CHAPTER 1

INTRODUCTION AND PROBLEM STATEMENT

1.1 INTRODUCTION

"The availability of well designed technology is critical in the empowerment process, therefore each of us needs to be sensitive to ways in which we contribute to, or detract from, this process. Because we hold within our hands so valuable a component of the process, we must always keep at the forefront of our minds the true purpose for utilising our skills, creating an environment in which deaf individuals can make informed decisions, communicate, project themselves and relate effectively with others. Without innovative technology, these activities would be very difficult for some deaf individuals and impossible for many. But we must never forget that this process is a means to an end. The empowerment of deaf and hard of hearing people" (Davila, 1994:9).

The reported telephone use by Individuals Fitted with a Cochlear Implant (IFCI) is highly topical. The ability of some individuals with a profound hearing loss to communicate without the benefit of lip-reading, following multichannel cochlear implantation, has been documented in recent literature (Cohen, Waltzman, & Shapiro, 1989). Not all IFCIs have this ability and aspects such as the cause of hearing loss, the duration of loss prior to implantation, support systems, emotional and personality differences, have an impact on the quality of telecommunication in Individuals Fitted with Cochlear Implants (IFCIs)

(Melville, 2003). A hearing loss limits the ease of acquisition of a verbal communication system. This situation leads to additional problems, such as understanding the hearing world, acquiring academic skills needed to graduate from school and integrating successfully into the greater hearing society.

Normal hearing comprises of sound waves picked up from the environment by the outer ear structure (Cochlear Corporation, 1999; Martin, 1997). The sound travels to the middle ear, which consists of an air-filled structure with a tympanic membrane and a chain of three bones (Cochlear Corporation, 1999; Martin, 1997). The incoming sound causes the structures in the middle ear to vibrate. These vibrations move to the structure in the inner ear that is responsible for hearing namely the cochlear (Cochlear Corporation, 1999). The cochlea consists of tiny hair cells and fluid, which convert the mechanical vibrations into electrical nerve impulses, which travel to the base of the brain via the auditory nerve where the impulses are perceived by the brain as sound (Cochlear Corporation, 1999; Martin, 1997). As it is a delicate process for sound waves to travel from the environment to where the brain perceives the sound as significant and many minute structures are involved, it is self-evident that structural and/or transmitting problems may occur. These transmission problems are commonly referred to as a hearing loss.

A profound sensorineural hearing loss (SNHL) occurs because critical structures in the inner ear and cochlea have been damaged in such a way that sound can not be transmitted to the brain (Katz, 2002; Martin, 1997; & Mueller & Hall, 1998). In recent years more effective ways have been developed to bypass these damaged structures and to stimulate the sensation of hearing by means of a Cochlear Implant (Dorman & Loizou 1997).

A Cochlear Implant (CI) is an electronic prosthetic computerised device implanted into the cochlea of individuals with severe-to-profound bilateral SNHL. It replaces certain functions of the cochlea using electrical currents to stimulate receptors in the inner ear (Staller, Beiter & Brimacombe, 1994; Tucker, 1998). Sound is translated into electrical impulses and delivered directly to the auditory nerve, via an electrode array. These electrodes are surgically implanted into the inner ear. The internal electrode array and receiver, together with an externally worn headset and speech processor, provide sound, which is perceived by the recipient. The function of the speech processor is to divide the input auditory signal from the microphone into frequency bands. These correspond to the number of stimulating electrodes in the implanted device. This is called a *coding strategy*. The coding strategy is programmed into the speech processor, in order to determine the rate and manner in which the input signal is presented to the stimulating electrodes. This programming of speech coding strategies into the speech processor is generally referred to as a *map* (Moor & Teagle, 2002). Through a map, it is possible for the recipient to hear speech. This has significant influence in developing and improving speech and listening skills (Easterbrooks, 1997; Ling, 1990).

The implant consists of a microphone, worn behind the ear (BTE), which picks up sound and transmits it to the speech processor through a thin cord. The speech processor converts critical characteristics of the acoustic signal into digitally coded electrical signals and returns them to the headset-transmitting coil. The transmitting coil is held in place, by means of internal and external magnets. The special digital code and power from the speech processor is transmitted across the skin via the transmitting coil, using a high-frequency radio signal, to the array of electrodes implanted into the cochlea. The implant uses the coded signal to determine the stimulus characteristics, which are delivered to the appropriate electrodes. These electrodes stimulate the remaining auditory nerves (via a map, done by an Audiologist) and the brain perceives the sensation of sound. In Figure 1.1 a schematic display of the basic functioning of a CI is provided (Cochlear, 2001).

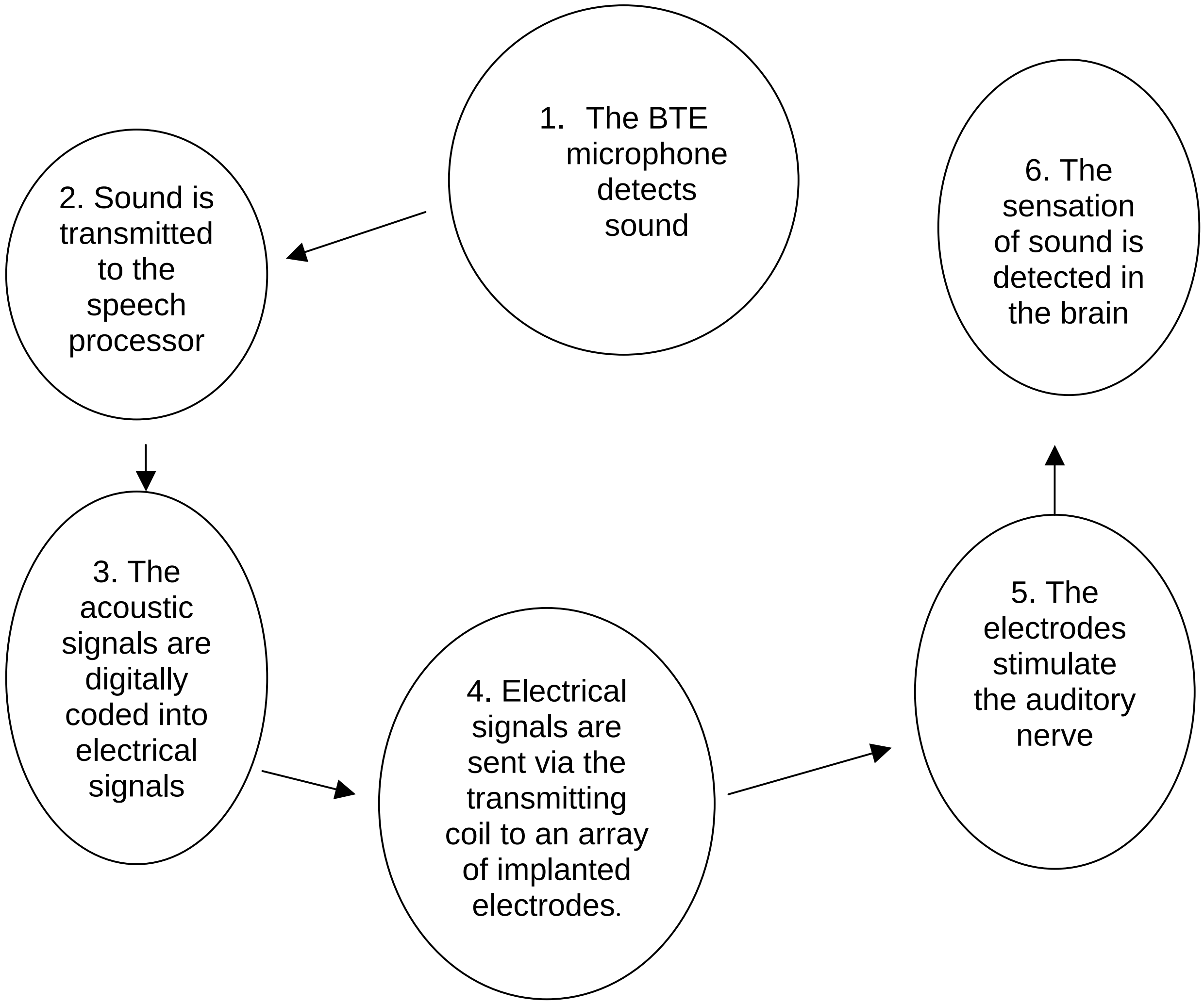


Figure 1.1 Schematic display of the basic functioning of a CI

In many cases conventional hearing aids do not provide effective results for individuals with severe-profound SNHL. This happens due to the fact that the hearing aid cannot make speech loud enough for them to hear, and sometimes too loud or indistinctive to understand (Dorman & Loizou 1997). A CI differs fundamentally from a hearing aid. It does not amplify sound, but translates sound into electrical impulses, which are delivered straight to the auditory nerve, which perceives these impulses as sound (Boswell, 2002; Brown, Clark, Dowell, Martin & Seligman, 1985; Hay, 1997; & O'Donoghue, Nikolopoulos, Archbold & Tait, 1998). A CI offers benefits to its users, ranging from detecting environmental sounds (which prior to the implant had been unknown to its users) to the successful use of a telephone (Boswell, 2002; Cochlear Corporation updated, 2002; David, Ostroff, Shipp, Nedzelski, Chen, Parnes, Zimmerman, Schramm & Seguin, 2003; Faber & Grontved, 2000; Osberger & Maso, 1993; Tait, Nikolopoulos, Archbold & O'Donoghue, 2001; Valimaa, Sorri, & Lopponen 2001; & Waltzman, Cohen & Shapiro, 1989).

1.2 HISTORICAL WITHVIEW OF THE COCHLEAR IMPLANT

In order to appreciate the recent developments with CIs and to support the rationale for the present study, a historical withview of the CI provides insight into the development of the device. The history of the CI dates back some 200 years. In 1790, Alessandro Volta put a metal rod in each of his ears and connected the rods to batteries. He reported that the experiment had caused him to hear sound although there had been some unpleasant side effects. The same electrical stimulation, although much refined, is used today in cochlear implants (CIs) (Ling, 1990). Although the CI was initially relatively successful, it has continued to improve and recipients have shown improvements in speech communication skills (Levitt, 1991). In 1957 Djoumo and Eyries published the first report, documenting the electrical stimulation of the auditory system in a deaf individual (Katz, 2002). William House performed the first single-channel CI operation in the United States of America (USA) in 1961. This CI consisted of a hardwire gold electrode placed in the scala tympani via the ear canal and round window (Katz, 2002).

In 1978, Dr Graeme Clark from the University of Melbourne, became the first to implant a CI (developed by him), in a postlingually deafened adult. This was to become known, worldwide, as a "cure" for severe-profound hearing loss (Aubin, 1995; Cochlear Corporation, 1999). The first implant had 10 electrodes. In 1982, in Melbourne, a device with 22 electrodes, the Nucleus 22, was implanted for the first time. 1985 marked the beginning of a whole new direction for CIs, as the first child, a ten-year-old boy, was successfully implanted. In 1986, the CI was approved for use in adults by the Food and Drug Administration (FDA), in the United States of America (Boswell, 2002; Cochlear Corporation updated, 2002). In 1994, the SPECTRA processor, with the SPEAK coding strategy, was released. Another breakthrough came in 1990, when an 18 month-old baby was successfully implanted and the FDA approved CIs for use in children (Boswell, 2002; Cochlear Corporation, 1999).

Three manufacturers offer CIs

1. Advanced Bionics Corporation, manufacturer of the Clarion device,
2. MED-EL Corporation, manufacturer of the COMBI 40+ and
3. Cochlear Corporation, manufacturer of the Nucleus device (Moore & Teagle, 2002, & Katz, 2002). The Nucleus device was used exclusively in this study in order to ensure homogeneity in the results.

Alexander Graham Bell, who invented the telephone in 1876 and helped bring many hearing people into contact with one another, was a teacher of the Deaf and was also married to a Deaf woman. He was particularly interested in promoting the welfare of

Deaf people (Ling, 1990). The application of a telecommunication apparatus by persons with a hearing loss has always been problematic, as they rely heavily on speech reading and other non-verbal cues in order to fully comprehend a spoken message. In 1964, Weibrecht, who was a Deaf physicist, started the Teletype (TTY) Deaf network. The TTY machine sent messages across telephone lines via a modified modem. In the mid-1970's a new electronic portable machine was invented, namely the Telecommunication Device for the Deaf (TDD). These devices enable instant communication for individuals with a hearing loss similar to communication with a telephone. The negative consequence was that it did not help to bring persons with hearing loss into contact with hearing people who were not TDD-users. In 1990, the Americans with Disabilities Act was passed and the USA telecommunications relay service was started (Naito & Murakami, 2000). This relay service enables TDD-users to get in touch with individuals with normal hearing using the assistance of trained operators.

1.3 CONDITIONS NECESSITATING RESEARCH

Studies have shown that the advantages of the CI include improved self-perceived communication skills, an increase in the frequency of conversation with others, self-confidence and an enhanced communicative and interactive family life (Faber & Grontved, 2000). An important factor is the capability of these individuals fitted with cochlear implants (IFCIs) to communicate effectively using the telephone. The use of the telephone *"is one of the imperatives of contemporary life. With the expansion of the* *mobile phone market it is estimated that more than 50% of the European population owns and uses mobile phones" (Tait, Nikolopoulos, Archbold & O'Donoghue, 2001:47).*

People communicate on a social, professional and business level with friends, relatives and colleagues via the telephone. Business appointments, social engagements and emergency calls are all quickly made by telephone, especially if a person can perceive sound normally and does not have to depend on additional cues and lip reading. This leads to a sense of independence (Valimaa, Sorri, & Lopponen 2001). Individuals with a hearing loss, who depend on speech reading or need additional cues to follow a conversation, have in the past had little or no opportunity of using a standard telephone effectively or even at all (Valimaa, et al. 2001). Independence may, therefore, be considerably reduced through a lack of the ability to communicate with a regular telephone. This may lead to the phenomenon where people with a hearing loss become isolated and shut themselves off from the expanding structure of society that the telephone has helped to create (Erber, 1985). People who communicate frequently can interact more freely with other members of society and live independently in most contexts.

A new way of looking at the use of technology in the educational and employment settings for individuals with a hearing loss, was brought about by the increased employment opportunities and the fact that recently, more children with disabilities are accommodated in public schools (Ertmer, 2002). It is therefore important that as education and employment grow in variety and complexity, so too must the tools they use grow, to keep pace with these changes as the need for specially designed adaptive technology will only increase (Davila, 1994).

In order to communicate successfully via a telephone, open set speech is important. Studies on adult users of multichannel CI systems show that approximately 25 % of subjects had some level of open set speech recognition skills, using the telephone (Summerfield & Marshall, 1995). Cohen, et al. (1989) reported that 23% of adults implanted with the Nucleus Multichannel device at New York University Medical Centre demonstrated a significant increase in telephone communication ability. In yet another study done by Lalwani, Larky and Wareing (1998), it was reported that with half of the postlingually deafened adults implanted with the Clarion Multi-Strategy device were able to understand at least 75% of sentence material presented with the telephone. Telephone use seems to be emerging as a high priority with IFCIs, in their desire to become part of the hearing life in every possible way.

Certain skills are necessary for any normal hearing person to communicate via the telephone. It is therefore important that an IFCI who will be attempting to use the telephone has certain auditory skills and speech intelligibility. According to Ling (1990:9) *"The person to whom speech is addressed must be able to detect, discriminate, identify and comprehend the spoken message".* A study done to investigate the effect of a multichannel cochlear implant on speech discrimination and the functional benefit of CI in postlingually deafened adults, showed that one year after switching on the implant, the majority of the recipients were able to use the telephone with a familiar speaker. All the recipients were able to recognise speech through the auditory modality only and had thus gained good functional benefit from the implant. The improvement in the quality of life was reported to correlate with an improvement in the ability to communicate in everyday life because social isolation was reduced and this contributed to the benefits that patients were reported to have gained from their cochlear implants (CIs) (Valimaa, et al. 2001).

Recently, pager communications and cellular phone services that have a "short message system" (sms)/text message-service have been developed for speech as well as non-speech communication (Naito & Murakami, 2000). More active communication with one another as well as with the hearing world is now possible. Another type of telephone used is a "hearing-aid-compatible telephone" that has an induction loop that is either built into the handset or fitted separately. Unfortunately not all mobile telephones are hearing aid compatible (Cohlear Corporation. 1999).

Another problem IFCIs experience is that telephones, landline as well as mobile telephones, have a limited frequency range (300Hz-3400 Hz) (Tait, et al. 2001). Global System for Mobile Communications (GSM) phones are known to CI systems, but are subject to intermittent interference. GSM is one of the technologies, which is used in mobile networks. GSM is digital technology and consists of a network of basic stations with antennas, which communicates with mobile phones in the 900MHz frequency band to make cordless communication possible (Jürgens, 2003). The basic reason for the disturbance in quality of transmission is the broad-spectrum radio signal (originally 217

Hz pulse bursts) that is generated in the mobile phone during transmission (Sorri, Huttunen, Valimaa, Karinen & Lopponen 2001). GSM telephones usually work via a digital system (Jürgens, 2003). Analogue systems appear to be the most compatible with CIs. The problem experienced with digital systems is that sound is transmitted using a radio wave that produces a higher degree of Electromagnetic Interference (EMI). *"The amount of EMI produced depends on the type of digital signal being used by the carrier. The fastest radio wave produces the highest amount of EMI. When cochlear implant users hold digital phones next to their microphones, they frequently hear buzzing" (Tearney, 2002:1).*

This leads to problems for IFCIs to communicate optimally when using a mobile/cellular telephone. Different telephones will continue to be developed for people with normal hearing. It is therefore important to understand whether and how individuals with a hearing loss can adapt effectively to use these telephones. Research on the topic will improve the social environment IFCIs operate in.

The USA Cochlear Corporation sent out a questionnaire, in 1988, to 281 recipients of the Nucleus device (Waltzman, Cohen, & Shapiro, 1989). A total of 51 % of the respondents claimed that they were able to have an interactive telephone conversation either always or sometimes. The survey's conclusion was that not enough evidence was available to make a definitive statement regarding telephone competency. Although many of the IFCIs had reported communication capability when using the telephone, their ability was never formally assessed. The purpose of this study was to evaluate the ability of IFCIs to communicate via the telephone without the benefit of speechreading or additional cues.

The research question that needs to be answered is which type of telephone will enable a person with a cochlear implant to achieve the best speech discrimination for communication?

1.4 PROBLEM STATEMENT

Sorri, Huttunen, Valimaa, Karinen, Lopponen, (2001), found that possible incompatibility problem between cochlear implants, landline telephones and GSM phones have not previously been explored in a systematic manner. The use of telephones and mobile/cellular telephones by IFCIs was researched using a questionnaire. Differences were found between two implant systems. Neither Nucleus Spectra users nor SPRint users could understand the messages at all, under any of the test conditions. Substantial differences were found between the implant systems tested and some slight differences were also found between the two GSM models. It is clear that other implant systems and GSM combinations and different telephones should still be tested.

The problem statement is whether a telephone exists that is compatible with IFCIs for providing optimal communication without interference.

1.5 DEFINITION OF TERMS

Terms and concepts used in this study, as well as all other important and relevant concepts that are fundamental to the research study, are explained. Where there is contrwithsy about specific terms it is discussed and the most appropriate term is used.

1.5.1 Auditory speech discrimination

Literature contains different definitions for auditory speech discrimination. Different definitions found in the literature are discussed and the researcher will reside with one of these definitions.

Auditory speech discrimination refers to the skill of the listener to identify small differences in similar sound properties between vowels and consonants and depends on auditory acuity and attention (Cochlear Corporation, 1999).

Auditory discrimination is a process that consists of interconnected abilities enabling the receiver to detect sounds as a sensory event and make cognitive sense of this sound. It is obvious that this process involves a sensory modality together with perceptual-cognitive skills to make cognitive sense of the sensory event (Barrie, 1995).

Auditory speech discrimination is a measure of the ability to differentiate between various speech sounds, nonsense syllables, monosyllabic and multisyllabic words, (Nicolosi, Harryman,& Kresheck, 1996: 30).

These definitions are very similar and the researcher resides with auditory speech discrimination as the ability of the listener to discriminate differences in sounds, words and sentences and to make cognitive sense thereof.

1.5.2 Cochlear Implant

A cochlear implant is an electromagnetic device that performs the function of the damaged or absent hair cells (Cochlear Corporation updated, 2002; Martin, 1997:444; & Nicolosi, Harryman, Kresheck, 1996: 63). It is an electronic prosthetic computerised device implanted into the cochlea of individuals with severe-to-profound bilateral SNHL. Sound is translated into electrical impulses and delivered directly to the auditory nerve, via an electrode array. These electrodes are surgically implanted into the inner ear. The internal electrode array and receiver, together with an externally worn headset and speech processor, provide sound that is perceived by the recipient.

1.5.3. Deaf

The use of the capital letter “D” refers to the cultural definition of deafness, which relates to the use of Sign Language as first language by members of the Deaf community (Padden & Humphries, 1988:2).

1.5.4. deaf

The lowercase “d” in the word deaf is used to describe the physical impairment of being unable to hear most or all sounds. It will be used to refer to the degree of hearing loss in the categories of severe (71dB-90dB) and profound (91dB or greater), based on the pure-tone average of the unaided thresholds of the better ear (Scheetz, 1993:47).

1.5.5 Hearing loss

It is a general audiological term that is used to describe all degrees of loss of sound sensitivity regardless of the cause or the site of the impairment within the auditory system. It can be described as an abnormality of structure or function that is physiological, psychological or anatomical (Martin, 1997:12,467; Mueller & Hall, 1998:929; Nicolosi, Harryman, Kresheck, 1996: 81; & Paul and Quigly, 1994:15).

1.5.6 Mapping

The programming of different speech coding strategies into the speech processor of the cochlear implant is generally referred to as a *map* (Moor & Teagle, 2002). Through a map, it is possible for the recipient to hear speech. The mapping has significant influence on the development of improving speech and listening skills (Easterbrooks, 1997; Ling, 1990).

1.5.7 Open-set

Open-set refers to the auditory ability of a person to exactly hear spoken words or sentences without speech reading or any options from which to choose the correct stimuli. (Katz, 2002).

1.5.8 Postlingual hearing loss

Postlingual hearing loss refers to a hearing loss that occurred after speech and language was acquired (Cochlear 2001:6; Nicolosi, Harryman & Kresheck, 1996: 82).

1.5.9 Prelingual hearing loss

Prelingual hearing loss refers to a loss of hearing sensitivity that occurred before the development of speech and language skills. It may be congenital or adventitious (Cochlear 2001:6; Nicolosi, Harryman, & Kresheck, 1996: 82).

1.5.10 Sensorineural hearing loss

A sensorineural hearing loss is the loss of sound sensitivity, resulting from a pathological condition in the inner ear or along the nerve pathway from the inner ear to the brain stem. The ossicles and membranes of the ear are intact but the tiny hair cells that line the cochlea have been damaged. The damaged hair cells do not allow the electrical impulses to reach the remaining nerve fibres, which carry the information of sound to the brain. A sensorineural hearing loss may be cochlear or retrocochlear, depending on the site of the lesion. Sensorineural losses may be caused by several factors including genetic causes, injury, illness, the natural aging process and certain toxic medication (Cochlear Corporation, 1999:5; Martin, 1997:12; Mueller & Hall, 1998: 958; & Nicolosi, Harryman & Kresheck, 1996: 82).

1.5.11 Speech coding strategy

Speech coding strategies refer to the function of the speech processor to divide the input auditory signal from the microphone into frequency bands. These correspond to the number of stimulating electrodes in the implanted device (Moore & Teagle, 2002). Speech coding strategies are methods of converting incoming sound into electrical signals. Different strategies process sound in fundamentally different ways. There are three different speech coding strategies used in the Nucleus products namely, SPEAK, Continuous Interleaved Sampling (CIS) and Advanced Combination Encoders (ACE) (Cochlear Corporation, 1999).

1.6 ABBREVIATIONS

ACE	Advanced Combination Encoders
ALD	Assistive Listening Devices
BM	Baseline measurement
BTE	Behind the Ear
CI	Cochlear Implant

CIs	Plural form of Cochlear Implant
CID	Central Institute for Deaf
CIS	Continuous Interleaved Sampling
IFCI	Individual fitted with a Cochlear Implant
IFCIs	Plural form of Individual fitted with a Cochlear Implant
EMI	Electromagnetic interference
FDA	Food and Drug Administration
FM	Frequency Modulation
GSM	Global System for Mobile Communication
SMS	Short message system/text message via a mobile phone
SNHL	Sensorineural hearing loss
SNR	Signal-to-noise-Ratio
TTY	Teletype deaf network
TDD	Telecommunication Device for the Deaf
T1	Telephone one (Telkom landline telephone Venus Series XXX)
T2	Telephone two (The Nucleus telephone adapters)
T3	Telephone three (The TEKNIMED AURIALD, TE 2002 ENZER CWP60)
T4	Telephone four (The Phone-amp)
T5	Telephone five (Nokia 3110)
USA	United States of America

1.7 LAYOUT OF CHAPTERS

The chapter layout states the headings of all the chapters included in the study, with a short description of the content and value of each.

Chapter 1

Chapter one presents literature and perspectives on current issues. Research studies by other professionals are discussed in order to formulate the problem statement and to provide an introduction and orientation to the present study. Relevant terminology is explained and an withview of the contents of each chapter is provided.

Chapter 2

This chapter provides theoretical perspectives on the topic such as communication skills necessary for telephone use, speech discrimination of individuals fitted with a cochlear implant, and variables affecting the quality of the conveying message with the telephone. This chapter investigates telecommunication devices that are currently used and discusses recent studies regarding telecommunication in individuals fitted with cochlear implants.

Chapter 3

The methodology used in the study is presented. The aims are stated along with a detailed discussion of the research design and the materials, instruments, coupling and procedures used for the gathering of data.

Chapter 4

The results of the study are presented, according to the sub-aims as stated in the methodology section. Under each sub-aim, a short withview is provided of the most important findings. Results are displayed using tables and graphs. The data is interpreted and discussed with reference to relevant literature. The findings of the research are presented and discussed in order to answer the research question.

Chapter 5

Relevant conclusions are drawn in relation to each sub-aim in order to answer the research question proposed in Chapter 1. Findings are critically evaluated. Recommendations for further research are discussed. The limitations and strengths of the current study are discussed.

1.8 CONCLUSION

As a result of the theoretical and practical issues discussed above, it is clear from reviewing the literature, that telephone use seems to be emerging as a high priority with IFCIs, in their desire to become part of the hearing life in every possible way. Various aspects that influence IFCIs' ability to utilise a telephone successfully are briefly discussed. Literature reveals that possible incompatibility problems between cochlear implants, landline telephones and GSM phones have not previously been explored in a systematic manner. It is important that implant systems, together with GSM devices and various telephones need to be tested in order to determine which best enables the IFCIs to make the optimum use of a telephone for communication.

1.9 SUMMARY

This chapter serves as the rationale and background for the present study. Certain shortcomings, needs and contrwithsies about the research topic are identified in order to formulate the problem statement. An withview of cochlear implants is given and the history as well as current conditions necessitating the need for research regarding the topic, is discussed. Relevant terminologies used in the study are explained for clarification. Abbreviations and the chapter layout complete the introductory chapter. The need for researching the use of various telephones by individuals fitted with a cochlear implant is discussed.

CHAPTER 2

TELEPHONE USE BY INDIVIDUALS FITTED WITH A COCHLEAR IMPLANT

2.1. INTRODUCTION

"*If all my possessions were taken from me with one exception, I would choose to keep the power of communication, for by it I would soon regain all the rest" (Daniel Webster in Van Tatenhove, 1987:185).*

Communication is a basic need in order for humans to live a quality life (Louw, van Ede & Louw, 1998; Sternberg, 1998). Normal hearing individuals use the telephone daily to make business arrangements, schedule appointments, make emergency calls and to stay in touch with relatives and friends. Individuals who have a hearing loss cannot perform these basic functions and thus where telephonic arrangements have to be made, they are dependent upon others to make the call on their behalf.

This chapter contains a theoretical perspective regarding telephone use by IFCIs. Although IFCIs are a heterogeneous group, they possess many different individual characteristics, which may influence results of studies they participate in (Parker & Irlam, 1995). Therefore it is necessary to research which characteristics of IFCIs influence their ability to use the telephone. It is also necessary to understand the skills needed by an individual to communicate with a telephone, as well as the factors influencing the speech discrimination of IFCIs, both when using and when not using a telephone. This chapter will focus on speech discrimination of IFCIs and what skills are required to communicate successfully with a telephone. Previous research regarding telephone use in IFCIs will also be discussed.

2.2 SPEECH DISCRIMINATION OF INDIVIDUALS FITTED WITH A COCHLEAR IMPLANT

In many cases conventional hearing aids do not provide effective results for individuals with severe-profound SNHL. This happens due to the fact that the hearing aid cannot make speech loud enough for them to hear, and sometimes too loud or indistinctive to understand (Dorman & Loizou 1997). This has a negative impact on a person's speech discrimination and ability to communicate successfully. A CI differs fundamentally from a hearing aid. It does not amplify sound, but translates sound into electrical impulses, which are delivered straight to the auditory nerve which perceives these impulses as sound (Boswell, 2002; Brown, Clark, Dowell, Martin & Seligman, 1985, Hay, 1997; & O'Donoghue, Nikolopoulos, Archbold & Tait, 1998). This benefits it's users as it leads to more success in detecting environmental sounds, discriminating speech (which prior to an implant was impossible) and successful use of a telephone (Boswell, 2002; Cochlear Corporation updated, 2002, David, Ostroff, Shipp, Nedzelski, Chen, Parnes, Zimmerman, Schramm & Seguin, 2003; Faber & Grontved, 2000; Osberger & Maso, 1993; Tait, et al. 2001; Valimaa, et al. 2001; & Waltzman, Cohen & Shapiro, 1989).

Relatively few studies have been published regarding adult IFCIs. Evidence from the published literature shows that prelingually deaf children who have received CIs, continue progression in open-set speech abilities without reaching a plateau a few years after implantation (O'Donogue, et al. 1998; Waltzman, et al. 1989). Open-set speech ability depends largely upon speech discrimination of speech without speech reading. Achieving auditory open-set speech discrimination is necessary especially when using a telephone, as the speaker cannot be seen, and the listener cannot use the speaker's body language, facial expression or speech reading to enhance the meaning of the message (Tucker, 1998). Congenital and prelingual deaf individuals fitted with a CI can develop considerable open-set speech understanding. Postlingual deafness however, correlates with better post-operative performance, but both pre- and postlingual deafened individuals fitted with a CI continue to show significant improvement with open-set speech recognition with time (Allen, Nikolopoulos & O'Donoghue; 1998; & Waltzman, Roland & Cohen, 2002). The assumption can therefore be made that adults, although prelingually deaf, on receiving the implant learned to listen and developed significant open-set speech discrimination abilities after implantation (O'Donoghue, Nikolopoulos, Archbold & Tait, 1998). This implies that IFCI's speech discrimination skills improved considerably and that the CI enables an individual to obtain a higher level of these skills.

Speech discrimination however does not depend solely on the auditory stimulus, regardless of the presence a CI (O'Donogue, et al. 1998). In order to understand any spoken message the listener should possess *linguistic knowledge, real world* *experience, social knowledge* and *physical knowledge* as well as *cognitive context* (O'Donogue, et al. 1998; Owens, 1999).

The above pre-requisites can be described as follows:

Linguistic knowledge refers to the phonologic, lexical, syntactic and semantic features of the specific language in which the message is delivered. Linguistic knowledge is the foundation for language development, competency and perception. Prelingual IFCIs do not have this foundation prior to the implant and that is why these skills need to be developed in order to reach linguistic competency, which can then lead to successful verbal communication without cues, with a telephone.

Real world experience refers to the knowledge of past and current world events.

Social knowledge refers to the way people use language to interact (O'Donoghue, et al. 1998; Owens, 1999).

Physical knowledge refers to the two communicators' perception of the people, places and objects that form the context of a conversation (Owens, 1999).

Cognitive context includes the shared knowledge between the two communicators about the physical world.

These factors influence speech discrimination, which in turn can have an influence on the ability of IFCIs to successfully use the telephone. Certain communication skills are also necessary to take into account when telephone use is discussed.

2.3 COMMUNICATION SKILLS NECESSARY FOR TELEPHONE USE

In order to fully understand a spoken message the listener must be able to detect, discriminate, identify and comprehend what the speaker is saying (Ling, 1990).

Auditory discrimination is a process, which consists of interconnected abilities enabling the receiver to detect sounds as a sensory event and to make cognitive sense of this sound. It is obvious that this process involves a sensory modality together with perceptual-cognitive skills to make cognitive sense of the sensory event (Barrie, 1995). In order for an individual to make cognitive sense of the sensory input these auditory skills need to interact and flow in a chain.

The *auditory skills* needed are explained in order in Figure 2.1

Auditory acuity or detection

Refers to sensory responses to sound (Barrie, 1995; Cochlear Corporation, 1999).

↓

Auditory attention

Alerts the listener to sound that is followed by the registration of the sound.

Changes in a sound field, the start of a new sound, the mind-set of the listener, physical state and motivation are a few of the factors that might have an influence on a listener's auditory attention (Barrie, 1995)

↓

Auditory discrimination

This refers to the skill of the listener to identify small differences in similar sound properties between vowels and consonants and depends on auditory acuity and attention (Barrie, 1995; Cochlear Corporation, 1999).

↓

Auditory memory

This refers to the skill of the listener to retain awareness of the sound in its absence in order to be able to match, contrast and recognise sounds (Barrie, 1995), and can only be achieved if acuity, attention and discrimination skills are aurally intact.

Figure 2.1 Auditory perception skills needed to comprehend a spoken message.

These auditory perception skills are necessary and together a spoken message can be discriminated and perceived. Factors associated with differences in individuals regarding speech discrimination have been described in recent literature (Geers, Brenner & Davidson, 2003; O'Donogue, et al. 1998), and are worth mentioning in the present study, as these factors indicate why not all IFCIs implanted in this country, could be used in the study. Some of these include: associated handicaps, coding strategies used, frequency of programming, type of communication mode, fully active electrode array, rehabilitation strategies, family and community support, educational settings, non-verbal intelligence and smaller family size.

Speech signals must be heard first before they are recognised. As pure-tone signals contain frequencies from 125 Hz-8000 Hz it is estimated that speech can be understood at a level of 300 Hz-3000 Hz (Tait, et al. 2001). An interesting fact is that these frequencies use the same bandwidth as that of a telephone line. Most devices, including a CI, reproduce sound signals with a range of 200 Hz –7500 Hz (Moore & Teagle, 2002). As each speech sound has a unique set of frequencies, it is vital for speech understanding that an implant should be able to transmit a broad range of frequencies and should have sufficient resolution for frequencies within that range so that the sound of the language can be identified. The rationale for IFCIs hearing and understanding speech sounds is present in each individual's speech coding strategy. Due to the fact that individual differences and different frequencies play a role in conversing successfully with the telephone, the questions arise how and why telephones differ and which telephones an IFCI would use the most successfully?

2.4 VARIABLES AFFECTING TELEPHONE COMPETENCY

A survey was conducted, on implanted adults and parents of children with CIs, to determine the benefits of the implant, as perceived by adult recipients and the parents of children with implants (Tucker, 1998). The age of the respondents varied form 11 to 79 years of age, of whom 78% were postlingually deaf and 19% prelingually deaf. The time that the device had been used varied from one month to 18 years. Eighty one percent of the respondents indicated that the implant enabled them to communicate using the telephone. Several respondents mentioned that the quality of the telephone or the person, to whom they spoke, made a significant difference in how the message was understood. This serves as a rationale for the present study, as auditory open-set speech recognition is achievable for most recipients (post- and prelingual) provided the certain conditions are met and rehabilitation and mapping is optimised (Waltzman, Roland & Cohen, 2002).

As already mentioned, it is necessary to achieve auditory open-set speech recognition, especially when using a telephone, as the speaker cannot be seen, and the listener cannot use the speaker's body language, facial expression or speech reading to enhance the meaning of the message. In theory, once an IFCI achieves open-set speech recognition, he or she should be able to converse successfully via the telephone (Tucker, 1998; Valimaa, Sorri & Lopponen, 2001; & Waltzman, Roland & Cohen, 2002). Such a statement however cannot be generalised because of the influence of various factors such as the quality of the telephone and the speaker's voice (Tucker, 1998).

In order to understand what type of problems IFCIs experience when conversing with the telephone, the quality of the telephone, the speaker's voice and different speech-coding strategies must be taken into account (Moore & Teagle, 2002, Tucker, 1998 Wolmarans, 2003).

2.4.1. The quality of the telephone

The quality of the telephone depends on a variety of factors (see Figure 2.2), such as electro-magnetic interference (EMI), telecoils, different speech processors and problems associated with different types of telephones (Tucker, 1998)

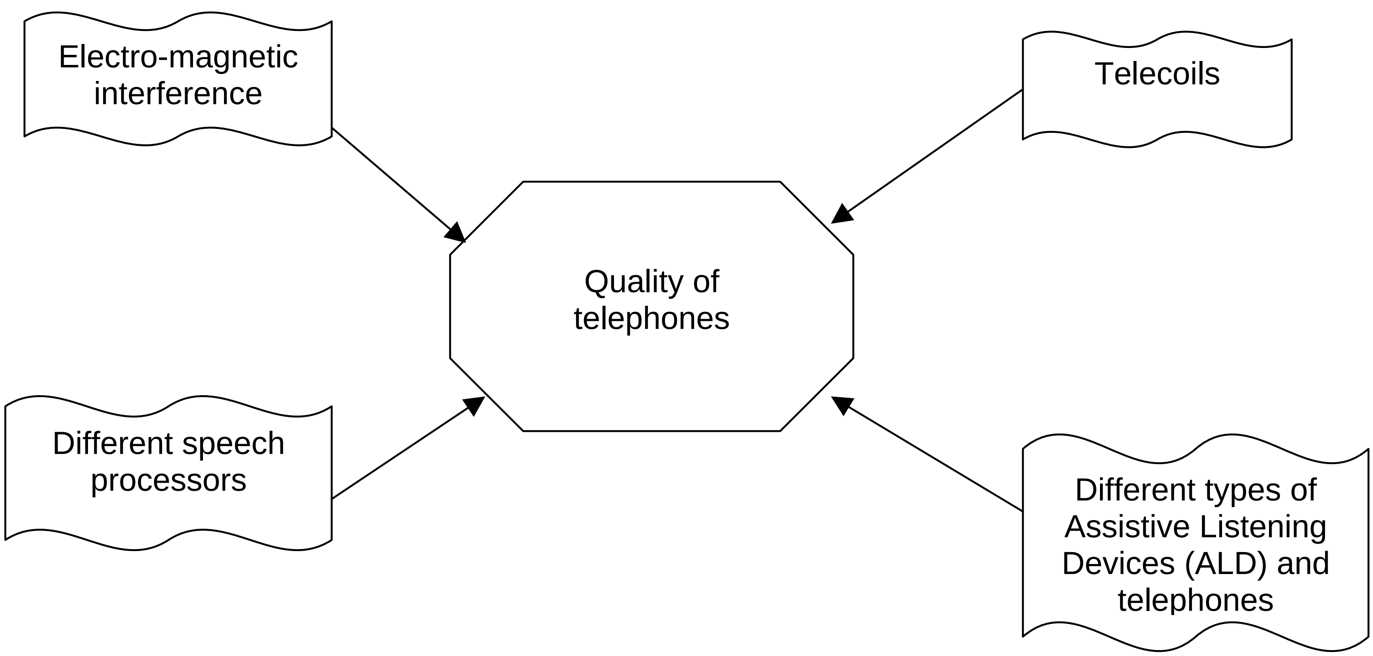


Figure 2.2 Variables affecting the quality of the telephones

2.4.1.1 Electro-magnetic interference (EMI)

The quality of the telephone depends upon the clarity of the message. The clarity can be influence by EMI. EMI is present in appliances such as mobile/cellular telephones, radio, television transmitters and other electronic devices (Clifford, Joyner, Stroud, Wood, Ward, & Ferhandez, 1994; de Cock, Spruijt, van Campen, Plu, & Visser, 2000; FDA Consumer, 1994; Heukelman, 2003, Jürgens, 2003; & Wolmarans. 2003). Interference results from the detection of electromagnetic fields emitted by the mobile/cellular phone (Van Vliet, 1995) as well as other electronic devices. Some CIs are more prone to be influenced by EMI, such as the Spectra Nucleus speech processor. A telecoil is also very sensitive to EMI (Wolmarans, 2003). This influences the clarity of the message and could therefore have a significant influence on the perception and discrimination of the message.

2.4.1.2 Telecoils

As described above, an IFCI is dependent upon a plug-in type telecoil (except the ESPrit 3G users) when using a device such as a telephone. In South Africa, general landlines operate with a restricted frequency bandwidth of 4 kHz. This might cause even normal-hearing individuals to have difficulty hearing words that have a high-frequency sound (Jürgens, 2003; Wolmarans, 2003). Another feature of landlines is that they work on an analogue system. An analogue system causes the least amount of

EMI with individuals using a CI. Therefore it can be concluded that a message delivered with a telephone working on an analogue system, would be clearer.

According to Wolmarans (2003), a telecoil and a transformer both function as a magnetic induction. Sounds are picked up and amplified by a microphone. The output of the amplification is connected to the induction loop that generates a magnetic field, which correlates with the speech sound. The receiver telecoil is a coil that serves as input for the speech processor. If this coil is placed in the correct orientation inside the magnetic field, the speech signal emanating from the amplifier can be measured. The aim with a telecoil is to enhance the signal-to-noise ratio (SNR). The importance of a telecoil is that it correlates with speech sounds, thus making speech sounds clearer and easier to discriminate. The assumption can be made that telephones with a telecoil will provide IFCIs with more speech discrimination than a telephone without a telecoil.

2.4.1.3 Different speech processors

A CI should not just be regarded as a hearing system, but seen as a communication system, because of the constant new developments and the expansion of the CI's potential. Today, various speech processors are available, each with unique features, depending on their various speech coding strategies (Moore & Teagle, 2002). There are however subtle differences between these speech processors, which influence the quality of speech discrimination, and in turn will have an impact on telephone competence.

The behind the ear (BTE), ESPrit 3G differs from the other Nucleus speech processors as it has a built-in telecoil. This is designed to make telephone use clear, simple and attachment free, enabling wireless access to assistive listening devices and audio induction loops. The ESPrit 3G has a T-switch that enables the IFCI to hear while on the telephone and giving wireless access to an array of assistive listening devices and telephones (Cochlear Corporation, 1999).

The speech processors found in this range are

- Body-worn Nucleus Spectra and Sprint Speech Processor

This speech processor is a small computer worn on the body and connected to the headset by cables (Cochlear Corporation, 1999). A Microphone in the headset receives sound and converts it into electrical signals (Cochlear Corporation, 1999).

- The ESPrit and ESPrit 3G speech processors

These are multichannel ear-level BTE speech processors that are connected to the transmitting coil by a thin cable. In addition, the Nucleus ESPrit 3G speech processor has a built-in telecoil incorporated into the speech processor (Cochlear Corporation, 1999). These speech processors differ in the speech coding strategies they support and will be discussed in more detail later in this chapter.

2.4.1.4 Different types of telephones

Different companies manufacture telephones, which satisfy the different needs of the consumer market. Some telephones are made with a telecoil and some without. Digital telephones such as mobile/cellular telephones utilise a GSM digital signal. GSM is the fastest of the digital signals, and the faster the transmission rates are, the more prone they are to EMI (Tearney, 2002). GSM telephones are known to disturb CI systems. The basic reason for this is the broad-spectrum radio signal generated in the mobile/cellular phone during transmission, approximately 217 Hz pulse burst (Sorri, et al. 2001). This differs from analogue systems and their EMI as no GSM signal is emanated and the transmission rates are slower (Heukelman, 2003). There are various telephones on the market, both locally and internationally. Due to the limited amount of previous research concerning this topic and as this is the first research project of its kind, only five telephones were selected on which preliminary results would be obtained.

According to Tearney (2002), no mobile/cellular telephone on the market has yet been designed especially for use with a CI system. The improvements in CI technology have yielded better discrimination among its users. According to Tearney (2002) an important consideration that influences telephone compatibility with a CI is whether the signal being used is analogue or digital. Sorri, et al. (2001) assessed the use of a telephone by testing two mobile/cellular telephone models, the Nokia 3110 and 6110, with different CI systems. It became clear that other implant systems and GSM mobile/cellular telephones also need to be assessed. The problems found with mobile/cellular telephones call for technical development of GSM phones to facilitate mobile/cellular telephone use with any implant combination.

Technical interference emanates from digital systems via a radio wave (217 Hz pulse burst), which produces a high degree of EMI. The EMI causes a buzzing sound when held next to a CI and this causes disturbances when listening to the message (Tearney, 2002; Sorri, et al. 2001). According to Tearney (2002), who is an IFCI herself, an analogue system has generally been found to be more compatible with an IFCI as EMI is less likely to cause interference.

It became clear to the researcher that there is a need for CIs and telephone-compatibility. There is an urgent need for a working relationship between practising audiologists and telephone companies interested in developing telephones. The shortcomings of the current generation of telephones could be identified, examined and researched with a view to developing the next generation of effective and compatible telephones.

Some hearing aid compatible telephones have an induction loop that is either built into the handset or fitted separately. To the best of the researcher's knowledge no study has yet been conducted into which type of telephone, currently available, provides the CI's speech processor, with the best speech discrimination, in such a way that the IFCI can obtain the optimum use of a telephone. This paucity in the literature serves as the rationale for this study. Five different telephones have been examined in order to determine which best meets the needs of IFCIs and their speech processors.

It is conclusive therefore that the quality of a telephone depends largely on the presence of a telecoil, electromagnetic interference as well as the different type of speech processors and different types of telephones. These factors affect the IFCI's ability to successfully converse with a telephone.

2.4.2 Quality of the speaker's voice.

The second variable affecting telephone competence is that of the quality of the speaker's voice (Tucker, 1998). The human voice contains, in its acoustic structure, a wealth of information regarding the speaker's identity and emotional state (Belin, Zatorre, Lafaille, Ahad, & Pike, 2000). A person's emotional state influences his or her voice quality. Voice quality is important when communicating by telephone, as the listener cannot see the speaker's non-verbal behaviour. Voice quality also influences the rate of the listener's perception of the conveyed message. This has an impact on speech discrimination and the perception of the message conveyed via the telephone. Studies have shown that frequency levels differ between genders (Chun, 1987; Mullennix, Stern, Wilson, & Dyson, 2003). It had been determined that the fundamental frequency of a typical male is 100 Hz, and that of a female is 200 Hz (Makela, Alku, Makinen, Valtonen, May, & Tiitinen, 2002). Fundamental frequency and its harmonics determine the temporal dynamics of speech in the human auditory cortex and the speech specificity arises out of cortical sensitivity to the complex acoustic structure (Chun, 1987). Male and female voices differ in pitch and loudness. Pitch is determined by length and volume of the vocal folds (Meyer, 1988). Pitch indicates the gender of the speaker, maturity of the speaker, intonation patterns and melody of speech, subtle variations of time, speed, inflection, stress and volume (Greene, 1972). This has a significant influence on speech discrimination, especially when communicating via a telephone, where the listener cannot depend upon additional cues such as speech reading.

Another factor that is important for speech discrimination with a telephone, even with normal-hearing individuals, is that of the familiarity of the speaker's voice (Tucker, 1998). It is easier to communicate with a familiar person via the telephone, as the frequency range, pitch, loudness and other acoustical characteristics of that person's voice are familiar.

These factors serve as rationale in this study for using unfamiliar voices, in order to determine beyond a reasonable doubt, which telephone best enables speech discrimination between familiar and unfamiliar male and female voices.

2.4.3 Types of Speech Coding Strategies

The third variable found to have an effect on telephone competency with IFCIs, is the different type of speech coding strategies. A map is a programme in the internal device of the IFCI's speech processor, which contains certain speech coding strategies (Moore & Teagle, 2002). These speech-processing strategies are methods of converting incoming sounds into electrical signals. Different strategies process sound in fundamentally different ways. The map does the temporal coding of sounds. This strategy is stored into the memory of the speech processor. The map refers to how a speech processor translates the pitch, timing and loudness of sounds into electronic signals. The information is then coded and sent to the electrodes implanted into the cochlea (Cochlear Corporation, 1999). In order to exploit the present technology of a CI device, it is necessary to understand the electrical stimulation related to the coding of speech sounds. There are three different Speech Coding Strategies used in the Nucleus products namely, SPEAK, Continuous Interleaved Sampling (CIS) and Advanced Combination Encoders (ACE) (Cochlear Corporation, 1999).

- The SPEAK Speech Coding Strategy is used in the Spectra Nucleus speech processor. This strategy divides the incoming signal into 20 frequency pitch bands. Each of these bands is assigned to one of the 22 implanted electrodes in the cochlea. The electrode is sequentially stimulated, depending on the various sounds. The louder a sound is, the more electrodes will be activated (Cochlear, 1999:12). The SPrint Nucleus speech processor supports SPEAK, CIS and ACE (Cochlear, 2001:12).

- The CIS Speech Coding Strategy only stimulates a fixed number of electrodes, regardless of the incoming sound information. The advantage with CIS is that electrodes are stimulated at a higher rate, which provides details about timing information for speech (Cochlear, 2001:12).

- ACE combines the number of stimuli with the rate, thus combines the best characteristics of both SPEAK and CIS, in order to provide the best optimal pitch and timing information (Cochlear, 2001:12). ESPrit Nucleus CIs are coded with SPEAK and ACE (Cochlear, 2001).

It is clear that each different speech coding strategy provides for differences in speech discrimination because of timing, variation in frequency bands etc. These factors will also influence telephone use, as a CI with one type of speech coding strategy, might be more compatible with one type of telephone, than another implant with a different speech coding strategy.

One of the advantages of a well-balanced map can be found in the enhancement of the IFCI's speech discrimination abilities. When SPEAK was programmed into the speech processor of children with a severe-profound hearing loss, it contributed significantly to improved speech discrimination skills (Geers, Brenner & Davidson, 2003). According to Wouters, Geurts, Peeters, Van den Berghe and van Wieringen (1998), speech recognition results obtained in a quiet environment can be very good for implantees, using the speech coding strategies described above. It should be kept in mind that performance might degenerate when noise or other interfering sounds are present. This problem is not restricted to IFCIs, as normal hearing people have the same problem. The impact for IFCIs might be more severe, because of the Signal-to-Noise Ratio (SNR) (Wouters, et al. 1998). When assessments are done with IFCIs, especially assessments involving the telephone, the performance of normal hearing individuals under similar conditions should be taken into account. It should be considered that background noises or other interference might also affect the speech discrimination of normal hearing individuals when using a telephone. IFCIs have less experience on the telephone and have to use their listening ability to a much higher extent than normal hearing individuals. A CI also differs from normal hearing in that it not only enhances the sound that the IFCI is listening to, but also any background noises. A battery of tests conducted on open-set speech recognition revealed significant improvements in word and sentence scores, as new technology generated new speech coding strategies (David, et al. 2003).

2.5 TELECOMMUNICATION DEVICES CURRENTLY USED

New technological developments expand the telecommunication market and new telephones are continually being introduced. In order to find a telephone that correlates with the needs of an IFCI it is necessary to look at the advantages and disadvantages of various telephones and telephone devices currently in use.

Relay services were introduced in order to help people with hearing problems integrate into society and for them not to be deprived or limited by obstacles they may face because of their hearing loss (Naito & Murakami, 2000). The first relay service was in the form of Teletype network (TTY). The TTY machine sends messages across telephone lines via a modem. In 1970 the Telecommunication Device (TDD) for the deaf was introduced which enables instant communication for individuals with a hearing loss. Today a TDD is used to put individuals with a hearing loss in touch with normal hearing individuals with the assistance of trained operators (Australian Communication Exchange, 2000, Naito & Murakami, 2000). This creates a problem, as communication between two people needs to be mediated by an operator, which may take longer and can discourage people from having intimate, private conversations. Despite this drawback, relay services provide a means of communication to individuals who would previously not have had the opportunity to use the telephone.

Relay services however have not proven to be universally successful.
In the USA the Disability Act of 1990 compelled telephone companies to provide relay services (Naito & Murakami, 200). It had a major impact on the deaf community of the USA as it brought more individuals into contact with one another (Naito & Murakami, 200). Relay services in Australia also proved to meet the needs of individuals with a hearing loss (Australian Communication Exchange, 2000). However, these successes are in contrast to those found in Japan. Japanese individuals with a hearing loss were economically supported, but telecommunications were difficult due to the absence of text telephones and relay services (Naito & Murakami, 2000). In South Africa, relay services did not have the desired effect, due to various factors and therefore did not prove to be successful (Jürgens, 2003).

New technological developments have led to pager communications and the use of mobile/cellular telephones, which enhance non-verbal communication. These developments provided individuals with a hearing loss, with more active telecommunication possibilities (Naito & Murakami, 2000). Text messages/sms produced by a mobile/cellular telephone have become a very popular means of communication for people with a hearing aid or CI (Naito & Murakami, 2000). Electronic mail and facsimiles are also used extensively to stay in contact with friends and family as well as in business. It is important to note that new research opportunities arise as technology develops and these telephones need to be tested and compared against those currently used in order to determine the best possible telephone for IFCIs.

2.6. RESEARCH REGARDING TELECOMMUNICATION

Extensive research has been conducted on IFCIs and telephone use, and it is important to take cognisance of the findings and shortcomings of these studies, in order to determine what has already been achieved to successfully fulfil the telephone needs of IFCIs. When speech discrimination for telephone use is examined, there seems to be good correlation between subjective experience and objective testing (Parker & Irlam, 1995). A study on telephone use by a multi-channel IFCI was done in 1985 (Brown, et al. 1985), when it was discwithed that a particular IFCI had had telephone conversations on a regular basis with relatives and friends. CID Everyday Sentences were used to assess his ability to discriminate speech and this IFCI scored 47% speech recognition in these tests, which was consistent with his own reports of telephone use. The study in

1985 was conducted without the use of any ALD or special telephone commercially available to IFCIs today (Brown, et al. 1985). Due to this lack of availability of any ALD or special telephones the present study is being conducted to gain more insight on the efficacy of various modern-day devices, which are currently commercially available.
Studies conducted on children fitted with a CI reveal that they do develop telephone competence, but take several years to acquire an understanding of the spoken language upon which the use of a telephone depends, ranging from only answering the telephone and calling someone, to using the telephone to have a conversation (Lalwani, Larky, & Wareing, 1998; Sheenan, 2003 & Tait, et al. 2001).

Studies have been conducted in order to determine the quality adult IFCIs's telephone use after implantation. Cohen, Waltzman, & Shapiro, (1989) reported that 23% of the implantees at New York University Medical Centre were able to use the telephone successfully. Most IFCIs report good telephone competence, but the first standardised tests to quantify results, was undertaken by Cohen, et al. in 1989. Their findings suggested that IFCIs' reported telephone abilities do not always reflect their competence and that motivation and confidence play a significant role in their success. Literature reveals that both with children and adults, the ability to use a telephone improves with the development of auditory skills (Tait, et al. 2001). Therefore experience seems to be extremely relative in the use of a telephone, as experience enhances confidence and with confidence more and more skills are practised and enhanced (Tait, et al. 2001). However, these findings were based on questionnaires that focused on telephone skills. Subsequently these IFCIs were assessed through assessment tools in order to determine whether their actual abilities reflected their own perception of telephone use.

This study will assess the participant's speech discrimination abilities (using various telephones) by using an actual test condition, rather than written questionnaires, to determine not only their own perception of their abilities, but their actual abilities with various telephones

2.7 CONCLUSION

Alexander Graham Bell stated that, when working with deaf individuals, professionals should keep in mind that as they can learn to talk intelligibly, they should be encouraged to use the same language as the community in which they live (Ling, 1990). The same principle should therefore apply to their ability to use a telephone. Telephone competency is a reality and more and more IFCIs demonstrate the ability to communicate successfully using a telephone (Sorri, et al. 2001). The same telephone competency could therefore be expected from an IFCI who has mastered open-set speech discrimination, when compared to a normal hearing person.

In the light of the discussion in this chapter it is evident that certain factors influence the speech discrimination of IFCIs, and that an investigation is needed to identify factors which may contribute to higher levels of telephone performance (Waltzman, Cohen, Gomolin, Green, Shapiro, Hoffman & Roland, 1997). It is obvious that speech discrimination, open-set abilities and confidence plays a big role in both adult and children IFCIs who wish to communicate via a telephone. It is important to note that it has been documented in the literature that both adults and children who were fitted with a CI have managed to use the telephone with some degree of success. There is however a hiatus in the literature, as to whether a specific telephone meets all the needs of the CI and the people relying on it.

2.8. SUMMARY

Communication is a basic need of all human beings, the telephone being one of the more commonly used modes of communication. IFCIs experience difficulties using a telephone. This chapter highlights speech discrimination in the CI population and the pre-requisites in order to gain these skills, as it is vital for successful telephone use. The communication skills necessary for telephone use and the variables affecting telephone competency are discussed in detail. Research studies regarding telephones currently used by IFCIs are critically evaluated. This study aims to provide preliminary results in order to stimulate research regarding various types of telephones, and which telephone, currently available, is the most compatible with IFCIs. It aims to empower technologists working in this field to actively take note of the need for development and continuous research regarding various devices that will enable more IFCIs to receive the maximum speech discrimination with the minimum interference.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTON

The introductory Chapters 1 and 2 contained the rationale for this study and an withview of the literature which is relevant to telephone usage, telephone devices and IFCIs. This study aims to provide preliminary results to stimulate future research in the regard of different telephones for IFCIs. In order to execute such a study, well-defined aims and sub-aims are necessary. This chapter describes the various aims and steps taken, (i.e. the research design, the participants, the material and apparatus used), to determine the aims.

3.2 AIMS OF THE STUDY

The aim of this study was to determine which landline telephone and/or mobile or cellular telephone will enable a person with a cochlear implant to achieve the best subjective experience and objective speech discrimination scores.

In order to reach the above aim the following sub-aims were formulated:

3.2.1 To determine the subjective experience and objective speech discrimination scores obtained by a group of individuals fitted with a cochlear implant measured by different voice-types.

3.2.2 To determine the subjective experience of speech discrimination of a group of individuals fitted with a cochlear implant obtained with four landline telephones and one mobile/cellular telephone.

3.2.3 To determine the objective speech discrimination scores of a group of individuals fitted with a cochlear implant obtained with four landline telephones and one mobile/cellular telephone.

3.2.4 To compare the subjective experience and the objective speech discrimination scores of a group of individuals fitted with a cochlear implant obtained with four landline telephones and one mobile/cellular telephone.

3.3 RESEARCH DESIGN

"A research design is a strategic framework for action that serves as a bridge between research questions and the execution or implementation of the research. Research designs are plans that guide the arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to the research purpose with the economy in procedure" (Terre Blanche & Durrheim, 1999:50).

For the purposes of this study an applied, exploratory, descriptive, research design was used (Struwig, Stead, 2001 & Terre Blanche, Durrheim, 1999). Applied research usually aims to contribute towards practical issues of problem solving and decision-making. The specific research design further aims to broaden findings that may be applied in a specific context in order to assist decision-makers in drawing conclusions about the particular problems being dealt with (Terre Blanche & Durrheim, 1999).

Exploratory research investigates a field where little research has been done in order to develop and simplify ideas and formulate relevant questions for more defined investigation in the future (Struwig & Stead, 2001)

In this study the practical problem to be solved was to determine which telephone provided the best speech discrimination scores for participants with a cochlear implant. A descriptive study aims to describe certain phenomena completely and accurately by measuring relationships and to provide explanations to determine the influence one variable has on another (Struwig, Stead, 2001 & Terre Blanche, Durrheim, 1999). Objective measurements were made by using various telephones and applying different assessments. The findings of this study will guide the cochlear implant users, as well as audiologists who are involved in their rehabilitation, in the decision-making process for selecting a telephone, which should provide the best speech discrimination for IFCIs

3.4 SAMPLE

The aim of sampling was to select a group that would be representative of the population from which the researcher aimed to draw conclusions. A large enough sample should be obtained to allow the researcher to make inferences about the population (Terre Blanche & Durrheim, 1999). The selected participants had to adhere to certain criteria in order to ensure that they were representative of the target group.

3.4.1 Participants

Participants were adults with CIs, who had to adhere to the following criteria in order to take part in the present study.

3.4.2 Criteria for the selection of participants

It is essential to set relevant criteria to ensure accuracy of the research. With the selection criteria the research aims to use homogenous factors, which represents the bigger part of this group and eliminates variables that might influence the results. The following criteria were chosen for this study, and the rationale for the decision is discussed.

3.4.2.1 Geographical feasibility

The execution of this study required the use of specific equipment, such as audiometers, soundproof rooms and different telephones and connections. The University of Pretoria provided all these facilities. Consequently participants were required to travel to the University campus in Pretoria where the assessment was conducted. The researcher therefore, decided to limit the prospective participants to IFCIs living in the Gauteng Province and who were implanted by the Pretoria Cochlear Implant Team.

3.4.2.2 Cochlear implantation

A person with a Nucleus CI and one of the following speech processors (either an ESPrit-22, ESPrit-24, Sprint or 3G.) could participate in this research.

3.4.2.3 Age

There is a hiatus in the research on adults and because open-set speech recognition tests were developed and standardised on adults (Waltzman, Cohen, Gomolin, Green, Shapiro, Hoffman & Roland, 1997), the researcher anticipated better and more functional results if only adults participated in the present study.

Recipients were required to be between the ages of 18 and 60 years. As a participant in this research project the participant was required to possess adequate language skills. A person above 18 years is expected to have acquired these particular skills. After the age of 60, normal ageing can affect perceptual skills, attention, concentration, memory, speed of processing, language, hearing and central auditory processing skills in a negative manner (Cohen, 1987). The researcher's decision to select only adults, was based on the fact that evaluation of the speech perceptual abilities of children, can be influenced by the child's linguistic abilities, which may invalidate research results (Miyamoto, Osberger, Robbins, Myres, Kessler, Pope, 1991; O'Donoghue, et al. 1998). Most assessment tools for speech discrimination have been adapted from those developed for adults and can present problems for children with insufficient language skills, cognitive immaturity and linguistic and auditory delays.

The researcher used adult participants, rather than children, because adults have a more evolved language structure, whilst the language structure of children is continuously developing (Owens,1999). More reliable results could be drawn from adult participants, especially where telephones are concerned.

3.4.2.4 Language

Participants had to be English or Afrikaans mother-tongue speakers. Material used in conducting the research was originally in English, and was translated into Afrikaans by Mrs Muller from the University of Stellenbosch in 1988 (Muller, 2004).

Due to the linguistic differences between Afrikaans and English, this might be considered a shortcoming in the study. The aim however was to determine which telephone provides the best speech discrimination results in the mother tongue of each particular participant. Participants could not be tested in a language that was not their mother tongue as this might have influenced the results of the baseline measurement of their speech discrimination ability and the outcome of the speech discrimination results. Tests, which are not presented in a participant's mother tongue, can lead to poorer results that cannot be validly interpreted (Keith, 1988). Linguistic cognition such as syntax, phonology and morphology plays a role in the discrimination of speech sounds. It was necessary to conduct the study in the mother tongue of participants due to the fact that linguistic problems may lead to speech discrimination problems (Lemme & Hedberg, 1988), which would not be representative of the actual ability of participants to converse with a telephone in their mother tongue.

Although South Africa officially recognises eleven indigenous languages, this study was restricted to available standardised test material in English. Afrikaans was the only other language the researcher was fully conversant with and into which the tests were translated. Afrikaans speaking participants had to be included, as the use of only English speaking participants would have led to the inclusion of too few participants who adhered to the selection criteria.

3.4.2.5 Duration of device use

Recipients had to be implanted and switched on for at least 12 months prior to this study. There is evidence that the benefits derived from a CI, develop with a long period of time and improve with continued use (Nevins & Chute, 1995; Dowell, Blamey & Clark, 1995). Furthermore, improvement of recognition of open-set words is associated with the consistent use of the device with a lengthy period of time (Spencer, Tye-Murray, Kelsay, & Teagle, 1998). This criterion was selected to ensure consistency.

3.4.2.6 Participant's ability to use the telephone

In order to determine which device provides the best speech discrimination results, the participants who took part in this research study had to consider themselves to be competent telephone communicators, i.e. the participants must have confidence and a history of using a telephone. Every prospective participant had to answer in the affirmative to three questions on telephone use.

3.4.2.7 Open set speech discrimination

Recipients were required to score a minimum of 30% in open-set speech discrimination tests. Open-set test results, which do not offer alternatives, can more accurately reflect a level of speech discrimination (Waltzman, et al. 1997). Cohen, et al. (1989) is of the opinion that a post-operative CID sentence test score (CID is an open-set speech discrimination test measuring open-set speech discrimination) of 50% or more, appears to be a good predictor of usable telephone skills. Brown, et al. (1985), found that a person with a CID score of 38% during conventional testing was still able to use the telephone effectively. The researcher decided to use 30% speech discrimination scores for sentence test material as cut-off criterion. The rationale behind this decision is based on the fact that few of the prospective participants had received formal aural rehabilitation after their implantation and therefore no formal telephone rehabilitation. Furthermore, little quantifiable research has been done on IFCIs, telephone use and speech scores, to validate a 50% cut-off.

3.4.2.8 Additional communication disabilities

In order for participants to understand test procedures, they should not have been diagnosed with any additional physical, neurological, emotional or communication disabilities caused by the hearing loss, as this could have influenced the validity of the results.

3.4.3. Uncontrollable factors

Certain aspects, discussed below, could not be controlled and were therefore not taken into account in selecting the participants.

3.4.3.1 Period of hearing loss prior to implantation

A shorter length of deafness correlates with better post-operative performance and evidence in literature confirms that all subjects usually continue to improve with time (Waltzman, Roland, & Cohen 2002). Other research has shown that there does not appear to be a meaningful relationship between the onset of deafness and speech discrimination performance (Somers, 1991). If the period of hearing loss prior to implantation had been taken into account, there would have been too many uncontrollable variables.

3.4.3.2 Auditory rehabilitation

Auditory rehabilitation is an intervention program that aims to minimise the communication problems that occur due to a hearing loss and to minimise the effect and adaptation to amplification in psychosocial and educational areas (Hull, 2001). The aspect that could not be controlled was whether or not recipients had received the same degree of auditory rehabilitation. Not all recipients, whose names were obtained from the University of Pretoria Cochlear Implant team, had been able to receive the same degree of auditory rehabilitation due to various reasons such as geographical, logistical or personal choice.

3.4.3.3 Type of cochlear implant processor

The types of Nucleus speech processors that are currently commercially available from Cochlear Corporation are the SPrint, ESPrit 22, ESPrit 24, SPectra and the ESPrit 3G (Cochlear Corporation, 1999). There are certain differences in features and mapping options between the various processors that could have an influence on the speech discrimination abilities of participants when used with different telephones. However, it was decided not to limit participation to a particular type of processor, as this would limit the number of participants who could take part in this research. It was assumed that each participant would have an optimal Map regardless of which speech processor was used.

3.4.4 Description of participants

Ten participants, four females and six males, five English-and five Afrikaans speakers were included in this research study and their ages ranged from 23-59 years. The duration of device use varied from one year to as much as 10 years. The types of speech processors tested were the ESPrit 22, ESPrit 24 and ESPrit 3G. No Spectra recipient could be found that adhered to the selection criteria. All the participants scored more than 30% in open-set speech discrimination tests through free-field (not using the telephone) at an intensity level of 65-75dB, using the Phonetically Balanced word list as used by the University of Pretoria. None of the participants had any additional disabilities. See Table 3.1 for a summary of the main features of the participants used in the study.

Tabel 3.1: Description of participants

Number	Gender	Age	Language	Type of speech processor	Duration of device use	Average open-set speech discrimination score 65-75dB	Additional disability present
1	Female	23	English	3 G	4 years	60%	None
2	Male	25	Afrikaans	E24	3 years	65%	None
3	Male	35	English	3 G	1 year	60%	None
4	Female	53	Afrikaans	3 G	1 year	65%	None
5	Female	36	Afrikaans	E 24	4 years	65%	None
6	Male	33	English	3 G	3 years	55%	None
7	Male	53	Afrikaans	E 22	8 years	50%	None
8	Female	59	English	3 G	1 year	50%	None
9	Male	57	English	E24	10 years	55%	None
10	Male	23	Afrikaans	3G	1 year	60%	None

3.4.5 Communicators

Communicators were persons used to present the open-set sentences with the various telephones. Communicators had to be adults with no history of either speech or hearing problems. There were three communicators. The first communicator had to be familiar to the participants, and the second two communicators had to be unfamiliar to the participants.

3.4.5.1 Criteria for the selection of communicators

The criteria for the familiar communicator: This had to be someone familiar to the participant, who had regular contact by means of the telephone, and with whom the participant had confidence to communicate with with the telephone. The familiarity of the speaker's voice is important for speech discrimination with a telephone, even with normal-hearing individuals (Tucker, 1998). It is easier to communicate via the telephone with a familiar person, as the frequency range, pitch, loudness and other acoustical characteristics of that person's voice, are familiar. The communicator had to speak the same language as the participant, with clear, functional articulation, to ensure reliability in the study, as second language speakers often have an accent, which can influence speech discrimination. These results were compared to the findings with an unfamiliar voice, to determine the best telephone.

The criteria for the unfamiliar communicator: The human voice contains, in its acoustic structure, a wealth of information regarding the speaker's identity, emotional state and gender (Makela, Alku, Makinen, Valtonen, May, & Tiitinen, 2002; Meyer, 1988). Therefore the same speakers, one male and one female, were used throughout the study, in order to compare speech discrimination with a male and a female's voice. The communicators had to be proficient in both English and Afrikaans to ensure reliability of results. Communicators did not have any speech-related problem, and had to use clear speech production. The communicators should not have had any previous form of telephone communication with the selected participants, or else their voices would not have been unfamiliar (Chun, 1987).

3.4.5.2 Description of communicators

Three communicators were used to speak to the participants. The three speakers included an unfamiliar male, unfamiliar female and a person (male or female) who was familiar to the participant. The unfamiliar male and unfamiliar female who were chosen by the researcher were both bilingual and had no history of any speech or hearing problems. All three communicators had clear speech without any articulation problems.

3.5 APPARATUS AND MATERIAL

The reliability of a study is enhanced when multiple indicators are used to measure the same result (Neuman, 1997). Apparatus and material used in the study are detailed below.

3.5.1 Apparatus

The following apparatus was used in order to achieve the various sub-aims of this study.

3.5.1.1 Audiometric apparatus

All audiometric assessments (speech discrimination tests) were conducted using a GSI 61-audiometer. The audiometer was calibrated in February 2003 and met the requirements of the SANS 0154-2000 (South-African National Standards, 2000). Speech discrimination assessments for open-set speech discrimination scores in table 3.1 and baseline measurements were executed in a sound proof booth supplied to the University of Pretoria by the Industrial Acoustics Company Inc. The environment met the SANS 0182-1998-standard (South-African National Standards, 2000).

3.5.1.2 Landline compatible devices

The following landline compatible devices were used:

- **Telephone one (T1): Telkom Series XXX telephone (Model 1500)**

This telephone includes a built-in telecoil. Using an electromagnetic field, this coil connects with the earpiece that is responsible for the amplification of the signal (Jürgens, 2003). This telephone was used separately as a testing apparatus, as well as when the different devices had to be plugged into a standard telephone. The rationale for selecting this telephone is that this landline telephone, which is manufactured by Telkom South Africa, is currently one of the most commonly used home and office telephones and is easily obtainable at telephone shops and regular retail outlets (Jürgens, 2003).

- **Telephone two (T2): Nucleus telephone adaptor.**

The Nucleus telephone adaptor ESPrit model no N94046F ISSI, Jan 2000 was used for ESPrit users and the Nucleus telephone adaptor SPrint model no N94045F ISSI, Jan 2000 for Spectra and SPrint users. The rationale for selecting this telephone adaptor is that the Nucleus adaptor is a registered trademark of Cochlear Limited. This adaptor is used to provide a direct connection from the telephone to a speech processor for the Nucleus cochlear implant system. The telephone adaptor is compatible with telephones that have detachable handset cords with four-way modular plugs (Melville, 2003).

- **Telephone three (T3): TEKNIMED AURIALD, TE 2002 (ENZER CWP60)**.

The rationale for selecting this telephone is that it is a high quality telephone that produces a strong magnetic field for use with a hearing aid or CI that has a “T” switch, and is manufactured by a South-African company, Acoustimed Hearing Services-Acoustimed (Pty) Ltd.

- **Telephone four (T4): The Phone-amp**.

The phone amp is an in-line receiver amplifier and designed to provide increased volume of the incoming sound at the telephone receiver. The Phone-amp is compatible with telephones that have a detachable handset cord with four-way modular plugs (Jürgens, 2003). The Phone-amp volume is controlled by a rotary volume control located at the front of the Phoneamp. The maximum sound amplification provided by the Phone-amp is 12 dB louder than normal sound perceived. To decrease or increase the volume, the volume control is used. This allows adjusting the volume level to the recipients' personal needs (Jürgens, 2003). The rationale for selecting this telephone is that Telkom South Africa also manufactures the Telkom telephone amplifier (known as the Phone-amp), it is easily obtainable at telephone shops and regular retail outlets, and is cost-effective (Jürgens, 2003).

3.5.1.3 Mobile/cellular telephone

Mobile/cellular telephones operate on a different frequency-bandwidth to landline telephones and via a different system (the GSM, as already discussed). A mobile/cellular telephone was selected based on the fact that the researcher wanted to compare the results of landline telephones with those of a mobile telephone.

- **Telephone five (T5): Nokia 3110**

The rationale behind selecting this hand piece was, because it was previously tested with IFCIs, and it was recommended that various CI systems needed to be tested in combination with GSM mobile telephones (Sorri, et al. 2001).

3.5.1.4 Tape recorder

- **Double Dolby system Marantz magnetic tape recorder (model CP430)**

The VU meters of a double Dolby system Marantz magnetic tape recorder were used to monitor the incoming volume of the speaker's voice. This was done in order to control and define the delivery volume of test materials, through the telephone's microphone. A CI provides sensory input only and this should be taken into account when tests that are designed to determine the benefit of speech discrimination after implantation, are administered. There should be more focus on measuring the sensory input of the device and less on the perceiver's linguistic or social knowledge, especially where telephones are tested (O'Donogue, et al. 1998). The volume requirement was that the VU-meter should stay between 65-75dB SPL.

3.5.2 Material

The test material that was used consisted of the following:

- The Phonetically Balanced Spondee word list (Afrikaans and English) as used by the University of Pretoria to determine at what intensity level the participants received more than 30% speech discrimination (the word lists are included in Appendix E)

- CID (Central Institute for Deaf) open-set sentences were chosen. The motivation for the choice of sentences is that sentences are more representative of spontaneous speech than the production of single words (Yorkston and Beukelman, 1981). This will most likely be a more accurate reflection of the participants true telephone abilities than when words only are used.

- To enhance the reliability of the study, the researcher used different sentences each time a different device was used. The sentences were grouped in the same order of difficulty. For Afrikaans speaking participants the Afrikaans version of CID sentences were used. These sentences were translated in Afrikaans by Muller 1988 (Muller, 2004). Afrikaans and English sentences are included in Appendix D.

3.6 PROCEDURES

The procedures followed in executing the study are stipulated. Ethical considerations and a pilot study are included to ensure validity and clinical feasibility (Leedy, 1993). The main study describes the selection of the participants, collection, recording and analysis of data.

3.6.1 Ethical considerations

Ethical considerations are essential in every research project, especially where humans are involved (Foxcroft, 2000). The procedure followed was approved by the Research and Ethics Committee of the Faculty of Humanities, University of Pretoria (See Appendix C).

The essential purpose in ethical consideration is to protect the welfare and the rights of research participants (Terre Blanche & Durrheim, 1999). A letter requesting permission to obtain the records of the cochlear implant recipients was submitted to the Pretoria Cochlear Implant Team (See Appendix A).

The subjects who adhered to the requirements for participation were informed about the aims and procedures of the study and what their participation would involve. They were requested to sign a letter of informed consent confirming their voluntary participation in the study (See Appendix B)

3.6.2 Pilot study

A pilot study is an important part of a research project (Dane, 1990), as the purpose is to determine whether the experimental setting is suitable and appropriate with regards to the participants, and if the study is clinical feasible (Leedy, 1993). The researcher conducted this pilot study in accordance with the above mentioned factors, It also enabled the researcher to familiarise herself with the testing procedures and to allow for any changes needed in the data collection procedures used for the main study.

3.6.2.1 Aims of the pilot study

The following aims were formulated for conducting the preliminary study :

- To ascertain the time required for one participant to complete the test protocol stipulated in 3.6.3.3 (Leedy, 1993)
- To establish whether the incoming volume of speech was monitored correctly by the different communicators
- To familiarise the researcher and the communicators with the data collection procedures stipulated in 3.6.3.2.
- To ascertain whether the data collection procedures instructions were carried out efficiently and that everyone involved understood what was expected of them (Leedy, 1993).

3.6.2.2 Criteria for the selection of the participant for the pilot study

The same criteria described under 3.6.3.1 (criteria for selection of participants) and 3.4.5.1(criteria for the selection of communicators) were followed.

3.6.2.3 Description of the participant taking part in the pilot study

A 23 year old, Afrikaans speaking male was the participant. He used a 3G speech processor and the duration of his implant had been 12 months. His average open-set speech discrimination score with intensity levels between 65-75dB SPL , was 60%.

3.6.2.4 Procedures followed for the pilot study

The same participant and data collection procedures as outlined for the main study, were followed (3.6.3.1 and 3.6.3.2). This was to ensure that procedures were viable and to make any necessary changes before the main study was conducted.

3.6.2.5 Results of the pilot study

The results in terms of the above-mentioned aims indicated that the approximate time needed to complete the test protocol was 45 minutes. It was determined that the communicators monitored the incoming volume effectively. The researcher and communicators familiarised themselves satisfactorily with the procedures. It was determined that before the actual test procedure commenced, an example sentence on the first telephone should be provided to familiarise the participant with the process. Apart form this; no changes in terms of instruction were needed.

3.6.3 Main study

As the pilot study did not indicate any changes to the final test procedure and due to the small number of participants, the Department of Statistics, from the University of Pretoria, South Africa, recommended that the participant in the pilot study could be included in the data analysis process of the main study. The following participant selection and data collection procedures, reinforced by the results of the pilot study, were carried out.

3.6.3.1 Participant selection procedure

- The first step in the execution of this study was to consult with the Cochlear Implant Team of the University of Pretoria. The names of adults with cochlear implants, within the Gauteng area were obtained from the team.

- A letter inviting IFCIs to participate in this study and to determine candidacy (see Appendix B) was sent to the prospective participants. This letter contained the following information as proposed by Tesner (1995):
  - Identification of both the person and the organisation conducting the research.

- The rationale of the study.
- Guarantees regarding the confidentiality of the participant and that any information they may provide would be treated as confidential.

- The letters also enquired whether the IFCI was competent in telephone use. The prospective participant had to return his or her response to the researcher by electronic mail before a certain deadline

- Three questions were asked in the letter, upon which the prospective participant had to answer in order to determine competence in telephone use:
    - Firstly, whether the IFCI was an active user of his or her implant.
    - Secondly, whether the IFCI considered him/herself to be a competent telephone user and
    - Lastly, if the particular IFCI who considered him-/herself to be a competent telephone user (due to the first two questions), would participate in the current study.

- Every participant who was willing to participate was requested to provide written consent to participate in the study and to acknowledge that the purpose of his or her role and the procedures to be followed, had been explained to them, as a safeguard for both researcher and participant (Leedy, 1985). (See Appendix B)

- According to Leedy and Ormrod (2001), postal surveys have limitations as the response rate for returns are generally 50% or less. Efforts were made to maximise the return rate, by contacting family members of IFCI by telephone prior to, and after posting the letters, encouraging the IFCIs to participate in the study.

- After the researcher received back the response letters, the number of IFCIs who were to take part in the study could be determined.

- A convenient date and time was arranged with each participant for assessment. The assessment was conducted in a quiet room isolated form outside sounds in the Department of Communication Pathology at the University of Pretoria. This was done to ensure clear speech discrimination without additional problems of background noise.

- Each participant was assessed individually during the course of one day. As most of the participants had day jobs, the assessment took place on Saturdays so as not to interfere with their business or private lives, and to ensure that noise levels remained constant during every test. No students were present on campus during weekends, as no lectures were scheduled on Saturdays.

- Each participant was requested to bring someone to the assessment, with which they could comfortably communicate using the telephone. This person (male or female) had to comply with the basic criteria discussed in 3.4.5.1

- Clear instructions were provided to each participant and an example was provided to rule out any confusion.

- Precautions were taken during this study to ensure that the participant's focus was fully on the sensory input of the sentences delivered with the telephone by the communicators, and was not influenced by the content and context of the sentences. The input signal from the spoken voices was kept constant by a VU-meter. Participants were also questioned informally after the testing procedure in order to determine subjectively which device provided the clearest perception of the spoken message.

3.6.3.2 Data collection procedures

- Different telephone companies were contacted and the rationale for the study was explained to them. A request was made to borrow the various devices from them in order to complete the study (See request to borrow a device in Appendix F).

- A speech discrimination test, using the Phonetically Balanced Spondee word list was conducted with participants to determine at what intensity, speech could be discriminated.

- An open-set speech discrimination assessment, using nine CID sentences with the same conditions, which were used during the rest of the study (three sentences for each different voice-type), was carried out on each of the participants. The researcher used the audiometer and speech audiometry between 65-75dB SPL to determine whether they had open-set speech discrimination abilities of 30% or more. This percentage was used as the baseline measurement for each individual against which performance with each telephone was measured.

- Participants who had 30% or more speech discrimination scores were then assessed with nine open-set CID sentences per device.

- The participant was required to sit in an office with the researcher. Each participant was instructed to listen with the particular device, to the sentence being spoken, and thereafter to repeat word-for-word as it was heard. The intensity of the speaker's voice was monitored and controlled by the VU-meter of the tape-recorder and had to stay between 65-75dB SPL.

- The three communicators, who represented the three different voice-types and spoke the sentences, were in a separate room, isolated from outside noises.

- The participant was required to listen to a set of three sentences with each of the five devices. A randomised design was used where voices and telephones were randomly changed after every three sentences to ensure the validity of the study (Dane, 1990).

- The participants used the different telephones to listen to nine different open set CID sentences per device.

- Each participant listened to the three different sentences of the CID-open set sentences in their mother tongue whilst using each of the five different telephones.

- Each communicator received a list of sentences he or she had to read, as well as a sequence schedule to know when it was his or her turn to call to the office where the participant was asked to listen to the sentences.

- The communicator had to dial the number of the room in which the participant was and wait for the participant to request the communicator to say the sentence. After saying the sentence the communicator had to wait for the participant to request the next sentence. After the third sentence was spoken, the communicator could disengage the call.

- The researcher sat in the same room as the participant to organise the process. The instructions given to the participant were that when he or she hears the telephone ring, to answer it, and to ask the communicator to present the first sentence.

- After each sentence the participant was asked by the researcher to complete two tasks. First they were asked to rate the intelligibility of the sentence on a percentage scale from 0-100%. This served as the subjective experience. Secondly they were asked to attempt to repeat the sentence word- for-word. The researcher kept score of the number of key words repeated correctly by the participant. This served as the objective measurement. After these two tasks were completed the participant had to request the communicator to present the next sentence.

The following adjustments were made to ensure validity.

- In order to monitor the incoming volume of the speakers' voice the VU meter of the tape recorder was used. The requirement was that the VU-meter should indicate the intensity of the voices to be between 65-75dB SPL.

- When speaking, the mouthpiece of the telephone had to be at least 15 cm away from the communicators' mouth, to avoid acoustic feedback.

- "Live" voices were used during the assessment, as pre-recorded material could have had an influence on the quality of sound presented to the participants. In a study by Clark, Tong and Martin (1981) better (34%-36%). Speech discrimination scores were rather recorded with "live" voice than with pre-recorded material. Hence the researcher decided to use "live" voices for the purposes of this study. Input of voice was however controlled by the VU-meter of the tape recorder.

- CID sentences, telephones and voices were used in random order during each assessment (randomising of sentences and telephones was done by the Department of Statistics of the University of Pretoria, South Africa), to ensure that the participants did not familiarise him/herself with the sentences, voices or telephones, thereby influencing the measurements negatively (Dane, 1990).

- Everyday communication is largely determined by a person's ability to understand the connected discourse of the speaker. To evaluate speech discrimination accurately poses a challenge, because speech discrimination depends on both subjective and objective observations (Shiroma, Iwaki, Kawano, Kubo & Fundsaka, 1997). By using subjective ratings of assessing speech discrimination by the IFCI, under test conditions, a crosscheck is made by the researcher to the objective data obtained (Cienkowski & Speaks, 2000). It became evident to the researcher that in order to obtain valid data and to determine the best use of a telephone by an IFCI, subjective experience of the participant's perception should be taken into account. This serves as a rationale for assessing the participant's speech discrimination ability of each device, by using both objective measures and subjective experiences.

3.6.3.3 Data recording procedures

The following procedure was used in testing speech discrimination through open-set sentences. See Table 3.2 for an example of the data-recording sheet.

Table 3.2 Example of data recording sheet

	Familiar voice-objective score	Familiar voice-subjective experience	Unfamiliar male voice-objective score	Unfamiliar female voice-subjective experience	Unfamiliar female voice-objective score	Unfamiliar female voice-subjective experience
Baseline measurement						
Telephone 1						
Telephone 2						
Telephone 3						
Telephone 4						
Telephone 5						

The researcher obtained the objective speech discrimination score, counting the number of words correctly repeated by the participants, after listening with the different telephones to the sentences delivered by the communicators (These sentences and words that had to be repeated correctly can be viewed in Appendix D). The correct number of words was recorded and calculated mathematically to obtain a percentage. After each sentence the participant was asked to give his or her own estimated percentage of how well he or she subjectively experienced the sentence. This served as the subjective experience score. The participant had to listen to nine sentences per telephone. Three of the nine sentences were communicated by a familiar voice. Three other sentences were communicated by an unfamiliar male voice and the remaining three sentences were communicated by an unfamiliar female voice. The objective score and subjective experience of all the sentences were recorded, calculated and processed mathematically to obtain a percentage.

3.6.3 Data processing and analysis

Obtaining meaningful results from data collected, depends upon statistical processing (Leedy, 1993). The research results obtained in the study were analysed statistically in consultation with Prof Groeneveld and Dr van der Linde of the Department of Statistics, University of Pretoria. The data collected in the present study was analysed using a split-plot design with main-plots and sub-plots. The least square mean was calculated for all telephones, voice-types and telephone-voice-type combinations. The researcher interpreted the P-values in conjunction with the means. Data processing was performed using the SAS statistical program (Levin, 1987). Graphs and tables will be used to display statistical results.

3.7 SUMMARY

This chapter described the research methodology in order to determine the main aim as well as the sub-aims for the study. The research design was discussed and the criteria for participants as well as a description of chosen participants were tabled. Material and apparatus used in the execution of the study were discussed and the procedures for data recording, processing and analysis concluded the chapter. Results obtained based on this methodology, will follow in the next chapter.

CHAPTER 4

DESCRIPTION AND DISCUSSION OF THE RESULTS

4.1 INTRODUCTION

This chapter will present and interpret the results of the study in terms of the sub-aims formulated in Chapter 3. The design used was a split-plot design. Significant interaction between telephones and voices was found and will be discussed using P-values and average percentages based upon statistical analyses. The P-value is a statistical term, which determines the statistical value between measurements (Steyn, Smit, du Toit & Strasheim, 1994). In this study the P-values were determined by using the SAS statistical program (Levin, 1987). A P-value, equal or less than 0.05 indicates a significant difference between measurements (Steyn, Smit, du Toit & Strasheim, 1994). In this study, measurements were applied to telephones and voices. The smaller the P-value, the more significant the difference (Steyn, Smit, du Toit & Strasheim, 1994).

Results will be presented in graphs and tables and described and interpreted in order to draw conclusions, in accordance with the formulated sub-aims.

4.2 DESCRIPTION AND DISCUSSION OF THE SUBJECTIVE EXPERIENCE AND OBJECTIVE SPEECH DISCRIMINATION SCORES OBTAINED WHEN MEASURED BY DIFFERENT VOICE-TYPES

This sub-aim formulated in 3.2.1 was *to determine the subjective experience and objective speech discrimination scores obtained by a group of individuals fitted with a cochlear implant measured by different voice-types*.

The results are depicted in **Figure 4.1 and Table 4.1.**

Figure 4.1 is a graphic display of the average subjective experiences and objective speech discrimination scores by the participants during the assessment, using different voice types.

Table 4.1 illustrates the p-values of the percentages.

The standard variation for the statistical analysis of the p-values was 2.39 for subjective experience by participants and 2.48 for objective measurements. The percentage values will be described and discussed in conjunction with the p-values.

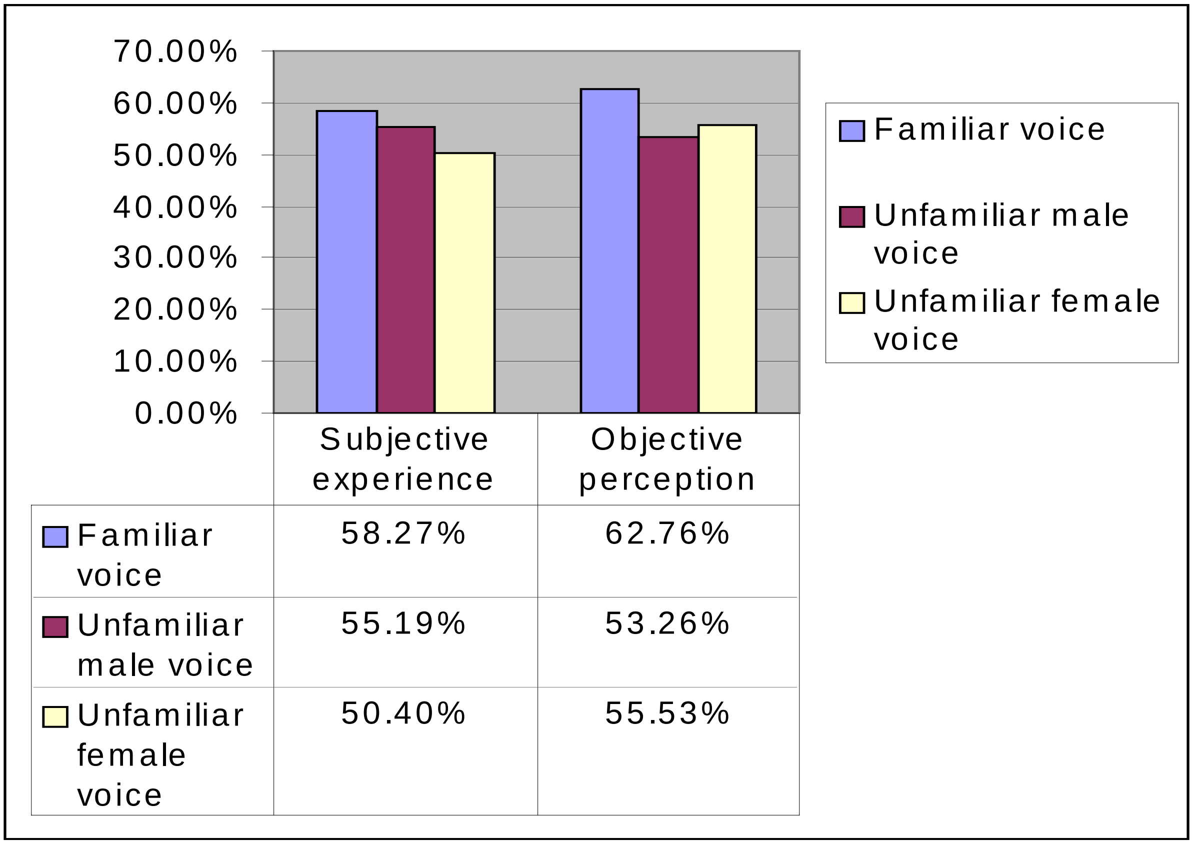


Figure 4.1 Subjective experience and the objective speech discrimination scores measured by different voice-types

Table 4.1 The P-values of subjective experience and the objective speech discrimination scores measured by different voice types

Voice type	**Unfamiliar male voice subjective**	**Unfamiliar male voice objective**	**Unfamiliar female voice subjective**	**Unfamiliar female voice objective**
Familiar voice	0.3634	0.0074	0.0212	0.0408
Unfamiliar male voice			0.1587	0.5166

Figure 4.1 and **Table 4.1** illustrates that the objective scores for all three voice-types were higher than the subjective experience by participants. The participants' objective

scores when listening to a familiar voice-type were the best (62.76%) followed by the objective score when listening to an unfamiliar female voice-type (55.53%). Statistically, speech discrimination when listening to a familiar voice differed significantly from speech discrimination when listening that of an unfamiliar voice.

In **Table 4.2**, p-values of the speech discrimination for objective scores when listening to an unfamiliar male voice and familiar voice, differed statistically the most (p=0.0074). The subjective experience (p=0.0212) as well as the objective scores (p=0.0408) when listening to an unfamiliar female voice differed statistically from the scores obtained when listening to a familiar voice. This illustrates that there is a difference in the perception of the voice type. It is evident that when listening to a familiar voice, the scores indicated better perception abilities both subjectively experienced as well as objectively, in comparison to listening to unfamiliar voice-types. The objective perception score when listening to an unfamiliar male voice-type was the lowest (53.26%). The participants' subjective experience when listening to a familiar voice-type was the best (58.27%), followed by the unfamiliar male voice-type (55.19%). The subjective experience when listening to the unfamiliar female voice-type was the lowest (50.40%).

Participants perceived a familiar voice (regardless of the gender), better than unfamiliar voices. Of the subjective experience when listening to unfamiliar voices, it was obvious that the male voice was perceived better than the female's voice.

Using different voice-types and measuring speech discrimination of each type, proved to have been significant, because a statistical difference was found between scores when listening to the familiar voice and unfamiliar voice types. An examination of the percentages makes it reasonable to assume that different voice-types influence speech discrimination. Participants discriminated and perceived a familiar voice (regardless of the gender), better than the unfamiliar voices. When looking at perception of discriminating speech as subjectively experienced by the participants when listening to the unfamiliar voices, it was clear that a male voice was perceived better than a female voice. The opposite was scored when objective discrimination scores were measured, as a female voice was perceived better than a male voice. Statistically, however there was no significant speech discrimination difference between female and male voices. The only significant conclusion was that familiar voices were better heard than the unfamiliar voices (regardless of gender).

As mentioned in Chapter 2, the quality of the speaker's voice (Tucker, 1998) plays a role in perception and discrimination scores with a telephone. This was observed throughout the study, where different voices were measured. The reason is that different voices have different qualities. Verbal auditory information, such as a voice, where the listener knows the speaker, is stored in the voice selective areas in the human auditory cortex (Belin, et al. 2000; Meij & van Papendorp, 1997). Although the perception of familiar speaker-relation plays a major role in human communication, little is known about its neural basis. Voice selective regions can be found bilaterally along the upper bank of the superior temporal sulcus. This area may represent the counterpart of the face-selective areas in the human visual cortex (Belin, et al. 2000).

According to Meij and van Papendorp (1997), practical aspects of memory such as auditory memory, are stored in particular areas of the human cerebral cortex.
The researcher is of the opinion that this serves as an explanation for the phenomenon in the current study, where speech discrimination when listening to familiar voices, had a higher score than when listening to an unfamiliar voice. Listeners are able to understand familiar voices because of prior knowledge stored in the auditory cortex.

The biological and linguistic differences that exist between male and female voices can account for the differences in the speech discrimination scores (Awan, 1996; Boone, McFarlane, 1994; Chun, 1987; Greene, 1972, Meyer, 1988; & Mullennix, et al. 2003). Studies have shown that frequency levels differ between genders (Chun, 1987; Mullennix, Stern, Wilson, & Dyson, 2003). Studies determined that the fundamental frequency of a typical male is 100 Hz, and that of a female is 200 Hz (Makela, Alku, Makinen, Valtonen, May, & Tiitinen, 2002). Fundamental frequencies and its harmonics determine the temporal dynamics of speech in the human auditory cortex and the speech specificity arises out of cortical sensitivity to the complex acoustic structure (Chun, 1987). Male and female voices differ in pitch and loudness. Pitch is determined by the length and volume of the vocal folds (Meyer, 1988). Pitch indicates the gender of the speaker, maturity of the speaker, intonation patterns and melody of speech, subtle variations of time, speed, inflection, stress and volume (Greene, 1972). This has a significant influence on speech discrimination, especially when communicating via a telephone, where the listener cannot depend upon additional cues such as speech reading.

Although procedures for testing male and female voices were carried out in the same manner, differing scores were recorded. This phenomenon might be explained by the fact that individuals with a high frequency SNHL can discriminate voices with a lower fundamental frequency better than a higher fundamental frequency (Katz, 2002; Martin, 1997). A male voice has a lower fundamental frequency than a female voice (Makela, Alku, Makinen, Valtonen, May, & Tiitinen, 2002). SNHL refers to a loss in hearing due to damage to the cohlear hair cells (sensory) or the auditory nerve (neural). Most SNHL is sensory and the loss is worse in the higher frequencies (Easterbrooks, 1997; Katz, 2002, Martin, 1997; & Mueller and Hall, 1998). The participants all displayed worse SNHL at higher frequencies than at lower frequencies.

Another explanation for the fact that the subjective experience with unfamiliar voices differed from the objective scores with unfamiliar voices might reside in the fact that the subjective experience depends upon individual differences. IFCIs are a heterogeneous group, influenced by the different features among them such as the duration of deafness, degree of aural rehabilitation etc. (Melville, 2003). These individuals also differ in personality, comfort levels and experience with different speakers, which might have an influence on their experience of different voice-types (Melville, 2003).
As subjective measurement is an expression of a participant's own perception of awareness of speech and as a person's physiological perception contributes directly to his or her improvement, the researcher is of the opinion that more positive results will be obtained in rehabilitation, if unfamiliar male voices were listened to before exposing IFCIs to unfamiliar female voices. (Louw, van Ede & Louw, 1998; Sternberg, 1998).

Differences in voice-types have implications for telephone rehabilitation. The fact that perception scores of familiar voices were higher than unfamiliar voices is an indication that rehabilitation should start with familiar voices. Experience and motivation plays a significant role in acquiring successful telephone abilities as this enhances confidence and with increased confidence, a greater number of skills are practised and enhanced (Cohen, et al. 1989; Tait, et al. 2001). In rehabilitation, a familiar voice will motivate an IFCI, and help him or her to gain the experience necessary for developing telephone competence to progress to unfamiliar voices.

Although objective and subjective experience differences regarding perception scores with unfamiliar male and female voices were experienced, they did not statistically differ significantly. This implies yet again that telephone rehabilitation should progress from familiar to unfamiliar voices. When regarding the literature and the evidence that high frequencies are more difficult to discriminate, it is advisable to start rehabilitation with unfamiliar voices, with male voice-types.

4.3 DESCRIPTION OF THE SUBJECTIVE EXPERIENCE OF SPEECH DISCRIMINATION OBTAINED WITH FIVE DIFFERENT TYPES OF TELEPHONES

The second sub-aim formulated in 3.2.2 was t*o determine the subjective experience of speech discrimination of a group of individuals fitted with a cochlear implant obtained with four landline telephones and one mobile/cellular telephone*

The results are depicted in **Figure 4.2**, which is a graphic display of the average subjective experience, and **Table 4.2**, which displays the p-values for the average subjective experience.

Figure 4.2 is a graphic display of the average subjective experience of speech discrimination scores of the sentences as experienced by the participants during the assessment using five different telephones and compared to the Baseline Measurement (BM).

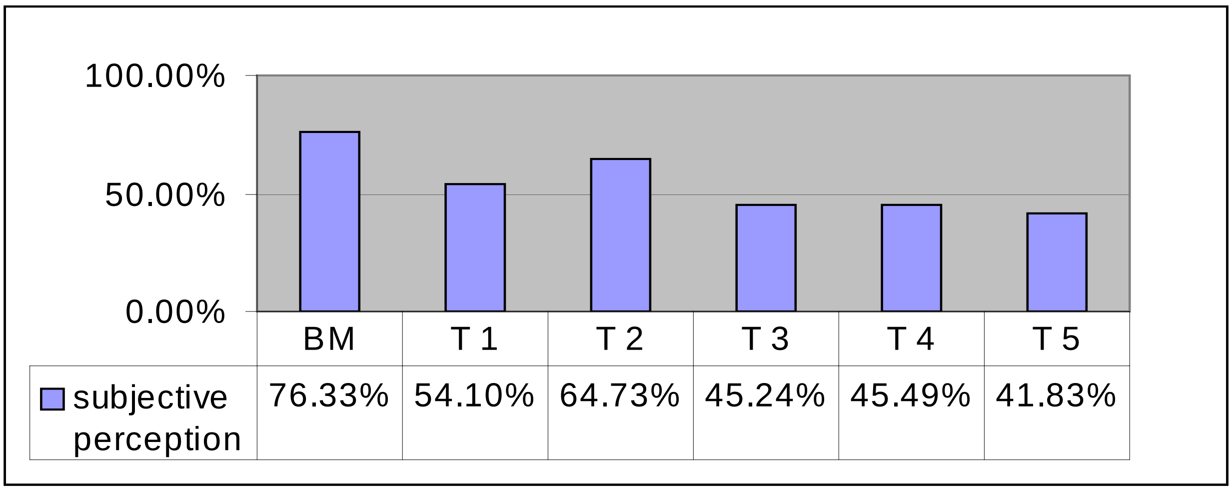


Figure 4.2 Subjective experience of speech discrimination obtained with five different types of telephones

Table 4.2 displays the p-values of the subjective experience of speech discrimination scores measured by using different telephones and should be read in conjunction with **Figure 4.2**. The standard variation for the statistical analysis of the p-values was 3.38 for subjective experience values.

Table 4.2 The P-values of the subjective experience of speech discrimination obtained with five different types of telephones

Telephone	T1	T2	T3	T4	T5
BM	<0.0001	0.0164	<0.0001	<0.0001	<0.0001
T1		0.0276	0.0657	0.0736	0.0112
T2			<0.0001	<0.0001	<0.0001
T3				0.9584	0.4765
T4					0.4448

Figure 4.2 displays the differences in the subjective experience of the participants of their speech discrimination scores when using different telephones. The BM score refers to the speech discrimination of the participants without using a telephone. The BM score is there to determine if and how the use of a telephone influences the speech discrimination results. The participants' subjective experience of speech discrimination when listening without a telephone was better in percentage (76.33%) and in statistical value, as it differed significantly from subjective experience scores when using a telephone, as displayed in **Table 4.2** (T1p=<. 0001), (T2p=0.0164), (T3p=<. 0001), (T4p=<. 0001), (T5p=<. 0001). The subjective experience when listening with T2 (p=0.0164) was slightly less significant than when other telephones were used. Taking into account the percentages of participants' subjective experience of their speech discrimination scores (as displayed in **Figure 4.2**), it is clear that participants' subjective experience was, that speech was easier to discriminate with T2 (64.73%). Participants perceived speech discrimination with T1 (54.10%) second best. Subjective experience of speech discrimination with T5 (41.83%) was the least. Subjective experience of participants with T3 (45.24%) and T4 (45.49%) was very close and it is interesting to note in **Table 4.2,** that participants' subjective experience of their scores with T3, T4

and T5 did not differ in a statistically significant manner from each other. Statistical differences as displayed in **Table 4.2** were with the use of T2, as the perception of participants when using T2, differed from T1 (p=0.0276), T3 (p=<0.0001), T4 (p=<0.0001) and T5 (p=<0.0001). Statistical differences were also present regarding subjective experience when using T1 and T5 (P=0.0112), emphasising less perception from participants when using T5, in regards to T1.

4.4 DESCRIPTION OF THE OBJECTIVE SPEECH DISCRIMINATION SCORES OBTAINED WITH FIVE DIFFERENT TYPES OF TELEPHONES

The third sub-aim formulated in 3.2.3 was *to determine the objective speech discrimination scores of a group of individuals fitted with a cochlear implant obtained with four landline telephones and one mobile/cellular telephone.*

Figure 4.3 is a graphic display of the average objective speech discrimination scores of the sentences as experienced by the participants during the assessment using five different telephones and compared to the Baseline Measurement (BM).

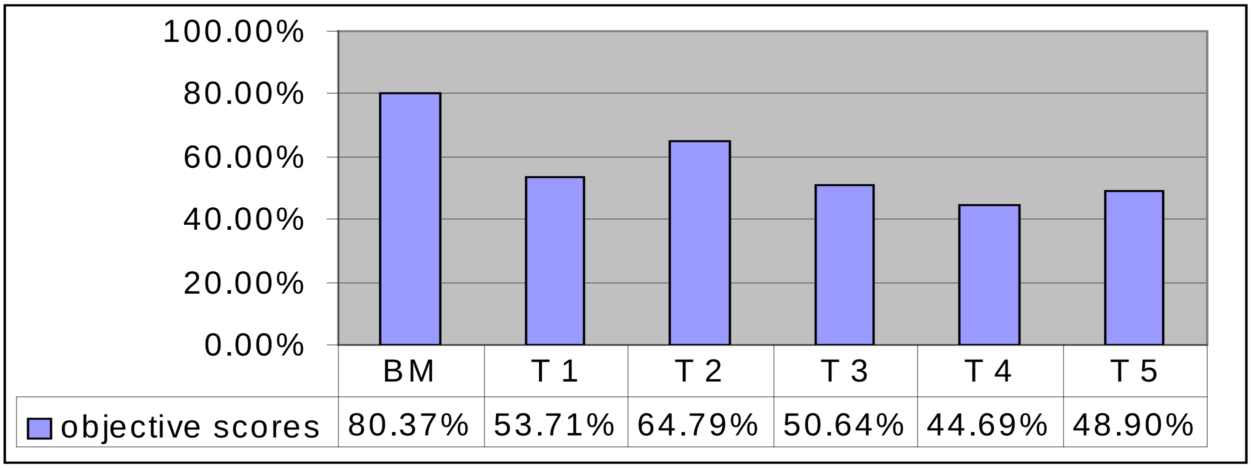


Figure 4.3 Objective speech discrimination scores obtained with five different types of telephones

Table 4.3 displays the p-values of the objective speech discrimination scores measured by using different telephones and should be applied to **Figure 4.3**. The standard variation for the statistical analysis of the p-values was 3.50 for objective values.

Table 4.3 The P-values of the objective speech discrimination scores obtained with five different types of telephones

Telephone	**T1**	**T2**	**T3**	**T4**	**T5**
BM	<0.0001	0.0020	<0.0001	<0.0001	<0.0001
T1		0.0268	0.5369	0.0706	0.3331
T2			0.0049	<. 0001	0.0016
T3				0.2313	0.7253
T4					0.3968

Figure 4.3 displays the differences in speech discrimination by participants when using different telephones. The percentage speech discrimination scores obtained by the participants when listening to sentences without a telephone were the highest (BM=80.37%). The P-values of the BM in **Table 4.1** differ statistically significantly from

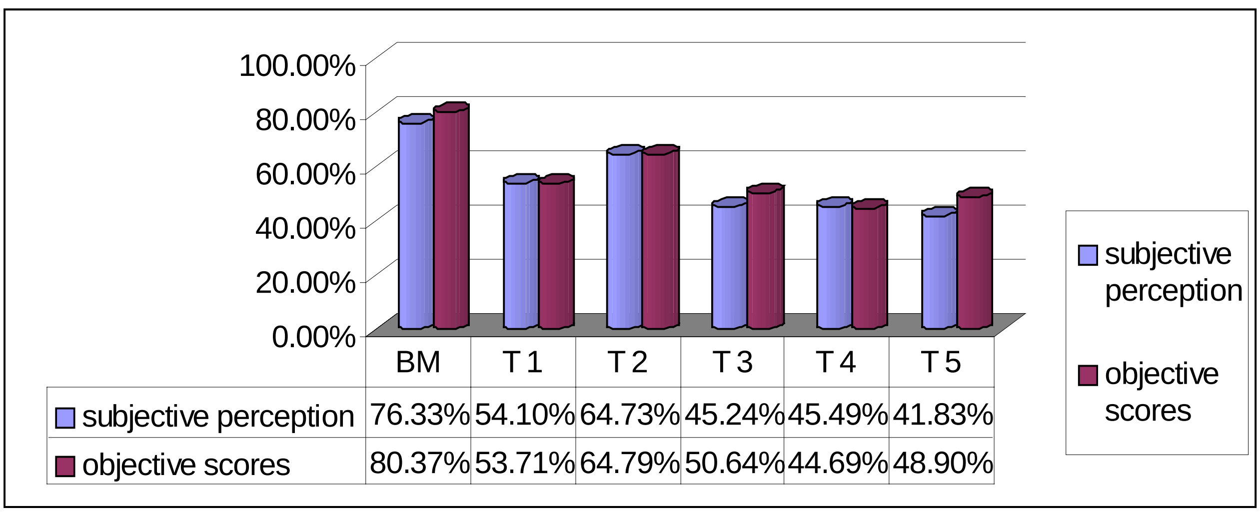
all the other scores when using a telephone. The speech discrimination score obtained when using the BM differs statistically the most from those scores obtained when listening to T1 (p=<0.0001), T3 (p=<0.0001), T4 (p=<0.0001) and T5 (p=<0.0001). This is of high statistical significance. The P-values of the speech discrimination score obtained when listening with T2 (p=0.0020), although also of great significant value, is less significant than the P-values of T1, T3, T4 and T5. Scores obtained with the BM were similar to those obtained with the subjective experience.

Similar to the scores obtained with the subjective experience, the speech discrimination score obtained by participants when using T2 (64.79%) was the highest of all the scores obtained when a telephone was used. Statistically, speech discrimination when using T2 proved to be of high value as it differed significantly from T1 (p=0.0268), T3 (p=0.0049), T4 (p=<0.0001) and T5 (p=0.0016). The highest statistical difference was noted between the scores obtained by T2 and T4 (p=<0.0001). When taking the percentages into account it is clear that speech discrimination with T2 (64.79%) had a higher percentage than speech discrimination with T4 (44.69%). Similar to scores obtained with the subjective experience, speech discrimination with T1 (53.71%) obtained the second highest score, although it did not differ statistically from any other telephone except T2 (p=0.0268). Speech discrimination with T3 (50.64%) and T5 (48.90%) proved to be less than T2 (64.79%) and T1 (53.71%), but more than T4 (44.69%). Although speech discrimination scores with telephones differed, only speech discrimination with T2 differed statistically from all the telephones and no other statistical differences were found.

4.5 DESCRIPTION AND DISCUSSION OF COMPARISON BETWEEN THE SUBJECTIVE EXPERIENCE AND THE OBJECTIVE SPEECH DISCRIMINATION SCORES OBTAINED WITH FIVE DIFFERENT TYPES OF TELEPHONES

The last sub-aim formulated in 3.2.4 was *to compare the subjective experience of the individuals with the objective speech discrimination scores of a group of individuals fitted with a cochlear implant obtained with four landline telephones and one mobile/cellular telephone.*

Figure 4.4 is a graphic display of the comparison between the subjective experience and the objective scores of speech discrimination when listening to five different types of telephones and compared to the Baseline Measurement (BM).



	BM	T 1	T 2	T 3	T 4	T 5
subjective perception	76.33%	54.10%	64.73%	45.24%	45.49%	41.83%
objective scores	80.37%	53.71%	64.79%	50.64%	44.69%	48.90%

Figure 4.4 Comparison between the subjective experience and the objective speech discrimination scores obtained with five different telephones

Table 4.4 displays the p-values of the comparison between the subjective experience and the objective speech discrimination scores measured by using different telephones and should be applied to **Figure 4.3**. The standard variation for the statistical analysis of the p-values was 3.50 for the objective values.

Table 4.4 The P-values of the comparison between the subjective experience and the objective speech discrimination scores obtained with five different telephones

Tel.	**T1sub**	**T1 ob**	**T2 sub**	**T2 ob**	T3 sub	**T3 ob**	**T4 sub**	**T4 ob**	**T5 sub**	**T5 ob**
BM	<0.0001	<0.0001	0.0164	0.0020	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
T1			0.0276	0.0268	0.0657	0.5369	0.0736	0.0706	0.0112	0.3331
T2					<0.0001	0.0049	<0.0001	<.0001	<0.0001	0.0016
T3							0.9584	0.2313	0.4765	0.7253
T4									0.4448	0.3968

The fact that this BM score was the highest objectively and with the subjective experience displayed in **Figure 4.3,** indicates that speech is better discriminated when listening without the use of a telephone, and that speech discrimination deteriorates when any telephone is used in conjunction with a CI. The BM cut-off point for participation in this study was 30% with open-set sentences. Recent studies showed that IFCIs with good open-set speech discrimination skills would be able to converse successfully with a telephone (Tucker, 1998; Valimaa, Sorri & Lopponen, 2001; Waltzman, Roland & Cohen, 2002). Therefore it is safe to assume that if an IFCI obtained more than 30% open set speech discrimination, he or she would be able to converse successfully with a telephone. The question arises as to what role the different telephones with different technical features and different communicators play, in the interpretation of sounds heard with the telephone. The BM of all the participants selected to take part in this study comfortably exceeded the 30% cut-off point. As the BM represented speech via live voice, it was clear that speech through live voice was better perceived than speech via a telephone. This indicates that there are still some technical features in telephones that influence speech discrimination negatively. Nevertheless participants perceived more than 30% speech discrimination with every telephone, which indicated that participants were moderately successful in using the telephone.

An examination of the subjective experience and objective speech discrimination scores of participants makes it reasonable to assume that T2 differed the most from the other telephones, presenting with the best percentage for speech discrimination withall (see **Figure 4.3**). From the percentages in **Figure 4.3**, it is apparent that T5 presented with the lowest percentage for subjective experience speech discrimination by participants and T4 the lowest for objective speech discrimination.

These findings can be explained by one of the factors explored in chapter 2, namely the quality of the telephone (Tucker, 1998). This factor seemed to be justified by the findings in this study, as speech discrimination with different telephones with different qualities used in the study, produced different results. The quality of the telephone proved to be a significant factor in how the spoken messages were understood. The quality of the telephone depends largely upon factors such as EMI and the telecoil. (Tucker, 1988), as was evident with the telephones used in this study. T1 and T2 each contain a built-in telecoil, whereas T3 and T4 do not have a telecoil. Speech discrimination results when using T1 and T2 were of high statistical significance and produced better results than the other telephones without a telecoil. A telecoil is very sensitive to EMI, and reduces the amount of EMI (Wolmarans, 2003). T1 and T2 could emit lesser amounts of EMI than other telephones, because they consisted of a built-in telecoil, and this explains why scores with T1 and T2 were more significantly better than T3 and T4.

T1 was perceived as being the second best telephone as illustrated by the percentages in **Figure 4.3** and **Table 4.4**. This is of great significance as T1 is a Telkom telephone, used widely in South Africa (Jürgens, 2003). It is a standard telephone with a built-in telecoil, mostly used in homes and offices, and requires no plug-ins for IFCIs as in the case of T2. This makes T1 a more popular and available telephone to use.

The researcher is of the opinion that the reason why T5 did not prove to be of significant value with the subjective experience might be due to the technical differences and specifications of mobile/cellular telephones, the T5 being a mobile/cellular telephone. The presence of EMI interferes with the quality of mobile/cellular communication (Clifford, et al. 1994; de Cock, et al. 2000; Heukelman, 2003; & Jürgens, 2003). Mobile/cellular telephones utilise a GSM digital signal. GSM is the fastest of the digital signals, and the faster the transmission rates are, the more prone they are to EMI (Tearney, 2002). Interference of speech discrimination results from the detection of electromagnetic fields emitted by the mobile/cellular telephone (van Vliet, 1995). The EMI causes a buzzing sound when held next to a CI and this causes disturbances when listening to the message (Tearney, 2002; Sorri, et al. 2001). This interference serves as the technical explanation why the speech discrimination scores of T1 and T2 are higher than T5's. Another explanation is that T5 was a mobile/cellular telephone, which operated on a digital signal, as opposed to T1 and T2, which operated on an analogue system (Jürgens, 2003). An analogue system causes the least amount of EMI with individuals using a CI. Therefore it may be concluded that a telephone working on an analogue system's message would be clearer. This was true for T1 and T2.

The importance of a telecoil is that it correlates with speech sounds and therefore makes speech sounds clearer and easier to discriminate (Jurgens, 2003, Wolmarans, 2003). The assumption was made in chapter 2 that telephones with a telecoil will provide IFCIs with more and clearer speech discrimination than a telephone without a telecoil. This was proven to be correct, as speech discrimination with T1 and T2, the telephones with built-in telecoils, proved to be better instruments for telecommunication than T3, T4 and T5. This serves as an explanation as to why previous studies conducting telephone competency led to poorer results with IFCIs (Sheenan, 2003, Sorri, et al, 2001), as the technicalities regarding the actual telephones were not examined or taken into any significant account.

Another explanation why the telephone that scored the lowest with the subjective experience differed from the telephone that scored the lowest with the objective scores (see **Figure 4.3** and **Table 4.4**) might be due to the fact that individuals differ in personality, comfort levels and experience (Melville, 2003). During the execution of the study, a number of participants indicated that they had tried to utilise a mobile/cellular telephone in the past for communication with little success. Experience and motivation play a significant role in acquiring successful telephone abilities as confidence is enhanced. With increased confidence, a greater number of skills are practised and developed (Cohen, et al. 1989; Tait, et al. 2001). As the subjective experience is an expression of a participant's own perception of awareness of speech and as a person's physiological perception contributes directly to his or her improvement, the researcher is of the opinion that more positive results will be obtained in rehabilitation, if unfamiliar male voices were practised before exposing IFCIs to unfamiliar female voices. (Louw, van Ede & Louw, 1998; Sternberg, 1998).

Alexander Graham Bell stated that professionals should keep in mind, when working with deaf individuals that as they can learn to talk intelligibly, they should be encouraged to use the same language as the community in which they live (Ling, 1990). The same principle should therefore apply to their ability to use a telephone. Telephone competency is a reality and more and more IFCIs demonstrate the ability to communicate successfully, using a telephone (Sorri, et al. 2001). The same telephone competency could therefore be expected from an IFCI who has mastered open-set speech discrimination, when compared to a normal hearing person. *"The bulk of the responsibility for the research on this problem should lie with the mobile/cellular phone industry. It is helpful to recognise the difference between products and identify factors that will make a certain type more acceptable. A well documented problem is necessary, informing manufactures to promote improvement upon understanding in order to reach a solution regarding factors such as EMI"* (Van Vliet, 1995).

4.6 Conclusion

The main-aim of this study was *to determine which telephone would enable a person with a cochlear implant to achieve the best subjective and objective speech discrimination scores*

Regarding the various voice-types, the familiar voice proved to be the best perceived. This also has far-reaching implications that should be of value to clinicians working on telephone rehabilitation with IFCIs. Rehabilitation should focus on starting telephone-education by using a familiar voice. Only when the person with a CI has achieved independent usage with familiar voices, should unfamiliar voices be introduced. Although there were percentage differences in the unfamiliar voice-group, the researcher is of the opinion that rehabilitation should progress from the familiar voice firstly, to the unfamiliar male voice and only then to the unfamiliar female voice. This is due to the fact that the subjective experience of the unfamiliar male voice scored higher than the unfamiliar female voice. As subjective experience is an expression of a participant's own perception of awareness of speech and as a person's physiological perception contributes directly to his or her improvement, the researcher is of the opinion that more positive results will be obtained in rehabilitation, if unfamiliar male voices were practised before exposing IFCIs to unfamiliar female voices. (Louw, van Ede & Louw, 1998; Sternberg, 1998).

The fact that the BM scores were the highest, measured objectively and with the subjective experience, indicates that speech is better discriminated when heard without the use of a telephone, and that speech discrimination deteriorates when any telephone is used in conjunction with a CI. The fact that the P-values obtained when participants used T2 differed from the BM in a lesser statistical manner, to P-values obtained for T1, T3, T4 and T5, indicates that participants' speech discrimination as well as their subjective experience of their own scores when using T2, were better than when using T1, T3, T4 and T5 (see **Tables 4.1 and 4.2**). This indicates that T2 might have an advantage with the other telephones and that T2 might be the answer to the question as to which telephone meets the communication needs of an IFCI most successfully. T2 was also the telephone with which the participants scored the highest speech discrimination, measured objectively (64.79%), as well as the one they experienced subjectively as the best (64.73%). The subjective experience of speech discrimination ability and the objective score differed by only 0.04% (**Figures 4.1 and 4.2**). The fact that speech discrimination scores and the subjective experience with T2 differed from scores and experience with every other telephone in a significant manner indicates that T2 is the best telephone to use for speech discrimination by an IFCI.

Speech discrimination with T4 perceived the lowest percentage score and differed statistically the most from discrimination scores with T2, indicating that speech discrimination with this telephone is the least favourable of the five telephones that were tested. Speech discrimination scores as well as the subjective experience of participants with T1 indicated it to be the second best telephone. The fact that the speech discrimination scores and subjective experience of participants with T3, T4 and T5 did not show significant statistical differences and had poorer percentage scores than T1 and T2, lead to the conclusion that these telephones are not of significant value for telephone use by IFCIs.

4.7 Summary

In order to reach the main aim of the study, research results were discussed under each of the sub-aims. Research results were depicted in graphical and table formats. Conclusive answers were given to reach the aim of the study in order to determine which landline telephone and/or a mobile/cellular telephone will enable a person with a cochlear implant to achieve the best subjective experience and objective speech discrimination scores.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1. Introduction

As professionals strive towards providing every deaf person with the best competency for effective communication, we must provide the necessary accessories that will limit additional external interference (Sandlin, 2000). Research on these devices and accessories is therefore necessary to provide IFCIs with the best equipment they need to communicate to the best of their ability and meet the expectations they set for themselves. The study aimed to explore different types of telephones in order to evaluate the efficiency of various telephones and discuss what features influence the success of speech discrimination with these telephones. In this chapter the study will be evaluated in terms of strengths and limitations. The results of each sub-aim will be summarised together with clinical and theoretical implications. Recommendations for future research will conclude this final chapter.

5.2. Evaluation of the research methodology

An examination of the research methodology employed in this study provides insight regarding the value of the study for clinical implementation and future research. It is important to be aware of the strengths and limitations of the study, as they need to be taken into consideration if a follow-up or comparative study should be performed. The practical application of the findings is also of importance as they can assist in the planning of rehabilitation programmes.

5.2.1 The strengths of the study

- Results of this study can be considered as valid and reliable on account of the guidelines discussed in Methodology, Chapter 3.

- The literature suggested that objective measurements alone might not provide an accurate reflection of speech discrimination abilities and subjective experience offer an efficient, reliable alternative for the assessment of speech discrimination (Cienkowski & Speaks, 2000). One of the strengths of the current study is that both subjective experience and objective assessment measures were used to determine which telephone provides the highest speech discrimination score, and is judged to be the most user friendly.

- The fact that different voice-types were used to evaluate each telephone proved to be significant and has implications for future research, and also for the practical application and clinical use of the findings.

- The data gathering and recording procedures were effective in eliciting good co-operation from the subjects and ensuring reliable results.

- The data processing was effective as percentage- and statistical significant results were obtained.

5.2.2 The limitations of the study

- The period of hearing loss prior to implantation varied from participant to participant. As a shorter length of deafness correlates with better post-operative performance, this criterion differed in all IFCIs (Waltzman, Roland, & Cohen 2002). This should be taken into account when future research is conducted.

- The degree of auditory rehabilitation received by participants was not taken into account. The reason is that not all recipients had received the same degree of auditory rehabilitation due to various reasons such as accessibility or personal choice.

- Similar to the hearing-impaired population, the CI population consists of a heterogeneous group of people where the following aspects vary: cause of deafness, duration of deafness, home location and ages (Melville, 2003). All these factors were taken into account and the IFCIs who lived in the Gauteng area were contacted to participate in this study, because of accessibility reasons. None of the other factors mentioned above could be kept constant.

- Only a limited number of telephones were assessed.

- No comparison was made between the different CI-processors used by participants. There are certain differences in features and mapping options between the various CI-processors that could influence the participants' speech discrimination abilities whilst using various telephones. However, because of the geographical location and other criteria, the similarity of CI-processors was not included as a selection criterion as this would have limited the number of participants who could have taken part in this research.

- Although South Africa has eleven official languages, test material is only available in English and Afrikaans. The participants in this study were either English or Afrikaans speaking, and no other languages or ethnic speakers were used.

5.3. Summary and conclusive discussion of findings and implications of the study

- The objective and subjective experience Baseline Measurement (BM) score, which presents the use of the CI alone, was higher than any score where the CI was used with the telephones.

- T2 (Nucleus telephone adaptor) differed statistically significantly from all the other telephones, and recorded the highest speech discrimination scores, both objectively and subjectively. This proved that it was the best telephone for telecommunication in terms of this study.

- T1 (Telkom Series XXX) was the second best telephone for subjective experience and objective speech discrimination.

- T3 (Teknimed auriald), T4 (Phone Amp) and T5's (Nokia 3110) subjective experience scores did not differ significantly from one another and had little statistical value and cannot be regarded as significant for telecommunication in terms of this study.

- Objective measurement of T4 (Phone Amp) indicated the lowest Speech discrimination scores.

- Objective measurements of T4 (Phone Amp) indicated the lowest Speech discrimination scores. The objective measurements of T5 (Nokia 3110) scored the second lowest Speech discrimination scores. Both the subjective experience measurements of T4 (Phone Amp) and T5 (Nokia 3110) were the lowest, which leads to the conclusion that T5 (Nokia 3110) was the least favourable for telecommunication in terms of this study.

- Regarding the different voice types it was statistically clear that familiar voices were subjectively and objectively perceived better than unfamiliar voices.

- Objective scores were higher than subjective experience scores, implying that participants did not have confidence in their telephone abilities.

- Of the unfamiliar voices it was clear that male voice was subjectively better perceived than female voice. Objectively however female voices proved to be better perceived. No statistical differences were however noted. The difference in speech discrimination scores may be due to the biologic and linguistic differences (Awan, 1996; Boone & McFarlane, 1994; Chun, 1987; Greene, 1972; Meyer, 1988 & Mullennix, et al. 2003) as well as differences in fundamental frequency between male and female voices (Turner & Hurtig, 2000). This conclusion is the researcher's own perception and could not be confirmed by previous research in literature.

- Objective scores were better in most telephone-voice combinations than subjective experience scores. This was proved in all three sub-aims, and it is concluded that participants were unsure of their own abilities. The fact that the context in which the sentences were provided to participants was unfamiliar could have influenced this outcome.

- With regards to the telephone-voice combination, T4 (Phone Amp) scored the least with subjective experience and objective familiar voices and objectively with the unfamiliar female voice, whereas T5 (Nokia 3110) scored the least subjectively with the unfamiliar male voice. T4 (Phone Amp) can thus be seen as the telephone that provides the poorest speech discrimination and cannot be regarded as significant for telecommunication in terms of this study.

5.3.1 Theoretical and clinical implications of the results

The following implications are applicable to all three sub-aims.

The BM represents "live" voice, which was better than speech discrimination measured when using any telephone. As the study's aim was to determine the type of telephone that is responsible for the best speech discrimination, little attention is given to the BM score and discussion and implications focus on differences between the various telephones and voices and their clinical and theoretical implications.

It is clear that EMI and telecoil indeed have definite influences on the speech discrimination scores. The Nucleus telephone adaptor Telkom series XXX telephone has a built-in telecoil. The Nokia 3110 is a mobile/cellular telephone. EMI is present in mobile/cellular telephones (Clifford, et al. 1994; de Cock,et al. 2000; Heukelman, 2003 & Jürgens, 2003). Interference results form the detection of electromagnetic fields emitted by the mobile/cellular telephone (van Vliet, 1995). This can serve, as a technical explanation why the Telkom telephone (T1) and the Nucleus telephone adaptor (T2) resulted in higher speech discrimination scores than the mobile/cellular telephone (T5), both subjectively and objectively. Both the Nucleus adaptor and Telkom telephone contain a built-in coil to eliminate any EMI. The Telkom telephone (T1) is used widely in South Africa, and is a standard telephone used in homes and offices. It contains a built-in telecoil and requires no plug-ins, as in the case of the Nucleus telephone adaptor. It can be concluded that the Telkom telephone (T1) is a telephone that is available to all CI users. The researcher recommends that rehabilitation with telephone use should start firstly with the CI adaptor (T2) and then commences to T1 (Telkom telephone).

The Phone-Amp (T4) scored the least with subjective experience and objective familiar voices and objective female voice. The phone-Amp (T4) is an amplifier, with no telecoil or other device to eliminate EMI. This emphasised the significance of a built-in telecoil in eliminating EMI, which has an influence on speech discrimination.

The researcher concludes that rehabilitation should start with the Nucleus Telephone adaptor (T2) and/or Telkom telephone (T1), rather than an amplifier such as the Phone-Amp (T4) or a mobile/cellular-telephone (T5).

The fact that perception scores of familiar voices differed from unfamiliar voices indicates that rehabilitation should start with a person whose voice is familiar to the IFCI. This in accordance with current literature confirms the fact that familiar verbal information is stored in the memory of the auditory cortex (Belin, et al. 2000; Meij & van Papendorp, 1997).

Experience and motivation plays a significant role in acquiring successful telephone abilities, as this enhances confidence that in turn inspires the IFCI to practise and improve his/her telephone communication skills. In rehabilitation a familiar voice will motivate an IFCI, and help him/her gain the experience necessary for developing telephone competence and progressing to unfamiliar voices. Although differences were experienced subjectively and objectively regarding perception scores with unfamiliar male and female voices, they did not differ significantly, indicating yet again that rehabilitation should progress from familiar to unfamiliar voices. Gender should however, not be regarded as a high priority. Rehabilitation should focus on starting telephone-education by using a familiar voice. Only when the CI has proved independent use of the telephone with the familiar voices, should unfamiliar voices be introduced. Although there were few differences within the unfamiliar voice-group the researcher is of the opinion that rehabilitation should continue from the familiar voice to the unfamiliar male voice and only then to the unfamiliar female voice. This is due to the fact that with the subjective experience measurements, the unfamiliar male voice scored higher than the unfamiliar female voice. As the subjective experience measurements reflect the conscious experience of the participants, the researcher is of the opinion that more positive results will be obtained in rehabilitation if unfamiliar male voices are used before unfamiliar female voices are introduced.

This study serves as a preliminary study in order to assess some of the commercially available, technology-developed telephone devices, and to determine which products allow for optimum speech discrimination with the minimum technology interference regardless of the type of CI.

5.4. Recommendations for future research

The researcher is of the opinion that the study proved to be beneficial and valuable. There are various telephones on the market, both locally and internationally, which need to be tested in order to determine their compatibility with CIs. Due to limited previous research available, nationally, concerning this topic and as this is the first researching project of its kind in South Africa, only five telephones were selected form which preliminary results were obtained. The findings of this research study should encourage future in-depth research regarding this topic. A more extensive range of telephones and different types of CI's should be used and compared to the findings in this study.

Mobile/cellular telephones should be assessed in a separate study, as landlines and mobile/cellular telephones use different systems. The need exists for various models and types of mobile/cellular telephones to be tested on a larger population of IFCIs in order to determine which cellular/mobile telephone is the best suited for use by IFCIs. The mobile/cellular telephone industry should be included in this research, as information obtained will direct them in programming, developing and manufacturing mobile/cellular telephones for optimal use by IFCIs. The challenge for research into this problem should be directed at the mobile/cellular telephone industry. Differences in products could be analysed and factors identified which would improve speech discrimination on mobiles/cellular telephones.

Future research should focus on how to bridge the gap between speech discrimination scores of "live" voice (BM) and speech discrimination scores with a telephone. Differences were found in the present study between familiar and unfamiliar voices as well as male and female voices. Research, using different types of voices from different cultures and ethnic groups might prove to be valuable, as differences in fundamental frequency characteristics exist between various ethnic groups (Awan, 1996). Children's voices should also be used to enhance the spectrum of influence of different voices on speech discrimination scores with telephones.

It is further recommended that the level of knowledge of telephone education of therapists working in the field of CIs and IFCIs, be assessed, in order to enhance clinician's rehabilitation skills and to provide the IFCI with more communication options. The need for future research is emphasized by the fact that even amongst the limited number of five telephones used in this study, significant differences in speech discrimination were identified. The importance for IFCIs is that they may start using a telephone with the wrong type of internal device, resulting in negative experiences and discouraging them from further developing the ability to use a telephone as a means of communication. Future research should assess how many IFCIs are able to use a wide variety of telephones successfully and how to improve open-set perception skills with telephones during rehabilitation. Coding strategies could be revised or technologists could develop CI-friendly systems that eliminate EMI and other technological interference to make the mobile/cellular telephone more accessible to more IFCIs.

5.5 Concluding remarks

In conclusion, the researcher anticipates the need that further research will be necessary in order to determine which telephones best meet IFCIs needs regarding speech discrimination in order to maximise telephone usage. It is important to note that new research opportunities will arise as technology develops. The findings of this research study should encourage future research regarding this topic. A more extensive range of telephones should be used and compared to the findings in this study.

Better technology and upgraded devices will continue to be introduced into the general market and thus it is important to understand how these telephones may be used or adapted by people who have a CI and who want to use the telephone to enhance their quality of life. The researcher anticipates that research on this topic will not only improve the social environment and quality of life of a IFCIs, but will also improve the involvement of the telephone companies in the technological development of hearing assistive listening devices.

> *"Despite the fact that plasticity of the auditory system as well as neural survival play a significant role in ultimate performance, the technology of CI has not yet reached a level where implantation is the final step in the process, rather it is the first step in a labour-intensive process. The implant provides the access to*

auditory stimuli these individuals were previously denied, but the ability to maximise the potential of these devices is most likely dependent upon a combination of the identified externals elements and perhaps a few others not yet determined" (Waltzman, et al. 1997:347).

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