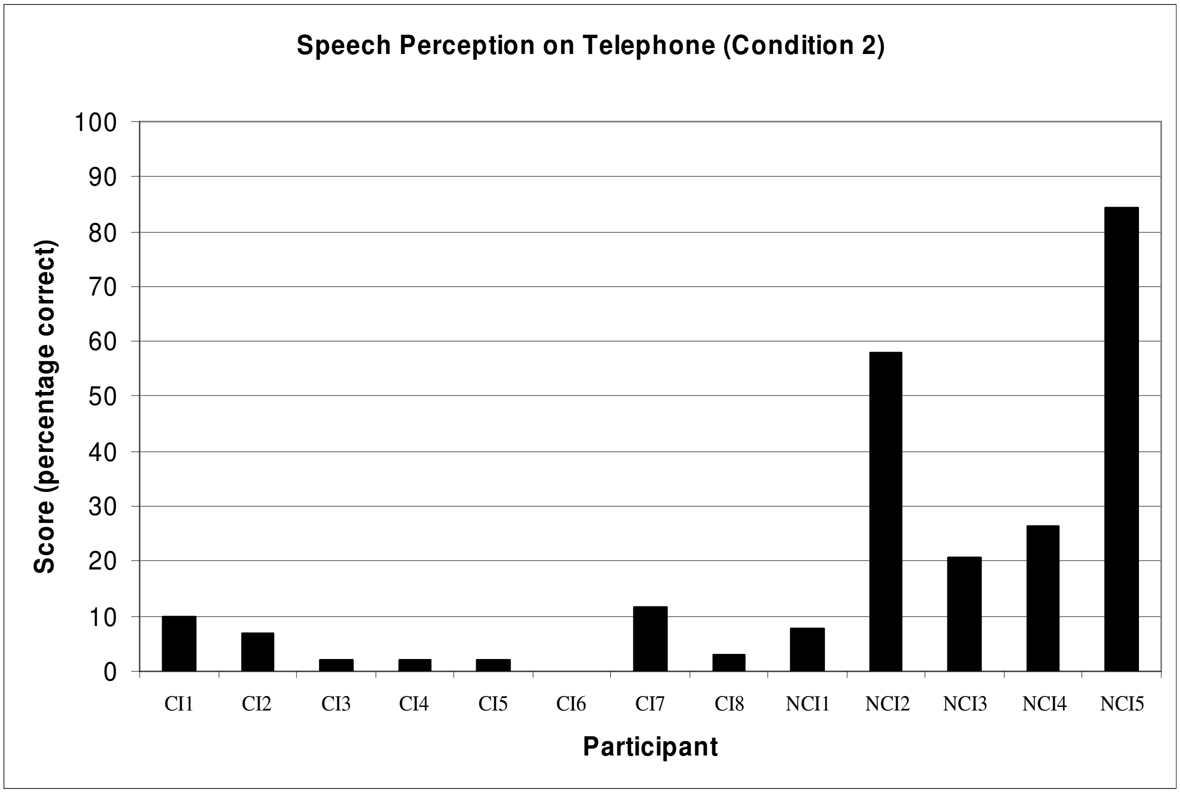


Figure 5: Speech perception scores (in percentage correct) for Condition 2. The individual results for cochlear implant candidates (CI) and non-candidates (NCI) are shown.

Condition 3: CI vs NCI. The results for the 13 participants in Condition 3 are displayed on Tables 3 and 4, and Figure 6. The scores for the CI participants ranged from 0 to 34 words correct (out of 102) with a mean of 8.21. The scores for the NCI participants ranged from 20 to 98 words correct (out of 102) with a mean of 60.4. Due to the lack of homogeneity variance between the two groups, a Mann-Whitney Rank Sum test was performed to determine whether speech perception on a simulated telephone frequency response differed between CI candidates and non-candidates. The test was significant [$T(11) = 53$, $p<0.01$], indicating there was a difference in speech perception via the filtered telephone between the CI and NCI groups. The results indicate that the NCI group perceived a significantly greater number of words in the filtered telephone condition than the CI group.

Comparison of Conditions within Groups

CI Candidates. An analysis of variance test (ANOVA) was performed to determine whether speech perception differed between the three conditions for the CI group. No significant difference was found among the means [$F(2,14) = 3.0.7$, $p=.078$], indicating that the CI group perceived speech no better in the soundfield than on the telephone conditions.

Non-Candidates. An ANOVA was performed to determine whether speech perception differed between the three conditions for the NCI group. A significant difference was found among the means [$F(2,14) = 11.89$, $p=<.005$]. Post-hoc Tukey tests were then performed to identify the source of the significant difference. The alpha level was adjusted to account for multiple *t*-test comparisons (Schiavetti & Metz, 2000). Results indicated there were significantly more words perceived correctly on Condition 1 than Condition 2 ($q=6.70$, $p<.005$) and on Condition 3 than

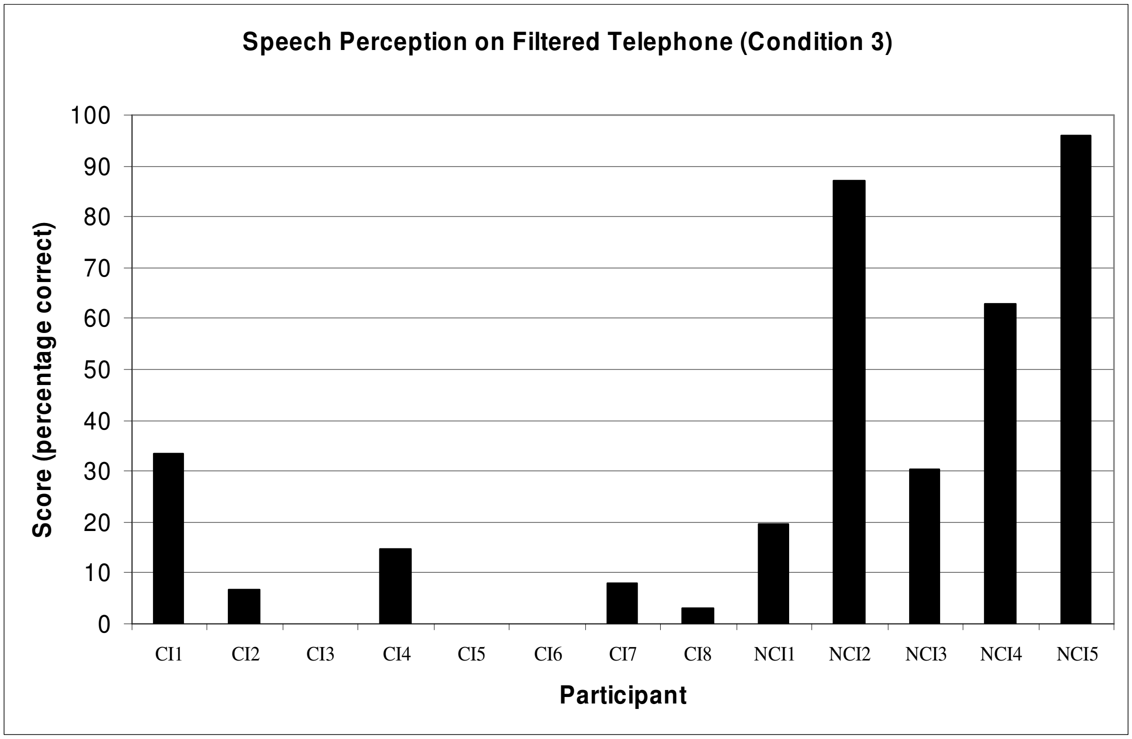


Figure 6: Speech perception scores (in percentage correct) for Condition 3. The individual results for cochlear implant candidates (CI) and non-candidates (NCI) are shown.

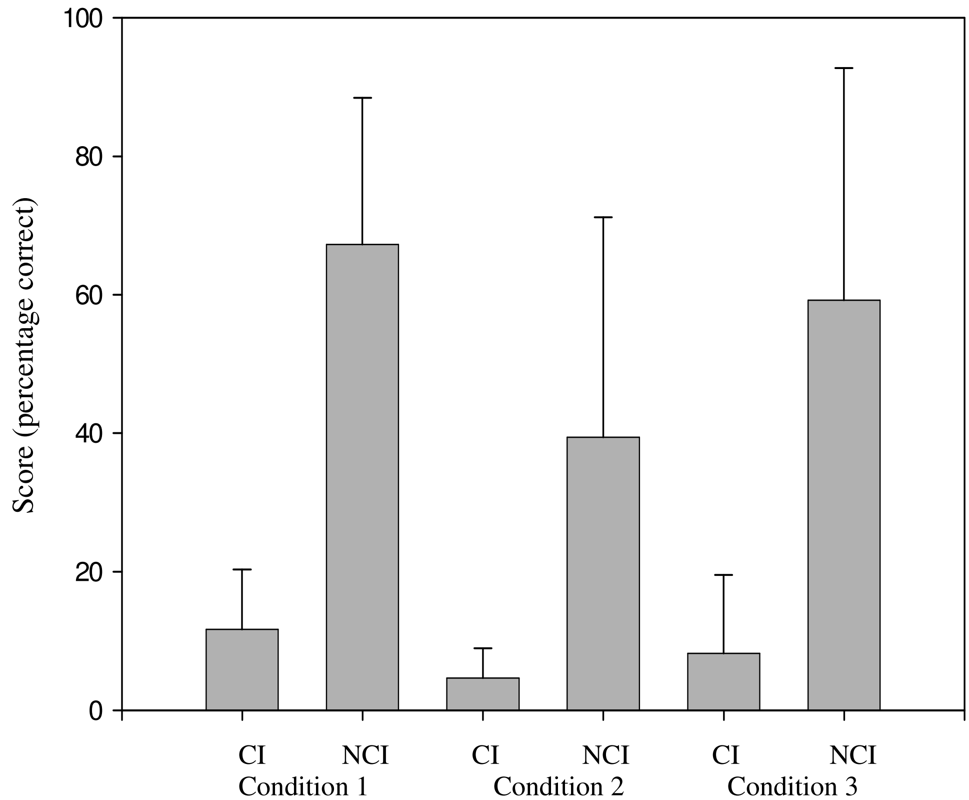


Figure 7: Mean speech perception scores for Conditions 1-3, comparing the cochlear implant candidate group (CI) and non-candidate group (NCI).

Condition 2 (q=20.20, $p<.05$). There was no significant difference between the number of words perceived correctly between Condition 1 and Condition 3.

Group Correlation across Conditions

To determine whether a relationship existed between the results for Condition 1 and the results for Conditions 2 and 3, a series of Pearson product-moment correlations were performed. Among the CI group, the correlation between Condition 1 and Condition 2 was not significant (r = 0.44; p=0.26). The correlation between Condition 1 and Condition 3 was significant (r = 0.80; p=0.01), indicating that as scores for unfiltered aided speech perception in a soundfield increased, so too did scores on the filtered telephone condition. Among the NCI group, the correlation between Condition 1 and Condition 2 was significant (r = 0.96; $p<.05$). In addition, the correlation between Condition 1 and Condition 3 was significant (r = 0.94; $p<.05$). The significant correlation between Condition 1 and the two telephone conditions would indicate that for the NCI group, increases in scores for unfiltered aided speech perception in a soundfield correspond with an increase in speech perception scores on both telephone conditions. The group correlations among the various conditions are displayed in Figure 8 for the CI group, and Figure 9 for the NCI group.

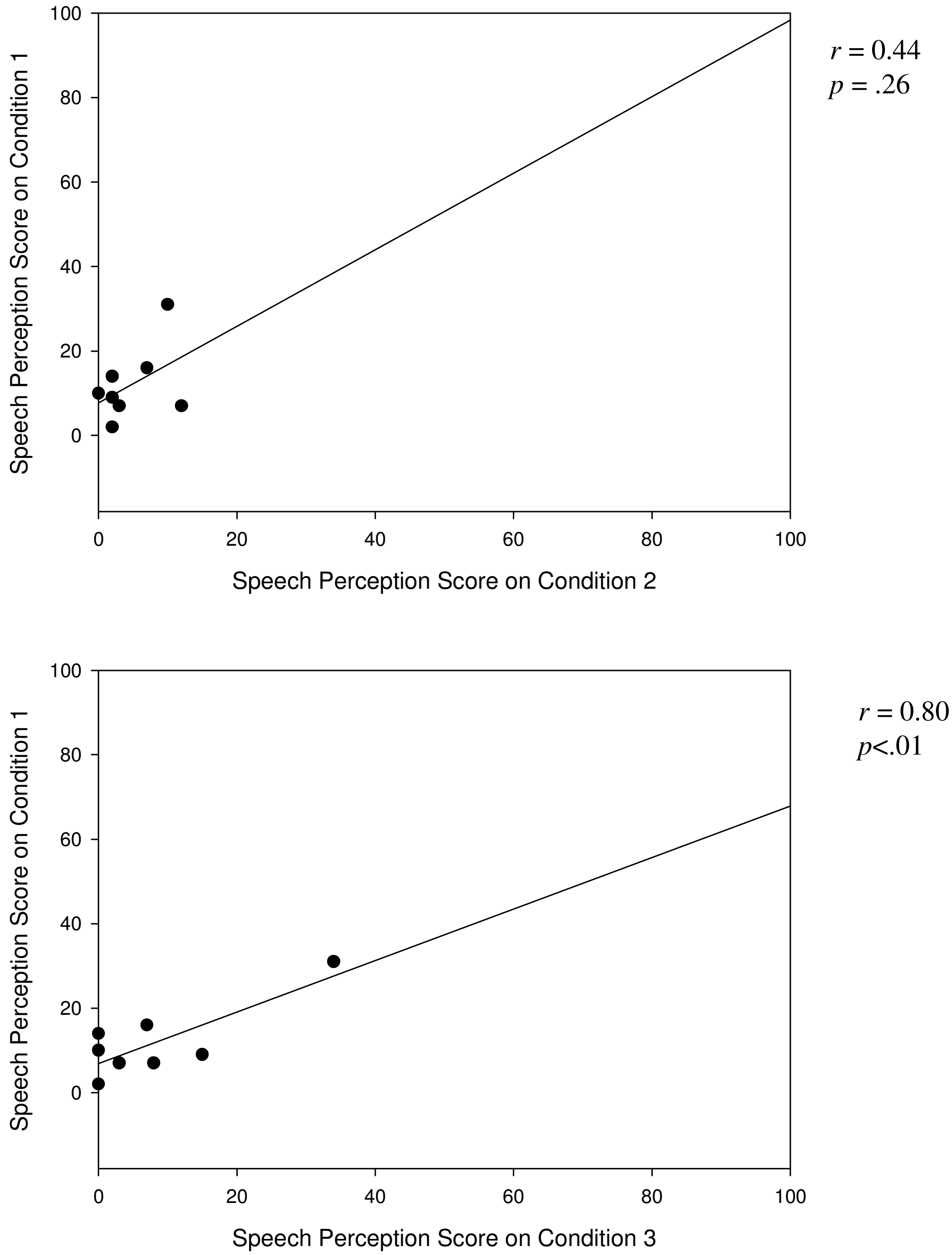
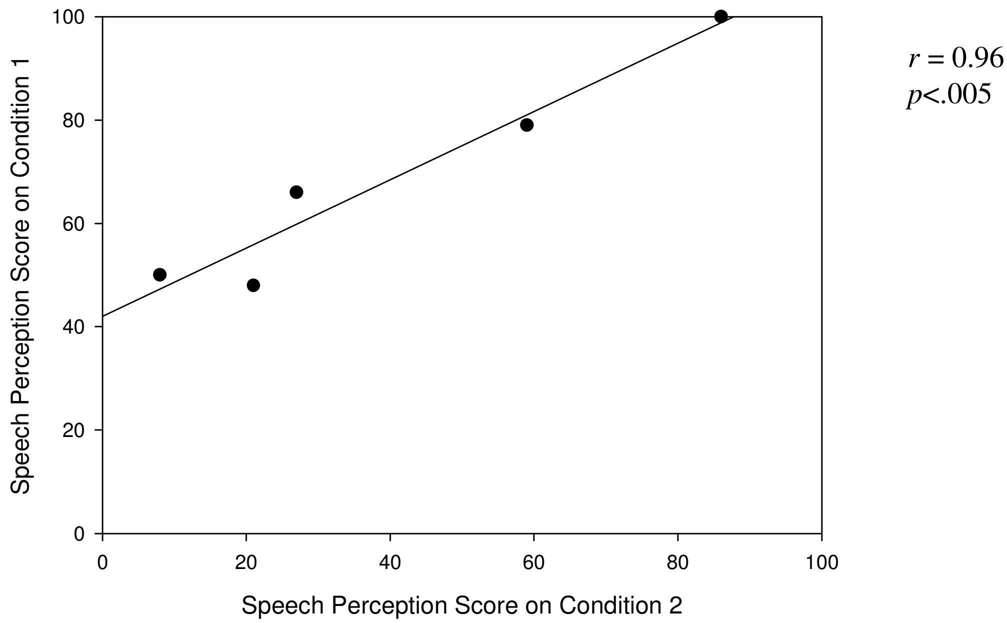


Figure 8: The relationship between speech perception scores on Condition 1 and Condition 2, and between Condition 1 and Condition 3 for each participant in the cochlear implant candidate (CI) group. A line of best fit is superimposed on the data. The corresponding correlation coefficient (*r*) is reported.



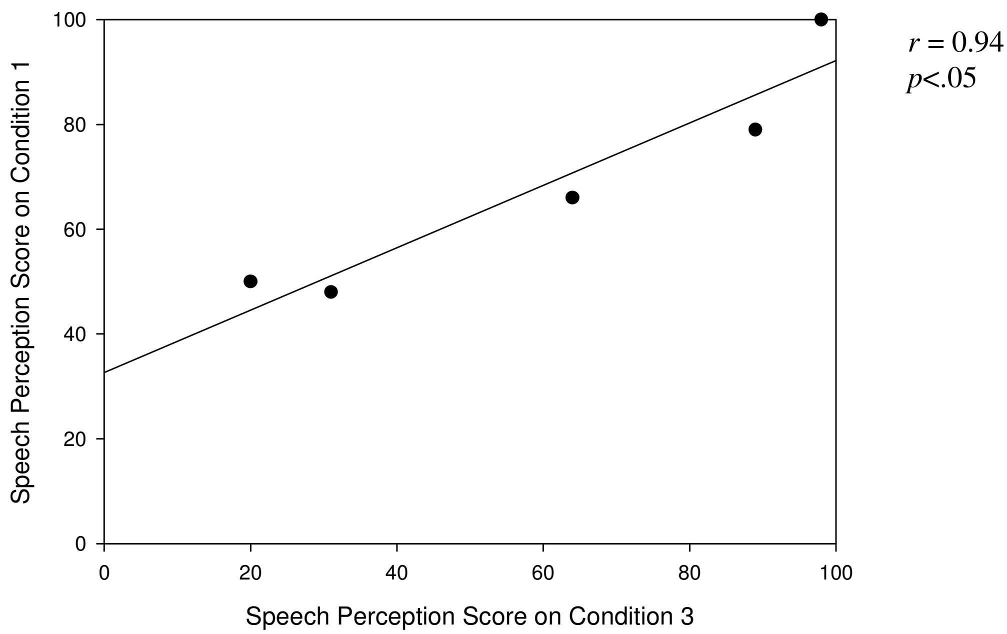


Figure 9: The relationship between speech perception scores on Condition 1 and Condition 2, and between Condition 1 and Condition 3 for each participant in the cochlear implant non-candidate (NCI) group. A line of best fit is superimposed on the data. The corresponding correlation coefficient (*r*) is reported.

Telephone Questionnaire

All questionnaires provided to the CI and NCI participants were returned to the researcher. Among the entire group of participants, ten were completed at the time of the speech perception testing. The remaining three participants completed the questionnaire within one week of the speech perception testing. One of the questionnaires (CI7) had a number of unanswered questions; however, it was still included in the overall evaluation of self reported telephone use. The questions were separated into five themes; (1) understanding a signal on the telephone, (2) initiating telephone calls, (3) receiving telephone calls, (4) sound quality over the telephone and (5) quality of life issues. A list of questions allocated to each theme can be found in Appendix 5. The responses are summarised as below according to each theme.

Theme 1: Understanding a Signal on the Telephone

This theme involved 16 questions relating to various aspects of understanding a signal on the telephone. Responses for Theme 1 are found in Table 5 for the CI group and in Table 6 for the NCI group. The similarities that were identified between the CI and NCI groups are described as follows: All of the CI and NCI participants were reportedly able to recognise a dial tone on the telephone and most were able to recognise a busy signal. All participants were able to tell the difference between an environmental sound and a voice. Approximately two thirds of the CI and NCI groups reported to be uncomfortable with their ability to converse with strangers. Both CI and NCI groups showed similar difficulty in understanding stranger's voices, regardless of whether the topic was familiar or not. A similar number of CI and NCI respondents indicated that they had to finish telephone conversations simply due to their inability to hear. The primary differences that were identified between the CI and

NCI groups were as follows: Only half of the CI group were able to tell if the caller was a man, women or a child. In comparison, all of the NCI group could differentiate between these callers. Less than half of the CI group participated in more than a yes-no conversation, while all of the NCI group were capable to do this. Only half of the CI group could understand a familiar voice talking on a familiar topic while the entire NCI group responded that they could do so either all or most of the time. The CI group had more difficulty hearing male voices while the NCI group had more difficulty hearing female voices.

Scoring for Theme 1:

In order to summarise and quantify the results obtained for Theme 1, responses to each of the 16 questions were assigned a score. A high score was indicative of ability to understand a signal on the telephone. Scores for each of the 16 questions were summed and are shown in Table 7. The mean scores for the CI and NCI groups are depicted in Figure 10. In general, the CI group presented with lower scores compared to the NCI group. The scores for the CI participants ranged from 3 to 21 with a mean score of 11.63. The scores for the NCI participants ranged from 13 to 22 with a mean score of 15.40. A *t*-test was performed to determine whether self-reported understanding a signal on the telephone differed between the CI and NCI groups. The *t*-test was not significant [$t(11) = -1.30$, $p=0.22$], indicating that the was no significant difference in self-reported “understanding a signal on the telephone” between CI and NCI participants.

Table 5: Responses of cochlear implant candidate (CI) participants to each question in Theme 1: Understanding a Signal on the Telephone. Scores are presented according to the percentage of CI participants responses.

Q16	On the telephone, can you recognize a Dial tone?	Yes 100%	No 0%	
Q17	On the telephone, can you recognize a Busy signal?	Yes 86%	No 14%	
Q18	On the telephone, can you recognize a Voice?	Yes 57%	No 14%%	Sometimes 29%%
Q20	Do you feel comfortable with your ability to converse with strangers on the telephone?	Yes, most of the time 12.5%	Yes, some of the time 12.5%	No 75%
Q23	Can you tell the difference between a human voice and an environmental sound on the telephone?	Yes, most of the time 37.5%	Yes, some of the time 62.5%	No 0%
Q24	Can you tell if the other caller on the telephone is a man, woman, or child?	Yes, most of the time 12.5%	Yes, some of the time 50%	No 37.5%
Q25	Can you recognize familiar voices on the telephone?	Yes, most of the time 12.5%	Yes, some of the time 62.5%	No 25%
Q27	Can you participate in more than a "yes" – "no" conversation on the telephone?	Yes, most of the time 14%	Yes, some of the time 29%	No 57%
Q28	Can you understand a familiar caller on the telephone if the topic of the call is familiar?	Yes, most of the time 29%	Yes, some of the time 42%	No 29%
Q29	Can you understand a familiar caller on the telephone if the topic of the call is unfamiliar?	Yes, most of the time 0%	Yes, some of the time 37.5%	No 62.5%
Q30	Can you understand a stranger on the telephone if the topic is familiar?	Yes, most of the time 0%	Yes, some of the time 37.5%	No 62.5%
Q31	Can you understand a stranger on the telephone if the topic is unfamiliar?	Yes, most of the time 0%	Yes, some of the time 12.5%	No 87.5%
Q38	In general, how much difficulty do you have hearing females over the telephone?	Great difficulty 29%	Some difficulty 71%	No difficulty 0%
Q39	In general, how much difficulty do you have hearing males over the telephone?	Great difficulty 43%	Some difficulty 57%	No difficulty 0%
Q40	How often do you have to end a telephone call before the conversation is complete, specifically because you had difficulty hearing?	Most of the time 29%	Some of the time 42%	Never 29%
Q51	During an average telephone conversation, how often do you have to ask for the speaker to repeat themselves, or ask for clarification of what they said?	Most of the time 71%	Some of the time 29%	Never 0%

Table 6: Responses of cochlear implant non-candidate (NCI) participants to each question in Theme 1: Understanding a Signal on the Telephone. Scores are presented according to the percentage of NCI participants responses.

Q16	On the telephone, can you recognize a Dial tone?	Yes 100%	No 0%	
Q17	On the telephone, can you recognize a Busy signal?	Yes 100%	No 0%	
Q18	On the telephone, can you recognize a Voice?	Yes 40%	No 0%	Sometimes 60%
Q20	Do you feel comfortable with your ability to converse with strangers on the telephone?	Yes, most of the time 20%	Yes, some of the time 20%	No 60%
Q23	Can you tell the difference between a human voice and an environmental sound on the telephone?	Yes, most of the time 40%	Yes, some of the time 60%	No 0%
Q24	Can you tell if the other caller on the telephone is a man, woman, or child?	Yes, most of the time 60%	Yes, some of the time 40%	No 0%
Q25	Can you recognize familiar voices on the telephone?	Yes, most of the time 20%	Yes, some of the time 80%	No 0%
Q27	Can you participate in more than a "yes" – "no" conversation on the telephone?	Yes, most of the time 40%	Yes, some of the time 60%	No 0%
Q28	Can you understand a familiar caller on the telephone if the topic of the call is familiar?	Yes, most of the time 60%	Yes, some of the time 40%	No 0%
Q29	Can you understand a familiar caller on the telephone if the topic of the call is unfamiliar?	Yes, most of the time 20%	Yes, some of the time 40%	No 40%
Q30	Can you understand a stranger on the telephone if the topic is familiar?	Yes, most of the time 20%	Yes, some of the time 40%	No 40%
Q31	Can you understand a stranger on the telephone if the topic is unfamiliar?	Yes, most of the time 0%	Yes, some of the time 40%	No 60%
Q38	In general, how much difficulty do you have hearing females over the telephone?	Great difficulty 60%	Some difficulty 20%	No difficulty 20%
Q39	In general, how much difficulty do you have hearing males over the telephone?	Great difficulty 20%	Some difficulty 80%	No difficulty 0%
Q40	How often do you have to end a telephone call before the conversation is complete, specifically because you had difficulty hearing?	Most of the time 0%	Some of the time 60%	Never 40%
Q51	During an average telephone conversation, how often do you have to ask for the speaker to repeat themselves, or ask for clarification of what they said?	Most of the time 60%	Some of the time 40%	Never 0%

Table 7: Scoring for questions relating to Theme 1: Understanding a Signal on the Telephone. The scores for each cochlear implant candidate (CI) and non-candidate (NCI) are listed.

Question	**CI1**	**CI2**	**CI3**	**CI4**	**CI5**	**CI6**	**CI7**	**CI8**	**NCI1**	**NCI2**	**NCI3**	**NCI4**	**NCI5**
16	1	1	1	1	1	1	1	0	1	1	1	1	0
17	1	1	1	1	1	1	0	1	1	1	1	1	1
18	2	2	0	0	1	2	0	1	2	1	1	0	1
20	1	0	2	0	0	0	0	0	0	2	1	0	0
23	2	1	1	2	2	1	1	1	2	2	1	1	1
24	2	0	1	1	1	0	0	2	2	2	1	1	2
25	2	0	1	1	1	0	1	1	1	2	1	1	1
27	2	1	0	0	1	0	0	2	1	2	1	1	2
28	2	2	1	1	1	0	0	2	1	2	1	2	2
29	1	0	1	0	1	0	0	1	0	2	0	1	1
30	1	0	1	0	1	0	0	1	0	2	0	1	1
31	1	0	0	0	0	0	0	0	0	1	0	1	0
38	1	1	1	1	1	2	0	0	1	0	2	0	0
39	1	2	1	2	1	2	0	1	2	1	1	1	1
40	1	1	0	2	1	0	0	1	0	1	0	1	1
51	0	1	0	0	0	1	0	1	0	0	1	0	1
Total	**21**	**13**	**12**	**12**	**14**	**10**	**3**	**15**	**14**	**22**	**13**	**13**	**15**

	Mean	**Std Dev**
CI	**11.63**	**5.15**
NCI	**15.40**	**3.78**

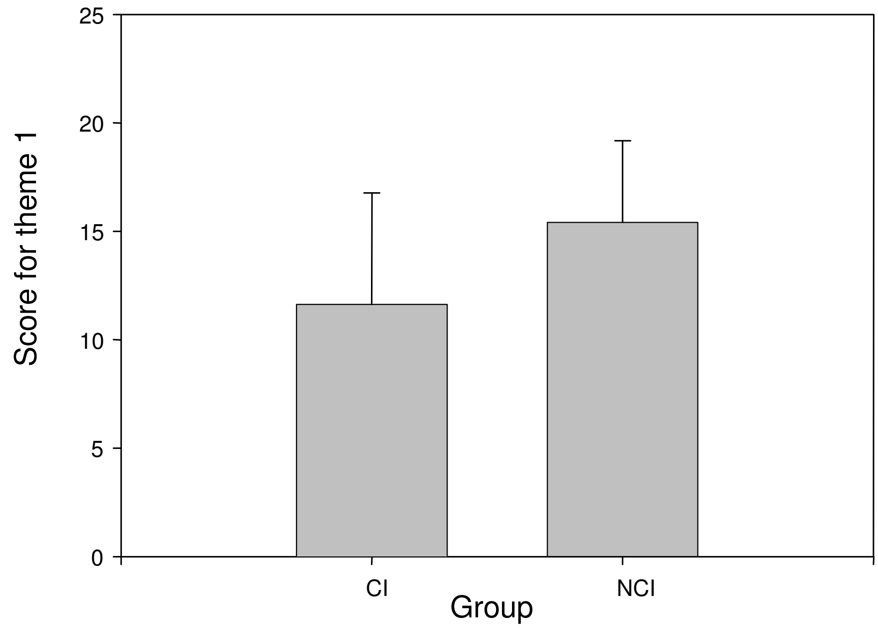


Figure 10: Mean scores for cochlear implant candidate (CI) and non-candidate (NCI) groups for Theme 1: Understanding a Signal on the Telephone. A high score is equated with similarly high understanding of a signal on the telephone.

Theme 2: Initiating Telephone Calls

This theme involved eight questions related to various aspects of initiating a telephone call. Responses for Theme 2 are found in Table 8 for the CI group and in Table 9 for the NCI group. The similarities that were identified between the CI and NCI groups were as follows: All participants reported to make less than 5 telephone calls per day. In general, most of the CI and NCI groups reported not to use the telephone to make appointments or to conduct business. All of the CI group and most of the NCI group indicated that their hearing loss discouraged them from using the telephone. The primary differences that were identified between the CI and NCI groups were as follows: The NCI group reported to initiate telephone calls more often than the CI group. Most of the NCI group reported to call family and friends, compared with less than half of the CI group. The entire CI group reported that they would not initiate a telephone call to ask for information about a product or service, whereas more than half the NCI group did so.

Scoring for Theme 2:

In order to summarise and quantify the results obtained for Theme 2, responses to each of the eight questions were assigned a score. A high score was indicative of ability and likelihood to initiate telephone calls. Scores for each of the eight questions were summed and are shown on Table 10. The mean scores for the CI and NCI groups are depicted in Figure 11. The scores for the CI participants ranged from 0 to 9 with a mean score of 2.5. The scores for the NCI participants ranged from 1 to 10 with a mean score of 5.4. A *t*-test was performed to determine whether self-reported understanding a signal on the telephone differed between the CI and NCI groups. Although the scores for the NCI were generally higher than the CI group, the

Table 8: Responses of cochlear implant candidates (CI) to each question in Theme 2.

Responses are presented according to the percentage of CI participants responses.

Q10	Do you initiate telephone calls?	Yes, most of the time 0%	Yes, some of the time 37.5%	No 62.5%
Q12	Do you initiate telephone calls to Friends or family?	Yes 37.5%	No 62.5%	
Q13	Do you initiate telephone calls to make appointments?	Yes 25%	No 75%	
Q14	Do you initiate telephone calls to ask for information about a product or service?	Yes 0%	No 100%	
Q15	Do you initiate telephone calls to conduct business?	Yes 12.5%	No 87.5%	
Q41	How many outgoing telephone calls per day do you place on average?	Less than 3 86%	3 to 5 14%	6 to 10 0%
Q43	Does your hearing impairment sometimes discourage you from using the telephone?	Yes 100%	No 0%	
Q44	If you use a cellular/mobile phone, which do you prefer to talk on?	Mobile 29%	Landline / Only use landline 29% / 42%	Both are the same to talk on 0%
Q48	Do you feel comfortable ringing someone on the telephone to ask for information about a product or service?	Yes, most of the time 14%	Yes, some of the time 0%	No 86%

Table 9: Responses of cochlear implant non-candidates (NCI) to each question in Theme 2. Responses are presented according to the percentage of NCI participants responses.

Q10	Do you initiate telephone calls?	Yes, most of the time 20%	Yes, some of the time 60%	No 20%
Q12	Do you initiate telephone calls to Friends or family?	Yes 80%	No 20%	
Q13	Do you initiate telephone calls to make appointments?	Yes 40%	No 60%	
Q14	Do you initiate telephone calls to ask for information about a product or service?	Yes 40%	No 60%	
Q15	Do you initiate telephone calls to conduct business?	Yes 40%	No 60%	
Q41	How many outgoing telephone calls per day do you place on average?	Less than 3 80%	3 to 5 20%	6 to 10 0%
Q43	Does your hearing impairment sometimes discourage you from using the telephone?	Yes 80%	No 20%	
Q44	If you use a cellular/mobile phone, which do you prefer to talk on?	Mobile 0%	Landline / Only use landline 60% / 20%	Both are the same to talk on 20%
Q48	Do you feel comfortable ringing someone on the telephone to ask for information about a product or service?	Yes, most of the time 20%	Yes, some of the time 20%	No 60%

Table 10: Scoring for questions relating to Theme 2: Initiating Telephone Calls. The scores for each cochlear implant candidate (CI) and non-candidate (NCI) are listed.

Question	**CI1**	**CI2**	**CI3**	**CI4**	**CI5**	**CI6**	**CI7**	**CI8**	**NCI1**	**NCI2**	**NCI3**	**NCI4**	**NCI5**
10	1	0	1	2	1	0	1	0	0	1	2	1	0
12	1	0	1	1	1	0	0	0	0	1	1	1	0
13	1	0	0	1	0	0	0	0	0	0	1	0	0
14	0	0	0	1	1	0	0	0	0	0	1	1	0
15	2	0	0	2	2	0	0	0	0	0	2	2	0
41	2	1	1	1	2	1	1	0	1	1	1	2	1
43	0	0	0	0	1	0	0	0	0	0	0	1	0
48	2	0	0	2	1	0	0	0	0	0	2	1	0
Total	**9**	**1**	**3**	**10**	**9**	**1**	**2**	**0**	**1**	**3**	**10**	**9**	**1**

	Mean	**Std Dev**
CI	**2.50**	**2.88**
NCI	**5.40**	**3.91**

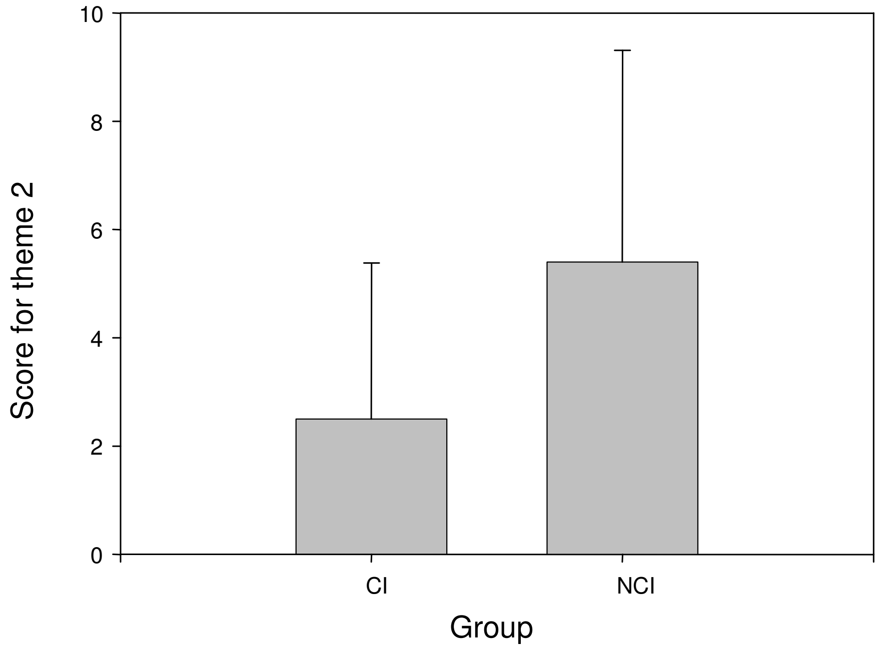


Figure 11: Mean scores for cochlear implant candidate (CI) and non-candidate (NCI) groups for Theme 2: Initiating Telephone Calls. A high score is equated with similarly high initiation of telephone calls.

test was not significant [$t(11) = -0.17$, $p=.85$], indicating no statistical difference in self-reported “initiating telephone calls” between the groups.

Theme 3: Receiving Telephone calls

This theme involved four questions related to various aspects of receiving telephone calls. Responses for Theme 3 are found in Table 11 for the CI group and in Table 12 for the NCI group. Similarities identified between the CI and NCI groups included both groups reporting to receive less than 3 telephone calls per day. In addition, over half of the CI and NCI groups reported they were not comfortable answering the telephone, unexpectedly. One difference identified between the CI and NCI groups was that only a quarter of the CI group reported answering the telephone, compared with the entire NCI group.

Scoring for Theme 3:

In order to summarise and quantify the results obtained for Theme 3, responses to each of the four questions were assigned a score. A high score was indicative of ability to receive telephone calls. Scores for each of the four questions are summarised in Table 13. The mean scores for the CI and NCI groups are depicted in Figure 12. The scores for the CI participants ranged from 0 to 4 with a mean score of 1.75. The scores were generally lower compared to the NCI group. The scores for the NCI participants ranged from 1 to 7 with a mean score of 3.60. A *t*-test was performed to determine whether self-reported understanding a signal on the telephone differed between the CI and NCI groups. The test was not significant [$t(11) = -1.73$, $p=0.11$], indicating no statistical difference in self-reported “receiving telephone calls” between the two groups.

Table 11: Responses of cochlear implant candidates (CI) to each question in Theme 3. Responses are presented according to the percentage of CI participants responses.

Q11	Do you answer the telephone?	Yes, most of the time 0%	Yes, some of the time 25%	No 75%
Q42	How many incoming telephone calls per day do you receive on average?	Less than 3 72%	3 to 5 14%	6 to 10 14%
Q43	Does your hearing impairment sometimes discourage you from using the telephone?	Yes 100%	No 0%	
Q49	Do you feel comfortable answering the phone if you are not expecting a call from someone?	Yes, most of the time 14%	Yes, some of the time 14%	No 72%

Table 12: Responses of cochlear implant non-candidates (NCI) to each question in Theme 3. Responses are presented according to the percentage of NCI participants responses.

Q11	Do you answer the telephone?	Yes, most of the time 40%	Yes, some of the time 60%	No 0%
Q42	How many incoming telephone calls per day do you receive on average?	Less than 3 80%	3 to 5 20%	6 to 10 0%
Q43	Does your hearing impairment sometimes discourage you from using the telephone?	Yes, most of the time 80%	No 20%	
Q49	Do you feel comfortable answering the phone if you are not expecting a call from someone?	Yes, most of the time 20%	Yes, some of the time 20%	No 60%

Table 13: Scoring for to questions relating to Theme 3: Receiving Telephone Calls. The scores for each cochlear implant candidate (CI) and non-candidate (NCI) are listed.

Question	**CI1**	**CI2**	**CI3**	**CI4**	**CI5**	**CI6**	**CI7**	**CI8**	**NCI1**	**NCI2**	**NCI3**	**NCI4**	**NCI5**
11	1	0	0	0	1	0	0	0	1	2	2	0	0
42	2	1	3	1	1	1	0	3	1	1	3	3	1
43	0	0	0	0	0	0	0	0	0	0	1	0	0
49	0	0	0	0	2	1	0	0	0	2	1	0	0
Total	**3**	**1**	**3**	**1**	**4**	**2**	**0**	**0**	**2**	**5**	**7**	**3**	**1**

	Mean	**Std Dev**
CI	1.75	1.49
NCI	3.60	2.41

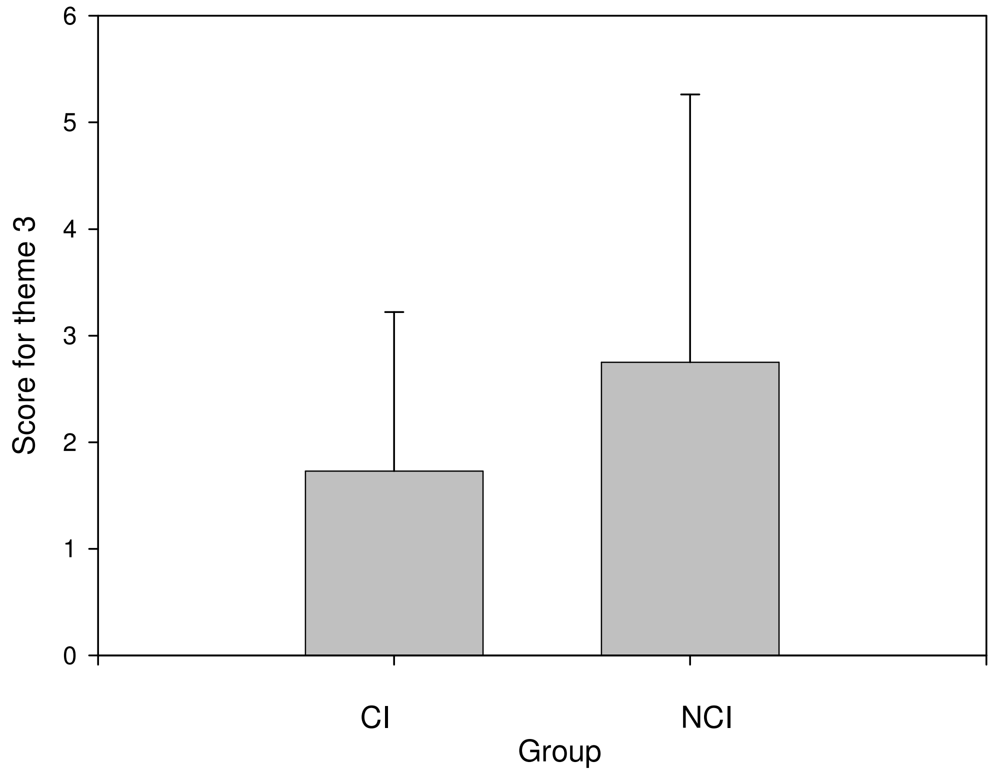


Figure 12: Mean scores for cochlear implant candidate (CI) and non-candidate (NCI) groups for Theme 3: Receiving Telephone Calls. A high score is equated with similarly high likelihood of answering telephone calls.

Theme 4: Sound Quality on the Telephone

This theme involved four questions related to aspects of sound quality on the telephone. Due to the qualitative descriptive nature of the questions, the responses were not scored in accordance with the subsequent themes. Responses for Theme 4 are found in Table 14 for the CI group and in Table 15 for the NCI group. Similarities identified between the CI and NCI groups included both groups feeling that speech over the telephone was the correct volume, and sometimes clear. None of the CI and NCI participants reported speech to be always clear. In addition, less than half of the CI and NCI participants reported speech over the telephone to be understandable. The major differences identified between the CI and NCI groups was that a greater percentage of the CI group felt that the sound on the telephone was much poorer compared with listening to someone in the same room, (without lipreading).

Theme 5: Quality of Life Issues

This theme involved two questions related to aspects of quality of life. Responses for Theme 5 are found in Table 16 for the CI group and in Table 17 for the NCI group. Both CI and NCI groups reported similarly that their inability to use the telephone affected their social life. When asked if they felt their life would be improved if they could use the telephone, over two thirds of CI and NCI reported yes, most of the time.

Scoring for Theme 5:

In order to summarise and quantify the results obtained for Theme 5, responses to each question were assigned a score. A high score was indicative of a reported high quality of life. The mean scores for the CI and NCI groups are listed in Table 18 and depicted in Figure 13. The scores for the CI participants ranged from 0 to 4 with a mean score of 2. The scores for the NCI participants ranged from 2 to 4 with a mean score of 2.80. A *t*-test was performed to determine whether self-reported quality of life differed between the CI and NCI groups. The test was not significant [$t(11) = -1.15$, $p=0.27$].

Overall Score for Questionnaire

The overall scores from each of the themes are shown on Table 19 and Figure 14. The scores for the CI participants ranged from 5 to 35 with a mean score of 19.62. The scores for the NCI participants ranged from 19 to 31 with a mean score of 25.4. A *t*-test was performed to determine whether self-reported telephone ability differed between the CI and NCI groups. Although there was a general pattern of lower scores among the CI group, the resulting test was not significant [$t(11) = -1.21$, $p=0.24$].

Table 14. Responses of cochlear implant candidates (CI) to each question in Theme 4.

Responses are presented according to the percentage of CI participants responses

Q33	Describe the quality of sound from a telephone compared to listening to someone in the same room without lipreading.	The sound is about the same 12.5%	The sound is a little poorer 12.5%	The sound is much poorer 75%				
Q34	Descriptions of sound quality over the telephone: (choose all that apply)	Clear 5%	Under-standable 16%	Far away 25%	Tinny 16%	Echo 11%	Fuzzy 11%	Other distortions 16%
Q36	Generally, I feel that speech over the telephone is:	Too soft 50%	Correct volume 50%	Too loud 0%				
Q37	Generally, I feel that speech over the telephone is:	Always clear 0%	Sometimes clear 71%	Never clear 29%				

Table 15. Responses of cochlear implant non-candidates (NCI) to each question in Theme 4. Responses are presented according to the percentage of NCI participants responses.

<table>
<tr><td>Q33</td><td>Describe the quality of sound from a telephone compared to listening to someone in the same room without lipreading.</td><td colspan="3">The sound is about the same
0%</td><td colspan="2">The sound is a little poorer
60%</td><td colspan="2">The sound is much poorer
40%</td></tr>
<tr><td>Q34</td><td>Descriptions of sound quality over the telephone: (choose all that apply)</td><td>Clear
0%</td><td>Under-standable
33%</td><td>Far away
17%</td><td>Tinny
0%</td><td>Echo
17%</td><td>Fuzzy
33%</td><td>Other distortions
0%</td></tr>
<tr><td>Q36</td><td>Generally, I feel that speech over the telephone is:</td><td colspan="3">Too soft
50%</td><td colspan="2">Correct volume
50%</td><td colspan="2">Too loud
0%</td></tr>
<tr><td>Q37</td><td>Generally, I feel that speech over the telephone is:</td><td colspan="3">Always clear
0%</td><td colspan="2">Sometimes clear
80%</td><td colspan="2">Never clear
20%</td></tr>
</table>

Table 16: Responses of cochlear implant candidates (CI) to each question in Theme 5. Responses are presented according to the percentage of CI participants responses.

Q45	Do you feel that your inability to use the telephone affects your social life	Yes, most of the time 33%	Yes, some of the time 33%	No 33%
Q46	Do you feel that your life would be improved if you could use the telephone?	Yes, most of the time 71%	Yes, some of the time 29%	No 0%

Table 17: Responses of cochlear implant non-candidates (NCI) to each question in Theme 5. Responses are presented according to the percentage of NCI participants responses.

Q36	Do you feel that your inability to use the telephone affects your social life	Yes, most of the time 20%	Yes, some of the time 40%	No 40%
Q37	Do you feel that your life would be improved if you could use the telephone?	Yes, most of the time 80%	Yes, some of the time 20%	No 0%

Table 18: Scoring for questions relating to Theme 5: Quality of Life. The scores for each cochlear implant candidate (CI) and non-candidate (NCI) are listed.

Question	**CI1**	**CI2**	**CI3**	**CI4**	**CI5**	**CI6**	**CI7**	**CI8**	**NCI1**	**NCI2**	**NCI3**	**NCI4**	**NCI5**
45	2	0	1	2	1	0	0	0	2	0	1	1	2
46	0	1	0	0	0	1	0	0	0	0	0	2	0
Total	**2**	**1**	**1**	**2**	**1**	**1**	**0**	**0**	**2**	**0**	**1**	**3**	**2**

	Mean	**Std Dev**
CI	**2**	**1.69**
NCI	**2.8**	**0.84**

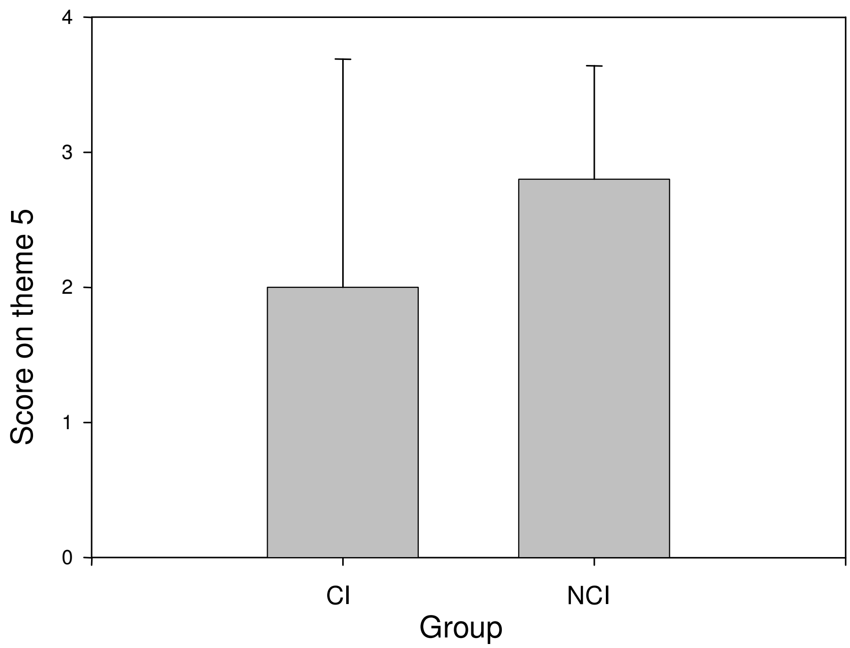


Figure 13: Mean scores for cochlear implant candidate (CI) and non-candidate (NCI) groups for Theme 5: Quality of Life. A high score is equated with similarly high reported quality of life.

Table 19: Scoring for Overall results for Telephone Use Questionnaire. The scores for each Theme for each cochlear implant candidate (CI) and non-candidate (NCI) are listed. In addition, a summed score is listed for each participant.

Theme	Participants												
	CI1	CI2	CI3	CI4	CI5	CI6	CI7	CI8	NCI1	NCI2	NCI3	NCI4	NCI5
Understanding on the telephone	21	13	12	12	14	10	3	15	14	22	13	13	15
Initiating telephone calls	9	1	3	10	9	1	2	0	1	3	10	9	1
Receiving telephone calls	3	1	3	1	4	2	0	0	2	5	7	3	1
Quality of life	2	1	1	2	1	1	0	0	2	0	1	3	2
Total Score:	**35**	**16**	**19**	**25**	**28**	**14**	**5**	**15**	**19**	**30**	**31**	**28**	**19**

	Mean	**Std Dev**
CI	**19.65**	**9.37**
NCI	**25.4**	**5.94**

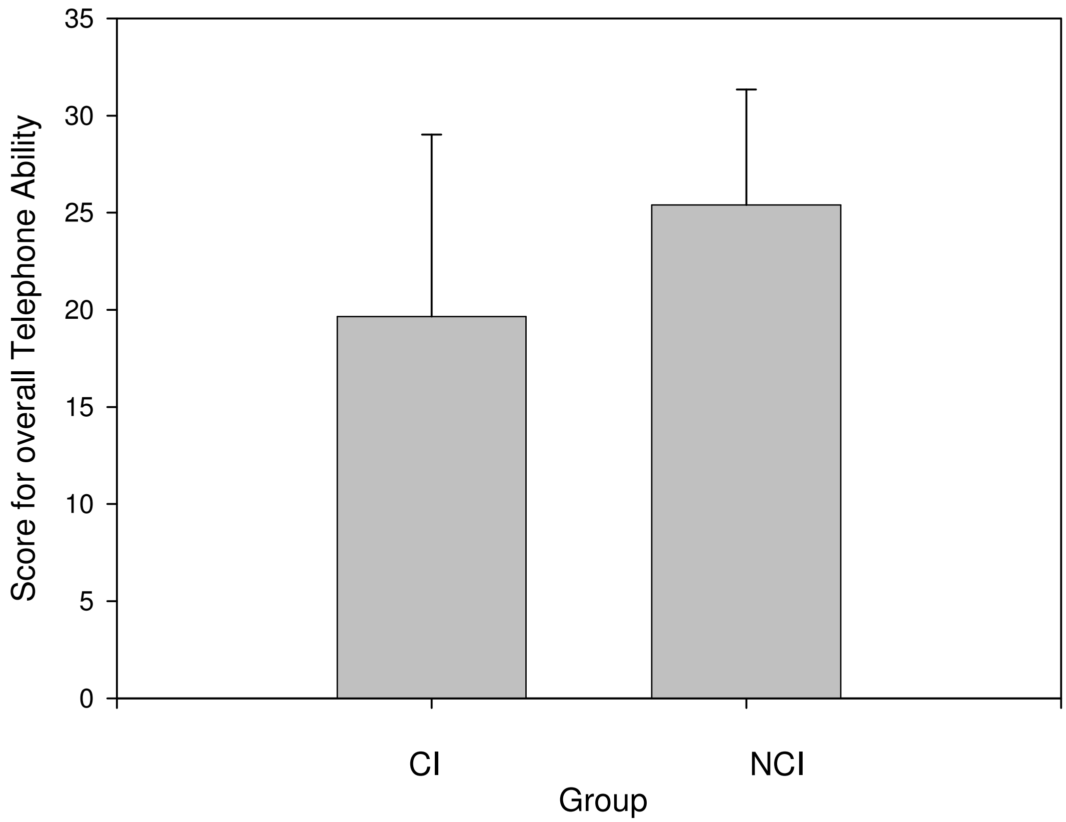
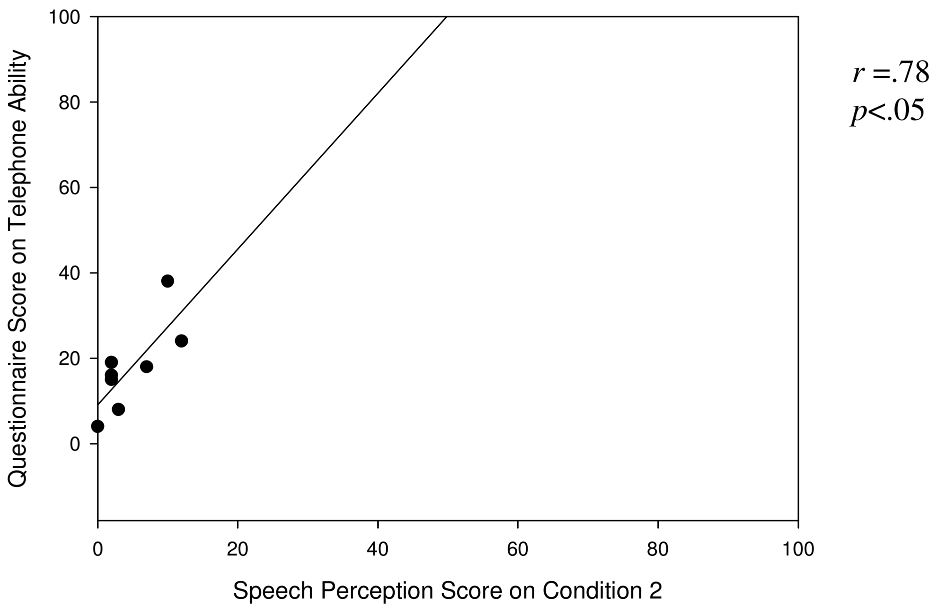


Figure 14: Mean scores for cochlear implant candidate (CI) and non-candidate (NCI) groups for overall Telephone Use and Ability. A high score is equated with similarly high ability to use the telephone.

Relationship between the Speech Perception Tests and Telephone Questionnaire

To determine whether a relationship existed between the results for the telephone questionnaire and the speech perception results for Conditions 2 and 3, a series of Pearson product-moment correlations were performed. Among the CI group, the correlation between the telephone questionnaire and Condition 2 was significant (r = 0.71; p<.05), as was the correlation between the telephone questionnaire and Condition 3 (r = 0.82; p=.01). The significant correlation between the telephone questionnaire and Condition 2 and 3 would indicate that for the CI group, increases in scores on the telephone questionnaire correspond with an increase in speech perception scores on Condition 2 and 3.

Among the NCI group, the correlation between the telephone questionnaire and Condition 2 was not significant (r = -.18; p=0.76), nor was the correlation between the telephone questionnaire and Condition 3 (r =.007; p=.99). The lack of correlations for the NCI group indicated that increased scores on the telephone questionnaire do not correspond with increased speech perception on the telephone. The group correlations among the various conditions are displayed in Figure 15 for the CI group, and Figure 16 for the NCI group.



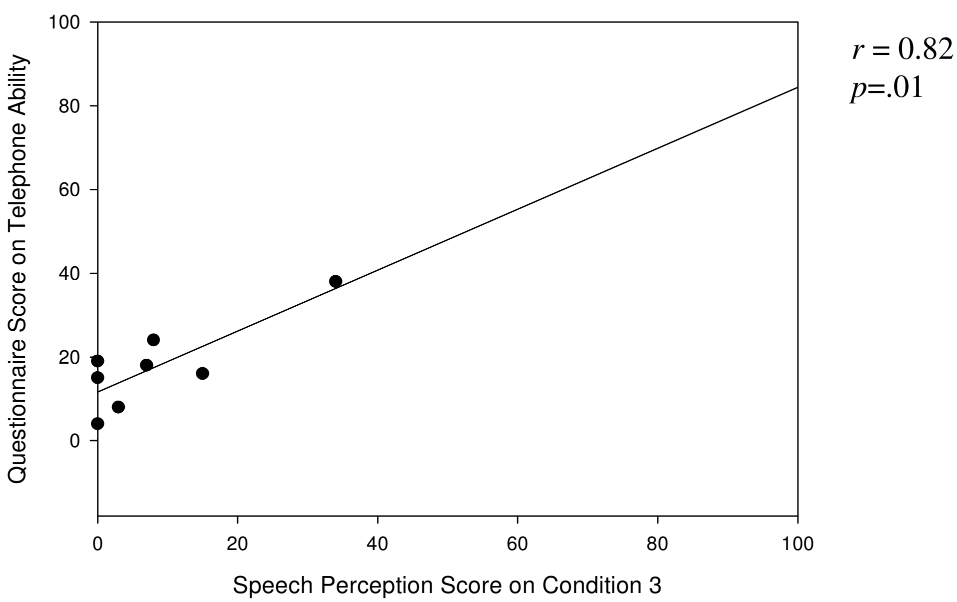
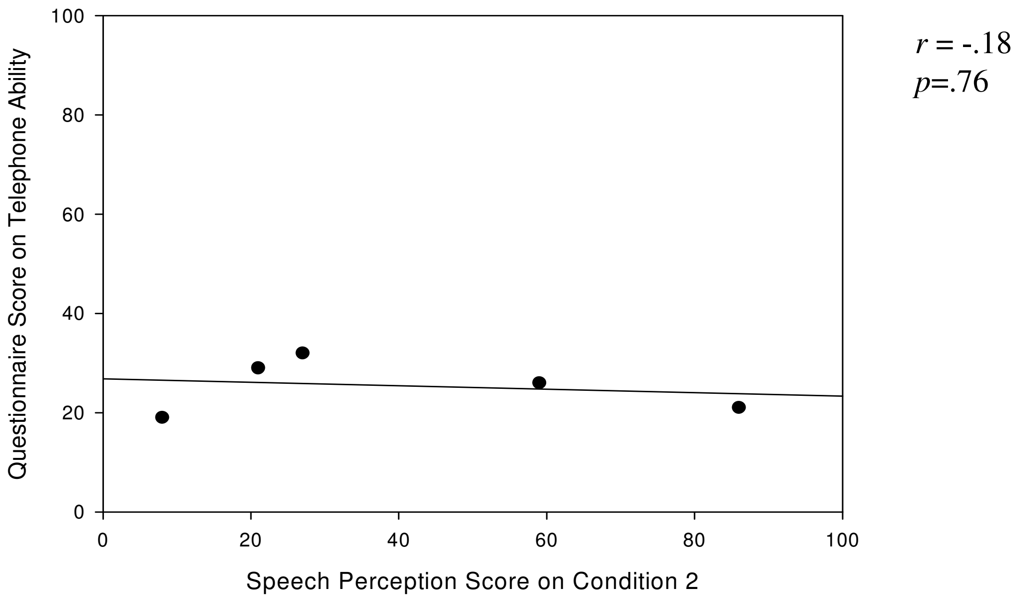


Figure 15: The relationship between overall score on the Telephone Questionnaire with speech perception scores Condition 2 (top graph) and Condition 3 (bottom graph), for each participant in the cochlear implant candidate (CI) group. A line of best fit is superimposed on the data. The corresponding correlation coefficient (*r*) is reported.



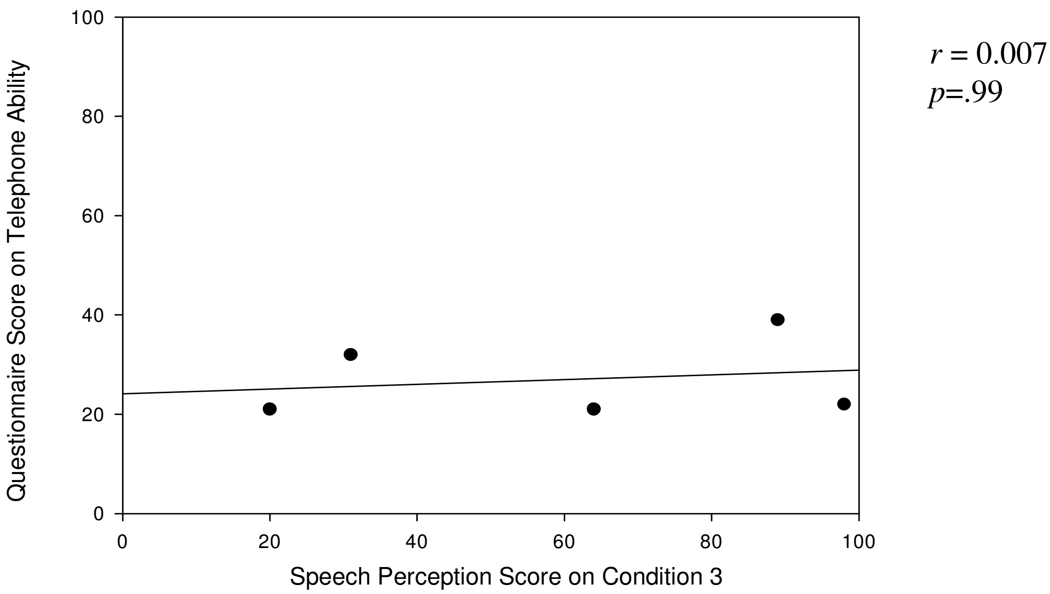


Figure 16: The relationship between overall score on the Telephone Questionnaire with speech perception scores Condition 2 (top graph) and Condition 3 (bottom graph), for each participant in the cochlear implant non-candidate (NCI) group. A line of best fit is superimposed on the data. The corresponding correlation coefficient (*r*) is reported.

Discussion

The aims of the present study were 1) to examine if there was a difference in telephone use and performance between cochlear implant candidates (CI) and non-candidates (NCI), and 2) to determine if there were any specific behaviours regarding telephone use that could separate candidates from non-candidates. To date, few studies has been conducted focusing on telephone use and performance in the severe to profound hearing impaired population, with little research, if any, on CI candidates. This study sought to investigate whether any differences existed in telephone use and performance between CI candidates and non-candidates, culminating in the determination of whether the assessment of telephone ability is a predictor for CI candidacy. A number of hypotheses were proposed to evaluate various aspects of telephone use and performance. The outcome of each is discussed below. Following the discussion, a profile of a CI candidate is presented.

Hypothesis 1: Compared to non-candidates, CI candidates will have significantly lower aided speech perception scores on the telephone (Conditions 2 and 3).

This hypothesis was prompted by a clinical suggestion that assessing the telephone ability of severe to profound hearing impaired listeners could separate CI candidates from non-candidates. Results from the present study indicated that CI candidates scored significantly lower than non-candidates for speech perception of words in sentences on the two telephone conditions. Results of the present study therefore provide support for Hypothesis 1.

One possibility for the difference between the groups is there may be a minimum level of speech perception on the telephone that can differentiate the two groups. For example, in the present study, all CI candidates perceived less than 12% of the words in Condition 2 (mean = 2.5%) whereas all but one non-candidate perceived greater than 20% of the words in that Condition (mean = 40.2%). Scoring below 20% of words correct for speech perception on the telephone, assessed using the CUNY sentences, may therefore indicate candidacy for a cochlear implant. To date, there have been no prior studies evaluating the differences in telephone performance between CI candidates and non-candidates. Previous studies have predominantly addressed telephone performance in the hearing impaired population as a whole (Holmes, 1984; Kepler, 1992; Terry, 1992) or in CI users (Cohen, 1989; Dorman, 1991; Ito, 1999; Tait, 2001; Adams, 2004; Cray, 2004). Results of the present study suggest that a threshold of speech perception may exist when using an assessment based on CUNY sentences on the telephone, whereby CI candidacy may be able to be predicted.

A second possibility for differences between the groups pertains to overall hearing levels. A discrepancy exists between the candidates and non-candidates in the differences between their pure tone averages (PTA). The PTA (average thresholds of .5, 1 and 2 kHz) of the CI candidates ranged from 80dB to 110dB, with a mean of 95dB, whereas the range of the non-candidates was larger, from 55dB to 100dB, with a mean of 80dB. The poorer hearing thresholds of the CI candidates may account for the poorer speech perception scores obtained on the telephone. The results of the present study are consistent with research by Holmes and Frank (1984). They found that speech discrimination scores on a limited bandwidth signal were lower in people with poorer hearing thresholds.

A third explanation regarding the lower speech perception scores on the telephone lies in the unfamiliarity of listening on the telephone. By means of the telephone questionnaire in the present study, a greater percentage of non-candidates than candidates reported practicing to improve their telephone skills. The additional exposure that the non-candidates have listening on the telephone may account for their improved speech perception in that specific listening condition.

It should be noted that candidacy for a cochlear implant is not only based on audiometric thresholds and speech perception scores. Hence, the use of an everyday test, such as the prospective candidate's telephone use and performance, would determine likely candidates based on general speech perception abilities only. Findings from the present study indicate that CI candidates have greater difficulty perceiving speech via the telephone, through both an objective test and through self-reports, than non-candidates.

Hypothesis 2: Both CI candidate and non-candidate groups will show no significant difference in speech perception between the three Conditions.

Results from the present study indicated that, while there was a trend for lower speech perception scores on the two telephone conditions (Conditions 2 and 3), when compared with the unfiltered signal (Condition 1), the differences between the conditions for the CI group were not statistically significant. Consistent with the Hypothesis, all CI participants achieved similar speech perception scores on the telephone as for an unfiltered signal presented in the soundfield. However, within the NCI group, speech perception scores on both the unfiltered signal in the soundfield and the filtered telephone condition were significantly higher than speech perception scores on the actual telephone condition. Therefore, the findings obtained in the present study partially accept Hypothesis 1.

The results from the present study indicate that, in accordance with the Hypothesis, speech perception scores for the CI group among the three Conditions were similar. It has been previously shown, that as hearing loss increases over 55dB, increasing audibility to the high frequencies will not increase overall speech perception (Ching, 1998; Hogan, 1998; Turner, 1999, 2006), and that increasing the bandwidth of a signal above 3000 Hz will also not significantly improve speech perception in hearing impaired listeners (Ching, 1998; Turner, 1999; Milchard, 2004). It is thought that speech perception does not improve, since despite the bandwidth widening and providing additional speech information, the additional information is simply not perceived by the hearing impaired listener (van Schijndel, 2001). As hypothesised, no increase in speech perception scores as the frequency response of the signal increased were observed for the CI group in the present study.

A possibility is offered as to why the NCI group, unlike the CI group, perceived differences between the Conditions. The overall hearing levels of the NCI group were better than the CI group, with a mean difference in PTA of 15dB between the two groups. The better hearing of the NCI group could account for the ability to perceive more words correctly on the unfiltered signal than the telephone. This is due to the ability to perceive the additional speech information on the unfiltered signal that was eliminated in the telephone condition.

Despite there being no significant difference between Conditions for the CI group, it was evident, for both the CI and NCI groups, that perceiving speech on the telephone was more difficult than perceiving speech from an unfiltered signal. The most difficult condition to perceive speech was on the telephone, followed by the filtered telephone, with the best condition to perceive speech on the unfiltered signal. The present study identified that speech perception on the telephone was more difficult than perceiving speech on either an unfiltered signal or the filtered telephone condition.

The lack of any significant difference between Conditions for the CI group is likely due to the lack of perception of the additional high frequency speech information made available as the bandwidth increased. In comparison, the differences between the Conditions for the NCI group are likely to be a result of overall better hearing levels.

*Hypothesis 3***:** *Both CI candidates and non-candidates will show a significant correlation between aided speech perception scores (Condition 1) and speech perception on the two telephone Conditions (Conditions 2 and 3),*

While the results for the NCI group in the present study showed a significant correlation between Condition 1 and 3 (r – 0.94) and Condition 1 and 2 ($r = 0.96$), the CI group only showed a significant correlation between Condition 1 and 3 ($r = 0.89$). Therefore, Hypothesis 3 was accepted in part. This hypothesis was prompted by the suggestion that telephone ability would correlate with normal speech perception, to the extent that scores for speech perception on the telephone could, in themselves, identify CI candidates.

Common between the two groups was a significant correlation between speech perception of an unfiltered signal in the soundfield and the subsequent speech perception on a filtered telephone condition. Recall that for both groups, the best listening Conditions were the unfiltered signal in the soundfield and the filtered telephone. Therefore, it is not surprising to see such a significant correlation between these two conditions. Speech perception scores on an unfiltered signal in the soundfield (Condition 1) were correlated with speech perception scores on the telephone (Condition 2) for the NCI group, but these conditions were not correlated for the CI group.

The findings of the present study show that while speech perception on Conditions 1 and 3 are similar, speech perception on Conditions 1 and 2 are different for the CI group. Performance on Condition 1 was related to Condition 2 for the NCI group, but not for the CI group. The most likely reason for the differences between the groups is due to overall hearing level; the NCI had overall better hearing levels than the CI group. The relationship regarding how well speech is perceived on the telephone ultimately relates to the hearing thresholds of the listener. When hearing thresholds are worse, speech perception on the telephone does not increase as the speech perception of an unfiltered signal in the soundfield does.

Another possible reason for the lack of correlation between Condition 1 and Condition 2 for the CI group is the small sample size in the present study and consequently the restriction in range of scores (Kantowitz, Roediger, & Elmes, 2001). It should be noted that the speech perception scores for the CI group on Condition 2 were very similar amongst all participants. The range of scores were 0 to 12 words correct, out of a possible 102 words correct. The possibility exists that, with a larger sample size, and a larger range of scores, a correlation between the two Conditions could have been apparent.

Within the NCI group, increases in scores for speech perception on an unfiltered signal in the soundfield were positively correlated with increases in speech perception scores on the telephone. Contrary to these findings, increases in speech perception on an unfiltered signal for the CI candidates did not relate to increases in speech perception on the telephone. The most likely explanation for the differences between the groups is the differences in hearing thresholds.

Hypothesis 4: Self reported telephone use will be poorer in the CI candidate group compared to the non-candidate group.

While there was a general trend for higher scores for the NCI group compared to the CI group in the telephone questionnaire, results from the present study indicated no significant difference between scores of the CI and NCI groups when the telephone questionnaire was analysed according to the five themes. Therefore, Hypothesis 4 was rejected.

There are several possibilities offered as to why no significant differences were found between the responses of CI and NCI groups. Firstly, the questionnaire was simply not correlated with perceiving words correctly on the telephone. While the questionnaire addressed a wide range of behaviour regarding telephone use, it did not reveal a relationship with the ability to understand speech on the telephone. Rather, the possibility exists that it may have correlated with other behaviour regarding the telephone, such as the hours of telephone use per day or confidence in using the telephone. A second explanation relates to the small sample size of the present study. It is evident that there was a trend for the NCI group to score higher than the CI group on all themes in the present study, in addition to an overall score from the telephone questionnaire. A larger sample size may have led to significant differences between these two groups, thus further supporting the trends that were found.

Another explanation is that the non-candidates may have reported their ability to use the telephone as poorer than it actually was. Despite reassurance that the information collected in the present study was confidential and would not be used towards consideration for a CI, it is possible that the non-candidates presented themselves as less capable in an effort to increase their likelihood of receiving a CI in the future. It may have been that they wanted to make themselves appear incapable of using the telephone with their hearing aids, thus endeavouring to be seen as unable to communicate in their present state.

The questionnaire in the present study complemented previous research also assessing telephone use by means of a questionnaire. It predominantly added information concerning the severe to profound hearing impaired population as a whole and aimed to identify key differences between those who were candidates for a cochlear implant and those who were not. The present study failed to identify responses to any one specific question from the telephone questionnaire that identified a direct link with CI candidacy. While no significant differences in self reported telephone use were found between the two groups, interestingly, when individual questions were analysed, a number of differences between the groups were found. The individual themes from the questionnaire are described as follows where differences between the groups occurred. Nevertheless, in the majority of questions, responses from the candidate and non-candidate groups were very similar.

Theme 1: Understanding a signal on the telephone. All non-candidates in the present study could differentiate the gender of the caller, recognise a familiar voice, and could participate in more than a 'yes-no' conversation. While some candidates could do the aforementioned skills, not everyone reported that they could.

Theme 2: Initiating telephone calls. In the present study, half of the non-candidates reported to initiate calls to ask for information about a product or service. In contrast, no candidates reported to do this. In the present study, 92% of respondents, which included the entire group of candidates and 80% of non-candidates, indicated that their hearing impairment discouraged them from using the telephone,. The findings of the present study are consistent with research by Kepler et al., where two thirds (69%) of people were discouraged from using the telephone. The greater proportion of participants in the present study that indicated being discouraged is most likely due to the differing characteristics of the samples: most participants (87.5%) in the study by Kepler et al had moderate to severe hearing losses, whereas all participants in the present study had severe to profound or profound hearing loss.

Theme 3: Receiving telephone calls. All non-candidates reported answering the telephone, compared with less than a third of candidates. In answering the telephone the implication is made that the speaker and the topic may be unfamiliar, and hence, only those who feel confident and able to carry out a conversation in those circumstances may be willing to answer the telephone. Undoubtedly, the present study identified that the more familiar the speaker and topic, the better the understanding for both candidates and non-candidates. This is consistent with past research (Kepler, 1992). As the speaker and topic became more unfamiliar, the non-candidates were more able to understand the conversation, when compared with the candidates. It may be that answering the telephone is related to the ability to perceive speech of an unfamiliar voice.

Theme 4: Sound quality over the telephone. When evaluating the quality of sound on the telephone compared to listening to a voice in the same room without lipreading, most candidates rated the sound as much poorer than the non-candidates.

Hypothesis 5: *Both CI candidate and non-candidate groups self reported use of the telephone should correlate with the results obtained for speech perception on the two telephone conditions (Condition 2 and 3).*

The results of the present study found a strong correlation between self-reported telephone use (the telephone questionnaire score) and speech perception scores on the two telephone Conditions (Condition 2 and Condition 3) for the CI group. In contrast, no significant correlation was found between self-reported telephone use and speech perception scores on the two telephone conditions for the NCI group. Therefore, Hypothesis 3 was accepted in part.

CI candidates were able to accurately perceive their telephone ability on the telephone questionnaire in the present study, where increases in self-reported telephone ability corresponded with increases in words perceived correctly on the telephone. Interestingly, no such relationship between the telephone questionnaire and performance on the telephone existed for the NCI group. There are a number of possibilities to explain this lack of correlation. Firstly, one disadvantage of using a questionnaire in the present study is that some participants may have incorrectly responded to a number of the questions in an attempt to either impress or play down their ability to use the telephone. All participants were aware that the study aim was to identify a link between CI candidacy and telephone performance. It is possible that some participants responded in ways that led to an incorrect perception of their ability to use the telephone in everyday life. Secondly, the telephone questionnaire was administered after the speech perception tasks were completed in the present study. It is a possibility that some participants responded according to how they felt they performed in the speech perception tasks.

Performance on the telephone can be predicted using self-reported telephone use for CI candidates, where increases in reported ability to use the telephone is reflected by an increase in the number of words perceived correctly on the telephone. However, for non-candidates, an increase in self-reported ability had no direct corresponding increased perception of speech on the telephone. Therefore, without prior knowledge enabling separation of CI candidates from non-candidates, speech perception on the telephone could not be predicted using responses to the questionnaire in the present study.

Profile of a CI Candidate

The results of the present study confirm previous research findings that people with a severe to profound hearing loss have difficulty communicating on the telephone (Holmes, 1984; Kepler, 1992; Terry, 1992). This difficulty occurs despite improvements in both hearing aid and telephone technology. Most participants in the present study felt that their life would be greatly improved if they could use the telephone. Results from the present study show that, on average, the NCI group could correctly perceive a significantly greater number of words on the telephone than the CI group. The present study also indicated an overall trend that non-candidates report to use the telephone in more difficult situations than do candidates, despite a lack of significant findings.

The findings of the present study have been summarised to produce a profile of a CI candidate's telephone use and behaviour, which is described as follows:

- A CI candidate is likely to recognise a dial tone and busy signal on the telephone.
- A CI candidate is likely to report that voices on the telephone sound much poorer than listening to a voice in the same room without lipreading.
- A CI candidate is unlikely to initiate telephone calls to ask for information about a product or service.
- A CI candidate is unlikely to answer the telephone.
- A CI candidate is unlikely to be able to understand a stranger talking on an unfamiliar topic.

Clinical Implications

The present study was carried out in response to a clinical suggestion that assessing a person's telephone use can be beneficial in the assessment of candidacy for a cochlear implant. One purpose of the present study was to determine whether evaluating telephone ability during a CI candidacy assessment is worthwhile, and whether it gave an indication as to the person's suitability for CI candidacy. The present study indicated that, while there are certainly significant differences in speech perception scores on the telephone between CI candidates and non-candidates, there is not yet a set way of determining telephone ability based on either a questionnaire or on speech perception tests on an unfiltered signal. This was due to both significant and insignificant correlations for both the candidates and non-candidates. While speech perception scores on the telephone condition were correlated with speech perception scores for an unfiltered signal for the non-candidates, there was no correlation for the candidates. Similarly, while scores on the questionnaire correlated with speech perception scores on the telephone for candidates, no such relationship existed for non-candidates. A likely reason for the insignificant relationships between speech perception on the telephone, speech perception on an unfiltered signal and responses to the telephone questionnaire is the small sample sizes of both the candidate and non-candidate groups. It is speculated that with a larger sample, significant findings may have occurred.

The inability to effectively use the telephone is likely to be an important question to be addressed during the assessment for a CI. As the present study has shown, responses from a questionnaire correlate with aided speech discrimination on the telephone for cochlear implant candidates. However, until both candidate and non-candidate groups show a correlation between these two variables, determining telephone performance by the means of a questionnaire on telephone use will not separate CI candidates from non-candidates. In the meantime, as shown in the profile of a CI candidate, a collection of behaviours regarding use of the telephone may indicate likely candidates.

Despite the lack of significant correlations to predict speech perception on the telephone from other sources, it is evident that CI candidates perform significantly poorer than non-candidates when perceiving speech on the telephone. Therefore, the ability to predict CI candidacy based on performance on an everyday task, such as using the telephone, could be used to highlight suitability of cochlear implants to both individuals with hearing loss and medical professionals. The inability to use the telephone can be used as a general tool that assumes that when hearing loss becomes so great that a person either has great difficulty or can no longer use the telephone, that referral for a cochlear implant is the correct and necessary action to be taken.

Limitations

The present study involved data from a total of 13 participants (eight CI candidates and five non-candidates) and, even though parametric statistics were used, the small sample size resulted in low statistical power (Schiavetti & Metz, 2000). The number of participants used in similar studies ranges from 8 (Veekmans, 2004) to 478 (Cray, 2004) and the possibility exists that a larger sample size may have yielded different results. Future research with larger sample sizes would increase the statistical power of the results and allow for greater generalisation of findings.

While the results from the present study indicate significant differences between the CI and NCI groups, it is important to note the large variability within each of the two groups, evident from the large standard deviations. While the small sample size may account for the large variability, it should be noted that other researchers have shown that large variability does exist within the severe to profound hearing impaired population (Flynn, 1998), and that a larger sample size may not have decreased this.

While great effort was taken to find a representative sample of CI candidates, it is recognised that the present study only included participants who lived in the Canterbury region of the South Island, New Zealand. In total, 27 individuals were invited to participate in the present study, of which only 13 accepted and took part. A limiting factor in participant selection was the small number of referrals for cochlear implant candidacy assessment that occurred during the data collection period of the present study.

In addition, the self-selecting nature of recruitment may have lead to a bias in sampling. In addition to participation as a result of having a CI assessment during the data collection period of the present study, all other potential participants were recruited by means of an introductory letter sent in the post. It was the participant's choice and responsibility to contact the researcher if they wished to participate in the present study. It is possible that only those people who felt that they performed poorly on the telephone were likely to participate. While great effort was taken to ensure and inform participants that the data was entirely confidential and anonymous, it is also possible that some people who were not candidates for a CI chose not to participate in case their participation disadvantaged their selection for a CI in due course.

In addition, the materials chosen to assess speech perception in each of the three listening Conditions may have altered the significance of the findings. The sentence lists were spoken by an Australian female, which may have lead to difficulties in speech perception by some participants. Informal comments by the participants included both positive and negative comments regarding the speaker's gender. No comments were made regarding the speaker's accent. It is acknowledged that the data obtained in the laboratory-like setting of a sound-treated booth at an audiology clinic may not generalise to a naturalistic setting, and therefore not be representative of the participant's ability to use the telephone in everyday life.

Directions for Future Research

In summary, the present study has shown that there are differences between CI candidates and non-candidates in their ability to perceive speech on the telephone and that they each exhibited differences in behaviour regarding telephone use. Future research, with a larger sample, may determine if there is a speech perception cut-off score on the telephone to separate CI candidates from non-candidates.

Interestingly, there was a significant difference in speech perception scores for the NCI group between Condition 2 and Condition 3 in the present study. The two telephone conditions were intended to both replicate the telephone line: Condition 2 was an actual recording of the sentence list on the telephone, and Condition 3 was filtered to telephone company specifications, to replicate the frequency response of the telephone. It was thought that these two signals would produce the same result. Results from the present study indicated that speech perception scores for the NCI group were significantly higher when listening to Condition 3 than Condition 2. Many participants in the present study made comments regarding the perception of background noise when listening to Condition 2 when compared with Condition 3. The apparent background noise may have caused the discrepancies in speech perception for the NCI group; however, it made no difference to the CI group. The better hearing levels of the NCI group may have accounted for the differences between the two groups. Future research could investigate the differences between the actual telephone condition and the filtered telephone condition, to determine the cause of the differences between the Conditions.

Future research should investigate ongoing improvements when using the telephone after receiving a cochlear implant, and compare it with pre-implant abilities. While responses to the telephone questionnaire in the present study indicated that when comparing research on CI users telephone abilities, speech perception on the telephone was poorer for a CI candidate than a CI user; further research could enable better understanding of ongoing improvements due to the CI.

Studies in the future should investigate both the CI candidate and non-candidate's ability to use the telephone in their own home or in their work environment. The possibility arises that while the present study has assessed telephone performance in a laboratory setting using a speech perception test that was recorded over a telephone line, that it was not representative to understanding speech on the telephone in everyday life. Factors such as background noise and signal interference that may occur during a telephone call were not controlled for in the present study. Such studies may indicate specific differences between the two groups.

Rubinstein et al. found that people who had a short duration of deafness would perform high on speech perception abilities with a cochlear implant. Duration of deafness was based on when people ceased to use the telephone. It is therefore suggested that those who can either still use, or have recently ceased using the telephone would make likely CI candidates based on probable high post-operative success. Future studies could evaluate duration of deafness and compare with participants reports on the length of time since they ceased using the telephone, to further evaluate this proposition. Duration of deafness, based on length of time since a person has been capable of communicating on the telephone, may predict suitability for a cochlear implant.

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Appendices

Appendix 1

Human Ethics Approval

Appendix 2

<u>CUNY Sentence List 31</u>:

1 The shop is having a sale on nightgowns.
2 Don’t go outside if it’s too cold.
3 Make my steak well done.
4 Will you lend me ten dollars until I can go to the bank?
5 Remember to stretch before you try to run a long distance.
6 Take these biscuits with you when you go to visit your grandfather.
7 Passover and Easter always seem to occur at the same time of the year.
8 Crash diets can really make a person very sick.
9 Computers make typing reports much easier.
10 Did you tape the concert they broadcast on the radio?
11 Who fed the goldfish?
12 What’s your address?

<u>CUNY Sentence List 32</u>:

1 Do parrots fly?
2 More people seem to catch colds in the winter than in the summer.
3 Vacuum the rugs and polish the furniture before the party tonight.
4 My nephew is having a party.
5 Don’t ever stand under a tree during a thunderstorm.
6 Did you put your savings in a high interest account?
7 My new shoes hurt.
8 Where do you store albums?
9 My friend was just fired from his job.
10 Will you be eating Christmas dinner at a restaurant or at home this year?
11 Please slice the meat by be careful not to cut your fingers.
12 Bring your runners to the exercise class.

<u>CUNY Sentence List 33</u>:

1	How many people are going to try out for the brass band?
2	How long will you have to keep that big cast on your broken leg?
3	Make sure you dress warmly on days when the temperature drops below freezing.
4	My boss is quitting.
5	Paint the outside of the house first.
6	Take off your skis when you leave the slopes.
7	My aunt and uncle live two blocks away.
8	I need trousers.
9	Remember to let the dog out before you go to school.
10	Does he get an allowance?
11	Why do people drink so much on new years eve?
12	I ate a big lunch today.

Appendix 3

Filter characteristics for Condition 3

Condition 3 was simulated with the following filters for CUNY sentences list 31: 2nd-order Butterworth high-pass filter at 44 Hz; 2nd-order Butterworth high-pass filter at 145Hz; hybrid 1st and 2nd-order Butterworth low-pass filter at 440 Hz; 14th order Butterworth low-pass filter at 3345 Hz. This filter characteristic was accurate above 65 Hz, but slightly underestimated the signal values below that frequency. This was unlikely to significantly affect listening performance. The signal through the 440 Hz low-pass filter was first filtered at the other three corner frequencies (44 Hz HPF, 145 Hz HPF, 3345 Hz LPF), and then the signal was split in two, with one stream being low-pass filtered at 440 Hz using a 1st-order Butterworth filter, and the other stream being low-pass filtered at the same corner frequency with a 2nd-order Butterworth filter. The resulting two signals were then added, producing a filter slope between these two.

Appendix 4

Telephone Questionnaire

1. What is your sex?
   a) Male
   b) Female

2. What is your present age? (years) ______

3. What is your highest level of education completed?
   a) High school
   b) Technical/community college/associate degree
   c) Batchelor's degree
   d) Master's degree
   e) Doctoral degree

4. How old were you when your hearing loss was identified?
   (years) ______

5. What was the cause of your hearing loss?

   ____

6. What is your method of communication? (choose one)
   a) Oral (talking)
   b) Manual (sign language)
   c) Both oral and manual

7. How long have you been wearing a hearing aid or hearing aids?
   years or months if less than 1 year) _____

8. Have you ever had:
   a) Sign language classes? Yes/No
   b) Speech reading or lipreading classes? Yes/No
   c) Auditory training? Yes/No
   d) Other rehabilitation? Yes/No

9. Can you understand some words without the use of lipreading?
   a) Yes, most of the time
   b) Yes, some of the time
   c) No

10. Do you initiate telephone calls?
    a) Yes, most of the time
    b) Yes, some of the time
    c) No

11. Do you answer the telephone?
    a) Yes, most of the time
    b) Yes, some of the time
    c) No

12. Do you initiate telephone calls to Friends or family? Yes/No

13. Do you initiate telephone calls to Make appointments? Yes/No

14. Do you initiate telephone calls to ask for information about a product or service? Yes/No

15. Do you initiate telephone calls to conduct business? Yes/No

16. On the telephone, can you recognize a Dial tone? Yes/No

17. On the telephone, can you recognize a Busy signal? Yes/No

18. On the telephone, can you recognize a Voice? Yes/No

19. How often do you use the telephone each day?
    (hours) ______

20. Do you feel comfortable with your ability to converse with strangers on the telephone?
    a) Yes, most of the time
    b) Yes, some of the time
    c) No

21. Do you use a telephone adapter when communicating on the telephone?
    Yes/No

22. Do you use a telecoil function on your hearing aid when communicating on the telephone?
    Yes/No

23. Can you tell the difference between a human voice and an environmental sound on the telephone?
    (choose one)
    a) Yes, most of the time
    b) Yes, some of the time
    c) No

24. Can you tell if the other caller on the telephone is a man, woman, or child?
    (choose one)
    a) Yes, most of the time
    b) Yes, some of the time
    c) No

25. Can you recognize familiar voices on the telephone?
    (choose one)
    a) Yes, most of the time
    b) Yes, some of the time
    c) No

26. Do you more than just tell the telephone caller to wait until you bring someone else on the line to help you understand?
    a) Yes, most of the time
    b) Yes, some of the time
    c) No

27. Can you participate in more than a "yes" – "no" conversation on the telephone?
    (choose one)
    d) Yes, most of the time
    e) Yes, some of the time
    f) No

28. Can you understand a familiar caller on the telephone if the topic of the call is familiar?
    (choose one)
    a) Yes, most of the time
    b) Yes, some of the time
    c) No

29. Can you understand a familiar caller on the telephone if the topic of the call is unfamiliar?
    (choose one)
    a) Yes, most of the time
    b) Yes, some of the time
    c) No

30. Can you understand a stranger on the telephone if the topic is familiar?
    (choose one)
    a) Yes, most of the time
    b) Yes, some of the time
    c) No

31. Can you understand a stranger on the telephone if the topic is unfamiliar?
    (choose one)
    a) Yes, most of the time
    b) Yes, some of the time
    c) No

32. Do you, or did you, practice to improve your telephone skills?(choose one)
    a) Yes
    b) No

33. Describe the quality of sound from a telephone compared to listening to someone in the same room without lipreading.
    (choose one)
    a) The sound is about the same
    b) The sound is a little poorer
    c) The sound is much poorer

34. Descriptions of sound quality over the telephone: (choose all that apply)
    a) Clear
    b) Understandable
    c) Far away – weak
    d) Hollow
    e) Tinny (ringing)
    f) Has echo
    g) Fuzzy
    h) Other distortions

35. Do you use a cellular/mobile phone? (choose all that apply)
    a) For personal use
    b) For business use
    c) For emergency use

36. Generally, I feel that speech over the telephone is:
    a) too soft
    b) correct volume
    c) too loud

37. Generally, I feel that speech over the telephone is:
    a) always clear
    b) sometimes clear
    c) never clear

38. In general, how much difficulty do you have hearing **females** over the telephone?
    a) great difficulty
    b) some difficulty
    c) no difficulty

39. In general, how much difficulty do you have hearing **males** over the telephone?
    a) great difficulty
    b) some difficulty
    c) no difficulty

40. How often do you have to end a telephone call before the conversation is complete, **specifically** because you had difficulty hearing?
    a) never
    b) occasionally
    c) regularly

41. How many outgoing telephone calls per day do you place on average?
    a) less than 3
    b) 3-5
    c) 6-10
    d) 10-15
    e) More than 15

42. How many incoming telephone calls per day do you receive on average?
    a) less than 3
    b) 3-5
    c) 6-10
    d) 10-15
    e) More than 15

43. Does your hearing impairment sometimes discourage you from using the telephone?
    a) yes
    b) no

44. If you use a cellular/mobile phone, which do you prefer to talk on?
    a) Cellular/mobile phone
    b) Residential land-line phone
    c) Both are the same to talk on
    d) I only use a land-line phone

45. Do you feel that your inability to use the telephone affects your social life
    a) Yes, most of the time
    b) Yes, some of the time
    c) No

46. Do you feel that your life would be improved if you could use the telephone?
    a) Yes, most of the time
    b) Yes, some of the time
    c) No

47. Which ear do you use most of the time on the telephone?
    a) Right ear most of the time
    b) Left ear most of the time
    c) I use either ear

48. Do you feel comfortable ringing someone on the telephone to ask for information about a product or service?
    a) Yes, most of the time
    b) Yes, some of the time
    c) No

49. Do you feel comfortable answering the phone if you are not expecting a call from someone?
    a) Yes, most of the time
    b) Yes, some of the time
    c) No

50. Do you feel that your daily usage of the telephone has decreased, as your hearing loss has become worse?
    a) Yes
    b) No
    c) Yes, but it is because of another reason other than my hearing loss:

____

51. During an average telephone conversation, how often do you have to ask for the speaker to repeat themselves, or ask for clarification of what they said?
    a) Most of the time
    b) Some of the time
    c) Never

This questionnaire was adapted from Kepler et al. (1992) and Cray et al. (2004)

Appendix 5

Questionnaire separated into five Themes.

Theme 1: Understanding a Signal on the Telephone

16. On the telephone, can you recognize a Dial tone?

17. On the telephone, can you recognize a Busy signal?

18. On the telephone, can you recognize a Voice?

20. Do you feel comfortable with your ability to converse with strangers on the telephone?

23. Can you tell the difference between a human voice and an environmental sound on the telephone?

24. Can you tell if the other caller on the telephone is a man, woman, or child?

25. Can you recognize familiar voices on the telephone?

27. Can you participate in more than a “yes” – “no” conversation on the telephone?

28. Can you understand a familiar caller on the telephone if the topic of the call is familiar?

29. Can you understand a familiar caller on the telephone if the topic of the call is unfamiliar?

30. Can you understand a stranger on the telephone if the topic is familiar?

31. Can you understand a stranger on the telephone if the topic is unfamiliar?
    d)

38. In general, how much difficulty do you have hearing **females** over the telephone?

39. In general, how much difficulty do you have hearing **males** over the telephone?

40. How often do you have to end a telephone call before the conversation is complete, **specifically** because you had difficulty hearing?

51. During an average telephone conversation, how often do you have to ask for the speaker to repeat themselves, or ask for clarification of what they said?

Theme 2: Initiating Telephone Calls

10. Do you initiate telephone calls?

12. Do you initiate telephone calls to Friends or family?

13. Do you initiate telephone calls to make appointments?

14. Do you initiate telephone calls to ask for information about a product or service?

15. Do you initiate telephone calls to conduct business?

41. How many outgoing telephone calls per day do you place on average?

43. Does your hearing impairment sometimes discourage you from using the telephone?

44. If you use a cellular/mobile phone, which do you prefer to talk on?

48. Do you feel comfortable ringing someone on the telephone to ask for information about a product or service?

Theme 3: Receiving Telephone Calls

11. Do you answer the telephone?

26. Do you more than just tell the telephone caller to wait until you bring someone else on the line to help you understand?

42. How many incoming telephone calls per day do you receive on average?

43. Does your hearing impairment sometimes discourage you from using the telephone?

49. Do you feel comfortable answering the phone if you are not expecting a call from someone?

Theme 4: Quality of Sound over the Telephone

33. Describe the quality of sound from a telephone compared to listening to someone in the same room without lipreading.

34. Descriptions of sound quality over the telephone: (choose all that apply)
    i) Clear
    j) Understandable
    k) Far away – weak

l) Hollow
m) Tinny (ringing)
n) Has echo
o) Fuzzy
p) Other distortions

36. Generally, I feel that speech over the telephone is:

37. Generally, I feel that speech over the telephone is:

Theme 5: Quality of Life

45. Do you feel that your inability to use the telephone affects your social life

46. Do you feel that your life would be improved if you could use the telephone?