CHAPTER ONE

A Review of the Literature: Early Intervention and the Development of Early Communication in Infants with Profound Hearing Loss
Introduction
A descriptive study of the speech and oral language development of infants born with a profound hearing loss who receive interventions focused on developing oral language is presented in this thesis. To date, studies of children with profound hearing loss who are identified early and receive early intervention have focused primarily on the development of language rather than specifically on oral language (Calderon & Naidu, 2000; Mayne, Yoshinaga-Itano, & Sedey, 2000; Mayne, Yoshinaga-Itano, Sedey, & Carey, 2000; Moeller, 2000; Yoshinaga-Itano & Apuzzo, 1998; Yoshinaga-Itano & Sedey, 2000; Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998). These studies have included children who used Total Communication (TC, the combined use of sign language and oral communication) as well as children who were learning language solely through listening and speaking. All children in these studies wore hearing aids. As the speech of infants with a profound hearing loss was described as poor (Calderon & Naidu, 2000), it is assumed that most of the infants and children with profound hearing loss relied on the sign component of Total Communication for the comprehension and expression of language. Thus, we have little data specifically on the oral language outcomes of infants whose profound hearing loss is identified early; who are fitted with the appropriate device (hearing aid or cochlear implant); and receive speech and auditory language stimulation (Yoshinaga-Itano, 2000).

The importance of early stimulation of the auditory pathway is supported by the literature on maturation of the brain and neural system (Rauschecker, 1999; Rauschecker & Shannon, 2002; Robinson, 1998a, 1998b) and critical periods for learning (Novak et al., 2000; Robinson, 1998b; Ruben & Schwartz, 1999; Sharma, Dorman, & Spahr, 2002). The positive impact of auditory stimulation in speech development is also well documented (Geers, Brenner, & Davidson, 2003; Oller & Eilers, 1988; Stark, 1991; Yoshinaga-Itano, 2000; Yoshinaga-Itano & Sedey, 2000). However, if infants with profound hearing loss receive limited benefit from hearing aids because they are unable to hear some or all of the speech signal, is early intervention still effective if the goal is the development of speech and oral language skills?

Early identification and intervention, including use of an appropriate hearing device (hearing aids or cochlear implant) and therapy to develop language skills, significantly reduces the
period of auditory deprivation experienced by an infant born with a hearing loss (Moore, Niparko, M.R, Miller, & Linthicum, 1994; Ponton, Moore, & Eggermont, 1999; Tibussek, Meister, Walger, Foerst, & von Wedel, 2002). However this may not be the situation for children born with a profound hearing loss who usually experience the greatest degree of auditory deprivation. They are unable to hear any sounds without a hearing aid (Moore et al., 1994; Ponton et al., 1999) and often miss many cues in the speech signal once they are appropriately amplified (Ling, 1989). Despite the limitations hearing aids may have for children with a profound hearing loss, these devices are typically used in infancy, with the hope they will provide them with some access to an auditory signal (Dillon, 2000). Then, to increase the amount of auditory information available, most infants with a profound hearing loss in Western countries, are then changed to a cochlear implant at around or after 12 months of age (Drinkwater, 2004).

For children with a profound hearing loss a cochlear implant has advantages over hearing aids for speech and oral language development (Geers, 2004; Svirsky, Robbins, Iler Kirk, Pisoni, & Miyamoto, 2000; Tomblin, Spencer, Flock, Tyler, & Gantz, 1999). This is because the cochlear implant provides a richer auditory signal across the speech range of frequencies than is possible via hearing aids for children who have limited residual hearing (Edwards & Tyszkiewicz, 1999; Geers, 2004). It is for this reason that a cochlear implant is usually the most effective hearing device for the development of intelligible speech and oral language skills in children with a profound hearing impairment (Geers, Nicholas, & Sedey, 2003; Novak et al., 2000; Ponton et al., 1999; Robinson, 1998a, 1998b; Svirsky, 2000; Svirsky et al., 2000; Uchanski & Geers, 2003). The marked improvements in outcomes for children who use a cochlear implant are due to changes in technology and programming strategies (Geers, 2004). These results have proven this technology to be cost-effective in the medium and long term in relation to educational achievement, socialisation, and employment prospects (Summerfield & Marshall, 1999).

Current guidelines provided by the Food and Drugs Administration (FDA) in the USA and the Therapeutic Goods Administration (TGA) in Australia recommend that infants with a profound hearing loss should not be fitted with a cochlear implant until they are 12 months of age (Drinkwater, 2004). This direction is largely a result of anaesthetic risk (Young, 2002). The minimum age recommendation has not previously been a significant issue, as most
infants with a profound hearing loss are at or past the age of 12 months by the time their hearing loss is identified, hearing aids are fitted and an evaluation for cochlear implantation is completed. However, in the future this will change as more infants present for services at a much younger age as a result of screening programs (Harrison, Roush, & Wallace, 2003).

The introduction of effective universal neonatal hearing screening programs has led to a significant increase in the number of infants identified with a hearing loss and receiving a hearing aid in the first 6 months of life (Health, 2004; Yoshinaga-Itano, 2003). The New South Wales (NSW) government was the first to initiate a hearing screening program across hospitals state-wide, in Australia. The introduction of this program in November 2001 has resulted in the average age of diagnosis of hearing loss falling from 18 months in the years before screening to 6 weeks. Similarly, the age of initial hearing aid fitting has fallen from 22 months to a current level of 3 months (Health, 2004). Such reductions in age at identification and hearing aids fitting are likely to increase the number of neonatal screening programs across Australia (and other countries). Therefore, clinicians working in the field of hearing impairment can realistically expect that, for the majority of children born with a hearing impairment, intervention can begin during the first year of life and even in the first months of life (Harrison et al., 2003; Yoshinaga-Itano, 2003). While this is a positive step, consideration needs to be given as to the most appropriate intervention for infants with profound hearing loss.

Infants with a profound hearing loss usually have limited access to sounds using hearing aids, however the minimum recommended age for cochlear implantation is 12 months. It has been demonstrated that infants with a profound hearing loss using hearing aids are likely to have delayed speech regardless of how early intervention starts (Dettman et al., 2005; Oller, Eilers, Bull, & Carney, 1985; Stoel-Gammon, 1988; Stoel-Gammon & Otomo, 1986; Yoshinaga-Itano & Sedey, 2000). It has also been demonstrated in small amount of literature available, that the short-term benefits of auditory stimulation and oral language outcomes in infants with a profound hearing loss who use cochlear implant before 12 months of age (Dettman et al., 2005; Houston et al., 2003; Schauwers et al., 2004). Unfortunately, the studies on infant cochlear implantation are limited in the areas of language studied and the amount of longitudinal information on speech and oral language development. Despite the extensive literature on early intervention, there are few studies that have investigated the effectiveness of auditory stimulation for early communication outcomes in infants with a profound hearing loss.
loss. There are also little data on the outcomes of cochlear implantation at 12 months of age and whether this is early enough for the development of typical early speech and oral language skills. It is the aim of this study to answer these questions.

**Early Intervention**

**Neonatal Screening Programs for Hearing Impairment**

Two studies of the language outcomes of children with hearing loss in the late 1990s were some of the first to demonstrate the benefits of identifying hearing loss in infancy (Yoshinaga-Itano & Apuzzo, 1998; Yoshinaga-Itano et al., 1998). Significantly better language outcomes were found in children whose hearing loss was diagnosed before 6 months of age than at 18 months of age (the then average age of diagnosis). These findings led to some of the first neonatal screening programs in the US, which resulted in more infants presenting at early intervention programs (Yoshinaga-Itano, 2003). The increasing numbers of young infants in early intervention programs is driving change in service delivery options, including cochlear implantation (Harrison et al., 2003).

**Early Intervention Outcomes for Infants with Hearing Loss**

Many studies demonstrate the benefits of early identification, fitting of hearing aids, and intervention in infants with significant hearing loss (Calderon & Naidu, 2000; Mayne, Yoshinaga-Itano, Sedey et al., 2000; Moeller, 2000; Robinshaw, 1996; Yoshinaga-Itano & Apuzzo, 1998; Yoshinaga-Itano et al., 1998). As stated above, Yoshinaga-Itano and Apuzzo (1998) were among the first to examine the language outcomes of infants diagnosed with hearing loss, fitted with hearing aids and receiving early intervention before the age of 6 months. The language outcomes of those infants were compared to a group of toddlers whose hearing loss was diagnosed and fitted with aids after 18 months of age. Significantly better language outcomes were demonstrated in the infants whose hearing loss was diagnosed prior to 6 months of age. However, these results should be expected. An infant diagnosed with a hearing impairment and receiving intervention prior to 6 months of age should have better language outcomes than a toddler diagnosed and starting intervention after 18 months of age. The later diagnosed infants would already have an 18 month language delay prior to fitting of hearing aids intervention. However, the benefits of early identification and intervention before 6 months of age have been substantiated by an additional study comparing outcomes of those
identified with a hearing impairment at this age with those diagnosed after 6 months (Yoshinaga-Itano et al., 1998).

Yoshinaga-Itano, Sedey, Coulter, and Mehl (1998) studied the receptive and expressive language abilities of 72 children whose hearing loss was diagnosed in infancy. These infants were fitted with hearing aids and in early intervention programs prior to 6 months of age. The development of this early identified group was compared with that of infants whose hearing loss was diagnosed after 6 months of age. Again, it was found that the infants whose hearing loss was identified prior to 6 months of age had better language development than those identified after this age. The authors examined more closely the language development of the group of infants who were identified after 6 months of age. This group consisted of infants and toddlers diagnosed with hearing loss between 7 and 34 months (average 16 months). This is a wide age range for diagnosis, and the inclusion of children identified as late as 34 months and may have skewed the results. Consequently, the authors divided them into four subgroups: those identified with hearing loss at 7-12 months; 13-18 months; 19-24 months; and 25 months or later. Further analyses showed no significant difference in language abilities between the four subgroups of later identified infants and toddlers. Yoshinaga-Itano et al. concluded that infants and toddlers with a hearing impairment who receive intervention after the age of 6 months are at a disadvantage with regard to language acquisition compared to infants whose hearing loss is identified prior to 6 months of age.

Mayne, Yoshinaga-Itano, Sedey, and Carey (2000) examined the long term expressive vocabulary development of infants aged 8-22 months with a hearing loss, most of whom had the hearing loss diagnosed before the age of 6 months. Again, the infants diagnosed with hearing loss prior to 6 months of age had better expressive vocabulary than infants diagnosed later. However, this was not the case for receptive vocabulary development in a study by Mayne, Yoshinaga-Itano, and Sedey (2000). They found no significant correlation between age at identification and receptive vocabulary development. This finding may be attributable to the fact that the evaluation was delivered using TC, and many of the signs for individual vocabulary items provide an obvious clue to the answer to the stimulus question. For example, for “show me ‘neck’”, the examiner would point to his/her own neck, leading children to the correct answer regardless of whether it was in their vocabulary.
Identification of a hearing loss prior to 6 months of age coupled with appropriate fitting of hearing aids and early intervention has its demonstrated benefits, but is the picture so much worse for infants whose hearing loss is diagnosed at 7, 8, or 9 months of age? Recent findings suggest that identification of hearing loss prior to 12 months of age has significant benefits for language acquisition compared to identification after this age (Calderon & Naidu, 2000; Moeller, 2000). Moeller (2000) studied the language outcomes at 5 years of age in children whose hearing loss was identified between the ages of 2 days to 54 months (average 18 months). The age at fitting of hearing aids and enrolment into intervention ranged from 3 weeks to 54 months (average 22 months). Moeller examined receptive vocabulary and verbal reasoning abilities. Children who were enrolled in intervention prior to 11 months had significantly better language abilities at 5 years than those enrolled in intervention after 11 months. This finding suggests that although identification of hearing loss prior to 6 months of age is ideal, children who are identified in the first year of life will achieve better language outcomes than later identified children. All of these studies have redefined the term “early intervention” in the field of hearing impairment.

**Neuroplasticity and Critical Periods for Auditory Development: The Impact on Speech and Oral Language Acquisition**

Early intervention assists infants with a hearing loss to access auditory stimulation at an early age when the auditory pathway is typically maturing and speech perception is developing (Robinson, 1998b; Sininger, Doyle, & Moore, 1999). Furthermore, it allows most infants fitted with hearing aids to take advantage of auditory neuroplasticity and optimal periods for learning (Ponton et al., 1999; Sininger et al., 1999). *Neuroplasticity* relates to the maturation or development of neural pathways for optimal functioning (Ponton et al., 2001). It can refer both to the process of redevelopment of neural pathways after brain injury and to the period of time taken for neural pathways to mature from birth, underlying the infant’s cognitive, motor and sensory developmental milestones. The maturation of neural pathways is associated with critical periods for development of motor, speech, and language skills (Robinson, 1998b; Syka, 2002).
A critical period refers to the period of time that is optimal for the acquisition of developmental skills (Ruben & Schwartz, 1999), but maybe it is better described an optimal period for development. The term critical period implies that a skill such as language can only be acquired during a particular time frame, usually the early years of life. However, there are literature reviews and studies demonstrating late acquisition of a first language (Vargha-Khadem, Carr, & Issacs, 1997), acquisition of a second language later in life (Flege, Munro, & MacKay, 1995; Johnson & Newport, 1989; Maybury, 1993) and re-acquisition of language after head injury (Mortenson, 2005). Adaptation of the brain and the neural system to accommodate language development outside of the critical period can occur regardless of whether the language is a first language, a second language or relearning of the first language (Johnson & Newport, 1989; Lee et al., 2003). However, the older people are when they develop a language, the less proficient they are likely to be using that language because rather than acquiring language they are learning language (Gordon, 2000). The younger children are, the more likely they are to naturally acquire language rather than have to learn language (Gordon, 2000). For children with a hearing impairment, the younger they begin listening and learning oral language the easier it will be to acquire these skills (Mayne, Yoshinaga-Itano, Sedey et al., 2000; Yoshinaga-Itano et al., 1998). This is not only because of the optimal period for learning but the optimal period for development and maturation of the auditory pathway (Sininger et al., 1999).

Development and Maturation of the Auditory Pathway in Infants
The brainstem auditory pathway is fully developed around 28 weeks gestation and relatively mature at the time of birth (Gordon, 2000). After birth the auditory system continues to develop and mature (Moore, 2002a; Sharma et al., 2002). Moore (2002a) traced the maturation of the human auditory cortex from gestation to early adulthood. The findings indicated there were three developmental periods; the perinatal period (3rd trimester – 4 months of age); early childhood (6 months – 5 years) and later childhood (5 – 12 years). Moore states that development in the perinnatal period is driven by axonal development and not reliant on external stimuli. During the early childhood phase, development occurring in the cortex is a result of stimuli or input from the lower auditory system. Maturation in the superficial cortical layers allow for communication between different parts of the cortex. In turn, complex auditory processing can occur. Sharma, Dorman and Spahr (2002) examined the central auditory system responses of 104 children after cochlear implantation. Their results
suggest that the central auditory system remains maximally plastic until 3 ½ years of age. Maturation continues for some children until 7 years of age; and after this age, plasticity is greatly reduced.

Maturation of the auditory pathway is affected by hearing loss as a result of the delay in auditory stimulation (Moore et al., 1994; Ponton et al., 1999; Sininger et al., 1999; Tibussek et al., 2002). Tibussek, Meister, Walger, Foerst, and von Wedel (2002) investigated the time frame for maturation of the auditory pathway by conducting a retrospective study on typically hearing and hearing-impaired children. The authors evaluated the auditory brainstem response (ABR) results of 85 children with typical hearing and 165 children with varying degrees of hearing impairment (ages 1 month to 16 years). None of the subjects had worn hearing aids. In particular, they examined the interpeak latencies of the ABR. Interpeak latencies demonstrate changes in the central auditory pathway. Results showed the children with hearing (control group) to have typical development of interpeak latencies wave I-III and wave I-V, with interpeak latencies decreasing over time, stabilising at approximately 2 years of age. That is, the interpeak latencies in typically developing children decreased as the auditory pathway matured. However, for children with hearing loss, the interpeak latencies did not decrease with age and typical interpeak latencies were not observed by 2 years of age, even in children with a moderate to severe hearing loss. The greater the degree of hearing loss the greater the interpeak latencies. For children with a profound loss ABR wave peaks were not detectable, indicating a very deprived auditory system. These findings suggest that the greater the hearing loss, the greater the delay in the maturation of the auditory pathway. In addition, maturation is affected by delaying auditory stimulation (Sininger et al., 1999).

Therefore, if the auditory system is to mature and develop so sound may be transmitted efficiently along the pathway, stimulation should occur at as early an age as possible with as much auditory access to sounds as possible (Moore, 2002b; Moore et al., 1994; Ponton et al., 1999; Ponton et al., 2001; Sininger et al., 1999).

**Development of Speech Perception Skills in Infants**

In typically hearing children, the foundations for early speech perception development are laid in the first year of life (Kuhl, 2004). Figure 1-A, shows a model of speech perception and speech production in the first year of life.
Infants respond to sounds in utero, and at birth have auditory capabilities that are optimised for perception of speech (Bertoncini, Bijeljac-Babic, Blumstein, & Mehler, 1987; Ramus, Hauser, Miller, Morris, & Mehler, 2000; Sansavini, Bertoncini, & Giovanelli, 1997). Neonates with can distinguish their mother’s voice and prefer to listen to her voice over others (Ruben & Schwartz, 1999). In addition, they can distinguish speech sounds from non-speech sounds (Trehub, 1973; Trehub & Rabinovich, 1972). During the first 2 months of life infants vocalise non-speech sounds, which develop into vowel-like sounds at 3 months (Jusczyk, Pisoni, & Mullennix, 1992). Around the age of 4 months infants have an auditory memory for speech syllable patterns (Saffran, Aslin, & Newport, 1996). At 6 months many infants have an auditory preference for vowel phonemes of their native language (Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992). This leads to infants’ recognition of sounds and sound sequences from their native language, which is developed by 9 months of age. At this age infants can distinguish sounds and sound sequences from their parents’ native language (Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993). This level of speech perception development facilitates canonical babble as infants’ speech perception skills are now developed to a point where they can discriminate words and their speech production imitates their parents’ native language (Jusczyk, 2002). In turn, this leads to the development of first word production at 12 months of age (Kuhl, 2004). Through continued exposure to speech
and further maturation of the auditory pathway, infants continue to develop speech perception skills (Kuhl, 2004; Kuhl et al., 1992; Moore, 2002b).

Early speech perception development in infants is facilitated by auditory stimulation (Kraus, 1999; Kuhl, 2004; Moore, 2002a). In addition, speech perception facilitates the development of early speech and oral language in children with typical hearing (Kuhl, 2004; Tsao, Liu, & Kuhl, 2004). Therefore, a hearing loss at birth is likely to affect speech perception development and in turn early speech and oral language development. Moreover, the later the auditory stimulation begins, the more difficult it may be to develop these skills in the long term (Sininger et al., 1999). For speech perception skills are to be acquired at a typical age, stimulation should occur at as early an age as possible (Moore, 2002b; Moore et al., 1994; Ponton et al., 1999; Ponton et al., 2001; Sininger et al., 1999).

Speech and Oral Language Development in Infants with Profound Hearing Loss

Limited auditory stimulation due to hearing loss in the first year of life will impact on the development of oral communication skills; and that the greater the hearing loss the greater the impact (Calderon & Naidu, 2000; Harrison et al., 2003; Moore et al., 1994; Ponton et al., 1999; Sininger et al., 1999; Tibussek et al., 2002). The view that a child with a moderate hearing loss may have better speech and language outcomes than a child with a profound hearing loss, because of the greater amount of usable hearing for the child with a moderate loss, is based on clinical observation as well as research (Calderon & Naidu, 2000; Obenchain, Menn, & Yoshinaga-Itano, 2000; Robinshaw, 1996; Wallace, Menn, & Yoshinaga-Itano, 2000; Yoshinaga-Itano & Sedey, 2000). However, several recent studies on early identification and intervention do not substantiate the contention that degree of hearing loss significantly affects language outcomes (Calderon & Naidu, 2000; Mayne, Yoshinaga-Itano, Sedey et al., 2000; Moeller, 2000; Yoshinaga-Itano & Apuzzo, 1998; Yoshinaga-Itano et al., 1998). That is, studies of early intervention have shown that degree of hearing loss was not a significant factor affecting language development, despite all infants in these studies wearing hearing aids. We therefore need to consider the factors that contribute to these findings. In these studies the children included those using oral language as well as those using TC. When the authors referred to language development they included both oral
language and signed language. It is a reasonable assumption that those with lesser hearing losses were represented in the oral language group and those with greater hearing losses were mainly represented in the TC group.

Calderon and Naidu (2000) studied the benefits of early identification and intervention for language, auditory discrimination and speech development. Results indicated a correlation between age at intervention and language development. However, there was no correlation between the age children entered early intervention and their auditory discrimination skills and speech production scores. The variable that correlated with auditory discrimination and speech production scores was degree of hearing loss. That is, the greater the hearing loss, the poorer their auditory discrimination and speech. Can these results be accounted for by communication mode? All infants in the study used TC. When using TC children may rely equally on signing, speech and audition, may favour audition and speech over signing, or conversely may favour signing over audition and speech. One factor affecting children’s use of audition and speech is their amount of usable hearing. For infants with profound hearing loss and little residual hearing, it is difficult and sometimes impossible to develop auditory discrimination skills (speech perception) which directly impact on speech development. As a result, their language ability may improve through signing but their oral and aural skills will be limited. The study by Calderon and Naidu (2000) highlights the fact that despite early intervention, infants with a profound hearing loss may still struggle to develop speech perception and speech using hearing aids alone. The inclusion in Calderon and Naidu’s study of children who used different communication modes does not enable us to determine how early intervention affects auditory and oral language development as opposed to language development based on use of sign language.

It is well documented that early intervention for infants with hearing loss, is important for the development of speech and language skills (Mayne, Yoshinaga-Itano, & Sedey, 2000; Mayne, Yoshinaga-Itano, Sedey et al., 2000; Moeller, 2000; Robinson, 1998b; Sininger et al., 1999; Yoshinaga-Itano & Apuzzo, 1998; Yoshinaga-Itano et al., 1998). However, there are few studies for speech and oral language development attained by infants diagnosed with a profound hearing loss who receive early intervention prior to 6 months of age, unless they have had a cochlear implant (Houston et al., 2003; Schauwers et al., 2004). As stated earlier it seems that most infants with a profound hearing loss in the abovementioned studies, were
using TC and therefore language results reported were likely to be sign language. The reason being that even with the advantage of high-powered hearing aids, many such infants may not be able to hear sufficient aspects of speech (suprasegmental and segmental) to develop the speech perception skills that underlie oral language development (Flexor, 1999). For the majority of infants with a hearing loss, hearing aids adequately amplify sound so that they are able to develop speech and oral language skills (Dillon, 2000). Infants with mild-moderate hearing loss can usually hear some or most speech sounds without hearing aids, but without amplification, their acquisition of oral language skills can be impeded (Flexor, 1999). Infants with a severe hearing loss are not able to hear speech sounds without hearing aids, though with appropriate amplification they are usually able to hear most or all speech sounds, assisting in the development of oral communication (Ling, 1989). Infants with a profound hearing loss may have no residual hearing across the speech range, and even with hearing aids they cannot detect or discriminate many speech sounds at conversation levels of loudness (Flexor, 1999). Consequently their speech and oral language development may still be significantly impaired despite early identification, hearing aid fitting and auditory stimulation.

As stated in the previous section, auditory stimulation is crucial in the maturation of the auditory pathway and in speech perception development (Moore, 2002a; Ray, Gibson, & Sanli, 2004; Tibussek et al., 2002). Speech perception skills acquired in the first year of an infant’s life lead to the acquisition of early speech skills and first words (Kuhl, 2004). Once first words emerge, infants continue to acquire speech and language skills with the greatest explosion of language in typically developing children occurring a little after 2 years of age (Paul, 1995b). In this period they move from single and two-word sentences to mastery of simple sentence structures (Owens, 1992). Auditory maturation and language development continue through to adolescence (and speech through to early school age), although the most crucial periods for development are the early years of life (Moore, 2002a; Paul, 1995c). It is evident that speech and oral language skills are underpinned by speech perception development, therefore the impact of a profound hearing loss on the development of speech and oral language skills is likely to be significant (Moore, 2002a; Ponton et al., 1999; Robinson, 1998b; Stoel-Gammon, 1988; Tibussek et al., 2002; Tsao et al., 2004). This raises the question; how effective is early auditory intervention for infants with a profound hearing loss?
Paediatric Cochlear Implantation: The Trend Toward Implantation for Infants

Today, it is widely accepted that for children with a profound hearing loss, a cochlear implant is usually the most appropriate hearing device if intelligible speech and oral language skills are to be acquired (Svirsky, 2000; Svirsky et al., 2000; Tomblin et al., 1999). For infants with a profound hearing impairment a cochlear implant may provide better access to sound than hearing aids can (Clark, 1997a; Drinkwater, 2004; Edwards & Tyszkiewicz, 1999). This is because the cochlear implant provides sound by directly stimulating the auditory nerve, rather than delivering sound via the damaged cochlea (Edwards & Tyszkiewicz, 1999).

Two recent studies have examined the rate of language development in children who received a cochlear implant (Novak et al., 2000; Svirsky et al., 2000). Novak et al. (2000) evaluated the rate of language development from the ages of 9-25 months in 14 young children who received a cochlear implant. They found that the oral language development of the children using a cochlear implant progressed at a rate comparable to that of typically hearing peers. However, the study had limitations. Two different tests were used to evaluate the children’s language, depending on their age and ability. One of these assessments was standardised and the other was a non-standardised assessment for children with a hearing impairment. Without the implementation of standardised assessments on all the children, the outcomes provide limited evidence. However, these results have been supported in a study by Svirsky, Robbins, Iler Kirk, Pisoni and Miyamoto (2000), who used a standardised test at regular intervals to assess the expressive language abilities of 70 children. The testing began 4 months prior to cochlear implantation and continued at 6 monthly intervals following surgery (6, 12, 18, 24 and 30 months post-implantation). Although there was a large amount of individual variability, the rate of expressive language development of the children (up to 2½ years post-cochlear implantation) was approximately the same as expected for typically hearing children. The authors suggested that while the children with a profound hearing loss had a language delay prior to cochlear implantation, the cochlear implant stopped the delay increasing further. The conclusion reached by the authors of both the above studies was that cochlear implantation at an earlier age would result in smaller delays in language development. That is, children who receive a cochlear implant at 18 months of age, who have been unable to develop oral language skills due to a lack of residual hearing, already have a speech and oral language delay of 18 months when compared with hearing age-mates. Although their
language may develop at a rate similar to that of hearing peers following cochlear implantation, they will still continue to have a speech and oral language delay of at least 18 months. Infants who receive a cochlear implant at 12 months of age and develop language at a normal rate will still have a 12 month speech and language delay. Therefore, the provision of a cochlear implant for infants even younger than 12 months may lead to a further reduction or possible elimination of a speech and language delay.

Rauschecker (1999) reviewed the literature on auditory cortical maturation and observed that changes in speech perception abilities in the first 6 months of life coincided with early speech development and in turn the acquisition of language skills. The basis for this comes from the work of (Jusczyk, 2002; Jusczyk et al., 1993; Jusczyl et al., 1992). The speech perception skills of infants in these studies have been measured by presenting auditory stimuli in the form of words in a strictly controlled laboratory situation. Depending on their age the infants would be presented with words to test their recognition of identical phonemic productions (2 months) or to determine whether nonsense words of their parent’s native language could be recognised (6 months). The infants’ responses were determined by sucking patterns (2 month olds) or turning to a puppet which was placed near the sound source (from 5-6 month of age). Soon after the infants are able to recognise phonemes from their parent’s language, the infants begin to babble using phonemes from that language (Kuhl, 2004). This babble then leads to the infants using words (Owens, 1992).

For children with a prelingual profound hearing loss, the development of speech and oral language skills without an adequate auditory signal will be difficult (Smith, 1975; Svirsky, 2000; Yoshinaga-Itano & Sedey, 2000). Rauschecker suggested that cochlear implants should be “strongly encouraged” (p. 79) in infants with a profound hearing loss to exploit the maturation period of the auditory cortex. That is, cochlear implantation at an early age for infants with a profound hearing loss who do not receive benefit from hearing aids will aid development of the auditory pathway at a time when it is most plastic. In turn, speech perception skills can develop that should facilitate the development of speech and oral language skills (Geers, 2004; Geers, Brenner et al., 2003; Geers, Nicholas et al., 2003; Houston et al., 2003; Schauwers et al., 2004).
Currently the recommended age for cochlear implantation is 12 months, but in the future, the opportunity for cochlear implantation prior to 12 months of age is likely to increase (Drinkwater, 2004). There will be more infants with a profound hearing loss identified and recommended as cochlear implant candidates well before 12 months as a result of hearing screening programs. The shift in age at diagnosis will raise the question of the effect of a cochlear implant on the early oral communication development of infants with profound hearing loss (Samson-Fang, Simons-McCandless, & Shelton, 2000).

Recent research indicates that for some aspects of language development, cochlear implantation prior to 12 months of age is advantageous (Dettman et al., 2005; Houston et al., 2003; Schauwers et al., 2004). While speech perception development has not been fully examined in the literature, pre-word learning (word-object association), early language and babble development have been evaluated.

Houston et al. (2003) studied the pre-word-learning skill (ability to pair sounds with objects) of 18 infants with profound hearing loss. Among the 18 subjects, 8 received a cochlear implant prior to or near their first birthday (activation between 7 months and 14 months) and 10 received a cochlear implant between 16 and 23 months. The development of pre-word learning was compared between both groups and with a group of typically hearing peers. Results showed that after 2-6 months of cochlear implantation use, the infants who received their cochlear implants prior to or soon after their first birthday had pre-word-learning skills similar to those of their hearing peers. This level of development was not demonstrated over the course of the study by the infants who received cochlear implants after 16 months of age. This appears to be one of the first studies to demonstrate a reduction in language age gap between infants with typical hearing and infants with a profound hearing loss who receive a cochlear implant prior to or soon after their first birthday. However, the study is limited in information on language outcomes after cochlear implantation. The infants’ ability to pair sounds with objects was demonstrated, but this does not show how language developed or how the children communicated.

Schauwers, et al. (2004) investigated the onset of babbling in infants who received a cochlear implant. In particular, they examined the onset of babble and the impact of the age at
implantation on speech perception and speech production. Ten infants with a congenital bilateral profound hearing loss and a control group of 10 infants with typical hearing aged 6-11 months participated in the study. All infants were educated orally (in Dutch) with the support of Dutch signs. Schauwers et al. found that all infants started babbling after 1-4 months of device activation. Moreover, typical babble development and age at implantation were significantly correlated. The onset of babble for the four youngest infants, who received a cochlear implant at 5, 6 or 8 months of age, was comparable to that of normally hearing infants. That is, the infants implanted at 5 and 6 months began to babble at 8 and 10 months of age, respectively. The two infants implanted at 8 months began babbling at 11 months of age. This age of babble onset fell within the normal range when compared that of hearing peers. While the findings of these studies are promising, we still have no insight into the long-term impact of early cochlear implantation on early speech and oral language development.

These two studies suggest that early infant cochlear implantation may “eliminate” the speech and language gap in the areas studied (Houston et al., 2003; Schauwers et al., 2004). However, the studies are limited with, the areas of language studied and the lack of longitudinal information on speech and oral language development (Dettman et al., 2005; Houston et al., 2003; Schauwers et al., 2004). Further detailed, longitudinal research for infants who receive a cochlear implant at such an early age is required in many areas of early communication, if we are to know the true benefits of cochlear implantation under 12 months of age.

The Cochlear Implant System
The cochlear implant is an electronic hearing device that bypasses the damaged cochlea and directly stimulates the auditory nerve (Edwards & Tyszkiewicz, 1999). The cochlear implant system consists of two pieces of equipment; an internal cochlear implant and an external speech processor (see Figure 1-B). The internal cochlear implant consists of a receiver-stimulator [6] and an electrode array [7], and is implanted during surgery. The speech processor includes a head-set (microphone [1], transmitter [5] and cords [2] and [4]) and a speech processor [3]). The speech sound is picked up by the microphone and sent to the speech processor. The signal is then analysed and digitised into coded signals by the program on the speech processor (Clark, 1997a). The program on the speech processor is also referred
to as the MAP. The coded signal is then sent to the transmitter coil, which sends it across the skull to the receiver-stimulator. The receiver-stimulator converts the code into electrical impulses which fire the electrodes situated in the cochlea and directly stimulate the auditory nerve. The signal is then sent along the auditory pathway to the cortex of the brain. Success of the cochlear implant is dependent on device-based specific parameters. These parameters include a) auditory nerve survival, b) electrode position in the cochlea, c) the MAP and d) speech processor coding strategies.
Research and Development in Cochlear Implant Systems

Throughout the years of research and development in cochlear implant systems, the main aim has been to improve the speech signal provided by the device (Clark, 1995; Psarros et al., 2002; Skinner, Fourakis, Holden, Holden, & Demorest, 1999; Skinner et al., 2002). An improved signal leads to better speech perception by the user (Geers, Brenner et al., 2003). To achieve this goal, modifications and improvements have been made to the software (speech coding strategies), and the hardware (the electrode arrays and speech processors) (Clark, 1995). Speech coding strategies have been refined to improve the signal by coding more information in the speech signal and making it more resistant to noise interference (Clark, 1997b).

In the early cochlear implant system development, the speech coding strategies focused on formants (the intense frequency regions of a vowel sound that determine the quality of that sound) (Clark, 1997a). The first speech coding strategy was the Nucleus F0/F2 strategy used with the WSP II speech processor. The F0 (fundamental frequency) and F2 (second vowel formant) were used to code speech. The speech signal provided by this strategy was limited, with its main benefit being suprasegmental information. Despite the limitations it led to improvement in the perception of connected speech (Clark, 1997b). However, to identify vowels through listening, a person must hear both the first formant (F1) and second formant (F2) (Boothroyd, 1986). As a result, the F0/F1/F2 speech coding strategy was developed. This strategy provided segmental information in the form of vowel discrimination, although again the information was limited (Clark, 1997a).

The development of the SPEAK (Cochlear Ltd) coding strategy in 1994 represented a new approach to coding speech (Skinner et al., 2002). SPEAK uses the tonotopic organisation of the cochlea. That is, if a high frequency sound is presented, the speech coding strategy stimulates the electrodes placed near the base of the cochlea. Conversely, the end of the electrode array which is situated closer to the apex of the cochlea is stimulated by low frequency sounds. Rather than extracting speech elements such as formants, the SPEAK strategy analyses the incoming signal using 20 digitally programmable band-pass filters and then selects up to 10 frequency bands which contain the maximum speech information (Skinner et al., 2002). Each frequency band stimulates specific electrodes. The SPEAK speech
coding strategy resulted in a significant improvement in speech perception of vowels and consonants when compared with previous speech coding strategies (Skinner et al., 1999).

Until the mid 1990s, most developments in cochlear implant system technology occurred through improving speech processing strategies, which meant upgrading the external speech processor (Clark, 1995). From the early 1980s through to the mid 1990s, when developments occurred in speech processing strategies and speech processors, the same multichannel cochlear implant was used; the Nucleus® CI22M (Clark, 1995). The first significant change of the internal section of the cochlear implant (Nucleus® CI24M) occurred in 1996. The Nucleus® CI24M, like the CI22M, had a multi-channel electrode array, but the Nucleus® CI24M had 24 electrodes, two more than the CI22M. This change allowed the cochlear implant to be programmed using higher stimulation rates and consequently led the way for the new generation of speech processing strategies (Psarros et al., 2002). The new speech coding strategies led to improved speech perception abilities (Skinner et al., 2002).

The Benefit of Up-to-date Speech Coding Strategies
Speech coding strategies have been developed over time to improve the speech signal available to the cochlear implant user (Pasanisi et al., 2002; Psarros et al., 2002; Skinner et al., 1999; Skinner et al., 2002). For infants, a speech coding strategy is required that helps them perceive all aspects of speech (Edwards & Tyszkiewicz, 1999). This is because they use the device for acquiring speech and oral language skills (Drinkwater, 2004). The speech coding strategy must provide a signal that permits discrimination of all suprasegmental aspects of speech as well as all consonants and vowels (Clark, 1997a). In addition, the strategy must code speech in manner that words and sentences can be perceived in both quiet and noisy environments. The cochlear implant must also be able to process the signal rapidly so that the infant does not miss information due to the fast pace of speech (Pasanisi et al., 2002).

The SPEAK speech coding strategy developed in 1994 was the first to allow young children and adults to perceive both the suprasegmental and segmental aspects of speech (Clark, 1997a). This paved the way for prelingually deafened infants to develop speech perception skills that facilitated more intelligible speech and better language development than other speech coding strategies (Geers, Brenner et al., 2003). Research shows that children with
Cochlear implants using the SPEAK speech coding strategy had better speech perception, speech, language, and literacy development than those on earlier strategies (Geers, 2002; Geers, 2003; Geers, Brenner et al., 2003; Geers, Spehar, & Sedey, 2002; Tobey, Geers, Brenner, Altuna, & Gabbert, 2003).

With the development of the CI24 two new coding strategies were devised: Continuous Interleaved Sampling (CIS) and the Advanced Combination Encoder (ACE) (Skinner et al., 2002). The CIS strategy provides high fixed rates of stimulation to a comparatively small number of channels on the electrode array (Wilson, Finley, Lawson, Wolford, & Zerbi, 1993). The ACE strategy uses both high stimulation rates and dynamic electrode selection with a comparatively large number of electrodes (Vandali, Whitford, Plant, & Clark, 2000). Research has been conducted to determine which speech coding strategy provides the best speech perception for adults and children (Pasanisi et al., 2002; Psarros et al., 2002; Skinner et al., 1999; Skinner et al., 2002).

Skinner et al. (2002) studied the speech perception skills of 12 adults newly implanted with the Nucleus® CI24, using the SPEAK, CIS and ACE speech coding strategies. Their aim was to investigate listener preferences and speech perception ability for the different speech coding strategies. Seven of the 12 subjects preferred the ACE strategy, with 6 of the 12 having better speech perception of sentences using this strategy than when using the CIS and/or SPEAK strategies. As there was a good correlation between the preferred strategy and speech recognition skills, the results suggested that ACE provided better sound quality and allowed users to understand conversational speech better than the other strategies tested.

There have been many studies of speech coding strategies and speech perception in adults (Skinner et al., 1999; Skinner et al., 2002; Vandali et al., 2000). However, it is important to investigate whether these results apply to the paediatric population. Psarros et al. (2002) reported on the speech perception abilities of children using SPEAK and ACE speech coding strategies. Seven subjects aged between 9 and 16 years who were experienced users of the SPEAK speech coding strategy participated in the study. Psarros et al. reported that speech perception scores for words and sentences in noise were significantly higher when using the ACE strategy. Pasanisi et al. (2002) also found that ACE had a positive impact on overall
speech perception in children. The findings of Pasanisi et al. demonstrated a statistically significant improvement in open-set word and sentence recognition using the ACE speech coding strategy. The greatest improvements were noted in speech perception scores obtained with background noise.

In summary, improvements in cochlear implant speech coding strategies have further enhanced speech perception abilities in children and adults with a profound hearing loss. This has had a positive impact on the acquisition of speech and language development of young children with prelingual profound hearing loss.

**Summary**

Studies demonstrate that children with hearing loss have significantly better speech and language outcomes when identified prior to 6 months of age (Mayne, Yoshinaga-Itano, & Sedey, 2000; Mayne, Yoshinaga-Itano, Sedey et al., 2000; Moeller, 2000; Yoshinaga-Itano et al., 1998). However, in most of these studies “language” has referred to communication developed through TC (sign and speech) as well as oral language learned through listening. All the children in these studies used TC, which means that those with a profound hearing loss were most likely to be relying on the sign component of TC for language development. Therefore we have little specific information on the speech and oral language outcomes of infants whose hearing loss is diagnosed early, and who are fitted with an appropriate hearing device (cochlear implant or hearing aid) and receiving speech and auditory stimulation.

Early intervention allows an infant to access auditory stimulation at a time when maturation of the auditory pathway and speech perception skills are typically developing (Sininger et al., 1999; Tsao et al., 2004). This is important in the acquisition of speech and oral language skills (Kuhl, 2004; Tsao et al., 2004). However for infants with a profound hearing loss with limited access to speech sounds even with hearing aids, the effectiveness of early auditory intervention is questioned.
Cochlear implants have significant benefits over hearing aids for speech and oral language development in children with profound hearing loss (Svirsky, 2000; Svirsky et al., 2000; Tomblin et al., 1999). However, the minimum age recommendation for infants with a profound hearing loss means that they typically will not have access to all speech sounds until after 12 months of age. This has implications for auditory pathway maturation, early speech perception acquisition, and speech and language development. With neonatal screening for hearing impairment, more infants with a profound hearing loss will be identified in the first months of life (Cone-Wesson et al., 2000; Health, 2004; Yoshinaga-Itano, 2003). As a result, we will see more infants who are identified as cochlear implant candidates before 12 months of age. These advances in technology are starting to shift the way we conceptualise use of the most appropriate hearing device to provide the most effective early intervention practice.

**Purpose of this Study**

This aim of this study was to answer the following questions by tracking the infants’ development over a two year period.

1. Does early auditory intervention result in sequential and age appropriate speech, receptive language and expressive language development for infants with a profound hearing loss?

2. What is the impact of early cochlear implantation on the sequential and age appropriate development of speech, and receptive and expressive language in infants with a profound hearing loss?

**Layout of the Thesis**

The assessments tools used over the two years of data collection changed as the infants communication skills began to develop. Moreover, the areas of communication development studied were detailed and analysed in different ways. These factors made it difficult to present the information in a cohesive style. Consequently, the thesis is laid out in the following way:

- This chapter, *Introduction* provides a literature review on hearing impairment, auditory pathway development, the effects of auditory deprivation on auditory pathway development, early identification of hearing loss, the use of hearing aids and
cochlear implants. In addition, a summary of the literature on speech and language
development and the affect of a hearing impairment on this development is included.

- The method details all assessments administered and the rationale for using them.
- Chapters 3-5 (3. Communicative Intention, 4. Speech, and 5. Language) are written as
  separate studies each reporting a detailed literature review for the area studied. The
  method section focuses on the analyses conducted. This is followed by a presentation
  of the results. A discussion completes the chapter, relating the findings to the current
  literature of the area of communication studied.
- The final chapter 6 Concluding Remarks discusses the findings in their entirety and the
  relevance of the study to the field as a whole.
CHAPTER TWO

Method
The method used to investigate the early communication development of infants with a profound hearing loss, was longitudinal. Measures were taken over a two year period at monthly intervals from 3 months pre-implantation to 6 month post-implantation. Further data were gathered 12- and 18-months post-implantation. Data were gathered using a variety of tools including, video-taped parent-child interactions, standardised testing and parent questionnaire. This method allowed for comprehensive measures of communication ability to be made in the areas of communicative intention, speech and oral language development.

**Participants**
Participants were recruited from families entering the program at the Sydney Cochlear Implant Centre (SCIC). At the time this study was conducted, SCIC was the only cochlear implant program in NSW and all infants evaluated for cochlear implantation in NSW were assessed through this program. Because SCIC has access to public health system rebates for the provision of a cochlear implant, its data base includes diverse socio-economic groups from both metropolitan and rural regions of NSW.

**Selection Criteria**
Criteria for an infant to be enrolled in the study were:

- having a congenital bilateral profound hearing loss
- having commenced the cochlear implant evaluation process no later than 12 months of age
- being enrolled in an auditory-verbal educational program
- having parents with good hearing and English as their first language. This criterion helped to ensure that infants in the study had parents who could provide intelligible oral English speech and language models for their child.

Over a 2 year period, eight infants aged 5 to 12 months met these selection criteria and were enrolled in the study. This cohort of infants participated in all three studies presented in this thesis. Of these eight infants, three were subsequently identified as having other factors apart from hearing loss impacting on their communication development. One infant (Infant 2) required reimplantation of the cochlear implant and did not have access to an auditory signal
for approximately 1 month. One infant (Infant 3) was affected by significant parenting problems during the study, and another infant (Infant 4) was diagnosed with a developmental delay during the study. The results for these infants are reported separately.

**AUDITORY-VERBAL THERAPY**

Auditory-Verbal Therapy (AVT) is an early intervention program consisting of 10 principles (Caleffe-Schenck et al., 1991). The aim is to work with parents to develop the listening, speech and language skills of the deaf or hearing impaired infant. Individual AVT sessions are usually weekly and continue until the child is ready for school. Therapists can achieve certification in AVT which is a three year process, however a therapist does not have to be a Certified Auditory-Verbal Therapist® to practice. It is the practice of AVT in a mentored clinical setting that leads to certification in AVT.

**INFANTS WHO UNDERWENT COCHLEAR IMPLANTATION BEFORE 12 MONTHS OF AGE**

The minimum age for cochlear implantation of 12 months as set by the TGA is a recommendation for surgeons and not a regulation (Drinkwater, 2004). Professor W.P.R. Gibson, clinical director at the Sydney Cochlear Implant Centre and experienced surgeon, conducted the first cochlear implant surgery for an infant under 12 months of age in Australia, the year prior to this study being conducted. He conducted the surgery for all infants in this study.

To date, infants have received cochlear implants prior to 12 months of age if their hearing loss is diagnosed in infancy and a surgeon and his team of audiologists and therapists are experienced in paediatric assessment, implantation and post-operative follow-up. The final decision to implant an infant before 12 months is at the discretion of the surgeon and the team. It is for this reason, there are two infants presented in this thesis who received their cochlear implants prior to 12 months of age.

Biographical Data

Table 2.1 provides a summary of the biographical data for the infants in this study. The table contains details of the infant’s gender, the education level of the parents, pregnancy details,
motor milestone development and cognitive assessment results. These data were collected because some of these factors have been identified in the literature as influencing speech and language skills in children with hearing loss (Geers & Brenner, 2003; Geers, Nicholas et al., 2003). Note however, that cognitive assessment was the only data used when looking at the results. The other factors such as sex, parent education and pregnancy were not considered in this thesis as the subject sample was too small. In addition, the children were not school aged as they were in the studies mentioned above. Motor milestone were not considered as they this development is the specialty of another allied health profession.

Table 2.1: Infants’ biographical data

<table>
<thead>
<tr>
<th>Infant</th>
<th>Sex</th>
<th>Father’s Education</th>
<th>Mother’s Education</th>
<th>Pregnancy</th>
<th>Motor Milestones</th>
<th>Cognitive Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Female</td>
<td>Secondary</td>
<td>Tertiary</td>
<td>Normal</td>
<td>Delayed</td>
<td>Normal</td>
</tr>
<tr>
<td>2</td>
<td>Female</td>
<td>Secondary</td>
<td>Secondary</td>
<td>Normal</td>
<td>Delayed</td>
<td>Normal</td>
</tr>
<tr>
<td>3</td>
<td>Female</td>
<td>Tertiary</td>
<td>Tertiary</td>
<td>High blood pressure</td>
<td>Delayed</td>
<td>Normal</td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>Secondary</td>
<td>Secondary</td>
<td>Normal</td>
<td>Delayed</td>
<td>Delayed</td>
</tr>
<tr>
<td>5</td>
<td>Female</td>
<td>Secondary</td>
<td>Secondary</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>6</td>
<td>Male</td>
<td>Secondary</td>
<td>Secondary</td>
<td>Normal</td>
<td>Normal</td>
<td>Not permitted</td>
</tr>
<tr>
<td>7</td>
<td>Female</td>
<td>Secondary</td>
<td>Secondary</td>
<td>Normal</td>
<td>Delayed</td>
<td>Normal</td>
</tr>
<tr>
<td>8</td>
<td>Female</td>
<td>Secondary</td>
<td>Secondary</td>
<td>Normal</td>
<td>Normal</td>
<td>Not permitted</td>
</tr>
</tbody>
</table>

Within the group of eight infants, six were female and two male. Three parents had tertiary level education with all others having completed some level of secondary school education; that is from Year 9 (10 years of school) to Year 12 (13 years of school). The development of gross motor skills was delayed in five of the eight infants. The gross motor delays may be accounted for in three infants; Infant 1 had LVAS (Large Vestibular Aqueduct Syndrome), Infant 4 had a developmental delay and Infant 7 did not have semi-circular canals. Inner ear malformations (LVAS and absence of semi-circular canals) and developmental delay can impact on motor development. The cause of a gross motor delay in the remaining two infants
(Infants 2 and 3) was not known. One child had a mild developmental delay. The parents of two children did not give permission for cognitive assessment. These two infants exhibited typical development throughout this study, as observed in the clinic by more than one experienced speech pathologist. The remaining five infants had results within the normal range on a test of cognitive development.

Table 2.2 on the following page, summarises information about each infant’s hearing loss and device interventions. The cause of hearing loss for most infants was assumed to be of a genetic origin, based on their family history. That is, five of the infants had siblings with a profound hearing impairment. Another (Infant 3) had confirmed evidence via a blood test that the hearing loss was of genetic origin. Six of the eight infants had their hearing loss diagnosed before 6 months of age. Most infants had hearing aids fitted within 1 month of diagnosis of their hearing loss. Infant 5 had a 4-month delay between diagnosis and hearing aid fitting. Her parents chose to delay hearing aid fitting in order to enjoy the early time with their baby without attending the many appointments that are required between hearing assessment and intervention. Infant 7 had a 5-month delay between diagnosis of hearing loss and hearing aid fitting. This was a result of hospitalisation for surgery, which delayed appointments for hearing aid fitting. The remaining two infants were diagnosed at 7 months of age, and both received their hearing aids immediately.
Table 2.2: Infants’ audiological data

<table>
<thead>
<tr>
<th>Infant</th>
<th>Cause of Hearing Loss</th>
<th>Age at Diagnosis (months)</th>
<th>Age at Hearing Aid Fitting (months)</th>
<th>Age at Entry to Study (months)</th>
<th>Age at CI Surgery (months)</th>
<th>Age at CI Activation (months)</th>
<th>Speech Coding Strategy</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Large vestibular aqueduct</td>
<td>7</td>
<td>7</td>
<td>11</td>
<td>15</td>
<td>15</td>
<td>SPEAK/ACE</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Genetic ●</td>
<td>7</td>
<td>7</td>
<td>11</td>
<td>15</td>
<td>15</td>
<td>SPEAK/ACE</td>
<td>Skin flap infection at site of CI. 12 months after first CI surgery, implant removed and new device put into alternative cochlea. Approx. 1 month without auditory signal.</td>
</tr>
<tr>
<td>3</td>
<td>Genetic ● ●</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>12</td>
<td>12</td>
<td>SPEAK/ACE</td>
<td>Born 7 weeks prematurely. Corrected age used until 2 years of age. Significant parenting problems during the period of the study.</td>
</tr>
<tr>
<td>4</td>
<td>Unknown</td>
<td>3</td>
<td>3</td>
<td>11</td>
<td>13</td>
<td>14</td>
<td>SPEAK/ACE</td>
<td>Developmental delay.</td>
</tr>
<tr>
<td>5</td>
<td>Genetic ●</td>
<td>2</td>
<td>6</td>
<td>8</td>
<td>15</td>
<td>16</td>
<td>SPEAK</td>
<td>At first surgery CI could not be inserted into cochlea due to location of facial nerve. Second surgery was successful in implanting new CI in alternative cochlea.</td>
</tr>
<tr>
<td>6</td>
<td>Genetic ●</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>8</td>
<td>9</td>
<td>ACE</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Mondini abnormality</td>
<td>2</td>
<td>7</td>
<td>12</td>
<td>16</td>
<td>16</td>
<td>ACE</td>
<td>Hirschsprung’s Disease – required bowel surgery before 6 months of age.</td>
</tr>
<tr>
<td>8</td>
<td>Genetic ●</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>8</td>
<td>8</td>
<td>ACE</td>
<td></td>
</tr>
</tbody>
</table>

● Infant had a sibling with profound hearing loss. ⭐ Testing via blood test confirmed genetic cause for hearing loss.
Three infants received cochlear implants at 12 months of age or younger, with the remaining five infants receiving an implant at ages ranging from 13 to 16 months. All infants in the study received the Nucleus® CI24M implant along with a body worn SPRint™ speech processor programmed with the latest available speech coding strategy. At the time of device activation, the first five infants in the study were “switched-on” with the SPEAK speech coding strategy. The three remaining infants who entered the study later were switched-on with the ACE™ strategy, which had superseded the SPEAK strategy by that time. Of the five infants using SPEAK, four were converted to ACE™ within 12-18 months of device activation, with one infant using the SPEAK speech coding strategy for the entire period of the study.

**Use of Chronological Age, “Hearing Age” and “Cochlear Implant Age”**
The data collected were analysed according to the chronological age, the hearing age and the cochlear implant age of the infants.

**Chronological Age**
Chronological age was used to compare the infants’ early communication development with that of typically developing infants. This enabled us to determine if any aspect of an infant’s communication skills was *within the normal range*. This term implies that the infant’s skills are equivalent to those of age-matched peers and commensurate with his or her chronological age. Chronological age was calculated from date of birth for all infants except Infant 3. Her age was calculated from the “due date” or date she was due to be born, as she was delivered 7 weeks prematurely. This is referred to as *corrected age*. This correction was applied until she was 2 years old (as calculated from date of birth), which was at the 12 month post-implant assessment. From this point her age was calculated from her date of birth.

**Hearing Age**
The infants all had a profound hearing loss and were therefore unable to hear sound until fitted with hearing aids. *Hearing age* was therefore calculated from the time the infant began wearing hearing aids. Hearing age adjusted the infant’s age to account for the period when the infant did not have access to sound. After the provision of hearing aids, some of the infants in
were able to hear some sound. The amount of hearing they had with hearing aids was assessed
during the pre-implantation phase of. During this phase the auditory responses of each infant were noted in addition to objective and behavioural audiological assessment. These responses indicated the benefit each infant received from hearing aids and whether a cochlear implant was a suitable option. The results indicated that while all infants responded to some sounds with their hearing aids, most could not hear all speech sounds with hearing aids alone. Some responded to suprasegmental cues of the sound stimulus, such as duration and intonation patterns, but only when presented at intensity levels louder than conversational speech (70-90SPL). A small number of infants responded to some low- and mid-frequency sounds at normal intensity levels, but did not respond to high frequency sounds at 2000Hz and above (see Appendix A for the infants’ aided audiograms). Hearing age therefore did not reflect when the infants had access to a significant amount of information in the speech signal.

**Cochlear Implant Age**
*Cochlear implant age* was calculated from the date of cochlear implant activation. A cochlear implant codes speech data across all frequencies, from low to high intensity sounds, by stimulating the auditory nerve directly. The coded electrical signal can provide more auditory information for most infants, children and adults with a profound hearing loss than the acoustic signal provided by high-powered hearing aids.

Table 2.3 on the following page, shows each child’s chronological age, hearing age and cochlear implant age at each post-operative assessment point. From this it can be determined whether development in a particular aspect of communication was commensurate with age-matched peers or affected by significant changes in auditory stimulation; that is, hearing aid fitting or cochlear implant activation. Hearing age results in an average adjustment relative to chronological age of 4.5 months (range 1-7 months). Cochlear implant age results in an average adjustment relative to chronological age of 13 months (range 8-15 months). That is, the infants had their cochlear implant activated when they were at a chronological age of 8-15 months.
Table 2.3: The infants’ chronological age (CA), hearing age (HA) and cochlear implant age (CIA) at device activation and 3, 6, 12 and 18 months post-implantation

<table>
<thead>
<tr>
<th>Infant</th>
<th>Cochlear Implant Activation</th>
<th>3 Months Post-Cochlear Implantation</th>
<th>6 Months Post-Cochlear Implantation</th>
<th>12 Months Post-Cochlear Implantation</th>
<th>18 Months Post-Cochlear Implantation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CA months</td>
<td>HA months</td>
<td>CIA months</td>
<td>CA months</td>
<td>HA months</td>
</tr>
<tr>
<td>1</td>
<td>15</td>
<td>8</td>
<td>0</td>
<td>19</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>8</td>
<td>0</td>
<td>18</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>10</td>
<td>0</td>
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Assessment Procedures

The areas of early communication evaluated included communicative intention, speech production, and receptive and expressive language skills. These areas were assessed as the infant moved from the prelinguistic to the linguistic stage of development. Each infant was assessed at regular intervals over a 2-year period, beginning 3 months pre-cochlear implantation. The timing of the assessments during this study are summarised in Table 2.4 on the following page. The table shows that assessments were carried out each month during the pre-implant evaluation and up to 6 months post-implantation. Subsequent assessments were carried out at 12 and 18 months post-implantation.

The evaluation protocol contained a range of assessments to target each area of development. The tasks included 1) videotaped parent-child interactions, 2) a parent questionnaire, 3) standardised language assessments, and 4) cognitive assessment. As this was a longitudinal study it was necessary to use a range of different tasks so that we could capture the infants’ development of skills as they progressed from the prelinguistic to the linguistic stage of communication.

All the assessment procedures that were administered, and their timings, are described in the method chapter. Specific analyses of the data for each of the developmental communication areas studied (communicative intention, speech and language) are described in detail in the relevant chapters.
Table 2.4: The assessment protocol for this study. The columns on the left show the assessments used and the shaded areas demonstrate the timing of their administration.

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**Key 1: Assessments tool used**
- CII – Communicative Intention Inventory
- DVA – Developmental Vocal Assessment
- CASALA – Computer Aided Speech and Language Analysis
- SALT – Systematic Analysis of Language Transcripts
- Vineland – Vineland Adaptive Behavior Scales
- Bayley’s – Bayley’s Scale of Infant Development

**Key 2: Assessment administration**
- Grey = Procedure administered
- Blue = Procedure administered if child unable to do Reynell-III tasks
- Yellow = Procedure administered (with parental permission) on one occasion during the study
- White = Procedure not administered
**Videotaped Interactions**

Communicative data were collected using parent-child interactions, videotaped in a clinical setting familiar to the child. This method for collecting information on the communication development of infants is supported by previous research (Coggins, 1998; Coggins & Carpenter, 1981; Coggins, Olswang, & Guthrie, 1987; Kublin, Wetherby, Crais, & Prizant, 1998; Robinshaw, 1996; Robinshaw & Evans, 1996; Yoshinaga-Itano, 1994). Videotaped parent-child interaction can be used with infants at any age (Yoshinaga-Itano & Stredler-Brown, 1992) and is likely to provide a realistic sample of communicative skills. The procedure for the videotaped interactions was based on the work of Coggins and Carpenter (1981), who used interactions between parents and children to analyse children’s communicative intention skills with the Communicative Intention Inventory (CII) (Appendix B).

**PROCEDURE FOR VIDEOTAPED INTERACTIONS**

Coggins and Carpenter (1981) outlined a number of procedures to be followed in collecting the data for use with this assessment tool. The first was that the session should be videotaped and monitored in an adjacent room by someone familiar with the inventory. Consequently, the parent-child interaction was video-taped in a clinical setting at the cochlear implant program. The videotaping procedure used a remote wall-mounted video system with a microphone placed less than 1 metre from the parent and infant.

Another procedure recommended to facilitate the collection of a representative communication sample, was that the room used for the interaction should be free from distracting stimuli, and a variety of activities should be provided. In addition, only the parent and child should be present as this should be more conducive to obtaining a representative communication sample than having an extra person in the room. Therefore, only the parent and infant were in the room. The researcher observed the session via a monitor in a nearby room. The videoed session was scheduled at either the beginning or the end of the child’s routine habilitation session and the children has a period of approximately 5 minutes to settle into the room or relax after their session before the taping began. The timing was determined by the convenience of the parent/infant’s schedule and/or the tiredness of the child. Taping at this time and place meant that parents did not have to make additional visits to the centre for the study and the infants were familiar with the setting.
It was also recommended that the parents should read a written statement (that the authors provided in their article) before the recorded session, designed to a) inform parents why they are being videotaped, b) request parents to follow the child’s lead wherever possible, and c) discourage parents from either sitting back or asking questions as a primary way of initiating interaction. Finally, if examiners wanted to compare their results with the preliminary findings of Coggins and Carpenter the interactions should be approximately 45 minutes in length.

In the present study there were several adaptations to this procedure. Firstly, the parents were not required to read the written statement. Rather they were given a Parent Information Sheet (Appendix C) which documented the purpose of the research. Prior to each interaction parents were asked to play with their child as they would at home, to keep some toys out of reach so the child had to request the desired toy, and to only assist their child with a toy when the child asked for help. This procedure used low structured tasks (in which the parent and child interact as they would at home) and elicitation tasks (in which the child’s communication was prompted by the parent either encouraging labelling or not assisting with a toy). This was based on research by Coggins et al. (1987), who suggested that useful information regarding communicative intentions can be obtained if more than one method of eliciting communicative intentions is used.

The second adaptation related to videoing for a maximum period of 15 minutes rather than 45 minutes per interaction during the pre-cochlear implant phase and for the first 6 months post-implantation. The youngest recipient of a cochlear implant in this study, was 8 months of age, and by 6 months post-implantation was 15 months of age. A 45 minute session is too long for some infants this age, and although some may have been able to cope with a longer procedure the protocol had to be uniform across all infants. Also, the videos were taken at the beginning or the end of a 1 hour habilitation session. A 45 minute interaction in addition to the session would have been taxing for both infants and parents. Therefore, the videoed sessions took approximately 15 minutes (or up to the length of the infant’s attention span. Shorter videoing procedures have been used in studies of communicative intention in infants (Robinshaw, 1996; Tait, Nikolopoulos, Lutman, Wilson, & Wells, 2001).
At the 12- and 18-month assessments, the infants were required to complete the extended play session (up to 45 minutes) as most were now over 2 years of age. This was in addition to the standardised assessments shown in Table 2.4. These extended play sessions involved the parent and child playing with four sets of toys (tea party, farm, transport and nurture) as outlined by Coggins (1987). However, for Infants 6 and 8 who were not yet 2 years of age at their 12-month assessment, the play session was reduced as their developmentally appropriate attention spans were shorter than those of the other infants. These sessions were based on the parent and child interacting with two sets of toys of their choice for 8-10 minutes each.

The third adaptation related to the use of toys. Rather than the four interaction scenes required in the protocol (tea party, farm, transport and nurture), a smaller range of toys was used for the pre-cochlear implantation part of the study to 6 months post-implantation. For the interactions taped in this period to 6 months after cochlear implant activation, a variety of toys suitable for infants and designed to elicit different types of communicative behaviour, such as requesting and commenting, were used (see Appendix D). Some of these toys could not be operated without the assistance of an adult (e.g. a toy in a container with the lid on tight) and other toys could be used by the child independently (e.g. stacking cups, telephone).

**Timing for Videotaped Interactions**

Videotaped interactions were scheduled each month, beginning 3 months pre-implantation and continuing to 6 months after device activation. Two additional sessions were scheduled at 12 and 18 months post-cochlear implantation.

**Analyses of Videotaped Interactions**

The videos of parent-child interactions were analysed for communicative intention, speech production and language development. Full details of the tools used to analyse these areas of development, the rationale for their use, the information obtained and the reliability of the data collection are presented in the following chapters in this thesis: Chapter 3 details communicative intention, Chapter 4 details speech development and Chapter 5 details language development.
Parent Questionnaire
The infant’s language development was also measured using a parent questionnaire, the Vineland Adaptive Behavior Scales (Sparrow, Balla, & Cicchetti, 1984). Parent questionnaires are recommended to be a part of an assessment protocol for infants with hearing loss because the parent’s input into the assessment of their child’s development can provide a more accurate picture of how they communicate in day-to-day situations (Yoshinaga-Itano, 1994). Use of a parent questionnaire also acknowledges the parent as an important source of information (Paul, 1995b). Parent report can be used to gather data on language with children of all ages. Some questions have been raised concerning the reliability and validity of parental reports on receptive language development (Thal, O’Hanlon, Clemmons, & Fralin, 1999; Tomasello & Mervis, 1994; Tomblin, Shonrock, & Hardy, 1989). However, it is argued that the advantages of parental reports outweigh the pitfalls (Dale, Bates, Reznick, & Morriset, 1989).

The Vineland Adaptive Behavior Scales, referred to here as “the Vineland”, consist of a standardised parent questionnaire used to investigate a child’s progress in a range of areas (called domains) including communication (receptive, expressive and written language), socialisation (play and leisure time, interpersonal relationships and coping skills), daily living skills (personal, domestic and community living skills) and motor skills (gross and fine motor). The Vineland provided an opportunity for parents to comment on their child’s development throughout the study. Parents are typically accurate reporters of their child’s abilities (Dale et al., 1989). This method can therefore be an effective means of gaining information concerning an infant’s communication development. In addition, both Coggings, Olswang, and Guthrie (1987) and Kublin, Wetherby, Crais, and Prizant (1998) have argued that standardised evaluation alone within the clinic does not always provide an accurate picture of an infant’s skills.

PROCEDURE FOR VINELAND QUESTIONNAIRE
The Vineland was administered via a parent interview either at the end of a therapy session or by telephone (within the week) if there was no time at the end of the session. The information was provided by the same parent, and all interviews were conducted by the one interviewer. Each interview took between 5 and 20 minutes, the length usually being determined by the
language level of the child. That is, the more language the child used the longer the interview took.

The parent was interviewed using a general questioning format. That is, information regarding the child’s language development was obtained by asking the parent questions that might elicit a number of responses, such as “Tell me about Sally’s speech and language” or “Tell me how Sally communicates with you”. If the parent’s response was too general, the interviewer was able to probe further with more specific questions, such as “When Sally tells you something, how many words might she use in a sentence?” This allowed the parent to provide information without being led by the interviewer or having to check off skills, (which could be distressing if the child had not made progress).

The Communication Domain of the Vineland was the only section administered, as the purpose was to document only the early communication development of the infants. The content of the communication section includes receptive, expressive and written language components, with skill development levels ranging from birth to adolescence. The receptive language component examines skills such as responding to sound, comprehension of words and instructions, and ability to attend. The expressive section, focusing on what a child says, evaluates skills ranging from responding to the caregiver, sound production and talking in words and sentences, to the expression of complex ideas. Finally, the written component examines letter and word recognition, and reading and writing skills. All three parts of the Communication Domain were administered.

**TIMING OF VINELAND QUESTIONNAIRE**
The Vineland was administered on seven occasions throughout the study. These points included three times (1st, 6th and 12th week) during the pre-cochlear implantation evaluation and four times (3, 6, 12 and 18 months) post-cochlear implantation. Except for the sixth week pre-cochlear implantation, the timing for all administrations of the questionnaire coincided with videoed interactions throughout the study in addition to standardised assessments 12 and 18 months post-cochlear implantation. This was done for the purpose of data comparison.
Standardised Language Assessments
Each infant’s progress in language skills was measured over time using standardised language tests. Standardised language assessments are efficient in showing whether a child’s skills are different from typically developing peers (Paul, 1995b). The child’s results are compared to normative data obtained from the population of children on which the assessments were standardised. The aim of teaching a child with a hearing impairment to listen and talk is eventually to have them integrated into mainstream school education (and society) (Calleffe-Schenck et al., 1991). Successful integration, where the child actively participates in class, requires the child with a hearing impairment to have speech and language skills similar to hearing peers. While standardised assessments measure a child’s development against a cohort of peers and indicate areas for intervention, they may not identify the specific language structures that require intervention (Paul, 1995c). Moreover, they do not tell us what the child understands when communicating with other people (Paul, 1995b). Therefore, they should be used in conjunction with other language measures such as functional videotaped assessment and parental report (Yoshinaga-Itano, 1994). A battery of assessment such as this may provide a more holistic picture of the child’s language skills than standardised assessment alone.

PROCEDURE FOR STANDARDISED LANGUAGE ASSESSMENTS
At the assessments 12 and 18 months post-cochlear implantation, a standardised language test was used. The test was either the Reynell Developmental Scales – III (Edwards et al., 1997) or the Preschool Language Scales – 3 (Zimmermen, Steiner, & Pond, 1991), depending on the infant’s language skills. Standard administration of these tests was used. The Reynell Developmental Scales – III was the preferred assessment and was administered to all infants. However, if an infant was unable to complete the initial tasks of this test, the Preschool Language Scales – 3 was used. Of the seven infants available for testing at each point, five were evaluated with the Reynell – III at the 12-month assessment and four at the 18-month assessment.

Reynell Developmental Scales – III (RDS-III)
The RDS-III is designed to evaluate the receptive and expressive language skills of children from the ages of 19 months to 7 years. This test was selected as part of the protocol and as the preferred standardised language assessment for several reasons. Firstly, the tasks follow an
appropriate developmental sequence, and completing them relies entirely on the child’s language skills; that is, there is no assistance of contextual clues to carry out the tasks. As a result the examiner knows whether the skill or concept examined has been consolidated by the child. In addition, the RDS-III uses toys and pictures throughout the evaluation rather than pictures alone, making the process enjoyable for children and therefore increasing the likelihood of their participation in the process. However, the RDS-III, like all language assessments of this type, is standardised on hearing children. The infants in this study had less auditory and language learning experience than this standard population, despite the benefits of early intervention. Consequently, some of the infants did not have the language level required to complete the RDS-III despite falling within the appropriate age range.

**Preschool Language Scale – 3 (PLS-3)**
The PLS-3 assesses receptive and expressive language skills from birth to 6 years of age. It was used to assess the language development of infants who were beyond the prelinguistic stage but unable to manage the initial tasks of the RDS-III. It was selected because, like the RDS-III, its tasks follow an appropriate developmental sequence and the assessment uses toys and pictures, encouraging the child’s participation in the process. However, the weakness of this test is that many of the early tasks are based on parent report. While parent report is a valid method of collecting data (Dale et al., 1989), the Vineland was already providing parental subjective report information about the infant’s development, and one of our goals was to assess language skills directly.

**Timing of Standardised Language Assessments**
The standardised language assessments were administered 12 and 18 months post-cochlear implantation.

**Cognitive Assessment**
Baley’s Scale of Infant Development (Baley, 1995) is a standardised assessment of cognitive and motor development for children aged 1 month to 42 months. It has been used in many studies examining the early speech and language development of children (Coggins et al., 1987; Dale et al., 1989; Rescorla & Bernstein Ratner, 1996; Rescorla & Fechnay, 1996; Stoel-
Gammon, 1985, 1987). Only the cognitive or Mental Scale, examining a variety of non-verbal and verbal skills, was administered. The non-verbal skills evaluated included memory, learning and problem solving, and the verbal skills evaluated included vocalisation, beginning of verbal communication and basis of abstract thinking.

**PROCEDURE FOR COGNITIVE ASSESSMENT**
A qualified psychologist experienced in working with children with hearing impairment administered the Baley’s Scale of Infant Development. The week prior to the assessment the psychologist spent time with the child in a therapy session, so the child was familiar with the examiner. The following week the Baley’s Scale of Infant Development was administered in the standard manner.

**TIMING OF COGNITIVE ASSESSMENT**
The Bayley’s was administered at any time throughout the study providing parent permission had been given. For Infants 1 and 2 this occurred in the pre-cochlear implant phase and for the remaining infants it occurred in the post-cochlear implantation phase. The parents of Infants 6 and 8 did not give permission for cognitive assessment.

**Summary**
The tasks described in this chapter focused on early communication development. They were administered at regular intervals to provide descriptive data about infants who received cochlear implants. The longitudinal data were gathered starting 3 months pre-cochlear implantation and concluding 18 months post-cochlear implantation. During this time the infants progressed from prelinguistic to verbal communication development.
CHAPTER THREE

Study 1: Development of Communicative Intention in Infants with a Profound Hearing Loss: Pre- and Post-Cochlear Implantation
Review of the Literature: Communicative Intention

Introduction

*Communicative intention* refers to an infant’s signalling of intent to communicate with others whether it is vocal, gestural, verbal or a combination of these (Paul, 1995a). Non-verbal (gestural and/or vocal) communicative behaviours are predictors of the emergence of first words (Goldin-Meadow & Morford, 1990; Robinshaw, 1996; Stokes & Bamford, 1990). That is, infants must realise the link between their gestures/vocalisations and the effect on another’s behaviour if they are to acquire these first words and subsequently language (Harding & Glinkoff, 1979).

Typically developing infants begin to develop gestural communicative intention at approximately 8 months of age (Paul, 1995a). Verbal communicative intention emerges between 12 and 18 months of age, and consistent use of words (verbal communicative intention) develops between 18 and 24 months (Chapman, 1981). Gestural/vocal/verbal development is referred to as the form of communicative intention. Other aspects of communicative intention that can be investigated are the types of communicative intention used (such as requesting and commenting) and the frequency of these acts used per minute (Paul, 1995a).

Although the body of research on communicative intention development in infants with hearing loss is small, the results consistently suggest that for infants in early intervention, hearing impairment does not affect the acquisition of nonverbal communicative intention regardless of degree of hearing loss (Caselli, 1990; Robinshaw, 1996; Yoshinaga-Itano & Stredler-Brown, 1992). However, hearing loss can impact on the development of verbal communicative intention (Robinshaw, 1996; Yoshinaga-Itano & Stredler-Brown, 1992) and the frequency of communicative intention (Yoshinaga-Itano & Stredler-Brown, 1992). In the studies by Robinshaw (1996) and Yoshinaga-Itano and Stredler-Brown (1992), all infants wore hearing aids, and findings demonstrated that the greater the hearing loss the greater the impact on verbal communicative intention. Moreover, infants with profound hearing loss either do not develop verbal communicative intention or are late in doing so. Robinshaw reported that the two infants with a profound hearing loss in her study were not able to use
auditory skills independently by the end of the study. This finding demonstrates the difficulty of children with a profound hearing loss in developing verbal communicative intention.

The development of verbal communicative intention and frequency of communicative intention appear to be affected by a profound hearing loss, even when hearing aids are used (Yoshinaga-Itano & Stredler-Brown, 1992). As a cochlear implant usually provides better access to all speech sounds than hearing aids for an infant with a profound hearing loss, this device may facilitate the development of early verbal communicative intention (Tomblin et al., 1999). However, there is little, if any literature on the communicative intention development (including types, forms and frequency) of infants with profound hearing losses whose hearing losses are identified early and who receive a cochlear implant (Yoshinaga-Itano & Stredler-Brown, 1992).

**Typical Communicative Intention Development**

Infants learn to communicate with others long before they use words (Lock, Young, Service, & Chandler, 1990). Initially they use gestures such as eye gazing, pointing, and crying (Paul, 1995a). As the skills develop, infants add vocalisations and babble to these gestures, which in turn lead to the use of words (Caselli, 1990; Masur, 1990; Paul, 1995c). Several aspects of communicative intention development have been reported in the literature (Caselli, 1990; Coggins & Carpenter, 1981; Harding & Glinkoff, 1979; Lock et al., 1990; Lutman & Tait, 1995; Tait & Lutman, 1997; Yoshinaga-Itano & Stredler-Brown, 1992). These aspects are the type of communicative intentions used, the form of these behaviours, and their frequency of use.

**Types of Communicative Intention**

Types of communicative intention refer to behaviours such as requesting objects or actions, commenting and protesting (Coggins & Carpenter, 1981; Wetherby, Cain, Yonclas, & Walker, 1988). These are early developing types of communicative intention that emerge between the ages of 8 and 18 months (Paul, 1995c). Specifically, requesting (objects and actions) appears from 10-23 months, commenting from 9-14 months, and protesting from 8-
18 months (Coggins, 1987). Later emerging communicative intention types are requesting information, answering, and acknowledging. These more advanced types are acquired around 18-24 months of age (Paul, 1995c): requesting information appears at 19-27 months, answering from 15-25 months and acknowledging from 15-27 months (Coggins, 1987). Requesting information, answering and acknowledging are considered later developing because they require the child to have some knowledge of the rules of conversation if the communicative intentions are to be used correctly (Paul, 1995c). Paul suggests that it is important to determine whether the child is using the full range of both early and later developing communicative intention types, as a small range may be indicative of future problems in communication development.

**Forms of Communicative Intention**

Along with the range of intention types, the form (i.e. gestural/vocal and verbal) the communicative intention takes should be investigated (Paul, 1995a). An infant’s message is often conveyed by gesture alone at 8-12 months of age (Chapman, 1981). Between 12 and 18 months infants use gestures with vocalisations (or protowords, vocalisations that sound like words but are not true words) and with words from 18-24 months (Chapman, 1981). These developmental stages of infants’ early or prelinguistic expressive communication can be monitored to determine their level of communicative intention development and whether their verbal communication is emerging at an age-appropriate level (Paul, 1995a).

**Frequency of Communicative Intention**

The third aspect of communicative intention development is the frequency with which an infant uses these behaviours during an interaction (Paul, 1995a). An infant who uses communicative intentions infrequently evidences an expressive communication problem (Paul, 1995c). To determine whether the rate of behaviour is appropriate, all forms should be included in the analysis; that is, both gestural/vocal and verbal forms (Coggins, 1987). Research shows that children aged 18 months use two communicative intentions per minute, and the rate increases to five per minute at 24 months (Paul & Shiffer, 1991; Wetherby et al., 1988).
The Relationship between Auditory Development and Communicative Intention Development

Gestural (nonverbal) communicative intention emerges in infants with a hearing impairment at similar ages to that in typically developing infants (Robinshaw, 1996; Yoshinaga-Itano & Stredler-Brown, 1992). Therefore, it seems the development of nonverbal types of communicative intention does not require infants to use auditory skills or speech perception development (Yoshinaga-Itano & Stredler-Brown, 1992). If auditory stimulation is not required, then development of the auditory pathway and speech perception skills is not crucial to the acquisition of nonverbal communicative intentions.

It does appear however, that auditory stimulation and speech perception development is required for the development of verbal communicative intention (or language) (Robinshaw, 1996; Sininger et al., 1999; Tsao et al., 2004; Yoshinaga-Itano & Sedey, 2000). In typically developing infants, the first 12 months of life speech perception skills are developed to a point where first verbal communication begins (Kuhl, 2004). By 12 months gestural communicative intention accompanied by a vocalisations are typically emerging (Chapman, 1981). At this age protowords and some single words are being produced by the infant (Paul, 1995c). Single word production is not usually consistent until 18-24 months of age, when an infant uses more verbal (words) than nonverbal (gestural) communicative intention (Chapman, 1981). Auditory stimulation is required for the development of speech perception, speech and verbal language skills (Sininger et al., 1999; Tsao et al., 2004; Yoshinaga-Itano & Sedey, 2000). Therefore, auditory stimulation will be essential for the development of verbal communicative intention.

The Effect of Profound Hearing Loss on Communicative Intention Development

There is limited research reporting the development of communicative intention in children with profound hearing loss (Robinshaw, 1996; Yoshinaga-Itano & Stredler-Brown, 1992). Although the age at identification of hearing loss and early intervention has changed significantly with the introduction of neonatal screening (Health, 2004; Yoshinaga-Itano, 2003), the procedure for hearing screening is relatively new and there are few reports on the communicative intention development and long term speech and oral language outcomes of this population. However, some prelinguistic research in the area of communicative intention has been conducted with infants who have a hearing impairment (Lutman & Tait, 1995;
As described in the previous section, in general children with any degree of hearing loss achieve nonverbal or gestural communicative intention at the same age as typically developing children. However, delays in communicative intention development of children with hearing loss are reported in the literature (Robinshaw, 1996; Yoshinaga-Itano & Stredler-Brown, 1992). Robinshaw conducted a longitudinal study with five infants with either a severe, severe-profound or profound hearing loss, who received hearing aids before 6 months of age. These infants’ gestural and vocal development and change to symbolic language was compared with infants with typical hearing. The groups were matched for age, social environment and cultural background. Robinshaw found that severe-profoundly hearing impaired infants followed a typical pattern of communicative and linguistic development if the hearing impairment was identified in the first 6 months of life and appropriate intervention was undertaken. However, this pattern may be delayed, particularly if the child had a profound hearing loss. It was verbal communicative intention development that was particularly affected, as the children with a profound hearing loss were unable to develop auditory independence by the end of the study. Participant numbers in that study were limited: one infant with a severe hearing loss, two with a severe-profound hearing loss, and two with a profound hearing loss. Therefore, only tentative conclusions can be drawn from it.

Yoshinaga-Itano and Stredler-Brown (1992) also reported that infants with a significant hearing impairment can achieve the gestural/vocal stage of communicative intention in accordance with their hearing peers. In a study of 82 infants with hearing loss, they found that deaf infants and toddlers had similar development of nonverbal communicative intention to infants with typical hearing. However, verbal communicative intention was delayed, particularly in children with a profound hearing loss. Moreover, the frequency of communicative intention decreased with a greater hearing loss. There were some limitations to this study. The participant sample was divided into two groups: hard of hearing (hearing loss of up to 69dB) and deaf (hearing loss greater than 70dB). There would be enormous variability in skills of the children in the “deaf” group due to the range of degree of hearing loss. Since children with a severe hearing loss have greater residual hearing than children with a profound hearing loss, it would have been of interest to separate the deaf group into
subgroups of severe and profound hearing loss. Another limitation was that the study was cross-sectional rather than longitudinal. A longitudinal study may have provided greater detail on the long-term acquisition of communicative intention.

It seems that infants who are not exposed to early auditory stimulation before 12 months of age are at risk of delayed verbal communicative intention (Sininger et al., 1999). However, infants with a profound hearing loss will typically have limited access to all or most speech sounds (Flexor, 1999). Therefore, it appears that auditory stimulation in early intervention is unlikely to be as effective for infants with profound hearing loss that for infants with lesser degrees of hearing loss (Calderon & Naidu, 2000; Robinshaw, 1996; Stoel-Gammon & Otomo, 1986; Yoshinaga-Itano & Sedey, 2000; Yoshinaga-Itano & Stredler-Brown, 1992). Consequently, infants with a profound hearing loss are at risk of having limited or delayed verbal communicative intention development, regardless of how early intervention begins (Robinshaw, 1996; Yoshinaga-Itano & Stredler-Brown, 1992).

Research on Cochlear Implantation and Communicative Intention Development

The findings of the detailed study of communicative intention by Yoshinaga-Itano and Stredler-Brown (1992), of infants using hearing aids, showed the areas of verbal communication development and frequency of communicative intention to be delayed. As discussed in the previous section, it is thought that this may be a result of the infants with profound hearing loss having limited access to sound. Therefore it may be hypothesised that these two aspects of communicative intention development could be improved if the infants received a cochlear implant. While there are some data on prelinguistic communication of infants with a profound hearing loss using cochlear implants, the data are not as extensive as that provided by Yoshinaga-Itano and Stredler-Brown (1992) (Lutman & Tait, 1995; Tait & Lutman, 1997).

One recent study of the outcomes of infants receiving cochlear implants may provide some insight into whether early cochlear implantation could positively impact on the development of verbal communicative intention. Schauwers et al. (2004) investigated the onset of babbling in 10 infants who received a cochlear implant. All infants started babbling after 1-4 months of cochlear implant use. The four youngest infants, who received cochlear implants at 5, 6 and 8
months of age began babbling from 8 and 11 months of age, which is the age at onset for babble in typically developing infants. The development of canonical babble is a result of auditory stimulation (Oller & Eilers, 1988; Oller et al., 1985; Stoel-Gammon, 1998) and the development of speech perception skills (Kuhl, 2004). Canonical babble impacts on the development of early words and early verbal language development (Davis & MacNeilage, 1995; MacWinney, 1998; Wallace et al., 2000). If infants with a profound hearing loss using hearing aids struggle to develop canonical babble (Oller & Eilers, 1988; Stoel-Gammon & Otomo, 1986), maybe cochlear implantation, which provides access to the speech signal, will facilitate canonical babble and in turn verbal communicative intention.

**Purpose of this Study**

There is little comprehensive information available on the communicative intention outcomes of infants with a profound hearing loss who receive early auditory and oral intervention. The purpose of this study was to answer the following questions:

1. Does early auditory intervention result in sequential and age appropriate communicative intention (types, forms and rate) development for infants with a profound hearing loss?
2. What is the impact of early cochlear implantation on the sequential development and achieving age appropriate communicative intention (types, forms and rate) for infants with a profound hearing loss?
Method

Videotaped Interactions
Communicative intention data were collected using parent-child interactions, videotaped in a setting familiar to the child. The method for collecting data has been described in chapter 2.

ANALYSIS OF COMMUNICATIVE INTENTION
The CII is a system designed to code communicative behaviours in young children and was used to analyse the infants’ communicative intention development. It is intended to be a criterion-referenced measure of a child’s intention to communicate and has been normed on hearing children aged 9-24 months. It has also been deemed an appropriate tool to use with hearing and hearing impaired infants and young children (Paul, 1995c; Yoshinaga-Itano & Stredler-Brown, 1992).

The CII codes intentional communicative behaviours into “commenting” (comment on action, comment on object), “requesting” (request for action, request for object), “protesting/rejecting”, “requesting information”, “answering” and “acknowledging”, with the latter three being the more advanced types of communicative intention. Refer to Table 3.1 on the following page for full definitions and examples of these types of behaviours. Within these types of intentions, behaviours are coded as gestural/gestural-vocal or verbal. Gestural/gestural-vocal indicates that the infant showed an intentional behaviour either via gesture alone or gesture while producing a sound. A behaviour coded as verbal indicates that the child communicated using either word(s) or word(s) with a gesture.
### Table 3.1: Definitions for coding types of communicative intention as described by Coggins and Carpenter (1981).

<table>
<thead>
<tr>
<th>Communicative Intention Behaviour</th>
<th>Description of Behaviour</th>
<th>Example of Behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EARLY DEVELOPING TYPES OF COMMUNICATIVE INTENTION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Commenting</strong></td>
<td>The child’s intentional behaviour draws the parent’s attention to an object or the movement of an object.</td>
<td>The child points to a wind-up toy moving across the floor while interacting with the parent.</td>
</tr>
<tr>
<td><strong>Requesting</strong></td>
<td>The child directs the parent to act upon an object.</td>
<td>The child either gestures/vocalises or verbalises at a toy so that the parent either gets the toy or makes it move again because it has stopped.</td>
</tr>
<tr>
<td><strong>Protesting/Rejecting</strong></td>
<td>The child shows disapproval of a parent’s action.</td>
<td>The child pushes the parent’s hand away as the parent moves to grab the child’s toy.</td>
</tr>
<tr>
<td><strong>LATER DEVELOPING TYPES OF COMMUNICATIVE INTENTION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Request for Information</strong></td>
<td>The child is able to make the parent provide information about the object or action.</td>
<td>The child loses a toy he/she was playing with and gestures “where” to get the parent to tell them the location of the toy.</td>
</tr>
<tr>
<td><strong>Answering</strong></td>
<td>The child responds to the parent’s request for information.</td>
<td>The parent asks “Do you want a drink?” and the child nods or says “yes” in reply.</td>
</tr>
<tr>
<td><strong>Acknowledging</strong></td>
<td>The child lets the parent know that the previous gesture or utterance was received.</td>
<td>The parent says “I can see your shoes” and the child responds by pointing to his/her shoe and saying “shoe”.</td>
</tr>
</tbody>
</table>

The CII form was completed by the researcher and an independent speech pathologist while watching the videotaped interactions together. For the communicative intentions observed and agreed upon by both examiners, a mark was placed in the box corresponding with the behaviour described on the form. With each individual repetition of a communicative intention, an additional mark was placed in the box. The additional mark was placed in the box only if the behaviour was a completely separate communicative intention. If a child...
continually commented on a toy by pointing over and over, this behaviour would be coded only once.

For a communicative intention to be coded the child must have been observed to have joint attention with the parent in the activity. Joint attention was determined if one or more of the following existed: parent and child were close together during the activity; parent and child had been close together during the activity; the parent and child had recent gestural/vocal or verbal contact with each other; the child had gazed toward the parent within 3 seconds of an intentional behaviour. In addition to joint attention, the child must have used a type of communicative intention that could be scored on the form (Coggins & Carpenter, 1981).

The data were analysed for types of communicative intention, forms (vocal/gestural versus verbal), and the number of communicative intentions demonstrated per minute defined as frequency of communicative intentions. The types were examined to determine which ones were used and the age at which they emerged for each infant. Documentation of the form of intention revealed when the child moved into the verbal stage of communication and the age at which verbal intent superseded gestural behaviours.

**Coding of Communicative Intention Types**
The types of communicative intention observed were divided into early developing behaviours (commenting, requesting, and protesting/rejecting) and later developing behaviours (request for information, answering and acknowledging).

**Coding of Communicative Intention Forms**
The communicative intention types were sub-divided into either gestural/vocal or verbal behaviour. This is referred to as the form of communicative intention. If a child’s behaviour consisted of pointing at a desired toy car, it would be coded as gestural/vocal. Likewise if the child pointed and said /ʊ/, it would be coded under the same form, that is gestural/vocal. However, if the child pointed at the car and said a word or a consistent word approximation such as /kal/, /ta/ or /a/, the behaviour would be coded under the verbal form.
Calculating Frequency of Communicative Intention
Frequency of communicative intention was calculated to determine whether the infants were communicating at a rate similar to their typically hearing peers. Frequency of communicative intention (communicative intentions per minute) was calculated by dividing the number of intentions during the interaction by the length in time of the video. This calculation was performed at each videotaped interaction for each infant.

Reliability of Analysis
Consensus agreement between the raters was used for scoring all videotapes. The researcher and an independent speech pathologist analysed the infants’ communicative intentions. If a communicative intention was agreed upon during the initial viewing of the behaviour it was rated and credited to the child. However, if there was disagreement, the communicative intention was reviewed and if consensus was not reached on the second viewing it was discarded. To ensure high reliability, training tapes were used until the raters reached 90% agreement. Reliability of procedures for communicative intention has been established (Coggins & Carpenter, 1981).

Results
Results are presented according to types of communicative intention, forms of communicative intention and frequency of communicative intention. Within each of these communicative intention categories the data are presented for pre- versus post-cochlear implant periods. In addition, outcomes are analysed in comparison to the infants’ chronological age, hearing age and cochlear implant age.

Types of Communicative Intention
Table 3.2 on the following page shows the chronological ages at which the types of communicative intention were first observed in the infants and whether they emerged in the pre-implantation phase or after implant activation. Early developing types of communicative intention were observed before the emergence of later developing communicative intention types in all infants. All three of the early developing types of communicative intention were
demonstrated by all except Infant 1. Half of the infants (Infants 1, 5, 6 and 8) developed all three types of later developing communicative intention by the end of the study.

Table 3.2: The infants’ chronological age in months at the time each type of communicative intention was first observed during an assessment. The shaded area indicates that the behaviour emerged pre-cochlear implantation. The white area indicates that the behaviour emerged post-cochlear implantation.

<table>
<thead>
<tr>
<th>Infant</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Request action or object</td>
<td>11</td>
<td>13</td>
<td>8</td>
<td>13</td>
<td>17</td>
<td>12</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Comment on action or object</td>
<td>11</td>
<td>12</td>
<td>11</td>
<td>18</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Protesting or rejection</td>
<td>11</td>
<td>8</td>
<td>11</td>
<td>17</td>
<td>12</td>
<td>17</td>
<td>13</td>
<td>13</td>
</tr>
</tbody>
</table>

| Requesting information | 16 | 21 | 21 | 28 | 22 |
| Answering | 18 | 14 | 26 | 18 | 13 | 22 | 22 |
| Acknowledging | 11 | 13 | 11 | 33 | 19 | 12 | 13 |

 Behaviour first observed pre-cochlear implantation
 Behaviour first observed post-cochlear implantation

**Types of Communicative Intention: Pre-Cochlear Implantation**

*Early Developing Types of Communicative Intention:* Table 3.2 shows that six (Infants 1, 2, 3, 4, 5 and 7) of the eight infants developed at least one type of communicative intention prior to cochlear implantation. Of these six infants, Infants 2 and 3 developed all three early developing types of communicative intention pre-cochlear implantation. The two infants (6 and 8) who did not demonstrate communicative intention during the pre-cochlear implant phase were chronologically too young to have developed this skill.
Later Developing Types of Communicative Intention: Three infants (Infants 1, 2, and 3) demonstrated one later developing or more advanced type of communicative intention prior to cochlear implantation. They were all observed to use the same type of communicative intention, acknowledging.

**TYPES OF COMMUNICATIVE INTENTION: POST-COCHLEAR IMPLANTATION**

Early Developing Types of Communicative Intention: The full range of early developing communicative intention types (requesting, commenting and protesting) were observed to have emerged at some point during the post-implant phase for five (Infants 4, 5, 6, 7, and 8) of the eight infants. This included Infants 6 and 8 who did not demonstrate communicative intention prior to cochlear implantation. (Infants 2 and 3 had developed the full range of early developing types of communicative intention pre-cochlear implantation.) Infant 1, who demonstrated only two of the three early developing communicative intentions, was not observed to protest during any interaction throughout the study.

Later Developing Types of Communicative Intention: The later developing communicative intention types (requests for information, answering, acknowledging), were first observed in five (Infants 4, 5, 6, 7 and 8) of the eight infants during the post-implantation phase. The full range of later developing types of communicative intention was acquired by four of the infants (1, 5, 6, and 8) over the course of the study. Another three infants (3, 4 and 7) acquired two of the three more advanced intentional behaviours. Infant 2 developed only one of the behaviours and, as can be seen in Table 3.2, this communicative intention type was acquired in the pre-implantation phase. She did not develop any new types of intention in the post-cochlear implantation phase of the study.
TYPES OF COMMUNICATIVE INTENTION: RESULTS IN COMPARISON TO CHRONOLOGICAL AGE, HEARING AGE AND COCHLEAR IMPLANT AGE

The infants’ results were compared to the normal development data provided by Coggins et al. (1987) and Paul (1995c). Figure 3-A on the following page, shows the chronological ages at which the types of communicative intention emerged for each infant, compared with the criterion-referenced data of young children with typical hearing (Coggins, 1987). When the development of communicative intention types of the infants in this study was compared with the data on typically developing hearing infants from Paul (1995c) and Coggins (1987), similar results were obtained. In Figure 3-A, if the grey box is to the left or along the corresponding oblong, the communicative intention type was developing commensurately with the infant’s chronological age. If the grey box is to the right of the striped oblong, the communicative intention type was delayed relative to chronological age.

Types of Communicative Intention: Chronological Age

Early Developing Types of Communicative Intention: The early developing types of communicative intention demonstrated by the infants were found to be appropriate to their chronological age for seven of the eight infants. That is, they were comparable to hearing peers and therefore within the normal range. Infant 4 was the only infant to show a delay in this stage of communicative intention, and that was for only one of the three early types of communicative intention; commenting on object.

Later Developing Types of Communicative Intention: Figure 3-A shows that the later developing types of communicative intention demonstrated by the infants were found to be appropriate to chronological age for six (Infants 1, 2, 3, 5, 6, and 8) of the eight infants. Infant 4 showed a delay in all later developing communicative intentions (answering and acknowledging; did not demonstrate request for information) and Infant 7 in one of two later developing communicative intention, requesting information.
Figure 3-A: The age in months at which the infants’ communicative intention types emerged (represented by the grey box), compared with the range of typical development (represented by the striped oblong).
Figure 3-A: The age in months at which the infants’ communicative intention types emerged (represented by the grey box), compared with the range of typical development (represented by the striped oblong).
Types of Communicative Intention: Hearing Age
Comparison with hearing age was made only for those infants whose types of communicative intention did not develop commensurately with their chronological age. Comparison with hearing age will indicate if the types of communicative intention they display are consistent with their age corrected for the period of auditory deprivation prior to hearing aid fitting.

Early Developing Types of Communicative Intention: Infant 4 was the only infant to demonstrate a delay in early developing communicative intention types relative to his chronological age. The intentional behaviour of commenting was first observed in this infant at 19 months of age, 16 months after hearing aid fitting. According to Coggins (1987), commenting is typically acquired between 9-14 months. Infant 4 acquired commenting at a hearing age of 16 months indicating delayed development. However, when comparing this result with the data from Paul (1995), who found that these behaviours developed from 8 to 18 months, it could be concluded that the emergence of Infant 4’s commenting was commensurate with his hearing age.

Later Developing Types of Communicative Intention: Infant 4 acquired answering 24 months after hearing aid fitting; Infant 7 acquired requesting information 22 months after hearing aid fitting. This indicated that the development of these later developing types of communicative intention was commensurate with their hearing age. However, the development of acknowledging in Infant 4, which emerged at 31 months of age, was delayed relative to hearing age.

Types of Communicative Intention: Cochlear Implant Age
Comparison with cochlear implant age was made only for the infant whose communicative intention type was delayed relative to chronological age or hearing age. The later developing communicative intention type of acknowledging was first observed 18 months after device activation for Infant 4. His development of this communicative intention type was commensurate with his cochlear implant age.
Forms of Communicative Intention
Table 3.3 shows the chronological ages at which each form of communicative intention, either gestural/vocal or verbal, were first observed in the infants over the course of the study. The data show that all but one infant (Infant 3) demonstrated a greater number of verbal intentions than gestural/vocal intentions during the study.

Table 3.3: Chronological age (in months) at emergence of gestural/vocal and verbal forms of communicative intention; and the age (in months) at which the infants were observed to use more verbal than gestural/vocal forms of communicative intention, that is, the age at which the infants became verbal.

<table>
<thead>
<tr>
<th>Infant</th>
<th>Age in Months</th>
<th>Gestural / Vocal</th>
<th>Verbal</th>
<th>Verbal &gt; Gestural / Vocal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant 1</td>
<td>11</td>
<td>18</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Infant 2</td>
<td>11</td>
<td>19</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Infant 3</td>
<td>8</td>
<td>16</td>
<td>Did not achieve</td>
<td></td>
</tr>
<tr>
<td>Infant 4</td>
<td>12</td>
<td>19</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Infant 5</td>
<td>11</td>
<td>18</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Infant 6</td>
<td>12</td>
<td>13</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Infant 7</td>
<td>13</td>
<td>18</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Infant 8</td>
<td>13</td>
<td>13</td>
<td>22</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3-B on the following page, presents the data on forms of communicative intention demonstrated by each infant over the 18 months of the study. The figure presents the percentage contribution of each form of communicative intent (either gestural/vocal or verbal) to the total number of forms of communicative intent for each infant.
Figure 3-B: Percentage of gestural/vocal versus verbal forms communicative intention for each infant at each pre- and post-implantation data point.
Figure 3-B: Percentage of gestural/vocal versus verbal forms communicative intention for each infant at each pre- and post-implantation data point.
Figure 3-B: Percentage of gestural/vocal versus verbal forms communicative intention for each infant at each pre- and post-implantation data point
FORMS OF COMMUNICATIVE INTENTION: PRE-COCHLEAR IMPLANTATION
Figure 3-B shows that gestural/vocal forms of communicative intention emerged pre-cochlear implantation for six (Infants 1, 2, 3, 4, 5 and 7) of the eight infants. The ages at which the infants’ gestural/vocal communicative intention emerged ranged from 8 to 13 months of age (see Table 3.3). None of the infants demonstrated verbal communicative intentions prior to cochlear implantation (see Figure 3-C). The age of the infants prior to cochlear implantation ranged from 5-15 months.

FORMS OF COMMUNICATIVE INTENTION: POST-COCHLEAR IMPLANTATION
Post-cochlear implantation all infants showed an increasing percentage of verbal forms of communicative intent although they continue to use gestural/vocal intentions. Most infants decrease their use of gestural/vocal communicative intention as verbal communicative intention increase. Infants 6 and 8 demonstrated only gestural/vocal forms of communicative intention, at the 5 and 6 months post-implantation respectively (see Figure 3-B), despite using verbal communicative intention prior to this indicating that development is not always linear. This corresponded to a chronological age of 12 months for Infant 6 and 13 months for Infant 8.

Verbal communicative intention appeared between 2 to 6 months post-cochlear implantation (see Figure 3-B). The infants ranged from 13 to 19 months of age at the onset of verbal development. At the completion of the study, seven of the eight infants reached the point where the number of verbal intentions exceeded their vocal/gestural communicative intention; that is they were using verbal language as their main means of communicating with others. The infants used predominantly verbal communicative intention from the ages of 13 to 34 months. Three infants (6, 7 and 8) reached this point before 2 years of age, two infants (1 and 4) before 2.5 years, and another two infants (2 and 5) before 3 years of age (see Table 3.3). Infant 3 did not reach the level of predominantly verbal communication during the study.
FORMS OF COMMUNICATIVE INTENTION: RESULTS IN COMPARISON TO CHRONOLOGICAL AGE, HEARING AGE AND COCHLEAR IMPLANT AGE

Forms of Communicative Intention: Chronological Age
Gestural/vocal development emerged for the eight infants from 8 to 13 months of age. Verbal development emerged from 13 and 19 months of age. The development of the infants’ gestural/vocal and verbal forms of communicative intention was within the normal range when compared with age-matched peers according to the norms published by Chapman (1981). As both forms of communicative intention (gestural/vocal and verbal) were within the normal range for their chronological age, no further comparisons were made with hearing age or cochlear implant age.

Frequency of Communicative Intention
Figure 3-C on the following pages, shows the rate of vocal/gestural versus verbal communicative intentions per minute at each assessment point throughout the study. The green line represents the frequency of gestural or gestural vocal forms per minute; the pink line represents verbal communicative intention forms per minute; and the blue line represents the combined total of all forms of communicative intention (gestural/vocal and verbal) per minute.

FREQUENCY OF COMMUNICATIVE INTENTION: PRE-COCHLEAR IMPLANTATION
Prior to cochlear implantation the frequency of communicative intentions per minute ranged from 0.0-0.3 per minute for 7 of the 8 infants. Infant 1 demonstrated the highest rate of communicative intention, producing an average of 1.1 communicative intentions per minute.

FREQUENCY OF COMMUNICATIVE INTENTION: POST-COCHLEAR IMPLANTATION
All infants increased their communicative intention rate in the post-implant phase and the mean rate increased from 0.99 at 18 months of age to 1.65 at 24 months of age. Infant 6 had the highest rate of communicative intention, demonstrating an average of 3.0 per minute at 24 months of age. Infant 7 showed the greatest increase in communicative intention rate moving from 0.1 per minute at 18 months to 1.1 per minute at 24 months. These calculations included both gestural/vocal and verbal intentions combined.
Figure 3-C: Frequency of communicative intention per minute at each pre- and post-implantation assessment.
Figure 3-C: Frequency of communicative intention per minute at each pre- and post-implantation assessment.
**Frequency of Communicative Intention: Results in Comparison to Chronological Age, Hearing Age and Cochlear Implant Age**

Table 3.4 summarises the number of communicative intentions per minute demonstrated by the infants at the point in the study at which they were 18 and 24 months of age. While the frequency of the infants’ communicative intention in interactions increased from 18 to 24 months of age, there was variability among the infants.

Table 3.4: The number of communicative intentions produced by the infants, per minute, at 18 and 24 months of age. All infants were in the post-implant phase of the study at these ages.

<table>
<thead>
<tr>
<th></th>
<th>Typical rate per minute</th>
<th>Infant 1</th>
<th>Infant 2</th>
<th>Infant 3</th>
<th>Infant 4</th>
<th>Infant 5</th>
<th>Infant 6</th>
<th>Infant 7</th>
<th>Infant 8</th>
<th>Mean rate per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 months of age</td>
<td>2</td>
<td>1.4</td>
<td>0.9</td>
<td>0.7</td>
<td>0.6</td>
<td>1.8</td>
<td>1.6</td>
<td>0.1</td>
<td>0.8</td>
<td>0.99</td>
</tr>
<tr>
<td>24 months of age</td>
<td>5</td>
<td>1.8</td>
<td>2.5</td>
<td>1.0</td>
<td>0.8</td>
<td>2.1</td>
<td>3.0</td>
<td>1.1</td>
<td>0.9</td>
<td>1.65</td>
</tr>
</tbody>
</table>

**Frequency of Communicative Intention: Chronological Age**

Frequency of communicative intention was compared to typical development at 18 and 24 months of age, so that comparison could be made with published findings. At 18 months of age, none of the infants showed a frequency of communicative intention commensurate with their chronological age (see Table 3.4). At 24 months of age, the infants continued to be delayed in the frequency of communicative intention with respect to their chronological age. At this age the infants demonstrated on average 1.7 communicative intentions per minute (range 0.8-3.0), which was considerably lower than that shown by typically developing infants (5 per minute).

**Frequency of Communicative Intention: Hearing Age**

Table 3.5, shows the frequency of communicative intentions per minute adjusted for hearing age and cochlear implant age. Four (Infants 2, 5, 6 and 7) of the eight infants had a communicative intention rate commensurate with their hearing age of 18 months. For the remaining infants (1, 2, 4 and 8) the frequency of communicative intention was delayed relative to hearing age. The frequency of communicative intention for all infants was delayed.
relative to their hearing age of 24 months. (Infant 8 did not reach a hearing age of 24 months during the study.)

**Frequency of Communicative Intention: Cochlear Implant Age**

The final assessment for each infant was conducted 18 months after device activation; therefore this was the only result for rate of communicative intention compared to cochlear implant age. Infant 1 demonstrated a frequency of communicative intention commensurate with a cochlear implant age of 18 months. For Infants 2, 3, 4 and 7, frequency of communicative intention was delayed with respect to their cochlear implant age.

Table 3.5: The number of communicative intentions produced by the infants, per minute, at 18 and 24 months hearing age (18 and 24 months after hearing aid fitting) and 18 months post-cochlear implantation (18 months since cochlear implant activation).

<table>
<thead>
<tr>
<th></th>
<th>Expected Rate</th>
<th>Infant 1</th>
<th>Infant 2</th>
<th>Infant 3</th>
<th>Infant 4</th>
<th>Infant 5</th>
<th>Infant 6</th>
<th>Infant 7</th>
<th>Infant 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 months hearing age</td>
<td>2</td>
<td>1.7</td>
<td>2.5</td>
<td>0.7</td>
<td>0.8</td>
<td>2.1</td>
<td>3.0</td>
<td>2.0</td>
<td>0.9</td>
</tr>
<tr>
<td>24 months hearing age</td>
<td>5</td>
<td>3.6</td>
<td>0.6</td>
<td>0.8</td>
<td>0.8</td>
<td>1.8</td>
<td>2.1</td>
<td>1.1</td>
<td>N/A</td>
</tr>
<tr>
<td>18 months cochlear implant age</td>
<td>2</td>
<td>3.6</td>
<td>0.6</td>
<td>0.8</td>
<td>1.9</td>
<td>2.0</td>
<td>2.1</td>
<td>0.7</td>
<td>N/A</td>
</tr>
</tbody>
</table>

- **N/A:** Rate of communicative intention appropriate for that age (either hearing age or cochlear implant age)
- **N/A:** Not applicable (child not old enough or not available for that assessment)

**Summary of Results**

The infants used both nonverbal and verbal forms of communicative intention at ages commensurate with hearing aged matches. The types of communicative intention emerged in a typical developmental sequence at appropriate ages for most infants. However, the frequency of communicative intention was delayed.
Discussion
The results of the infants’ communicative intention development were analysed in terms of types, forms and frequency to determine if the infants were performing at a level consistent with their chronological age, hearing age (time from hearing aid fitting) or cochlear implant age (time from cochlear implant activation). The infants all demonstrated both early and later-developing types of gestural/vocal and verbal communicative intention. The infants used appropriate nonverbal and gestural/vocal communicative intention during the pre-implant period when they were using hearing aids but they were too young at this point of the study (8 to 16 months) to use verbal communicative intention. Verbal communicative intention emerged between 2 and 5 months after cochlear implant activation. At this point the infants were aged 13-19 months, resulting in age-appropriate verbal communicative intention. However, while type and form of communication intention followed typical development, the infants’ frequency of communicative intention was delayed.

Types of Communicative Intention
The infants in the study developed the types of communicative intention behaviours in the same sequential order as reported for typically developing children (Coggins, 1987). Moreover, these infants, despite their profound hearing loss, also developed these types of communication intention behaviours within the age range reported for typically developing children (Coggins, 1987; Paul, 1995a). The full range of early developing types of communicative intention (commenting, requesting, and protesting) emerged across all infants with the exception of Infant 1 (no protesting) from 11 and 18 months of age. The first infants to use all early types of communicative intention (Infants 2, 3, 6 and 8) did so before or at the age of 13 months. Of these four infants, three (Infants 3, 6 and 8) were identified and aided before six months of age and were the youngest recipients of cochlear implants in the study (12 months of age or younger). That is, they had experienced a shorter period of auditory deprivation.

The later developing stage of communicative intention proved more difficult to acquire for all infants in the study. Four of the eight infants (Infants 1, 5, 6 and 8) developed all three of the later developing types of communicative intention between 18 to 22 months of age. Three infants in this group (Infants 5, 6 and 8) had their hearing loss identified and aided by 6
months of age and two infants (6, 8) were the youngest recipients of a cochlear implant (at 8 months of age), while the other two infants (Infant 1 and 5) were the oldest recipients of a cochlear implant, at 15 and 16 months of age. Although not all infants were observed to produce every type of later developing communicative intention, for those communicative intentions observed, development was commensurate with chronological age for six infants. Of the later developing communicative intentions produced, only two infants (4 and 7) failed to develop all types within the normal range for their age. These later developing communicative intentions were commensurate with either hearing age or cochlear implant age.

Only three infants were observed to use every type (both early and later developing) of communicative intention. Particular communicative intention types may not have been observed in the other infants for one of the following reasons. Firstly, they may not have had the opportunity to use that particular type of intention even though it was part of their repertoire. Alternatively, they may not have developed the behaviour by the completion of the study. Infant 1 did not demonstrate the early communicative behaviour of protesting, but had developed all other types including all three advanced types. As protesting is the first of the early behaviours to develop (Coggins, 1987) and she had demonstrated all other intentional types, it is probable that the absence of protesting was a result of this infant not having an opportunity to demonstrate this behaviour. However, for the four infants who did not demonstrate all later developing intentional behaviours, it may be that they had not developed these behaviours, as they were advanced types of communicative intention. Consequently, the development of some types later developing communicative intention was considered to be further delayed than cochlear implant age for Infants 2, 3, 4 and 7.

Three infants (Infants 2, 3 and 4) were not observed to use the communicative intention of requesting information. Yoshinaga-Itano & Stredler-Brown (1992), found that non-verbal requests for information correlated significantly with verbal communicative intention categories. Although Infants 2, 3 and 4 did develop verbal communicative intentions, they had the most delayed language development of the group (discussed in detail in Chapter 5), supporting the findings of Yoshinaga-Itano and Stredler-Brown. Requesting information is the only communicative intention type that requires the infant to independently seek information from a communicative partner. Unlike requesting, protesting, acknowledging, commenti
and answering which are either simple acts or call for the infant to respond to the communicative partner, requesting information requires an independent attempt on the infant’s part to acquire information (Coggins & Carpenter, 1981; Yoshinaga-Itano & Stredler-Brown, 1992). It seems to be the most advanced of the communicative intention types. Yoshinaga-Itano and Stredler-Brown suggest an absence of this type of communicative intention may be a predictor of future language delay.

FACTORS AFFECTING THE DEVELOPMENT OF COMMUNICATIVE INTENTION TYPES
There appeared to be several positive factors in the development of communicative intention types. The combination of early identification of hearing loss, hearing aid fitting before 6 months of age and cochlear implantation before or at 12 months of age is more likely to lead to the development of the full range of early communicative intention types at a younger age. These factors also appeared to facilitate the acquisition of the full range of later developing types of communicative intention. However, with later developing types of communicative intention, age at cochlear implantation appeared to have no effect.

Conversely, there were negative variables that affected the development of the full range of communicative intention types, in particular request for information behaviour in Infants 2, 3, and 4. Three of these infants had specific extraneous factors which may have contributed to these outcomes. The delayed development of communicative intention types in Infant 2 may be related to problems with her cochlear implant which led to the need for the device to be explanted and replaced with a new implant. Infant 2 did not develop new types of communicative intention after her second cochlear implant. It is possible that this is the result of the time she spent without auditory input (approximately 1 month) between the removal of the first device (due to infection) and the switch-on of her new implant in the contralateral ear. The negative impact on language development of implant malfunction or a signal affected by an unsuitable program or speech coding strategy has been reported by Geers (2002) and Geers, Brenner, & Davidson (2003).

Infant 3 was the second infant who did not develop all types of communicative intention. She did not develop requesting information or answering. During the period of the study she had been exposed to significant social and emotional trauma, which may have impacted on her
behaviour and development in this area. Such trauma has been demonstrated to affect communication development (Allen & Wasserman, 1985; Augoustinos, 1987).

Infant 4 was diagnosed with a developmental delay, which may have contributed to the delayed acquisition of all communicative intention types. Children with developmental delay demonstrate slower acquisition of milestones across all areas of development (McCathren, Yoder, & Warren, 1999; Yoder, Warren, & Biggar, 1997). While Infant 4's overall development was delayed, he acquired five of the six types of communicative intention. The only type he failed to develop was requesting information.

**Forms of Communicative Intention**
For all infants the development of the gestural/vocal stage of communicative intention was within the normal range (commensurate with their chronological age) (Chapman, 1981). The finding that nonverbal communicative intention developed commensurately with typically developing infants is consistent with previous studies (Robinshaw, 1996; Yoshinaga-Itano & Stredler-Brown, 1992). However, the results of verbal communicative intention development reported in this thesis are more positive than previous studies such as Yoshinaga-Itano and Stredler Brown (1992) who reported that infants with profound loss struggled to develop verbal communicative intention at a typical age. The present study found that verbal communicative intention emerged from 13 months of age or between 2 and 5 months post-cochlear implantation. By 12 months post-cochlear implantation all but one infant were using predominantly words rather than gestures to convey meaning in their communication with others. All the infants were implanted before or near their first birthday, whereas the infants in the study by Yoshinaga-Itano and Stredler Brown (1992) used hearing aids. It is possible that the improved auditory stimulation via the implant facilitated the development of age appropriate verbal communicative intention.

The finding that once a child begins to use verbal communicative intention consistently, the total quantity of non-verbal communicative intentions remains stable or decreases is consistent with previous studies (Lock et al., 1990; Robinshaw, 1996; Wood, Wood, Griffiths, & Howarth, 1986; Yoshinaga-Itano & Stredler-Brown, 1992). The fact that six of the seven infants assessed (Infant 2 was not available for assessment) were using more verbal than
gestural/vocal behaviours by 12 months post-cochlear implantation is positive. This result suggests that infants who are identified early and receive cochlear implants between the ages of 8 and 16 months can expect to be verbal children 12 months after device activation. Infant 3 was the only infant who did not master the single-word stage of language development during the study. This may be a result of significant social/emotional issues affecting her development, as already discussed.

While nonverbal and gestural/vocal communicative intention develops appropriately in children with profound hearing loss using hearing aids, it appears the use of a cochlear implant may facilitate the emergence and development of verbal communicative intention. This is supported by studies that demonstrate better verbal language development for infants and children with profound hearing loss who use cochlear implants when compared with those who use hearing aids (Geers, 2004; Svirsky, 2000; Svirsky et al., 2000; Tomblin et al., 1999). The two infants who were the youngest recipients of a cochlear implant (Infants 6 and 8) used verbal communicative intention at a much younger age (13 months) than the other infants in the study. They also used predominantly verbal communicative intention earlier than the remaining infants in the group. Infant 7 (the oldest to receive a cochlear implant at 16 months of age) also displayed consistent verbal communicative intention within the normal age range, however this infant was the only one of six who were implanted after 12 months of age to do this. This finding suggests the earlier an infant receives a cochlear implant, and less time in auditory deprivation, the earlier an infant reaches a level of predominantly verbal communication.

**Frequency of Communicative Intention**

The frequency or rate at which the infants produced communicative intentions was reduced in all the infants. At some points throughout the study a few infants demonstrated a frequency of use of communicative intention that was commensurate with their hearing age or cochlear implant age, but this was not a strong trend. In fact the frequency of communicative intention of almost all the infants was reduced relative to their chronological age, hearing age and cochlear implant age. This reduction in frequency of communicative intention is consistent with the findings of Yoshinaga-Itano and Stredler-Brown (1992).
It was thought that the reduced rate of communicative intention may have been a result of the parent-infant interaction. That is, the parent could have been dominating the interaction with the child. The interactions were subsequently analysed to determine if this had occurred. See Appendix H for parent interaction method and analysis. The analysis showed that parents produced facilitative interactions 51% to 63% (average 57%) of the time with their child. Interactions dominated by parents occurred 37% to 49% (average 43%) of the time. These results indicate that the parents predominantly demonstrated positive, language facilitating interactions with their infant. Consequently, parent interaction could not be considered a factor negatively impacting on the infants’ frequency of communicative intention.

**Early Auditory Stimulation and the Development of Communicative Intention: The Effect of Hearing Aids and Cochlear Implantation**

Early auditory stimulation was not expected to have an impact on the development of communicative intention types, as all six types of communicative intention can be expressed gesturally as well as verbally (Coggins & Carpenter, 1981). Early auditory stimulation was also not expected to impact on the development of gestural or gestural/vocal communicative intention as these forms of communicative intention can be developed without the need for audition (Yoshinaga-Itano & Stredler-Brown, 1992). In addition, the infants did not wear hearing aids long enough to determine the impact on verbal communicative intention, as they changed to a cochlear implant at an age when gestural/vocal development is occurring and verbal communicative intention is not necessarily expected in infants (Chapman, 1981; Paul, 1995a; Yoshinaga-Itano & Stredler-Brown, 1992). However, the infants in this study first used verbal communicative intentions 2-6 months following cochlear implant activation aged 13-19 months (average 16.7 months). As infants in previous studies were reported to use verbal communicative intention at later ages than the infants in this study (Robinshaw, 1996; Yoshinaga-Itano & Stredler-Brown, 1992), it appears that cochlear implantation facilitated the development of verbal communicative intention. For all infants in the study, including those with additional factors affecting their development, the average age at which verbal exceeded gestural/vocal communicative intention was 25 months. (Note that Infant 3 did not develop predominantly verbal communicative intention during this study.) This means that nearly all the infants with a profound hearing loss who received a cochlear implant prior to or near their first birthday were verbal communicators at around 2 years of age. This contrasts with the results of Yoshinaga-Itano and Stredler-Brown (1992), who reported that infants with a
profound hearing loss in their study were predominantly verbal between the ages of 30 and 36 months. Moreover, in the present study the two youngest infants to receive a cochlear implant (at 8 months of age) mastered verbal communication at the youngest age. This suggests that auditory stimulation via a cochlear implant at 8 months of age appears to take greater advantage of the critical period for speech perception development than when the implantation occurs after this age.

Early auditory intervention did not appear to have an impact on infants’ rate of communicative intention. This may be because the infants required more facilitation of their communicative intention in therapy and in their familiar environments such as home. Facilitation of communication can be done by creating motivation to communicate through the use of techniques such as “sabotage” (e.g. the therapist gives the child paper for drawing without the pencils. The child has to then request the pencils before he/she can draw). Alternatively, it may be that using hearing aids for the first year of life does not provide enough auditory information for infants with a profound hearing loss to attend to the communication acts that happen around them as typically hearing infants might. An infant with a profound hearing loss might not be able to learn the subtleties of this communication if the infant cannot hear what is happening around them. It may be that cochlear implantation needs to be considered at an earlier age than occurred in this study, to facilitate a higher rate or frequency of communicative intention.

Limitations of the Study
While the assessment process used to collect data for communicative intention provided useful information, it could be improved upon. The toys used for videoed parent-child interaction up to 6 months implantation (see Appendix D) were not suitable for the entire 1-6 month post-implantation phase. The toys were stimulating for infants aged 12 months and younger, but not as interesting for older infants due to their cognitive level (Schwartz & Heller Miller, 1988). During the post-implant phase from 1-6 months, the youngest infant was aged 8 months at the first videotaped interaction and 14 months of age 6 months post-implantation. The oldest infant was 16 months at the first videotaped interaction and 22 months of age at 6 months post-implantation. At these ages the cognitive levels of infants are vastly different to their level at the onset of the study and are changing rapidly (Owens, 1992).
Rather than selecting toys for the different phases of data collection, toys should be selected appropriate to the infants’ ages (Schwartz & Heller Miller, 1988). The original toy selection would be suitable for infants 12 month of age or younger. The toys used at 12 and 18 months post-implantation (see Appendix D) could be used for infants 13 months of age and older. One interaction box could be selected depending on specific interests. The effect of using the toys from the original protocol on the language outcomes is not known, but toys that take into consideration the infants’ age and gender may yield different results.

A larger subject sample would lend further weight to these findings for communicative intention types, form and frequency. As this research was undertaken before the introduction of neonatal hearing screening the number of participants was limited to the number of suitable infants available. All infants who met the selection criteria in NSW over a 2-year period participated in this study.

**Conclusions**

This is one of the first studies to provide in-depth longitudinal information about the acquisition of types, forms and frequency of communicative intention in infants who are managed to optimise their auditory skills including early cochlear implantation. In general, the infants demonstrated age-appropriate verbal forms and types of communicative interactions. However, the frequency of communicative intention was reduced. Early cochlear implantation appears to have been of benefit for the development of verbal communicative intention, but this was not the case for the development of communicative intention frequency. It may be that the infants did not have an adequate auditory signal at a young enough age to facilitate appropriate frequency of communicative intention by 18-24 months of age.

Overall, the findings from this study are positive. Early auditory stimulation with an appropriate hearing device (that provides access to speech sounds) appears positive for verbal communicative intention development. However, we need to consider what it may take to facilitate an increase in communicative intention frequency, which may assist in longer term language and communication development
CHAPTER FOUR

Study 2: Early Development of Speech in Infants with a Profound Hearing Loss: Pre- and Post-Cochlear Implantation
Review of the Literature: Pre-speech and Speech Development

Introduction
This is a descriptive study of the speech development of infants born with a profound hearing loss who receive early intervention focused on developing speech and oral language. The speech of young, typically developing children can be considered in terms of two distinct developmental stages: the pre-speech (or prelinguistic) stage and the speech stage (Ling, 1989). The pre-speech stage refers to an infant’s use of sounds such as cooing and babbling to interact with adults, which is a prerequisite skill for the acquisition and use of vowels and consonants to form words (Stoel-Gammon, 1998). The speech stage of development commences when a child begins to communicate using single words and is largely complete by 7 years of age (James, van Doorn, & McLeod, 2001; Kilminster & Laird, 1978; Ling, 1989). By this time most children use all speech sounds appropriately in conversation (Chirlian & Sharpley, 1982; Kilminster & Laird, 1978).

The first 12 months of life are important in the long-term development of speech skills (Kuhl et al., 1992; Sininger et al., 1999; Tibussek et al., 2002). Infants with typical hearing are born with speech perception skills that enable them to distinguish their mother’s voice over that of others (Ruben & Schwartz, 1999). From this point, via auditory stimulation, infants “fine tune” their speech perception development to a point where infants begin to acquire speech skills (Kuhl, 2004). By 12 months of age, infants know and use some of the sounds of their parent’s native language, and first words emerge (Jusczyk, 2002; Jusczyk et al., 1993; Kuhl, 2004). Therefore, facilitation of the auditory pathway is crucial in the development of speech perception and consequently of speech production skills (Sininger et al., 1999). Although complete mastery of speech may not occur until 7 years of age, a reduction in auditory stimulation in the first years of life affects speech development (Calderon & Naidu, 2000; Obenchain et al., 2000; Stoel-Gammon, 1988).

Early identification of hearing loss and intervention, including use of an appropriate hearing device (hearing aid or cochlear implant) and therapy to stimulate speech development, significantly reduce the period of auditory deprivation experienced by infants born with a hearing loss (Calderon & Naidu, 2000). However, for infants with a profound hearing loss, the effect of hearing aids on the development of pre-speech and speech development appears to
be limited (Calderon & Naidu, 2000; Obenchain et al., 2000; Smith, 1975; Stoel-Gammon, 1988; Stoel-Gammon & Otomo, 1986; Yoshinaga-Itano & Sedey, 2000). Current reports on pre-speech and speech development of infants with profound hearing loss who are identified, fitted with hearing aids and receive therapy prior to 6 months of age are not positive (Ling, 1976; Obenchain et al., 2000; Oller & Eilers, 1988; Oller et al., 1985; Stoel-Gammon, 1988; Stoel-Gammon & Otomo, 1986; Wallace et al., 2000; Yoshinaga-Itano & Sedey, 2000). Infants and children with a profound hearing loss, using hearing aids, have poor speech outcomes (Calderon & Naidu, 2000; Higgins, McCleary, Carney, & Laura, 2003; Obenchain et al., 2000; Oller & Eilers, 1988; Oller et al., 1985; Smith, 1975; Stoel-Gammon, 1988; Stoel-Gammon & Otomo, 1986; Yoshinaga-Itano & Sedey, 2000). Poor speech outcomes in children with hearing loss were common decades ago, at a time when early intervention was infrequent and hearing technology was less advanced than it is today (Ling, 1976; Smith, 1975). To see current studies still demonstrating poor speech outcomes, particularly when we have improved hearing technology (hearing aids and cochlear implants) and early intervention, is of concern.

Infants with a profound hearing loss usually have limited access to speech sounds when using hearing aids because of the extent of their hearing loss (Flexor, 1999). That is, they have such limited residual hearing that a hearing aid cannot adequately stimulate the cochlea across all the frequencies that are important for the perception of speech. As demonstrated in the literature cited above, limited access to speech sounds impacts on their long term speech development despite early intervention. Cochlear implants can provide access to all speech sounds for infants with a profound hearing loss, and are reported to have benefits over hearing aids when it comes to speech outcomes (Geers, 2004). However, cochlear implants are not recommended for children under the age of 12 months (Drinkwater, 2004; Young, 2002), leaving infants with profound hearing loss to develop pre-speech skills with hearing aids until they can swap to a cochlear implant. The minimum age recommendation for cochlear implantation has not as yet been a significant issue. As has been demonstrated in the recruitment of infants for this study (2 infants implanted in 24 months implanted before 12 months of age), most infants with a profound hearing loss are at or past the age of 12 months when their hearing loss is diagnosed and an evaluation for cochlear implantation is performed. However, this will change as more infants with a profound hearing loss present for services at a much younger age as a result of neonatal screening programs (Samson-Fang et al., 2000).
Typical Pre-speech Development
The progression from pre-speech to speech is an organised process, starting with new-born sounds such as fussing, crying, grunting, and moving to cooing and some glottal and velar sounds, with vowels emerging at 2-4 months of age (Bauman-Waengler, 2004). By 4-6 months of age these vowel sounds develop into vocal play, with the production of consonant-vowel combinations and “raspberries”, followed by variation in intonation and then reduplicated babbling (/mamama/, /dadada/) occurring at 6-10 months (Paul, 1995c).

Many studies have focused on the pre-speech development of typically developing infants (Davis & MacNeilage, 1995; Mitchell, 1997; Oller & Eilers, 1988; Stoel-Gammon, 1998). Stoel-Gammon (1998) described typical babble in infants. She found canonical babbling occurred from 7 months of age that usually consisted of reduplicated babbling (repetitive vocalisations such as /mamama/) and variegated babbling (varied vocalisations such as /bænædʌ/). While canonical babble predominates in the early stage of babble development, variegated babble increases after 9-10 months of age. Canonical vocalisations mark the start of phonetic sequences, and are a prerequisite to the development of first words (1988). The final stage of pre-speech development occurs at 10-12 months when infants use both variegated babbling and approximations of meaningful words, culminating in the emergence of single words (Paul, 1995c). At the time first words emerge, which is around 12 months of age, infants begin to vocalise in a manner that is characterised by adult-like intonation patterns, babble and words (Bauman-Waengler, 2004). This is known as jargon.

Typical Speech Development
Once an infant is using single words to communicate there are several aspects of speech that continue to develop which include the development of vowel/diphthong and consonant inventories and the acquisition or mastery of these phonemes (Bauman-Waengler, 2004). An inventory is defined as the group of phonemes the child can produce, regardless of how frequently the sounds are pronounced correctly in words (Robb & Bleile, 1994). Acquisition or mastery is defined as correct production of the phoneme in words most of the time. This is usually specified in terms of a percentage correct such as 85-90% correct production (Smit, 2004). In addition to phoneme development, improvements in speech intelligibility and
suppressions of phonological processes occur with age (Lowe, 1994; Watson & Scukanec, 1997b).

**Vowel and Consonant Development**

The following data on typical development of vowel and consonant development are reported for English speaking children. In the second year of life, children produce a small number of vowels (Selby, Robb, & Gilbert, 2000). These vowels include /i ɛ o æ oʊ/. By 3 years of age, children have acquired or mastered almost all vowels (Selby et al., 2000). James, van Doorn, and McLeod (2001) reported that children between the ages of 3 years and 3 years 11 months produce 94.9% of vowels correctly in monosyllabic words.

Consonant acquisition is not as rapid as vowel acquisition. At 2 years of age a child has an inventory of 12 consonants (/p, b, t, d, k, m, n, s, f, h, w, j/) (Watson & Scukanec, 1997b) but has only acquired four consonants (/m, n, h, g/) (Chirlian & Sharpley, 1982). From 2 ½ to 3 years of age a large expansion in phonology takes place (Bauman-Waengler, 1994), marked by an increase in both phonetic inventories and phoneme acquisition (Chirlian & Sharpley, 1982; Watson & Scukanec, 1997b). By 3 years of age children are likely to have increased the number of acquired consonants to 12 (Chirlian & Sharpley, 1982; Kilminster & Laird, 1978). After this point, the acquisition of consonants continues until approximately 7 years of age, when a typically developing child has mastered all sounds (Chirlian & Sharpley, 1982; Kilminster & Laird, 1978).

**Severity of Phonological Involvement (Speech Intelligibility)**

The severity of phonological involvement is another aspect of speech development. The severity of phonological involvement relates to speech intelligibility, which should improve as the child gets older (Garret & Moran, 1992; Shriberg & Kwatkowski, 1982; Watson & Scukanec, 1997b). One procedure used to determine the severity of a developmental phonological disorder affecting a child’s speech intelligibility was developed by Shriberg and Kwatkowski (1982), who estimated the severity of involvement by determining the percentage of consonants produced correctly (PCC). PCC is calculated as the number of correct consonants divided by the total number of correct and incorrect consonants, then multiplied by 100 (1982). This calculation has been used in studies as a measure of severity of
phonological involvement or speech intelligibility in children with typical hearing (Garret & Moran, 1992; Gordon-Brannan, 1994; Stoel-Gammon, 1987, 1994; Watson & Scukanec, 1997b). In addition, PCC is reported to be helpful in planning therapy for those with phonological delays or disorders and in evaluating the effectiveness of treatment for phonological disorders (Gordon-Brannan, 1994).

Shriberg and Kwiatkowski’s classification of PCC is as follows: PCC scores of 85-100 suggest normal speech intelligibility or mild severity of involvement. PCC scores of 65-84 indicate mild-moderate involvement. PCC scores of 50-64 indicate moderate-severe involvement, and PCC scores of less than 50 are classed as severe involvement. Severe involvement equates to highly unintelligible speech.

Watson and Scukanec (1997b) used this severity of phonological involvement calculation to comment on the phonological abilities of typically developing 2-year-olds. They studied 12 infants via videotaped parent-child interactions every 3 months over a period of a year. The infants’ speech was transcribed and analysed. Watson and Scukanec found that the children at 2 years of age typically demonstrated an average PCC score of 69 (range 53-91). This outcome reflected mild-moderate severity of involvement; that is, the speech of the 2-year-old children was at times mildly unintelligible. At 2 years 3 months of age the children demonstrated an average PCC score of 70 (range 51-91). An average PCC score of 75 (range 61-94) was recorded for the children at 2 years 6 months, and of 82 (73-99) for the children at 2 years 9 months. By 3 years of age the children had a PCC score of 86 (73-99), indicating that their speech at this age was largely intelligible.

**PHONOLOGICAL PROCESSES**

Phonological processes are sound changes that affect a class or sequence of sounds (Edwards & Shriberg, 1983). From the age of 2 years, typical children begin using more words and combining words (Paul, 1995a). At this time there are usually phonological processes operating in their speech (Lowe, 1994). Definitions of all phonological processes mentioned throughout this thesis are presented in Appendix E.
In typically developing children aged 2 years 6 months, Vardi (1991) found that processes such as final consonant deletion, unstressed syllable deletion, cluster reduction, assimilatory processes, reduplication, velar fronting, gliding, stopping and voicing are operating in their speech. By 3 years 6 months, processes such as final consonant deletion, reduplication, voicing, fronting of velars, stopping of /f, s/ and assimilatory processes have disappeared (Vardi, 1991). The remaining phonological processes operating in their speech continue to decline with age (Grunwell, 1987; Preisser, Hodson, & Paden, 1988; Watson & Scukanec, 1997b).

The Relationship between Auditory Development and Speech Development

The relationship between auditory development, speech perception and speech development was discussed in Chapter 1. In summary, the auditory system is fully developed at 5 months gestation with many changes occurring to the system throughout childhood (Moore, 2002b; Northern & Downs, 1984; Ponton et al., 2001). From simple levels of speech perception evident at birth, infants develop the ability to distinguish the vowels and consonants of their parent’s native language and to recognise language specific sound combinations (Jusczyk, 2002; Jusczył et al., 1992; Kuhl, 2004; Kuhl et al., 1992), at which time, canonical babble develops. Canonical babble leads to speech productions similar to those of the parent’s native language, with first words emerging at approximately 12 months of age (Kuhl, 2004; Owens, 1992). While the development of speech continues through to late preschool and school age, the first 12 months of life are important in laying the foundation of this development (Kuhl, 2004; Sininger et al., 1999). There is clear evidence in the literature to suggest the impact of hearing loss, which leads to a reduction in auditory stimulation during this period, is critically important for speech development (Kuhl, 2004; Moore, 2002a; Moore et al., 1994; Ponton et al., 1999; Sininger et al., 1999).

The Effect of Profound Hearing Loss on Pre-speech and Speech Development

PROFOUND HEARING LOSS AND PRE‐SPEECH DEVELOPMENT

The effect of a hearing impairment on prelinguistic speech or pre-speech skills has been well documented (Calderon & Naidu, 2000; Oller et al., 1985; Stoel-Gammon, 1988, 1998; Stoel-Gammon & Otomo, 1986; Yoshinaga-Itano & Sedey, 2000). Research has shown that infants
with a hearing impairment go through similar pre-speech (prelinguistic) vocalisation stages as their hearing peers (Marschark, 1993; Oller et al., 1985; Robinshaw, 1996). However, the effect of a profound hearing loss on pre-speech and speech development is often evident within the first year of life, usually around the time canonical babble should be emerging (Oller et al., 1985; Stoel-Gammon, 1988; Stoel-Gammon & Otomo, 1986).

Oller and Eilers (1988) implemented a longitudinal study documenting the onset of babble in 21 infants with typical hearing and 9 infants with severe to profound hearing loss. The infants with typical hearing started canonical babbling between 6-10 months of age (average 7 months). The infants with a hearing loss produced canonical babbling from 11-25 months of age (average 16 months), despite early amplification and “speech stimulation”. While all nine infants with a hearing loss produced canonical patterns at the onset of babble, the babble did not match the patterns of the infants with typical hearing. When six of the infants were followed up to 5-6 months after the onset of babble, three of the infants with hearing impairment demonstrated babble patterns similar to that of their hearing peers. The three infants who did not demonstrate typical patterns of babble or failed to develop any babble and did not go on to develop meaningful speech. Except that one of these infants was thought to be developmentally delayed (no assessment conducted) there was no reason given as to why these three infants failed to develop meaningful speech.

The finding of atypical patterns of babble development in the speech of infants with hearing loss is supported in studies by Stoel-Gammon and Otomo (1986) and Stoel-Gammon (1988). Stoel-Gammon and Otomo (1986) compared the babble development of 11 infants with typical hearing and 11 infants with hearing impairment. The hearing losses ranged from moderate to profound. The infants with hearing impairment, particularly those with severe-profound hearing loss, were found to have fewer consonants in their babble than infants with typical hearing. Moreover, the range of consonants may decrease over time. This impact on the babble development of infants with hearing loss was noted at 6-8 months of age.

A second study by Stoel-Gammon (1988) confirmed the findings of the previous study of atypical consonant repertoires in the babble of infants with severe-profound hearing loss. The prelinguistic consonant development of 14 infants with hearing loss was compared with that of 11 infants with typical hearing. The infants with hearing loss had consonant inventories
consisting mainly of bilabial and alveolar sounds. The infants with typical hearing showed equal proportions of bilabial and alveolar sounds and a few glottal sounds. Stoel-Gammon stated that although the findings were preliminary, they indicated that severe-profound hearing loss impacts on the consonant repertoire of prelinguistic babble.

The findings are consistent throughout the literature. Despite early intervention the effects of significant hearing impairment on prelinguistic or pre-speech development are evident within the first year of life. Consonant repertoires are smaller in range than those of typically hearing peers, and the development of canonical babble is often delayed and disordered. The differences in pre-speech development of infants with a hearing impairment are largely due to the hearing loss affecting the infants’ ability to hear their own vocalisations (Oller & Eilers, 1988; Stoel-Gammon, 1998; Yoshinaga-Itano, 2000).

It is of interest to note that Oller and Eilers (1988) thought it “surprising” that there was no overlap of age at onset of babble between the group of infants with a hearing loss and the group of infants with typical hearing. The authors considered that with early amplification and speech stimulation there should be some overlap between the two groups of infants. However, there are several reasons why this finding should not be surprising. Most infants in the study received hearing aids between 7 and 13 months of age. Four received hearing aids under 6 months of age. Infants with typical hearing develop canonical babble at approximately 7 months of age when they have had 7 months of auditory experience. Therefore, it may be that the infants with a hearing impairment also need at least 7 months of auditory experience before canonical babbling can be expected. If the infants with hearing loss are to develop canonical babble, it may not emerge until 7 months after hearing aid fitting. As a result, most infants with hearing impairment in the study should not have been expected to develop babble until after 12 months of age. While amplification may assist in the onset of canonical babble at some stage of an infant’s development, the degree of hearing loss also needs to be taken into consideration.

It is not stated in the studies discussed in the previous section, which infants, if any, had access to all sounds in the speech range with their hearing aids. If an infant cannot hear all speech sounds when wearing hearing aids, then pre-speech development will be affected.
Both Stoel-Gammon and Otomo (1986) and Oller and Eilers (1988) stated that audition plays a crucial role in the acquisition of pre-speech skills. However, neither study appears to take into consideration that the infants may not have been able to hear all speech sounds when using hearing aids. If the infants had a moderate to severe loss this may not have been a consideration, as they should have access to all speech sounds when wearing hearing aids. However, if the infants had a profound hearing loss, degree of hearing loss is a factor that may be pertinent in the analyses of the data.

**PROFOUND HEARING LOSS AND SPEECH DEVELOPMENT**
The impact of a profound hearing impairment on the development of speech is also well documented in the literature (Calderon & Naidu, 2000; Ling, 1976; Obenchain et al., 2000; Smith, 1975; Wallace et al., 2000; Yoshinaga-Itano, 2000). Yoshinaga-Itano & Sedey (2000) evaluated the speech production of 147 children with a hearing impairment, between the ages of 14 and 60 months. Their aim was to investigate whether there was a relationship between speech production and demographic and developmental factors. They found no demographic elements (age at diagnosis, mother’s education or gender) contributing to speech development. However, they found several significant predictors of speech intelligibility and phonemic inventories. Children with poorer speech intelligibility and smaller phonemic inventories had poor expressive language skills and a greater degree of hearing loss. These findings have been confirmed by other research (Calderon & Naidu, 2000; Obenchain et al., 2000; Wallace et al., 2000).

In a study of 80 infants, Calderon and Naidu (2000) investigated long and short term outcomes of speech, language and auditory skills following early identification of hearing loss and early intervention. They found that the greater the hearing loss, the poorer the auditory skills and speech production. Obenchain et al.(2000) also found that the greater degree of hearing loss the greater the impact on speech. They examined characteristics evident in the second year of life that may contribute to intelligible speech at 3 years of age. In addition to confirming that greater degrees of hearing loss impacted more on speech, they discovered that other characteristics, such as a small consonant inventory and lack of intonation in utterances, led to unintelligible speech in children with hearing impairment.
Wallace, Menn and Yoshinaga-Itano (2000) not only agreed that the greater the degree of hearing loss the poorer the child’s speech; they also reported that none of the children with a profound hearing loss in their study was judged to have intelligible speech over the duration of their research (82% of the children with mild to severe hearing loss were reported to have intelligible speech). Again, all children wore hearing aids. The nature of the profound hearing loss may mean that even with hearing aids, children may not be able to hear all speech sounds. This in turn impacts on speech intelligibility. While children with a profound hearing loss can develop oral language skills, their ability to communicate with others may be affected by poor speech intelligibility. For children with a profound hearing loss wearing hearing aids, the prognosis for speech development does not appear to be positive, despite early intervention.

The Effect of Cochlear Implantation on Pre-speech and Speech Development

There is conflicting evidence in the literature on the benefits of cochlear implantation on speech development. While some studies have shown that cochlear implantation has had a positive impact on speech development (Tobey et al., 2003; Uchanski & Geers, 2003), others demonstrate little or no benefit of cochlear implantation on speech production (Higgins et al., 2003; Tye-Murray, Spencer, & Woodworth, 1995).

Tye-Murray et al. (1995) investigated whether children acquired intelligible speech post-cochlear implantation, and how age at implantation influenced speech acquisition and errors. Their subject sample consisted of 28 prelingually deafened children using Total Communication (TC). All had at least 24 months (average 36 months) of cochlear implant experience. The authors reported that children with 24 months of cochlear implant experience acquired some intelligible speech, and that cochlear implantation before 5 years of age appeared to facilitate better speech production skills. Acquiring “some intelligible speech” (p.327) is not a strong statement supporting cochlear implantation as an intervention leading to better speech outcomes.

Eight years later, some studies are still showing minimal benefit of cochlear implantation on speech development. In a 5 year study, Higgins et al. (2003) described the speech characteristics of seven prelingually deafened children. All received cochlear implants after...
the age of 5 years and had been in a TC early intervention program. The children had persistent deviant speech behaviours and further developed deviant speech behaviours post-cochlear implantation, demonstrating little benefit of cochlear implantation on speech production.

However, these two studies have limitations in terms of their ability to assess the impact of cochlear implantation on speech development. Firstly, all subjects received their cochlear implants at late ages (up to 5 years) compared with today’s standards. Consequently, these children could have had at least 5 years of a limited auditory signal via a hearing aid during the period in which rapid speech and language development would be expected. Therefore, it would be unrealistic to expect that the children’s speech development would change drastically with the provision of a cochlear implant. A second issue is that the subjects used TC. As the children with a profound hearing loss may not have relied solely on audition to communicate, their auditory skills may not have been developed enough to appreciate, interpret and use all aspects of speech. According to Ling (1976), audition is the only sense capable of appreciating suprasegmental features, and all vowels and consonants in speech. Therefore, unless audition is used to facilitate speech development, many children with a hearing impairment will have speech errors. The findings of Tye-Murray et al, (1995) and Higgins et al. (2003) should be used as a guide for professionals as to which children may not receive great benefit from a cochlear implant.

In contrast to the above-mentioned findings, positive speech outcomes following cochlear implantation have been reported by Tobey et al. (2003) and Uchanski and Geers (2003). Uchanski and Geers (2003) examined the benefits of cochlear implantation in the acquisition of speech. They studied the speech acoustic characteristics of 181 cochlear implant users (using TC or oral communication) and 24 typically hearing children. The majority of their cochlear implant users produced speech with acoustic characteristics within the range found for children with typical hearing. This led to the conclusion that cochlear implantation had benefits for speech acoustic characteristics for children with profound hearing loss. These characteristics included voice onset time, second formant frequency, nasal manner, spectral moments, and duration of speech productions for words. Results also showed that more children had normal speech acoustic characteristics if they were from an oral communication program rather than a TC setting.
Tobey et al. (2003) also demonstrated that cochlear implantation in combination with oral education led to better speech production outcomes. They evaluated the speech production of children with 4 to 6 years of cochlear implant experience. They were seeking to determine if there were any factors that contributed to better speech development following cochlear implantation. The factors associated with better speech production skills for children with cochlear implants were length of time using a cochlear implant and education programs emphasising oral-aural communication. The use of oral communication in conjunction with cochlear implantation appears to facilitate better speech outcomes for children with a profound hearing impairment. However, one limitation in these studies and others is the age at which the children receive a cochlear implant. Comparison of early versus late implantation is usually made between less than 5 years of age versus later than 5 years of age.

Pre-speech and Speech Outcomes of Infants who Receive a Cochlear Implant

There are only a few studies of the pre-speech and speech outcomes of infants with a profound hearing loss who receive a cochlear implant near their first birthday (Houston et al., 2003; Schauwers et al., 2004). The reasons for a lack of information about cochlear implants in infants are that few infants with profound hearing loss were identified before 6 months of age (prior to newborn screening), and that cochlear implantation was deferred because of anaesthetic risk to infants, particularly under 6 months of age (Drinkwater, 2004; Samson-Fang et al., 2000; Young, 2002).

Ertmer et al. (2002) studied the vocal development of an infant who received a cochlear implant at 10 months of age, and compared his development with that of a girl who received a cochlear implant at 28 months of age. The child who received a cochlear implant at 28 months of age was found to have better vocal development in the first 12 months following cochlear implant activation than the infant who received a cochlear implant at 10 months of age. The older subject reached the canonical vocalisation level sooner and increased the proportion of post-canonical vocalisations over time, demonstrating that there was no benefit to providing a cochlear implant in the first year of life over implantation in the second or third year of life. However, there were several limitations to this study. Firstly, it is not possible to generalise from only 2 subjects. In addition, Ertmer et al. did not report the mode of communication for
both children. The 28-month-old child used TC and later changed to oral-aural
communication as her oral language skills developed, but the communication mode of the 10-
month-old was not stated. Finally, the 28 month old child was receiving more therapy than the
10 month old, which may have affected the outcomes.

These findings are contradictory to those of Schauwers et al. (2004), who investigated the
onset of babbling in infants who received a cochlear implant. The findings of Schauwers et al.
(2004) has been discussed in other sections of this thesis, but in summary the infants who
received a cochlear implant at 5, 6 and 8 months of age developed canonical babble at a
typical age. The onset of babble was delayed in infants implanted after 16 months. This
appears to be the only study of its kind evaluating the pre-speech development of a number of
infants who received cochlear implants. However, it is limited in that it provides no insight
into the long-term impact of cochlear implantation at this age on later speech development.
Overall, there is little literature on the long term pre-speech and speech development of
infants who receive cochlear implants.

Purpose of This Study
This study aims to answer the following questions:

1. Does early auditory intervention result in sequential and age appropriate pre-speech
   and speech development (phoneme inventories, phoneme acquisition, severity of
   phonological involvement, and phonological processes) for infants with a profound
   hearing loss?

2. What is the impact of early cochlear implantation on the sequential and age
   appropriate pre-speech and speech development (phoneme inventories, phoneme
   acquisition, severity of phonological involvement, and phonological processes) for
   infants with a profound hearing loss?
Method

Functional Assessment: Pre-speech and Speech Skills
A spontaneous pre-speech or speech sample was obtained from the infants at regular intervals pre- and post-cochlear implantation. Spontaneous speech samples were analysed for vowel, diphthong and consonant inventories, vowel, diphthong and consonant acquisition, severity of phonological involvement (speech intelligibility), and phonological process development. The videotaping procedure is detailed in the Chapter 2 of this thesis.

Analysis of Functional Pre-speech and Speech Assessment
Two assessments were selected to analyse the speech development of the infants in this study. The first was the Developmental Vocal Assessment (DVA) (Paul, 1995c), which was used to analyse each infant’s pre-speech skills. When the infants moved to the speech stage of development the Computer Aided Speech and Language Assessment (CASALA) (Blamey, 1997) was used to analyse their speech.

Analysis of Functional Assessment – Pre-speech Development
The DVA (Paul, 1995a) is presented in Appendix F. It provides a detailed analysis of an infant’s early speech development and examines infant vocalisations at the pre-speech stage and divides this stage of speech into five levels of development, from early grunts and vowels through to babble and emergence of first words. The DVA was completed using the general methodology described in Chapter 3. The pre-speech stage on the DVA in which most vocalisations were coded was regarded as the stage at which the infant was functioning in terms of pre-speech development. If there were approximately the same number of vocalisations across two stages, the infant was credited with the higher level of development. Once the infant was using phonetically consistent approximations of meaningful single words, the infant was deemed to be at the final pre-speech Stage 5, regardless of the number of vocalisations coded at previous stages. This occurred because these behaviours signified an important shift in the infant’s pre-speech development, that is, to the emergence of verbal language and the onset of the subsequent stage of speech development.

Analysis of Functional Assessment – Speech Development
CASALA (Blamey, 1997) is a computer program that analyses speech production from single word to conversational level. It was selected as part of the protocol as its level of analyses...
follows immediately from the pre-speech DVA. In addition, CASALA generates comprehensive reports including information such as the development of vowels, diphthongs and consonants, and phonological processes operating in an infant’s speech. CASALA is appropriate for analysing speech transcribed from a videotaped interaction.

For the CASALA analysis, the infants’ speech samples were transcribed from the video recordings of the 12 month and 18 month parent-child interactions. The entire sample of intelligible utterances was transcribed orthographically and phonetically using broad phonetic transcription. Both the orthographic (what the child said) and the phonetic (how the child said it) transcriptions were entered into the CASALA program. The Phonetic Inventory Report and the Phonological Processes Summary generated by the program were obtained for both the 12- and 18-month assessments. Results from these reports are presented in terms of phonetic inventories and phonemes acquired for vowels/diphthongs and consonants. In addition, the severity of impact on speech intelligibility is reported, as is phonological process development.

**Definition of Phonetic Inventories**
A phonetic inventory is defined as the group of sounds the infant is capable of producing. The phonetic inventory provides a more general picture of an infant’s phonological abilities than assessment of mastery of phonemes alone (Stoel-Gammon, 1987). A phoneme uttered at any time, either correctly or incorrectly during an interaction, was deemed to be a part of an infant’s phonetic inventory or repertoire. In other words, an infant who produced the sound /d/ correctly (e.g. in “don’t”), either regularly or on one occasion had this sound credited to the inventory. In the same way, if the infant substituted this sound for another (e.g. “date” for the word “gate”) /d/ was still credited to the repertoire as this production fell within the inventory criterion. That is, the infant was capable of producing that phoneme.

**Definition of Phoneme Acquisition**
In contrast, a phoneme was considered to be acquired by an infant if it was produced correctly 85% of the time. This figure was chosen to account for two factors in infant-toddler sound acquisition. That is, children in speech therapy are assumed to have acquired a sound if they are able to produce it correctly 90% of the time in conversation (Smit, 2004). However, there
are a number of phonological processes, such as final consonant deletion operating in the speech of children the same age as those in this study (Grunwell, 1987; Vardi, 1991). Therefore, the figure of 85% requires consistent production of a sound to be considered acquired, without penalty for overlying normal developmental patterns. Although most processes do not affect vowels, the criterion of 85% correct production was set for all phonemes, for consistency.

Vowels and Diphthongs Assessed
Table 4.1 shows the vowels and diphthongs evaluated. Vowels were labelled as front, mid or back. This was in accordance with the Australian English Monophthongs (Mannell & Cox, 2005) (see Appendix G). The vowel chart represents how the vowels and diphthongs are produced by the vocal tract. That is, front, mid or back of the mouth, with the tongue either in the lower part of the mouth, the mid or top. (The tongue placement generates the first and second formants, which allows the listener to identify one vowel from another.) Classification of vowels in this manner allowed comparisons with the literature on typical development. Diphthongs were evaluated as a separate group. This was because vowels are often investigated alone (James et al., 2001; Selby et al., 2000) rather than in conjunction with diphthongs. In addition, diphthongs can be more difficult to produce than vowels as they require blending two vowels within the one syllable (Blamey, 1997).

Table 4.1: Vowels and diphthongs evaluated in this study. Vowels are ordered by place of production (back, mid and front) according to Mannell & Cox (2005)

<table>
<thead>
<tr>
<th>Back Vowels</th>
<th>Mid Vowels</th>
<th>Front Vowels</th>
<th>Diphthongs</th>
</tr>
</thead>
<tbody>
<tr>
<td>/u/ - boot</td>
<td>/a/ - bark</td>
<td>/æ/ - bat</td>
<td>/ow/ - boat</td>
</tr>
<tr>
<td>/ʊ/ - book</td>
<td>/ʌ/ - but</td>
<td>/e/ - bet</td>
<td>/æ/ - bear</td>
</tr>
<tr>
<td>/o/ - ball</td>
<td>/ə/ - happen</td>
<td>/i/ - bit</td>
<td>/æ/ - tour</td>
</tr>
<tr>
<td>/ɑ/ - hot</td>
<td>/ɜ/ - bird</td>
<td>/ɜ/ - beat</td>
<td>/æ/ - bout</td>
</tr>
</tbody>
</table>

Examples

/ʊ/ - boot /æ/ - bat /
/ʊ/ - book /e/ - bet /
/ʊ/ - ball /i/ - bit /
/ɑ/ - hot /ɜ/ - beat /
/ɑ/ - book /æ/ - boat /
/ɑ/ - ball /æ/ - bear /
/ɑ/ - hot /æ/ - tour /
/ɑ/ - book /æ/ - bout /
/ɑ/ - ball /æ/ - boy /
Consonants Assessed
Consonant phonemes were grouped into one of four stages according to the developmental chart of sound teaching and acquisition by Ling (1976). The consonants evaluated and the stage to which they belong to are listed in Table 4.2. Stage 1 covers consonants produced at the front of the mouth (by the lips); Stage 2 includes consonants produced around the alveolar ridge and mid palate; Stage 3 covers consonants produced in the palatal-velar region; and Stage 4 covers later developing fricatives.

Table 4.2: Consonants evaluated in this study. Consonants are grouped by stages of development according to Ling (1976)

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Stage 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>b</td>
<td>p</td>
<td>m</td>
<td>w</td>
</tr>
<tr>
<td>/b/ - bat</td>
<td>/p/ - pat</td>
<td>/m/ - mat</td>
<td>/w/ - wet</td>
</tr>
<tr>
<td>/f/ - fat</td>
<td>/d/ - dog</td>
<td>/t/ - tag</td>
<td>/n/ - nag</td>
</tr>
<tr>
<td>/s/ - sag</td>
<td>/g/ - gate</td>
<td>/k/ - kite</td>
<td>/r/ - ŋate</td>
</tr>
<tr>
<td>/ð/ - thera</td>
<td>/v/ - yat</td>
<td>/θ/ - thing</td>
<td>/ð/ - ōther</td>
</tr>
</tbody>
</table>

Calculation of Severity of Phonological Involvement (Speech Intelligibility)
Severity of phonological involvement is related to speech intelligibility. The severity of impact of speech intelligibility was determined using the PCC (Shriberg & Kwiatkowski, 1982). This was calculated for each infant at both the 12- and 18-month assessments post-cochlear implantation.

Determining of Phonological Processes
Phonological processes operating in the infant’s speech were calculated by the CASALA program. Each phonological process was calculated as a percentage. The lower the percentage, the better the child’s speech production (Bauman-Waengler, 2004). Lowe (1994) examined the literature to determine criteria to indicate when a phonological process was operating in children’s speech and affecting speech intelligibility. These criteria ranged from a criterion of one sound change as constituting a phonological process, through to a criterion of the process operating in the child’s speech 20% of the time or more. According to Lowe, if a sound changes only once it is not a pattern. As stated earlier, a sound is deemed as being
acquired in therapy if it is produced correctly 90% of the time in conversation. Further, Shriberg and Kwaitkowski (1982) suggested that mild severity of phonological involvement be set at 85-100% consonants correct. With these criteria in mind, a phonological process was deemed to be affecting an infant’s intelligibility if it was present at least 10% of the time (that is, for 90% of the time the infant did not use that particular phonological process).

**RELIABILITY OF ANALYSES OF FUNCTIONAL PRE-SPEECH AND SPEECH ASSESSMENT**

Consensus transcription agreement (Shriberg, Kwaitkowski, & Hoffmann, 1984) with the researcher and an independent speech pathologist was used to analyse the infants’ vocalisations. If a vocalisation was agreed upon during the initial viewing of the behaviour it was rated and credited to the child. If there was disagreement, the vocalisation was reviewed and if consensus was not reached on the second viewing the vocalisation was discarded.

Ling (1976) recommended the procedure of using two raters to analyse the speech of children with a hearing impairment. He suggested that the two raters should have experience working with and listening to the speech of the hearing impaired, with one being familiar with the infant (the researcher in this study) and one with no previous knowledge of the infant (the independent speech pathologist in this study). This approach reduces the possibility of all ratings being biased; rating either too conservatively by someone who does not know the child or too liberally by someone who knows the child well (Guilford, 1954). In addition, Guilford indicated that this procedure also prevented any skewing for individual child ratings. This might occur if a rater knows that one child within the group should be performing better than another and possibly over-score on one type of vocalisations. Alternatively, if a rater knows that a child is not expected to perform well, vocalisation might be under-scored.
Results

Pre-speech Development

**Pre-speech Development Pre-cochlear Implantation**

Table 4.3 shows the point during the study at which the infants reached each pre-speech stage of development. It can be seen that all infants were at pre-speech Stage 1 of their development (crying, neutral and vegetative sounds) at the time of their first videoed interaction pre-implantation. Four infants (Infants 3, 4, 5, and 6) remained at this pre-speech Stage 1 of development throughout the pre-implantation phase, and four infants (1, 2, 7 and 8) progressed to pre-speech Stage 3 (variations in vowel production, some front sounds and pitch glides). Only one infant (Infant 2) was observed to fully develop pre-speech Stage 2 (cooing). For all other infants, vocalisations within pre-speech Stage 2 were observed, but their pre-speech skills were never predominantly at Stage 2 level of development.

**Table 4.3 Assessment point during the study when each of the five pre-speech stages of development were reached by each infant. Pre-speech stages were delineated according to Paul’s (1997) pre-speech stages**

<table>
<thead>
<tr>
<th>Infant</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Stage 4</th>
<th>Stage 5</th>
<th>First Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant 1</td>
<td>Start Pre</td>
<td>⚫️</td>
<td>Mid Pre</td>
<td>⚫️</td>
<td>3 months</td>
<td>3 months</td>
</tr>
<tr>
<td>Infant 2</td>
<td>Start Pre</td>
<td>⚫️</td>
<td>Mid Pre</td>
<td>End Pre</td>
<td>⚫️</td>
<td>4 months</td>
</tr>
<tr>
<td>Infant 3</td>
<td>Start Pre</td>
<td>⚫️</td>
<td>2 months</td>
<td>⚫️</td>
<td>4 months</td>
<td>4 months</td>
</tr>
<tr>
<td>Infant 4</td>
<td>Start Pre</td>
<td>⚫️</td>
<td>4 months</td>
<td>⚫️</td>
<td>5 months</td>
<td>5 months</td>
</tr>
<tr>
<td>Infant 5</td>
<td>Start Pre</td>
<td>⚫️</td>
<td>1 month</td>
<td>⚫️</td>
<td>2 months</td>
<td>2 months</td>
</tr>
<tr>
<td>Infant 6</td>
<td>Start Pre</td>
<td>⚫️</td>
<td>1 month</td>
<td>⚫️</td>
<td>4 months</td>
<td>4 months</td>
</tr>
<tr>
<td>Infant 7</td>
<td>Start Pre</td>
<td>⚫️</td>
<td>Mid Pre</td>
<td>2 months</td>
<td>5 months</td>
<td>5 months</td>
</tr>
<tr>
<td>Infant 8</td>
<td>Start Pre</td>
<td>⚫️</td>
<td>Mid Pre</td>
<td>⚫️</td>
<td>5 months</td>
<td>5 months</td>
</tr>
</tbody>
</table>

- Development of this stage was not evident or predominant during the study
- Pre-implant phase
- Months refers to months post-cochlear implantation that stage was achieved

**Pre-speech Development Post-cochlear Implantation**

The infants (Infants 3, 4, 5 and 6) who remained at Stage 1 of pre-speech development during the pre-implant evaluation phase moved to pre-speech Stage 3 shortly after cochlear implant activation. This level of development is characterised by variations in vowel production, some front sounds and pitch glides. Seven of the eight infants did not achieve pre-speech Stage 4 at any time during this research. Although vocalisations within Stage 4 were observed, their pre-
speech skills were never predominantly at this level of development. The final pre-speech Stage 5, characterised by variegated babbling, jargon and word approximations, was developed by all infants within the first 6 months (average 4 months) after cochlear implant activation. The emergence of words occurred simultaneously with the development of pre-speech Stage 5 for all infants. This signalled the end of the prelinguistic/pre-speech phase of development.

**Rate of Pre-speech Development**

Table 4.4 shows the length of time each infant took to reach each pre-speech stage of development. All the infants took approximately 8 months (range 7-10 months) to reach pre-speech Stage 5 from the point of their first pre-implant assessment. This occurred regardless of their progress prior to cochlear implantation.

Table 4.4: The length of time during the study that the infants took to reach each of Paul’s (1997) five stages of pre-speech development

<table>
<thead>
<tr>
<th>Typical Rate</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Stage 4</th>
<th>Stage 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant 1</td>
<td>0-4 months</td>
<td>1 month</td>
<td></td>
<td></td>
<td>6 months</td>
</tr>
<tr>
<td>Infant 2</td>
<td>1 month</td>
<td>2 months</td>
<td></td>
<td></td>
<td>7 months</td>
</tr>
<tr>
<td>Infant 3</td>
<td>6 months</td>
<td></td>
<td></td>
<td></td>
<td>2 months</td>
</tr>
<tr>
<td>Infant 4</td>
<td>7 months</td>
<td></td>
<td></td>
<td>1 month</td>
<td></td>
</tr>
<tr>
<td>Infant 5</td>
<td>9 months</td>
<td></td>
<td></td>
<td>1 month</td>
<td></td>
</tr>
<tr>
<td>Infant 6</td>
<td>4 months</td>
<td></td>
<td></td>
<td>3 months</td>
<td></td>
</tr>
<tr>
<td>Infant 7</td>
<td>1 month</td>
<td></td>
<td>5 months</td>
<td></td>
<td>3 months</td>
</tr>
<tr>
<td>Infant 8</td>
<td>1 month</td>
<td></td>
<td></td>
<td></td>
<td>7 months</td>
</tr>
</tbody>
</table>

Pre-implantation progress | Post-implantation progress

**Pre-speech Results Based on Chronological Age, Hearing Age and Cochlear Implant Age**

The comparison of the infants’ pre-speech development with that of typically developing children was made using the Developmental Vocal Assessment. From this their progress could be evaluated relative to chronological age, hearing age and cochlear implant age.

**Pre-speech Results: Chronological Age**

Figure 4-A shows each infant’s pre-speech development compared to their chronological age. The vertical bars indicate the age of the infant at the time the pre-speech stages were reached when compared with typical development. If the bar representing the infant’s age is below the
mid-line, it indicates that development is delayed relative to chronological age. Overall, the pre-speech development of the infants was delayed relative to their chronological age. Infant 8 was the only one to develop a pre-speech stage (Stage 3) equivalent to her chronological age.

Figure 4-A: Age in months, ahead or behind typical development for each stage of pre-speech development, based on the infants’ chronological ages. Stage 1 includes vegetative sounds and crying; Stage 2 includes cooing and pleasure sounds; Stage 3 includes vocal play, pitch glides and the emergence of consonant-vowel combinations; Stage 4 includes reduplicated babble and consistent intonation changes; Stage 5 includes variegated babble, proto-words and the emergence of single words (Paul 1995)

Pre-speech Results: Hearing Age

Figure 4-B on the following page shows the infants’ pre-speech development compared to their hearing age. Infant 5 developed pre-speech Stage 5 commensurate with her hearing age. Infants 1, 2 and 7 developed pre-speech Stage 3 equivalent to their hearing age. Infants 1, 5, 6 and 8 reached pre-speech Stage 5 consistent with their hearing age. For the remaining infants and pre-speech stages, results indicated that their development was further delayed relative to their hearing age.
Pre-speech Results: Cochlear Implant Age

Figure 4-C on the following page, shows the infants’ pre-speech development compared to their cochlear implant age. Infants 3, 4, 5 and 6 developed pre-speech Stage 3 commensurate with their cochlear implant age. Infant 7 developed pre-speech Stage 4 and Infants 2, 3, 4 and 7 developed pre-speech Stage 5 equivalent to their cochlear implant age. Pre-speech Stages 1 and 2 are not compared with cochlear implant age as these stages were developed by the infants prior to receiving their cochlear implants.
Speech Development

VOWELS AND DIPHTHONGS: INTRODUCTION
In the following section data are presented on vowel and diphthong inventories and acquisition, 12 and 18 months post-implantation. Vowel acquisition is the only aspect of vowel and diphthong development that was compared to the infants’ chronological age, hearing age and cochlear implant. This is because the literature on typical development of vowels in infants with typical hearing has not focused on inventories but has centred on acquisition of these phonemes. In addition, there appears to be little or no published data on typical development of diphthong inventories or acquisition.
Vowel and Diphthong Inventory Development 12 Months Post-cochlear Implantation: The infants’ vowel and diphthong inventories 12 months post-implantation are shown in Table 4.5. The shaded area signifies that phoneme was in the infant’s inventory. After 12 months of cochlear implant use, six of the seven infants (Infants 1, 3, 5, 6, 7 and 8), produced vowels across all three positions (front, mid and back). As a group, the infants produced slightly more mid vowels (average of three per infant) than front or back vowels (average of two per infant). One infant (Infant 4) did not produce vowels across all three positions. He produced mid vowels but was not observed to articulate front or back vowels. All the infants produced diphthongs. On average each infant produced three diphthongs (range 1-6). Overall, Infants 1, 5, and 7 had the largest total number of vowels and diphthongs.

Table 4.5: Vowel and diphthong inventories 12 months post-cochlear implantation. Place of articulation is from Mannel & Cox (2005)

<table>
<thead>
<tr>
<th>Infant</th>
<th>Back Vowels</th>
<th>Mid Vowels</th>
<th>Front Vowels</th>
<th>Diphthongs</th>
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<tbody>
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Vowel and Diphthong Inventory Development 18 Months Post-cochlear Implantation: Table 4.6 on the following page, shows the vowel and diphthong inventories 18 months post-implantation. All the infants were able to produce vowels across all positions (an average of three vowels for each position) 18 months post-implantation. They also used a variety of diphthongs. The infants’ inventories increased from an average of seven vowels and three diphthongs per infant to nine vowels and four diphthongs between the 12 and 18 months post-cochlear implant assessments.
Table 4.6: Vowel and diphthong inventories 18 months post-cochlear implantation for each infant. Place of articulation is from Mannel & Cox (2005)

<table>
<thead>
<tr>
<th>Infant</th>
<th>Back Vowels</th>
<th>Mid Vowels</th>
<th>Front Vowels</th>
<th>Diphthongs</th>
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*Not Available for assessment*

VOWELS AND DIPHTHONDS ACQUIRED

Vowels and Diphthongs Acquired 12 Months Post-cochlear Implantation: Table 4.7 shows the vowels and diphthongs acquired by the infants 12 months post-implantation. Shaded areas indicate 85% correct production of the vowel or diphthong by the infant. All infants had acquired some vowels across all three positions, with the exception of Infant 4. Overall, six infants (Infants 1, 3, 5, 6, 7 and 8) had acquired between 5 and 8 vowels and diphthongs.

Table 4.7: Vowels and diphthongs acquired by the infants 12 months post-cochlear implantation. Place of articulation is from Mannel & Cox (2005)

<table>
<thead>
<tr>
<th>Infant</th>
<th>Back Vowels</th>
<th>Mid Vowels</th>
<th>Front Vowels</th>
<th>Diphthongs</th>
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Vowels and Diphthongs Acquired 18 Months Post-cochlear Implantation: Table 4.8 shows the vowels and diphthongs acquired by the infants 18 months post-implantation. Five infants (Infants 1, 4, 5, 6 and 7) had acquired vowels across all vowel positions, 18 months post implantation. Infant 2 had not acquired front vowels and Infant 3 had failed to acquire back vowels. This result for Infant 3 was poorer than her result at the 12-month assessment where she had demonstrated acquisition of three of the four back vowels.

Table 4.8: Vowels and diphthongs acquired by the infants, 18 months post-cochlear implantation. Place of articulation is from Mannel & Cox (2005)

<table>
<thead>
<tr>
<th>Infant</th>
<th>Back Vowels</th>
<th>Mid Vowels</th>
<th>Front Vowels</th>
<th>Diphthongs</th>
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</thead>
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</table>

* Not Available for assessment

The number of vowels and diphthongs acquired increased between the 12- and 18-month assessments for five (Infants 1, 4, 5, 6 and 7) of the six infants available for both assessments. The average increased from four vowels and two diphthongs per infant at 12 months post-cochlear implantation to six vowels and two diphthongs per infant at 18 months post-cochlear implantation. At the 18-month assessment, differences in vowel and diphthong acquisition emerged between the infants. Four infants (Infants 1, 5, 6 and 7) had acquired 10 or more vowels and diphthongs while three infants (2, 3 and 4) had acquired six or fewer vowels and diphthongs. Of the infants with better vowel and diphthong acquisition (Infants 1, 5, 6 and 7) three were fitted with hearing aids prior to 9 months and one was fitted at 7 months of age. Three received their implants at 15-16 months of age while infant 6 received his at 8 months.

Vowel Acquisition Relative to Chronological Age, Hearing Age and Cochlear Implant Age
An infant’s development was judged to be at age equivalence with Selby, Robb and Gilbert (2000), by examining the vowels they had acquired and the overall number of vowels acquired. **12-months post-implantation** Vowel acquisition relative to chronological age,
Hearing age and cochlear implant age are outlined in Table 4.9 for data 12 months post-cochlear implantation. Vowel acquisition was delayed for all infants relative to chronological age 12 months post-cochlear implantation. However, the analysis for hearing age indicates that two infants (Infants 3 and 7) developed vowel acquisition equivalent to their hearing age by 12 months post-cochlear implantation. The final analysis looks at the development of vowel acquisition relative to cochlear implant age. At 12 months post-cochlear implantation, only four infants (Infants 1, 5, 6 and 8) had vowel acquisition commensurate with their cochlear implant age.

Table 4.9: Vowel acquisition development (85% correct production), 12 months post-cochlear implantation.

<table>
<thead>
<tr>
<th>Infant</th>
<th>Chronological Age (months)</th>
<th>Hearing Age (months)</th>
<th>Vowels Acquired</th>
<th>Development Equivalent to CA, HA or CIA</th>
<th>Typical Development Selby, Robb &amp; Gilbert, 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>28</td>
<td>21</td>
<td>a e</td>
<td>Cochlear Implant Age</td>
<td>15 months i o a d</td>
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<tr>
<td>3</td>
<td>25</td>
<td>22</td>
<td>i u u a e</td>
<td>Hearing Age</td>
<td>18 months i u u a d d e e</td>
</tr>
<tr>
<td>4</td>
<td>26</td>
<td>23</td>
<td>a</td>
<td>&lt; Cochlear Implant Age</td>
<td>21 months i u u a d d e e</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>24</td>
<td>u c a i</td>
<td>Cochlear Implant Age</td>
<td>24 months i u u a d d e e</td>
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<tr>
<td>6</td>
<td>21</td>
<td>20</td>
<td>o e i</td>
<td>Cochlear Implant Age</td>
<td>36 months i i u o e a d c e e</td>
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<td>Hearing Age</td>
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<td>8</td>
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<td>u c d æ i</td>
<td>Cochlear Implant Age</td>
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</tbody>
</table>

* Not Available for assessment
18 months post-implantation

Vowel acquisition relative to chronological age, hearing age and cochlear implant age are outlined in Table 4.10 for 18 months post-cochlear implantation. Vowel acquisition continued to be delayed for all infants relative to chronological age 18 months post-cochlear implantation. The analysis for hearing age indicates that at 18 months post-cochlear implantation, four infants (1, 5, 6 and 7) had vowel acquisition commensurate with hearing age. The final analysis looks at the development of vowel acquisition relative to cochlear implant age. Three infants (2, 3 and 4) continued to have delayed vowel acquisition relative to their cochlear implant age at 18 months post-cochlear implantation.

Table 4.10: Vowel acquisition development (85% correct production), 18 months post-cochlear implantation.

<table>
<thead>
<tr>
<th>Infant</th>
<th>Chronological Age (months)</th>
<th>Hearing Age (months)</th>
<th>Vowels Acquired</th>
<th>Development Equivalent to CA, HA or CIA</th>
<th>Typical Development Selby, Robb &amp; Gilbert, 2000</th>
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<td>Hearing Age</td>
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<td>2</td>
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<td>27</td>
<td>o a</td>
<td>&lt; Cochlear Age</td>
<td>21 months 1 u o e a d ə ʌ ɛ ə</td>
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<td>3</td>
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<td>24 months 1 u o e a d ə ʌ ɛ ə</td>
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**Consonant Inventory Development**

Consonant Inventory Development 12 Months Post-cochlear Implantation: The infants’ consonant inventories 12 months post-implantation are presented in Table 4.11, on the following page. Shaded areas indicate that the consonant was present in the infant’s inventory. All of the infants produced consonants across Ling’s (1976) consonant Stages 1 and 2, 12 months post-cochlear implantation. Two infants (Infants 1 and 7) produced consonants from Ling’s (1976) Stage 3, and one infant (Infant 7) produced one consonant from Ling’s (1976) Stage 4. As a group, the infants produced more of Ling’s (1976) Stage 1 than Stage 2 consonants.
Table 4.11: Consonant inventories 12 months post-cochlear implantation. Consonants are divided into stages of development according to Ling (1976).

<table>
<thead>
<tr>
<th>Infant</th>
<th>Ling’s Stage 1</th>
<th>Ling’s Stage 2</th>
<th>Ling’s Stage 3</th>
<th>Ling’s Stage 4</th>
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Consonant Inventory Development 18 Months Post-cochlear Implantation: The infants’ consonant inventories 18 months post-implantation are presented in Table 4.12. All the infants were able to produce consonants within Ling’s (1976) Stage 1 and Stage 2, 18 months post-cochlear implantation. Four infants (Infants 1, 5, 6 and 7) were also producing sounds within Ling’s (1976) Stages 3 and 4. Six of the seven infants had increased the number of consonants in their inventories from an average of 8 per infant (range 3-14) 12 months post-cochlear implantation to 12 per infant (range 4-18). One infant (3) regressed in her ability to produce consonants. Her inventory decreased from eight to five consonants between assessments.

Table 4.12: Consonant inventories 18 months post-cochlear implantation. Consonants are divided into stages of development according to Ling (1976).

<table>
<thead>
<tr>
<th>Infant</th>
<th>Ling’s Stage 1</th>
<th>Ling’s Stage 2</th>
<th>Ling’s Stage 3</th>
<th>Ling’s Stage 4</th>
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* Not Available for assessment
Consonant Inventory Development Relative to Chronological Age, Hearing Age, and Cochlear Implant Age

12 months post-implantation: Consonant inventory development relative to chronological age, hearing age and cochlear implant age at 12 months post-cochlear implantation are outlined in Table 4.13. Only one infant (Infant 7) had a consonant inventory developing equivalent to her chronological age at 12 months post-cochlear implantation. Three infants (Infants 1, 3, and 5) had inventories equivalent to their hearing age 12 months post-cochlear implantation and two infants (Infants 6 and 8) had consonant inventories equivalent to their cochlear implant age.

Table 4.13: Consonant inventory development 12 months post-cochlear implantation.

<table>
<thead>
<tr>
<th>Infant</th>
<th>Chronological Age (months)</th>
<th>Hearing Age (months)</th>
<th>Consonant Inventories</th>
<th>Development Equivalent to CA, HA or CIA</th>
<th>Typical Development Robb &amp; Beile (1994) Stoel-Gammon (1987)</th>
</tr>
</thead>
</table>
| 1      | 28                        | 21                   | b, p, m, w, h, d, t, n, j, s, k | Hearing age                            | 12 months  
  b, d, g, m, h  
  18 months  
  b, d, m, n, h, w, t, s  
  24 months  
  b, d, p, t, k, m, n, h, s, f, w, j  
  27 months  
  b, d, p, t, k, g, m, n, h, s, f, w, j, l  
  30 months  
  b, d, p, t, k, g, m, n, h, s, f, ñ, w, j, l  
  33 months  
  b, d, p, t, k, g, m, n, h, s, f, ñ, w, j, l  
  36 months  
  b, d, p, t, k, g, m, n, h, s, f, ñ, w, ð, j, l |
| 2      |                           |                      |                        |                                        |                                                        |
| 3      | 25                        | 22                   | b, p, m, w, d, t, n, l | Hearing age                            |                                                        |
| 4      | 26                        | 23                   | m, h, n                | < cochlear implant age                  |                                                        |
| 5      | 30                        | 24                   | b, p, m, w, h, t, n, j, ñ | Hearing age                            |                                                        |
| 6      | 21                        | 20                   | b, m, d, ñ             | Cochlear implant age                    |                                                        |
| 7      | 28                        | 21                   | b, p, m, w, h, ñ, d, t, n, l, ñ, s, k, ñ, v | Chronological age                      |                                                        |
| 8      | 22                        | 20                   | b, p, n, ñ             | Cochlear implant age                    |                                                        |

* Not available for assessment
18 months post-implantation: Consonant inventory development relative to chronological age, hearing age and cochlear implant age for 18 months post-implantation are outlined in Table 4.14. Four infants (Infants 1, 5, 6, and 7) had a consonant inventory developing equivalent to chronological age. The remaining infants did not have consonant inventories equivalent to their hearing age 18 months post-cochlear implantation. This included Infant 3 who did not maintain development of her consonant inventory between the 12- and 18-month assessments. At the 18-month assessment, Infant 2 had consonant inventory development equivalent to her cochlear implant age. The consonant inventory development of two infants (3 and 4) was delayed relative to their cochlear implant age.

Table 4.14: Consonant inventory development 18 months post-cochlear implantation. Development is expressed in terms of equivalence to chronological age, hearing age, or cochlear implant age

<table>
<thead>
<tr>
<th>Infant</th>
<th>Chronological Age (months)</th>
<th>Hearing Age (months)</th>
<th>Consonant Inventories</th>
<th>Equivalent to CA, HA or CIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34</td>
<td>27</td>
<td>b, p, m, w, h, f, d, t, n, j, l, f, s, g, k, ʧ, ʤ, z</td>
<td>Chronological Age 12 months b, d, g, m, h</td>
</tr>
<tr>
<td>2</td>
<td>34</td>
<td>27</td>
<td>b, p, m, w, t, l, f</td>
<td>Cochlear Implant Age 24 months b, d, p, t, k, m, n, (s, f, w, j)</td>
</tr>
<tr>
<td>3</td>
<td>31</td>
<td>28</td>
<td>b, p, m, d, f</td>
<td>&lt; Cochlear Implant Age 27 months b, d, p, t, k, g, m, n, (s, f, w, j, l)</td>
</tr>
<tr>
<td>4</td>
<td>32</td>
<td>29</td>
<td>b, m, h, n</td>
<td>&lt; Cochlear Implant Age 30 months b, d, p, t, k, g, m, n, (s, f, w, j, l)</td>
</tr>
<tr>
<td>5</td>
<td>37</td>
<td>31</td>
<td>b, p, m, w, h, f, d, t, n, j, l, f, s, g, k, ʧ, z</td>
<td>Chronological Age 33 months b, d, p, t, k, g, m, n, (s, f, ʧ, w, j, l)</td>
</tr>
<tr>
<td>6</td>
<td>30</td>
<td>29</td>
<td>b, p, m, w, h, d, t, n, j, l, f, s, g, k, ʧ, z</td>
<td>Chronological Age 36 months b, d, p, t, k, g, m, n, (s, f, ʧ, w, ʤ, j, l)</td>
</tr>
<tr>
<td>7</td>
<td>34</td>
<td>27</td>
<td>b, p, m, w, h, f, d, t, n, l, f, s, k, ʧ, r, ʤ, z, v</td>
<td>Chronological Age</td>
</tr>
<tr>
<td>8*</td>
<td></td>
<td></td>
<td></td>
<td>Not available for assessment</td>
</tr>
</tbody>
</table>

CONSONANTS ACQUISITION DEVELOPMENT
Consonants Acquired 12 Months Post-cochlear Implantation: Table 4.15 presents data on consonants acquired (85% correct) by the infants 12 months post-implantation. All infants had acquired some Stage 1 consonants. Five infants (Infants 1, 3, 5, 6, and 7) had acquired Ling’s (1976) Stage 2 consonants. Infant 7 had acquired a consonant from Ling’s (1976) Stage 3.
### Table 4.15: Consonants acquired by the infants 12 months post-cochlear implantation.

<table>
<thead>
<tr>
<th>Infant</th>
<th>Ling’s Stage 1</th>
<th>Ling’s Stage 2</th>
<th>Ling’s Stage 3</th>
<th>Ling’s Stage 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>b p m w h f d t n j l</td>
<td>s g k η r y</td>
<td>z θ ð v ʒ</td>
<td>3</td>
</tr>
<tr>
<td>2°</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
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<td>5</td>
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<tr>
<td>6</td>
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<td>7</td>
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</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Not available for assessment

**Consonants Acquired 18 Months Post-cochlear Implantation:** The consonants acquired 18 months post-implantation are presented in Table 4.16. All infants had acquired some consonants within Ling’s (1976) Stage 1. Six of the seven infants had acquired some consonants within Ling’s (1976) Stage 2. Four infants (1, 2, 6 and 7) had acquired at least one consonant from Ling’s (1976) Stage 3. Infant 7 had acquired one consonant from Stage 4. It appeared that acquisition of consonants was in sequential order. The first consonants acquired were mostly from Stage 1, followed by Stages 2 and 3.

### Table 4.16: Consonants acquired by the infants 18 months post-cochlear implantation.

<table>
<thead>
<tr>
<th>Infant</th>
<th>Ling’s Stage 1</th>
<th>Ling’s Stage 2</th>
<th>Ling’s Stage 3</th>
<th>Ling’s Stage 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>b p m w h f d t n j l</td>
<td>s g k η r y</td>
<td>z θ ð v ʒ</td>
<td>3</td>
</tr>
<tr>
<td>2°</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8°</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Not available for assessment

The number of consonants acquired increased within the infant group from an average of three consonants (range of 1-6) 12 months post-implantation to six consonants (range 1-11) at the 18-month assessment. However, the number of consonants for two of the infants (3 and 4) remained stable.
Consonant Acquisition Relative to Chronological Age, Hearing Age and Cochlear Implant Age

The infants’ consonant acquisition in relation to their chronological age, hearing age, and cochlear implant age is presented in Table 4.17. An infant’s development was judged to be at age equivalence with Chirlian and Sharpley (1982), by examining the consonants they had acquired and the overall number of consonants acquired. Only the data taken at the 18-month assessment are reported relative to chronological age or hearing age. This is because while there are some normative data available on phonetic inventories from 12 months of age, most data on phoneme acquisition start from 2 years of age (Chirlian & Sharpley, 1982; Kilminster & Laird, 1978; Stoel-Gammon, 1987).

Table 4.17: Consonant acquisition (85% correct production), 18 months post-cochlear implantation.

<table>
<thead>
<tr>
<th>Infant</th>
<th>Chronological Age (months)</th>
<th>Hearing Age (months)</th>
<th>Consonants Acquired</th>
<th>Development Equivalent to CA, HA</th>
<th>Typical Development Chirlian &amp; Sharpley (1982)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34</td>
<td>27</td>
<td>b, m, w, ñ</td>
<td>Hearing Age</td>
<td>24 months m n h g</td>
</tr>
<tr>
<td>2</td>
<td>34</td>
<td>27</td>
<td>b, m, ñ</td>
<td>Below Hearing Age</td>
<td>30 months m n h g p ng w t d k</td>
</tr>
<tr>
<td>3</td>
<td>31</td>
<td>28</td>
<td>b, p, ñ</td>
<td>Below Hearing Age</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>32</td>
<td>29</td>
<td>m</td>
<td>Below Hearing Age</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>37</td>
<td>31</td>
<td>b, p, m, w, d, n, j, ñ, r</td>
<td>Hearing Age</td>
<td>36 months m n h g p ng w t d k j f</td>
</tr>
<tr>
<td>6</td>
<td>30</td>
<td>29</td>
<td>b, p, m, w, h, d, n, j, s, g, ñ</td>
<td>Chronological Age</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>34</td>
<td>27</td>
<td>b, m, w, h, d, t, l, s, ñ, v</td>
<td>Hearing Age</td>
<td></td>
</tr>
<tr>
<td>8°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Not available for assessment

Of the eight infants only one, Infant 6, had consonant acquisition developing equivalent to his chronological age at the 18-month assessment. Three infants (Infants 1, 5 and 7) had consonant acquisition equivalent to their hearing age. For the remaining infants (2, 3 and 4) consonant acquisition was delayed relative to their hearing age. It is not possible to comment on consonant acquisition based on their cochlear implant age. This is because their cochlear implant age was 18 months and the published literature on typical consonant acquisition begins at 24 months of age.
SEVERITY OF PHONOLOGICAL INVOLVEMENT (SPEECH INTELLIGIBILITY)
A severity rating of phonological involvement is used to determine the intelligibility of the infants at the 12- and 18-month assessments. This was determined by calculating the percentage of consonants correct (PCC) in a connected speech sample (Shriberg & Kwaitkowski, 1982).

Severity of Phonological Involvement 12 Months Post-cochlear Implantation: PCC for each infant 12 and 18 months post-cochlear implantation is presented in Figure 4-D. The severity of phonological involvement was mild-moderate for Infant 7, moderate-severe for four infants (1, 3, 5 and 6), and severe for two infants (4 and 8).

Figure 4-D: Severity of phonological involvement 12 and 18 months post-cochlear implantation. Severity of phonological involvement was calculated as a percentage of consonants correct. The calculated figure was categorised from severe to mild degree of phonological involvement

Severity of Phonological Involvement 18 Months Post-cochlear Implantation: Overall, most of the infants improved in their score on the severity of phonological involvement rating between the 12 and 18 month post-cochlear implant assessments. Infant 7 improved her severity rating from mild-moderate at the 12-month assessment to mild at the 18-month assessment. Four infants (Infants 1, 3, 5 and 6) improved their severity ratings from moderate-severe to mild-moderate at the 18-month assessment. Although the PCC of Infant 4 improved between the 12- and 18-month assessments, his severity of phonological involvement remained severe.
Severity of Phonological Involvement (PCC) Relative to Chronological Age, Hearing Age and Cochlear Implant Age
Shriberg and Kwiatkowski’s (1982) PCC calculation and comparative data of children the same age developed by Watson and Scukanec (1997b) were used to establish if the infants’ severity of phonological involvement was appropriate for their age. Data were compared to the infants’ chronological age and hearing age. The infants’ PCC results compared to their chronological age at 12 and 18 months post-implantation are presented in Figure 4-E; and compared to their hearing age, 12 and 18 months post-implantation in Figure 4-F which are both located on the following page. Comparison was not made with the infants’ cochlear implant ages because the published data on speech severity ratings begin at 2 years of age. This did not allow for comparison at the 12 and 18 month post-implantation assessments.

Four infants (Infants 1, 3, 6 and 7) had severity of phonological involvement rating equivalent to their chronological age 12 months post-cochlear implantation. Three of the infants (3, 6 and 7) maintained development commensurate with their chronological age at the 18-month assessment. At this time, Infant 5 also had a severity of phonological involvement rating equivalent to her chronological age. The analysis of severity of phonological involvement relative to hearing age showed that Infant 5 was performing equivalent to her hearing age at 12 months post-cochlear implantation. The severity rating of the remaining two infants (Infants 4 and 8) was delayed relative to both their chronological age and hearing age. At the 18-month assessment Infant 1 had severity of phonological involvement rating equivalent to her hearing age. The severity rating of Infant 4 was delayed relative to both his chronological age and hearing age.
Figure 4-E: The results of the infants’ severity of phonological involvement, compared to their chronological age (or typical development)

<table>
<thead>
<tr>
<th>Infant</th>
<th>12 months post-implantation</th>
<th>18 months post-implantation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant 1</td>
<td>Above Normal Range</td>
<td>Below Normal Range</td>
</tr>
<tr>
<td>Infant 2</td>
<td>Above Normal Range</td>
<td>Below Normal Range</td>
</tr>
<tr>
<td>Infant 3</td>
<td>Normal Range</td>
<td>Normal Range</td>
</tr>
<tr>
<td>Infant 4</td>
<td>Normal Range</td>
<td>Below Normal Range</td>
</tr>
<tr>
<td>Infant 5</td>
<td>Above Normal Range</td>
<td>Below Normal Range</td>
</tr>
<tr>
<td>Infant 6</td>
<td>Normal Range</td>
<td>Below Normal Range</td>
</tr>
<tr>
<td>Infant 7</td>
<td>Normal Range</td>
<td>Below Normal Range</td>
</tr>
<tr>
<td>Infant 8</td>
<td>Normal Range</td>
<td>Below Normal Range</td>
</tr>
</tbody>
</table>

Figure 4-F: The results of the infants’ severity of phonological involvement, compared to their hearing age (time since hearing aid fitting). The transparent diamonds indicate that the infant’s development was determined to be commensurate with chronological age.

<table>
<thead>
<tr>
<th>Infant</th>
<th>12 months post-implantation</th>
<th>18 months post-implantation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant 1</td>
<td>Above Normal Range</td>
<td>Below Normal Range</td>
</tr>
<tr>
<td>Infant 2</td>
<td>Above Normal Range</td>
<td>Below Normal Range</td>
</tr>
<tr>
<td>Infant 3</td>
<td>Normal Range</td>
<td>Normal Range</td>
</tr>
<tr>
<td>Infant 4</td>
<td>Normal Range</td>
<td>Below Normal Range</td>
</tr>
<tr>
<td>Infant 5</td>
<td>Above Normal Range</td>
<td>Below Normal Range</td>
</tr>
<tr>
<td>Infant 6</td>
<td>Normal Range</td>
<td>Below Normal Range</td>
</tr>
<tr>
<td>Infant 7</td>
<td>Normal Range</td>
<td>Below Normal Range</td>
</tr>
<tr>
<td>Infant 8</td>
<td>Normal Range</td>
<td>Below Normal Range</td>
</tr>
</tbody>
</table>

12 months post-implantation
18 months post-implantation
**Phonological Processes**

The final results presented on the speech development of the infants are for phonological processes. There were 15 phonological processes (see Appendix E for definitions) observed in the infants at the 12- and 18-month evaluations. The number of infants who produced each phonological process at either the 12 or 18 month post-implantation assessment is presented in Figure 4-G.

![Figure 4-G: The number of infants producing each phonological process at the assessments 12 and 18 months post-cochlear implantation](image)

**Phonological Processes 12 Months Post-cochlear Implantation:** The most common phonological process at the 12-month assessment was final consonant deletion. This process was evident in the speech of all the infants. The next most common process was cluster reduction (five infants), then monophthongisation (three infants), followed by other fronting, reduplication and substitution (two infants each).

**Phonological Processes 18 Months Post-cochlear Implantation:** The most common phonological process at the 18-month assessment was cluster reduction (four infants), then final consonant deletion and other fronting (three infants), followed by initial consonant deletion and
monophthongisation (two infants each). The average number of phonological processes per infant decreased from four to three.

**Phonological Processes Development Relative to Chronological Age, Hearing Age and Cochlear Implant Age**

The phonological process development of all infants was equivalent to their chronological age (Grunwell, 1987; Vardi, 1991; Watson & Scukanec, 1997b). It should also be noted that the infants were not demonstrating phonological processes typical of deaf children (Vardi, 1991).

**Summary of Pre-Speech and Speech Results**

Table 4.18 provides an overview of the infants’ pre-speech development and their speech development at the end of the study, relative to their chronological age, hearing age or cochlear implant age.

<table>
<thead>
<tr>
<th>Table 4.18: An overview of the infants’ speech development 18 months post-cochlear implantation – all areas evaluated relative to chronological age, hearing age and cochlear implant age</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Infant</strong></td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>Infant 1</td>
</tr>
<tr>
<td>Infant 2</td>
</tr>
<tr>
<td>Infant 3</td>
</tr>
<tr>
<td>Infant 4</td>
</tr>
<tr>
<td>Infant 5</td>
</tr>
<tr>
<td>Infant 6</td>
</tr>
<tr>
<td>Infant 7</td>
</tr>
<tr>
<td>Infant 8</td>
</tr>
</tbody>
</table>

**PRE-SPEECH**

Prior to cochlear implantation the pre-speech skills of all infants were delayed. It took the infants approximately 8 months (from pre- to post-cochlear implant phase) to reach the final
pre-speech Stage 5, characterised by variegated babbling, jargon, and word approximations. At this point most of the infants’ pre-speech development was delayed relative to their chronological age. The infants reached the stage of first words soon after cochlear implantation. This early stage of linguistic/speech development, which signals the end of the prelinguistic/pre-speech phase, occurred between 2-5 months post-implantation (average 4 months post-implantation).

**SPEECH**

Findings demonstrate that by 18 months post-implantation the majority of the infants had typically developing speech in terms of consonant inventories, severity of impact on speech intelligibility and phonological process development. Vowel and consonant acquisition were delayed relative to chronological age for most of the infants. Infants 2, 3, and 4 had speech skills more delayed than the others in the group.

**Discussion**

At the commencement of this study, the infants were aged from 4 to 12 months of age. All were fitted with hearing aids and had received auditory, speech and oral language intervention between 1 and 7 months of age. The youngest to receive a cochlear implant was 8 months and the oldest was 16 months. Their speech development was followed from the pre-speech/prelinguistic stage prior to cochlear implantation through to 18 months post-cochlear implantation, when all infants were verbal. The results of the infants’ speech development were analysed in terms of vowel, diphthong and consonant inventories, vowel, diphthong and consonant acquisition, severity of phonological involvement (speech intelligibility), and phonological processes. Where possible the infants’ development was compared to their chronological age, hearing age (time from hearing aid fitting) and cochlear implant age (time from cochlear implant activation).

Overall results showed that pre-speech development was delayed for all infants. However, by 18 months post-implantation the majority of the infants had typically developing speech in terms of consonant inventories, severity of impact of phonological involvement on speech
intelligibility and phonological process development. Vowel and consonant acquisition was delayed compared to chronological age for most of the infants.

**Pre-speech Development**

All infants were at pre-speech Stage 1 of their development at their first pre-implant assessment (wearing hearing aids). Four infants (Infants 3, 4, 5 and 6) did not move from this stage until after cochlear implantation. Four infants (1, 2, 7 and 8) reached Stage 3 during the pre-cochlear implant phase, although they did not progress beyond this point until after cochlear implantation. Little pre-speech progress was made during the pre-implant stage despite the early age at diagnosis and hearing aid fitting of the infants in the study. This result may be a reflection of the infants’ significant hearing losses. Very few of the infants had residual hearing that could be aided in the speech range, indicating that the hearing aids were only of limited benefit for speech reception (see Appendix A for the infants’ aided audiograms). This finding is supported by the literature (Stoel-Gammon, 1988; Stoel-Gammon & Otomo, 1986; Wallace et al., 2000). The progress made in pre-speech skills of four infants prior to cochlear suggest that even limited access to speech sounds through hearing aids may provide some auditory stimulation to promote pre-speech development. However, these infants did not progress past this pre-speech stage, indicating that the hearing aids and early auditory intervention had limited benefit.

The findings in the pre-implantation phase of this study are consistent with reports in the literature that infants with a profound hearing loss can go through similar pre-speech vocalisations to their hearing peers (Marschark, 1993; Oller et al., 1985; Robinshaw, 1996), that infants with profound hearing loss have absent or delayed canonical babbling (Oller et al., 1985; Stoel-Gammon, 1988; Stoel-Gammon & Otomo, 1986), and that such differences in vocalisations between hearing impaired and typically developing infants are evident in the first year of life (Oller & Eilers, 1988; Oller et al., 1985; Stoel-Gammon, 1988).

Audition plays an important role in the development of babble and the development of speech (Oller & Eilers, 1988; Stark, 1991; Stoel-Gammon, 1998; Yoshinaga-Itano, 2000; Yoshinaga-Itano & Sedey, 2000). However, for this development to occur infants must have access to speech sound (Ling, 1976, 1989). According to the DVA, canonical babble begins when
infants are at pre-speech Stage 4. The infants in this study did not move past pre-speech Stage 4 until 2 to 5 months (average 4 months) post-implantation. This result is consistent with the findings of Schauwers et al. (2004). That is, for infants with a profound hearing loss, babbling develops after cochlear implantation. While only one infant was found to be predominantly at pre-speech Stage 4, all remaining infants produced vocalisations post-implantation that were categorised under pre-speech Stage 4. All infants reached Stage 5 (variegated babble, jargon and approximations of words) and the acquisition of first words within 6 months of device activation. The fact the infants in auditory intervention in this study did not move past the early pre-speech stages to develop babble until after cochlear implantation suggests that cochlear implantation facilitated attainment of the subsequent level of development.

In summary, the infant’s pre-speech development occurred in the sequential order found in typically developing children. However, typical pre-speech development was not possible for the infants with profound hearing loss while wearing hearing aids. It appeared that cochlear implantation facilitated attainment of the later stages of pre-speech development, as the infants did not pass pre-speech Stage 3 until after cochlear implant activation. First words were observed in all infants within 6 months of cochlear implantation.

Speech Development
By 18 months post-cochlear implantation, four of the seven infants available for assessment had consonant inventory development, speech intelligibility and phonological processes consistent with their chronological ages. This means that these infants with a profound hearing loss who received a cochlear implant between the ages of 8-16 months were following a typical pattern of development in these areas of speech production. Consonant and vowel acquisition, however, was delayed relative to chronological age.

With regard to vowel and consonant inventories and acquisition, all infants were developing both groups of phonemes in typical order of development. By 18 months post implantation, the infants produced a wide range of vowels, diphthongs and consonants, normal phonological processes and, for most, age-appropriate speech intelligibility. These results contrast with the literature citing poor speech outcomes of children with profound hearing loss (Higgins et al., 2003; Obenchain et al., 2000; Smith, 1975; Wallace et al., 2000; Yoshinaga-Itano, 2000). The
contrast in speech outcomes between the infants in the cited studies and those in this study is that the infants in this research received cochlear implants from between the ages of 8 and 16 months and were in an auditory-verbal education program with emphasis on auditory development. The use of audition has been suggested to be important in the development of speech in children with hearing impairment (Mitchell, 1997; Stark, 1991; Yoshinaga-Itano, 2000). In addition the benefits of auditory intervention in conjunction with cochlear implantation for speech development are also documented (Geers, 2002; Tobey et al., 2003).

While some of the infants showed limited speech development, four of the seven infants (Infants 1, 5, 6 and 7) assessed 18 months post-cochlear implantation, displayed good speech skills, with some aspects developing commensurately with their chronological age. Three of these (Infants 1, 5 and 7) were female, received a cochlear implant after 12 months of age and were the three oldest infants in the group. The remaining infant (Infant 6) was male, one of two younger recipients of a cochlear implant (8 months) in the study and the youngest infant at the time of the 18-month assessment. He had the best speech outcomes of the group, with all aspects of speech production (with the exception of vowel acquisition) developing commensurate with his chronological age. This finding is likely to be the result of this infant having access to all speech sounds at an earlier age than the other infants assessed 18-months post-implantation. By accessing sounds at an earlier age, his auditory development was facilitated within the first 12 months of life, which in turn may have provided better speech outcomes. This discussion however, should be considered cautiously as these findings were for only one infant in a small cohort. The overall finding that most (4 of 7) of the infants developed some age-appropriate speech skills soon after cochlear implantation may lend weight to the argument supporting early cochlear implantation and auditory stimulation for infants with profound hearing loss.

Poorer speech development in three of the infants (Infants 2, 3 and 4) may be accounted for. These infants demonstrated slower consonant and vowel development than the other infants in the group. Each of these infants had specific extraneous factors that may have contributed to these results. These factors were discussed in detail in Chapter 3. Infant 2 had required re-implantation 12 months after her original cochlear implant surgery, due to infection at the cochlear implant site. Infant 3 had been exposed to significant social and emotional trauma, which impacted on her behaviour and may have also affected her speech development. She
was the only infant to regress in speech skills between the 12- and 18-month assessments. The remaining infant (Infant 4) had a developmental delay, which may have affected his speech development.

Infant 3, whose vowel and consonant development had been among the most delayed in the group, had a severity of phonological involvement rating that was within the normal range for her age. This occurred because the sample of speech and language she produced in the parent-child interaction 18 months post-cochlear implantation was repetitious, consisting of simple words of consonant-vowel construction (her language development is further detailed in Chapter 5 of this study). Not only was her speech sample limited, but she appeared to be using words that were well practiced. As a result of using repeated, simply constructed words, she displayed a PCC that was appropriate for her age.

All infants were using phonological processes appropriate for their age, even those with delayed development in other areas of speech measured. One might assume that infants with a delay in all areas of speech development would also demonstrate delayed phonological process development. However, this was not the case in this study. The literature demonstrates that typically developing children aged between 18 months and 3 years of age have many phonological processes operating in their speech (Lowe, 1994; Preisser et al., 1988; Vardi, 1991). Consequently, the use of phonological process analysis alone to determine whether infants’ speech production is developing in a typical pattern may not be an appropriate speech measure between these ages. Using phonological process analysis in conjunction with other measures such as phoneme inventories and phoneme acquisition provides a more realistic picture of infants’ speech production development. These varying results between assessment tools emphasise the need to use a number of measures to ensure a valid assessment of speech development.

The examination of phonetic inventories provides an overview of the sounds infants are capable of producing and may help to identify sounds they are close to mastering (Robb & Bleile, 1994). Evaluation of acquired vowels and consonants helps determine which sounds infants have consolidated and which may require facilitation (Bauman-Waengler, 2004). The use of severity of phonological involvement and phonological process measures may be
premature with infants 18 months following cochlear implantation. However, the results attained at this age may provide a baseline for further evaluation 2 or 3 years following cochlear implantation. Moreover, these assessments would be useful tools in a longitudinal study, if the infants are to be studied for a longer period of time.

**Early Auditory Stimulation and the Development of Pre-speech and Speech Skills: The Effect of Hearing Aids and Cochlear Implantation**

**AUDITORY STIMULATION: PRE-SPEECH DEVELOPMENT**

The infants’ development of pre-speech followed the same pattern of development as that found in infants with typical hearing. However, little progress was made while the infants used hearing aids, despite early identification and auditory stimulation. Once fitted with a cochlear implant, the infants moved through the pre-speech stages at a comparable rate to typically developing children. However, despite their typical rate of pre-speech development, early auditory stimulation, and cochlear implantation between the ages of 8 and 16 months, their pre-speech development continued to be delayed. Therefore it seems that early intervention is not effective in the development of pre-speech skills in infants with a profound hearing loss. In addition, cochlear implantation at 12 months of age is not early enough to facilitate age appropriate pre-speech development. Even receiving a cochlear implant as young as 8 months of age appears to have created too much of a delay, making catch-up in the area of pre-speech development difficult. There is evidence to suggest that earlier implantation leads to typical pre-speech development (Schauwers et al. 2004). However, this study was limited to the emergence of babble development and further research is required in this area.

Despite the continued delay in pre-speech development, cochlear implantation was of benefit. The fact that no infant progressed past pre-speech stage 3 (vowels and varied pitch changes) until after cochlear implantation, suggests that the infants benefited from the improved auditory signal made available to them via the cochlear implant.
AUDITORY STIMULATION: SPEECH DEVELOPMENT
All infants were implanted between the ages of 8-16 months, at an age when speech
development is limited, therefore no conclusions can be reported on the effectiveness for
speech development of using hearing aids. However, as the infants made little progress in pre-
speech using hearing aids, it can be hypothesised that all aspects of their speech development
may have been delayed had they persisted with hearing aids.

The results of the study suggest that infants with a profound hearing loss in an auditory
intervention program, who receive a cochlear implant near their first birthday, can expect to
be producing a wide range of vowels and consonants by 18 months post-cochlear
implantation. In addition, they can expect to have consonant inventories, severity of impact on
speech (speech intelligibility) and phonological processes development commensurate with
their chronological age. This is contrary to reports on speech development in infants with a
profound hearing loss that infants with profound hearing loss have a limited range of
phonemes in their speech (Higgins et al., 2003; Obenchain et al., 2000; Smith, 1975; Wallace
et al., 2000; Yoshinaga-Itano, 2000). These results are also in conflict with the literature on
The major difference characterising participants in this study is that they received a cochlear
implant near their first birthday in conjunction with an auditory habilitation program. This
suggests that auditory intervention using a cochlear implant is effective in the development of
speech skills.

In general, the infants’ vowel and consonant acquisition was delayed when compared to their
chronological age. Only Infant 6 had consonant acquisition that was commensurate with his
chronological age. This infant received his cochlear implant at 8 months of age, which
supports the benefit of cochlear implantation before 12 months of age for consonant
acquisition or mastery. It was of interest to note that 12 months post-cochlear implantation,
most of the infants had vowel and consonant acquisition developing commensurate with their
cochlear implant age. This development improved 6 months later when their development in
the same area was commensurate with their hearing age (time since hearing aid fitting). This
finding implies an acceleration of development in this area. Perhaps in 6-12 months time this
development may be commensurate with most of the infants’ chronological ages.
Overall, the infants made progress in their speech development using a cochlear implant, despite the delay in their pre-speech development. The main area of delay in speech development pertained to phoneme acquisition or mastery (85% correct in speech). This might suggest that for phoneme acquisition, cochlear implantation between the ages of 8 and 16 months may not be early enough to attain typical development by 18 months post-cochlear implantation. Further longitudinal data would show whether the infants continued with delayed phoneme acquisition or accelerate in their rate of speech development. An accelerated rate of development may lead to typical phoneme acquisition 2 or 3 years after device activation. On the whole, cochlear implantation between the ages of 8 and 16 months, in conjunction with auditory habilitation and input from the parents, appears have a positive impact on long term speech development.

**Effect of Speech Coding Strategies**

Well into the study, seven of the eight infants were using the ACE speech coding strategy with one infant using SPEAK. Four of the seven infants using ACE, used SPEAK for approximately 12 months from initial switch-on at which time ACE was introduced into the paediatric clinics. While there are studies that show better speech perception skills using ACE when compared with SPEAK (Pasanisi et al., 2002; Psarros et al., 2002; Skinner et al., 2002), there is no evidence to suggest that one strategy improves long-term speech and language outcomes more than another.

For infants to develop speech and language skills using a cochlear implant, a speech coding strategy is required that helps them perceive all aspects of speech. These aspects include discrimination of all suprasegmental aspects of speech as well as all consonants and vowels. Both the SPEAK and ACE strategies provide a signal that does allow an infant to perceive all aspects of speech which was evident in the speech results of the infants. Although some aspects of speech were delayed and some infants had better speech outcomes than others, all infants were able to perceive speech using the cochlear implant signal. Therefore, no conclusion can be drawn as to the effect of each speech coding strategy on the development of speech.
Limitations of the Study
There are several limitations in this study. Firstly, the sample size is small. While there are some group trends with the present data set, a larger group size is necessary to define pre-speech and speech development within this population of infants. However, these findings do provide additional support for early implantation for a larger number of infants. Within a larger sample it would be useful to have more infants implanted before 12 months of age. Such a subject sample might allow for comparison of pre-speech and speech development between two groups of infants and contribute further to the debate about risk versus benefit of cochlear implantation under 12 months of age.

Finally, the study is limited in the length of time the infants were followed up. To follow these children over a longer period of time would provide further information on the acquisition of speech skills. It would be of interest to know whether the infants attained skills comparable to hearing peers in all aspects of speech development over time and maintained this level of development.

Conclusions
This is one of the first studies to provide in-depth longitudinal data on the pre-speech and speech development of infants, who were diagnosed, fitted with hearing aids and received early auditory intervention before 7 months of age, and then changed to a cochlear implant near their first birthday. The infants demonstrated delayed pre-speech development throughout the pre-implant and early post-implant phase. No infants progressed past the pre-speech stage until after cochlear implantation, and their phoneme acquisition continued to be delayed 18 months post-implantation. This may suggest that early auditory stimulation using hearing aids for infants with a profound hearing loss is minimally effective, despite early intervention. In addition, cochlear implantation may need to occur prior to 12 months of age to achieve typical development in all areas of speech at an earlier age. Earlier cochlear implantation, providing a clearer auditory signal, may take advantage of early speech perception development and may help achieve typical pre-speech and speech development at an earlier age. However, cochlear implantation between 8 and 16 months was early enough for some aspects of speech development.
New information has been presented in this thesis, on the positive effects of auditory intervention in conjunction with cochlear implantation on the pre-speech and speech outcomes in infants with a profound hearing loss. This new information, particularly regarding speech development, demonstrates that infants with a profound hearing loss, in an auditory intervention program, who receive a cochlear implant around their first birthday, can achieve typical development in some areas of speech. These areas include consonant inventory development, speech intelligibility and phonological processes. Moreover, the assessment protocol may provide clinical guidelines for evaluation for these infants. Further longitudinal research will show whether the infants maintain this level of development in the years to come. While much work is still required in the field, the methodology used and the outcomes of this study provide a base from which further research in the field can continue.
CHAPTER FIVE

Study 3: Early Development of Oral Language in Infants with a Profound Hearing Loss: Pre- and Post-cochlear Implantation
Review of the Literature: Oral Language Development

Introduction
This a descriptive study of the language development of infants born with a profound hearing loss who receive intervention focused on audition and oral language. Early intervention has benefits for optimal language development in infants with hearing loss (Calderon & Naidu, 2000; Mayne, Yoshinaga-Itano, Sedey et al., 2000; Moeller, 2000; Robinshaw, 1996; Yoshinaga-Itano & Apuzzo, 1998; Yoshinaga-Itano et al., 1998). However, the term “language” in these studies does not refer purely to oral language. All infants in these studies wore hearing aids and most used Total Communication (sign and speech) (TC) to develop their language skills. Calderon & Naidu, 2000 (2000) found that infants with a profound hearing loss had poor speech. Therefore, it is assumed that most of the infants and children with profound hearing loss in these studies relied on the sign component of TC for the comprehension and expression of language. Thus, we have little data specifically on the oral language outcomes of infants whose profound hearing losses are identified early, who are fitted with the appropriate device (hearing aid or cochlear implant), and receive speech and auditory language stimulation.

Oral language skills are facilitated by early speech perception development (Tsao et al., 2004). These early speech perception skills are developed through exposure to auditory stimulation and oral language (Kuhl, 2004). Therefore, hearing plays an important role in the development of oral language (Flexor, 1999; Jamieson, 1994). As auditory stimulation and speech perception are important in the development of speech and oral language, hearing loss, in particular a profound hearing loss, will affect development (Robinson, 1998b; Svirsky, 2000; Yoshinaga-Itano & Sedey, 2000). This raises the question to the effectiveness of early auditory intervention for infants with a profound hearing loss, who receive limited benefit from hearing aids, in the development of oral language development.

Cochlear implantation has been shown to have benefits over hearing aids for speech and language development in children with a profound hearing loss (Geers, 2004; Schauwers et al., 2004; Svirsky, 2000; Svirsky et al., 2000; Tomblin et al., 1999). This is because a cochlear implant can provide access to all speech sounds, which may not be available to the child with a profound loss while using hearing aids (Edwards & Tyszkiewicz, 1999). However, there is
little information about the long-term benefits of cochlear implants on oral language outcomes for infants with a profound hearing loss. (Robinson, 1998a). Recent research indicates that for some aspects of language development cochlear implantation prior to 12 months of age is advantageous (Houston et al., 2003; Schauwers et al., 2004). However, these studies are limited with regard to the areas of language studied and the amount of longitudinal data provided on the speech and oral language development of the infants.

**Typical Oral Language Development**

After months of exposure to oral language, infants generally begin to recognise and understand words by 8 months of age (Owens, 1992). By 12 months, they can usually follow simple instructions such as “clap hands” and “wave bye-bye”. In the second year of life comprehension typically expands rapidly (Paul, 1995a). Infants are usually able to identify major body parts such as “nose” and “eyes”. They generally begin to understand some personal pronouns and prepositions such as “in” and “on” (Owens, 1992). As they approach 2 years of age they are typically capable of understanding more than they can express, although many of the directions they respond to relate to their personal environment (Bloom & Lahey, 1978). By 3 years of age they are commonly comprehending two-part directions such as “get your hat and shoes” or “get your bag and put it on the table”. By the time a children reach the end of their preschool years, they are normally able to answer most questions, understand the concepts of “before” and “after”, and follow complex commands (Owens, 1992).

Expressively, infants typically begin using first words around their first birthday (Bloom & Lahey, 1978; Kuhl, 2004; Owens, 1992). Between 18 months to 2 years of age they usually begin to put two words together (Owens, 1992). This occurs around the time they have an expressive vocabulary of 50-80 words (Bloom & Lahey, 1978). At 2 years of age they are on average, able to use short sentences, although they are not complete in nature (with grammatical elements missing) (Brown, 1973). Between the ages of 2 and 3 years the length of infants’ sentences generally continues to increase (known as mean length of utterance – MLU) (Brown, 1973).
While some grammatical structures are used by young children prior to 2 years of age, many more usually begin to emerge after 2 years of age (Brown, 1973; Owens, 1992). These structures can include negatives, question forms, plurals, prepositions, pronouns, present progressive tense, past tense and the possessive –s (Owens, 1992). With the development of grammar, children’s sentences ordinarily develop from a simple form to a more complex level (Paul, 1995b). At 3 years of age they typically begin to use embedded clauses with subordinating and coordinating conjunctions (Brown, 1973). The typical development of grammar and MLU in young children from 1 to 4 years of age is presented in Table 5.1 on the following page. By the time children are ready for school they are usually able to express themselves clearly, reason, and problem-solve (Owens, 1992).
**Auditory Stimulation and Oral Language Development**

Maturation of the auditory pathway, auditory stimulation, language development and optimal
periods for development has been discussed in detail in Chapter 1. In summary, speech
perception skills developed in the first 12 months of life are important for the development of
language in infants with typical hearing (Jusczyk, 2002; Jusczyk et al., 1993; Jusczyl et al.,
1992; Kuhl, 2004; Sininger et al., 1999; Tsao et al., 2004). Oral language skills are acquired
through auditory stimulation and speech perception development (Kuhl, 2004). The later the
auditory stimulation begins, the more difficult speech and language acquisition may be in the long term (Robinson, 1998b). For children with a significant hearing loss, maturation of the auditory system is delayed until they have access to sound (Moore, 2002a; Moore et al., 1994; Ponton et al., 1999; Ponton et al., 2001; Sininger et al., 1999; Tibussek et al., 2002). Therefore if the auditory pathway is to be effectively stimulated, any hearing loss must be identified early, with fitting of hearing aids occurring at as early an age as possible (Ponton et al., 1999; Tibussek et al., 2002).

Early intervention is widely promoted to facilitate ideal language development to take advantage of critical periods of learning (Calderon & Naidu, 2000; Johnson & Newport, 1989; Mayne, Yoshinaga-Itano, & Sedey, 2000; Moeller, 2000; Samson-Fang et al., 2000; Sininger et al., 1999; Yoshinaga-Itano, 2003; Yoshinaga-Itano & Apuzzo, 1998). This is because language is more easily acquired when infants with hearing loss receive auditory and language stimulation at an early age (Singer et al., 1999; Tsao et al., 2004). However, infants with a profound hearing loss often have limited access to speech even with hearing aids (Flexor, 1999). Therefore, speech perception and consequently oral language development are likely to be delayed, regardless of how young an infant with a profound hearing loss received auditory early intervention using hearing aids.

**Profound Hearing Loss and Oral Language Development**

Many current studies of children with hearing impairment and early intervention do not report degree of hearing loss as a significant factor in language development (Calderon & Naidu, 2000; Mayne, Yoshinaga-Itano, Sedey et al., 2000; Moeller, 2000; Robinshaw, 1996; Yoshinaga-Itano & Apuzzo, 1998; Yoshinaga-Itano et al., 1998). This is because the children in these studies used TC. Consequently, these studies provide little insight into the oral language development of infants with a profound hearing loss.

Hearing loss affects the process of oral language acquisition in young children (Flexor, 1999; Jamieson, 1994). Children with mild-moderate hearing loss can often hear sound without hearing aids, but without amplification the acquisition of oral language skills can be impaired. This is particularly likely if they do not receive intervention to assist communication development (Flexor, 1999). Infants with a severe hearing loss are not able to hear speech
without hearing aids, but with amplification they are usually able to hear all speech sounds, which assists their development of their oral communication (Ling, 1989). However, children with profound hearing loss miss many cues in the speech signal even with appropriate amplification (Ling, 1989).

Most infants with a profound hearing loss can be aided in the speech range for low frequency sounds, it can be difficult to amplify high frequency sounds due to the degree of loss (Stelmachowicz, Pittman, Hoover, Lewis, & Moeller, 2004). This means that with hearing aids they may hear sounds that range in frequency up to 1000Hz. From 500-1000Hz, suprasegmental clues such as pitch, duration and intonation can be perceived, as can voiced consonants; all vowels can be detected and some vowels can be identified (Stelmachowicz et al., 2004). Extending hearing to 2000Hz provides more acoustic information, especially cues for voiceless consonants (with the exception of /f/, /s/ and /θ/) and most of the vowels can be identified (Stelmachowicz et al., 2004). For a child with a severe-profound hearing loss the impact of not having access to the frequency of 4000Hz on oral language development may not be significant until Brown’s (1973) Stage II when grammatical markers begin to emerge (see Table 5.1) (Estabrooks, 1998). Infants without aided hearing in the speech range at 4000Hz are not able to hear grammatical markers such as regular plurals (e.g. dogs), possessive -s (e.g. mum’s shoe), and contracted copula (e.g. she’s tall) (Estabrooks, 1998). In addition, other grammatical markers such as regular past tense -ed (e.g. jumped) are difficult to hear as they are not stressed in conversational speech. Although children with a hearing loss can be taught via visual methods (such as lip reading), they require metalinguistic skills to learn the rules for using plurals and other grammatical markers. By the time children are cognitively able to do this, their sentence and grammatical development may already be significantly delayed.

The literature indicates that a profound hearing loss will impact on the development of oral language (Gallaway, 1998; Obenchain et al., 2000; Wallace et al., 2000; Yoshinaga-Itano & Sedey, 2000). However, there is little information on the long-term oral language outcomes of infants with a profound hearing loss in early intervention. Therefore, we do not know how effective early intervention and auditory stimulation are for infants with a profound hearing loss who use hearing aids.
Research on Oral Language Outcomes for Children using Cochlear Implants

Cochlear implants have benefits over hearing aids for children with a profound hearing loss (Svirsky, 2000; Svirsky et al., 2000; Tomblin et al., 1999). Tomblin et al. (1999) compared the English language achievement of children using cochlear implants with children using hearing aids. All subjects were prelingually deaf and used TC. The children with cochlear implants achieved significantly better scores in expressive and receptive language development than those using hearing aids. Tomblin et al. also found that the language scores of the cochlear implant users increased over the years of cochlear implant use. That is, the cochlear implant group did not plateau in their language development but continued to show improvement. The rate of improvement for the cochlear implant users was significantly better than that of the hearing aid users. This led the authors to suggest that continued divergence in language skills should be expected between those with hearing aids and those with cochlear implants.

The findings of improved rate of language development after cochlear implantation were supported by the research of Svirsky et al. (2000), who examined the language development of children pre- and post-cochlear implantation. They found that the rate of language development after implantation exceeded that expected from unimplanted deaf children and was similar to that of children with normal hearing. They also reported that while there was little overall language development of the children using TC or oral communication, the children using oral communication were better oral communicators than those using sign and speech. Despite these positive findings on the auditory input of the cochlear implant, there is conflicting evidence in the literature as to which communication mode produces the better language outcomes for children who receive cochlear implants.

In many of the relevant studies, observations have been made between communication modes of the children with profound hearing loss using cochlear implants. Some have found no difference in language outcomes (Calderon & Naidu, 2000; McDonald Connor, Hieber, Arts, & Zwolan, 2000; Moeller, 2000) when using TC or oral language, whereas others have found that oral education led to better language skills (Geers, 2002; Geers, Nicholas et al., 2003). McDonald Connor et al. (2000) studied the speech, vocabulary and education (oral or TC) of 147 children who received cochlear implants in the preschool years or at elementary school age. They studied the relationship between teaching method and consonant production accuracy and vocabulary development. They found that across all the children in the study
there was little difference between the oral and TC groups for receptive vocabulary development and rate of improvement of vocabulary development. This is supported in outcomes of other studies of language outcomes of children with hearing loss (Calderon & Naidu, 2000; Moeller, 2000). However, these studies are not necessarily reporting oral language outcomes.

In contrast, Geers (2002) found that oral education facilitated better language skills than TC. She evaluated factors contributing to speech, language and literacy development in 136 children who had received a cochlear implant before 5 years of age. A battery of tests was used to evaluate speech perception, speech production, language (assessed both verbally and using TC) and reading after 4 to 6 years of cochlear implant use. After 4 to 6 years of cochlear implant use, the factors most strongly associated with achievement in auditory, speech, language and reading skills were nonverbal IQ, implant functioning and use of oral communication mode.

In another study, Geers, Nicholas et al. (2003) examined factors associated with the development of receptive and expressive language skills after cochlear implantation. A subject sample of 181 8- and 9-year-old children with cochlear implants who had received a cochlear implant before 5 years of age was used. Approximately half of the subjects used TC and the remaining subjects used oral communication. Results showed that the children with cochlear implants using oral communication had better language skills than those using TC. The better language skills were in number of words used, number of bound morphemes and number of syntactically complex structures.

While there is no strong support for one communication mode over another, it is consistently reported in the literature that the earlier a child receives a cochlear implant the better the outcome (Geers, Nicholas et al., 2003; Houston et al., 2003; Robinson, 1998a; Svirsky et al., 2000). In most studies of language outcomes, the children have been implanted in the preschool or school years. Therefore, comparisons of “early” versus “late” are often made between those implanted before or after 5 years of age (Geers, 2003; Geers & Brenner, 2003; Geers, Nicholas et al., 2003; McDonald Connor et al., 2000; Tye-Murray et al., 1995; Uchanski & Geers, 2003), or before and after 3 years (Miyamoto, Houston, Iler Kirk, Perdew,
& Svirsky, 2003). However, ideal early intervention has now been defined as ideally being less than 6 months but definitely not later than 12 months (Calderon & Naidu, 2000; Mayne, Yoshinaga-Itano, & Sedey, 2000; Mayne, Yoshinaga-Itano, Sedey et al., 2000; Moeller, 2000; Svirsky, 2000; Svirsky et al., 2000; Tomblin et al., 1999; Yoshinaga-Itano & Apuzzo, 1998; Yoshinaga-Itano & Sedey, 2000; Yoshinaga-Itano et al., 1998). For infants with a profound hearing loss, for whom hearing aids provide minimal access to speech sounds, receiving cochlear implants in the preschool years does not correlate with the redefined term of early intervention. At present, only a few studies are available on the language development of infants with a profound hearing loss who receive a cochlear implant near their first birthday (Houston et al., 2003).

**Cochlear Implantation in Infants and the Effect on Language Development**

The lack of information about cochlear implants in young children is largely attributable the failure to identify hearing loss in infancy (Wood et al., 1986; Yoshinaga-Itano & Stredler-Brown, 1992). A study by Houston et al. (2003) described in Chapter 1, has evaluated one aspect of language in infants who received cochlear implants at a young age. In summary, the authors compared the pre-word-learning skill (ability to pair sounds with objects) of typically developing infants with infants who received cochlear implants between 7 and 15 months of age; and between 16 and 23 months. After 2 to 6 months of cochlear implant use, only the infants who received their cochlear implants between 7 and 14 months of age had pre-word-learning skills similar to those of their hearing peers. That study is limited in the area investigated. The authors state that pre-word learning ability is an important prerequisite of word learning, which in turn is an important component of language learning. However, the ability to pair a sound with an object (pre-word learning) does not provide predictive information for future language development or information regarding how the child uses communication. However, the study did demonstrate the reduction in language age gap between infants with typical hearing and infants with a profound hearing loss who receive cochlear implants between 7 and 15 months of age.

Infants with a profound hearing loss have been found to have a language delay before they receive a cochlear implant. Studies show that cochlear implantation stops the language age gap from widening (Novak et al., 2000; Svirsky et al., 2000). Therefore, it would seem logical
that the earlier they receive an effective device for their hearing, the more likely it would be
that the gap in language between the infant with a hearing loss and a typically developing
infant is reduced. However, there are no studies examining the effect of cochlear implanta-
tion on the early oral language development of an infant with a profound hearing loss.

**The Purpose of this Study**
The aim of this study is to answer the following questions.

1. Does early auditory intervention result in sequential and age appropriate receptive and
   expressive language development (MLU, grammar and general language) for infants
   with a profound hearing loss?
2. What is the impact of early cochlear implantation on the sequential and age
   appropriate receptive and expressive language development (MLU, grammar and
   general language) for infants with a profound hearing loss?

**Method**
The language development of the infants was assessed longitudinally, using parent-child
interactions and parent questionnaires as well as standardised assessments. The parent-child
interactions formed the functional assessment. From the interactions spontaneous language
samples were obtained from the child. The spontaneous language samples were analysed for
mean length of utterance and grammatical development. The comprehensive questionnaire
provided the parents’ perspective on their child’s development. Finally, the standardised
assessment allowed comparison of the development of the infants in this study with typical
development.

**Functional Language Assessment**
A functional or non-standardised assessment can provide more accurate information on the
mistakes a child makes in conversation than standardised assessments can (Paul, 1995b), and
may fill the gaps in standardised assessments used with young children (Bain, Olswang, &
Johnson, 1992; Robinshaw & Evans, 1996). However, functional assessments should not be
used in isolation as they may not accurately identify expressive language areas in which children are performing significantly worse than their age matched peers.

The data for the functional assessment were collected using videotaped parent-child interactions. While videotaped interactions were recorded at regular intervals pre- and post-cochlear implantation, only the videos 12 and 18 months post-cochlear implantation were used in order to study the infants’ language development. The rationale for this was that the infants were only consistently producing verbal utterances at the assessments 12 and 18 months post-implantation. First words were observed in the infants 2-5 months post-implantation, but at that time the majority of the infants were considered to be emerging from the prelinguistic stage and not completely verbal in their communication. The infants were also aged between 21 and 30 months at 12 months post implantation, which was the first assessment point where progress such as grammatical development could be compared with that of hearing peers. The videotaping of the parent and child was detailed in Chapter 2.

**ANALYSIS OF FUNCTIONAL ASSESSMENT OF LANGUAGE**

The infants’ language elicited in the parent-child interaction was analysed using the Systematic Analysis of Language Transcripts (SALT) (Miller, Chapman, & Nockerts, 2002), 12 and 18 months post-cochlear implantation. For SALT analysis the entire sample of intelligible utterances was transcribed and entered into the computer program. The SALT program provides comprehensive reports based on the language samples, including mean length of utterance (MLU), word roots, grammar, sentence types (e.g. questions and statements) and discourse analysis. Only MLU and grammar were evaluated as the children were in the developing phase of language development (Paul, 1995b).

**Functional Expressive Language Assessment – MLU**

A child’s MLU is obtained by a functional assessment procedure, often calculated from a language sample obtained from a videotaped interaction. MLU represents the average length of an infant’s sentences or utterances. It is calculated by adding together the number of morphemes (words and bound morphemes such as plural –s, etc.) within each utterance from a spontaneous language sample. The MLU is the total number of morphemes divided by the number of utterances within the entire language sample. This formula is based on the work of Brown (1973) who reported typical MLU development (see Table 5.1) in infants and young
children. Brown (1973) found that MLU progressed in stages related to age. The benefit of using MLU is that it is a useful guide to syntactic development (Paul, 1995b).

**Functional Expressive Language Assessment – Grammatical Development**

The use of grammatical analysis in addition to MLU may provide more valid information about the child’s expressive language development (Paul, 1995b). In addition, analysis of a child’s grammatical development from a spontaneous language sample can identify children with specific language impairment (Dunn, Flax, & Sliwinski, 1996). Grammatical development begins at Brown’s Stage II when a child is consistently producing two-word utterances. This stage typically develops between 27-29 months. Only a few grammatical forms are evident before a child turns two, in Late Stage I.

**RELIABILITY OF FUNCTIONAL ANALYSES**

Consensus agreement between the raters was used for scoring MLU and grammatical development on all videotapes. The researcher and an independent speech pathologist analysed the infants’ language. If an utterance was agreed upon during the initial viewing of the behaviour it was rated and credited to the child. However, if there was disagreement, the utterance was reviewed and if consensus was not reached on the second viewing it was discarded.

**Parent Questionnaire – Vineland Adaptive Behavior Scales**

Language development data from the pre-implant phase to 18 months post-cochlear implantation were obtained using the Vineland Adaptive Behavior Scales (Sparrow et al., 1984). Administration details of the Vineland are provided in Chapter 2.

**ANALYSIS OF PARENT QUESTIONNAIRE**

The behaviours and skills listed on the questionnaire were scored or coded for each infant according to the information provided by the parent and using the scoring criteria in the Vineland Manual. The score allocated for a skill depended on the child’s level of development. The child received a mark of [2] if the activity or skill was performed habitually, [1] if it was emerging but not habitual, and [0] if it was never performed.
Alternatively, if a score could not be allocated to the behaviour or skill, it was coded. That is, [DK] (don’t know) was marked on the questionnaire if the parent had no knowledge of whether the child could perform the skill, and [N] was marked if there was “no opportunity” for the activity to occur e.g. a parent could not say the child had cutting skills because the child was permitted to use scissors. The infant’s scores were tallied for each section on completion of the analysis.

**Standardised Language Assessment**
The Reynell Developmental Language Scales – III (Edwards et al., 1997) is a standardised language test used with children aged 21 months to 7 years. This test was used to assess the language of the infants in the study at the 12- and 18-month assessments. At the assessment 12 months post-implantation all infants were old enough to be administered this assessment. If the first tasks of this test were too difficult for the infant, the Preschool Language Scales – 3 (Zimmermen et al., 1991) was administered. The Preschool Language Scales – 3 is also a standardised assessment that can be used with children from birth to 6 years of age. The standardised assessment procedures are detailed in Chapter 2.

**Results**

**Functional Language Assessment Systematic Analysis of Language Transcripts (SALT) – Overview**
SALT was used to analyse the infants’ functional language assessment. Data were analysed for mean length of utterance (MLU) and grammatical development. The SALT analyses at 18 months post-implantation showed that only one infant (Infant 7) had an MLU consistent with her chronological age. The MLU of the remaining infants was at a level consistent with their cochlear implant age. Only three (Infants 1, 6 and 7) of the seven infants used grammatical forms appropriate for their chronological age, while one infant (Infant 5) used forms equivalent to her hearing age. The remaining three infants (2, 3 and 4) had grammatical development that was delayed relative to their hearing age but equivalent to their cochlear implant age. Results for both MLU and grammatical development are discussed in detail in the following section.
**FUNCTIONAL LANGUAGE ASSESSMENT – MLU**

**MLU 12 Months Post-cochlear Implantation:** Table 5.2 shows the infants’ MLU development 12 and 18 months post-cochlear implantation. All infants were at a single-word level 12 months post-cochlear implantation. The MLU ranged from 1.15 to 1.77 with a mean of 1.4. Three of the seven infants (Infants 1, 6 and 8) were at Brown’s Early Stage I and four infants (3, 4, 5, and 8) were at Brown’s Late Stage I.

**MLU 18 Months Post-cochlear Implantation:** At 18 months post-implantation the group mean MLU increased slightly from 1.4 at 12 months post-implantation to 1.7. Six of the seven infants had increased their MLU and Infant 4 regressed. Four infants (Infants 1, 3, 5 and 6) were at Brown’s Late Stage I, which is the same number of infants at this level of MLU development, 12 month post-cochlear implantation. Only one infant (Infant 7) progressed beyond Brown’s Late Stage I. Infant 7 progressed to Brown’s Stage III with an MLU of 2.51. Infants 4 and 2 had the smallest MLU, and their results placed them at Brown’s Early Stage I.

**Table 5.2: Mean length of utterance 12 and 18 months post-implantation. SALT analysis has allocated a Brown’s stage of MLU development and the typical age range for that stage of MLU**

<table>
<thead>
<tr>
<th>Infant</th>
<th>12 months Post-implantation</th>
<th>18 months Post-implantation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chronological Age</td>
<td>MLU</td>
</tr>
<tr>
<td>1</td>
<td>28</td>
<td>1.23</td>
</tr>
<tr>
<td>2</td>
<td>34</td>
<td>1.27</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
<td>1.56</td>
</tr>
<tr>
<td>4</td>
<td>26</td>
<td>1.54</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>1.54</td>
</tr>
<tr>
<td>6</td>
<td>21</td>
<td>1.4</td>
</tr>
<tr>
<td>7</td>
<td>28</td>
<td>1.77</td>
</tr>
<tr>
<td>8</td>
<td>22</td>
<td>1.15</td>
</tr>
</tbody>
</table>

*Not available for assessment*
Functional Assessment – MLU Development compared with Chronological Age, Hearing Age and Cochlear Implant Age

The following sections report MLU results compared to typical MLU development (in analysis relative to chronological age). Where infants were delayed relative to chronological age their results were analysed relative to their hearing age (i.e. their age minus the age at which they received a hearing aids) or their cochlear implant age (their chronological age minus the age at which their cochlear implant was activated).

**MLU Development: Chronological Age**

Figure 5-A shows the infants’ MLU development 12 and 18 months post-cochlear implantation compared with their chronological age. MLU was developing commensurately with chronological age for three infants (Infants 3, 6 and 8) 12 months post-implantation; and for Infant 7 at the assessment 18 months post-implantation.

**MLU Development: Hearing Age**

Figure 5-B, on the following page, shows the infants’ MLU development 12 and 18 months post-cochlear implantation compared with their hearing age. Infants’ MLU was equivalent to hearing age at the 12-month assessment only. This was the case for four infants (Infants 1, 4, 5 and 7).
Figure 5-B: Mean length of utterance 12 and 18 months post-cochlear implantation, based on hearing age. Results above ‘0’ the line indicate MLU development equivalent to hearing age. Results below the line indicate delay compared to hearing age.

**MLU Development: Cochlear Implant Age**

Figure 5-C shows the infants’ MLU development 12 and 18 months post-implantation compared with their cochlear implant age. Development was commensurate with cochlear implant age at the 18-month assessment only. This was the case for six (Infants 1-6) of the seven infants.

Figure 5-C: Mean length of utterance 18 months post-cochlear implantation, based on cochlear implant age. Results above the ‘0’ line indicate MLU development equivalent to cochlear implant age. Results below the line indicate delay relative to cochlear implant age.

**FUNCTIONAL LANGUAGE ASSESSMENT – GRAMMATICAL DEVELOPMENT**
A summary of the infants’ grammatical development 12 months post-cochlear implantation is presented in Table 5.3 and 18 months post-cochlear implantation in Table 5.4, on the following page.

**Grammatical Development 12 Months Post-cochlear Implantation:** By 12 months post-implantation, six of the seven infants had used some form of grammatical structure. Three infants (Infants 1, 3 and 6) used only the negative “no”. Another three infants (5, 7 and 8) used a range of grammatical structures including possessive pronouns, prepositions, early question forms, present progressive (-ing), plurals, and possessive /-s/. Infant 7 demonstrated the greatest grammatical development of the group. Infant 4 had not developed any grammatical structures 12 months post-implantation.

**Grammatical Development 18 Months Post-cochlear Implantation:** By 18 months post-cochlear implantation, four of the seven infants (Infants 1, 5, 6 and 7) demonstrated an increase in use of grammar since the assessment 12 months post-implantation. Grammatical structures used by these four infants included plurals, questions, negatives, demonstratives, prepositions, articles, personal pronouns, the conjunction “and”, possessive pronouns, copulas, and the present progressive form “-ing”. Three infants (2, 3 and 4) did not use any grammatical forms.
Table 5.3: The infants’ grammatical development 12 months post-implantation

<table>
<thead>
<tr>
<th>-ing</th>
<th>Plural</th>
<th>Question</th>
<th>Negative</th>
<th>Article</th>
<th>Conjunction</th>
<th>Personal Pronoun</th>
<th>Possessive Pronoun</th>
<th>Possessive -s</th>
<th>Demonstrative</th>
<th>Copula</th>
<th>Preposition</th>
<th>Yes/no</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant 1</td>
<td>no</td>
<td>no</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>no, yes</td>
</tr>
<tr>
<td>Infant 2</td>
<td>No Assessment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infant 3*</td>
<td>no</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infant 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infant 5</td>
<td>no</td>
<td>me</td>
<td>mine, my</td>
<td></td>
<td>in</td>
<td>no</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infant 6</td>
<td>no</td>
<td>no</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infant 7</td>
<td>✓</td>
<td>✓</td>
<td>where</td>
<td>no, don’t</td>
<td>✓</td>
<td>off, outside</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>no</td>
</tr>
<tr>
<td>Infant 8</td>
<td>where</td>
<td>no</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
* Infant deemed to have normal severity of involvement (as discussed in previous chapter)

Table 5.4: The infants’ grammatical development 18 months post-implantation

<table>
<thead>
<tr>
<th>-ing</th>
<th>Plural</th>
<th>Questions</th>
<th>Negatives</th>
<th>Article</th>
<th>Conjunctions</th>
<th>Personal Pronoun</th>
<th>Possessive Pronouns</th>
<th>Possessive -s</th>
<th>Demonstrative</th>
<th>Copula</th>
<th>Preposition</th>
<th>Yes/no</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant 1</td>
<td>✓</td>
<td>what, where</td>
<td>no, not</td>
<td>a</td>
<td>they, you, it</td>
<td>my</td>
<td>✓</td>
<td>that, these</td>
<td>is, are</td>
<td>in, top</td>
<td>no, yep</td>
<td></td>
</tr>
<tr>
<td>Infant 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infant 3*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infant 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infant 5</td>
<td>✓</td>
<td>where</td>
<td>no,</td>
<td>my</td>
<td>✓</td>
<td>that, this</td>
<td>in, on</td>
<td>no, yeah,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infant 6</td>
<td>✓</td>
<td>what, where</td>
<td>no, don’t</td>
<td>the, a</td>
<td>and</td>
<td>he, it, we</td>
<td>my, mine</td>
<td>that, this</td>
<td>is</td>
<td>in</td>
<td>nah, no</td>
<td></td>
</tr>
<tr>
<td>Infant 7</td>
<td>✓</td>
<td>✓</td>
<td>what, where, which</td>
<td>no, don’t</td>
<td>the</td>
<td>and</td>
<td>it, they</td>
<td>✓</td>
<td>that</td>
<td>are,</td>
<td>is</td>
<td></td>
</tr>
<tr>
<td>Infant 8</td>
<td>No Assessment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
* Infant deemed to have normal severity of involvement (as discussed in previous chapter)
Grammatical Development compared with Chronological Age, Hearing Age and Cochlear Implant Age

The infants’ grammatical development was compared to typical development as described by Brown (1973) and Owens (1992). Table 5.5 and Table 5.6 show the infants’ grammatical development relative to chronological age, hearing age and cochlear implant age 12 and 18 months post-cochlear implantation, respectively.

Table 5.5: Grammatical development 12 months post-implantation, compared to chronological age, hearing age, and cochlear implant age.

<table>
<thead>
<tr>
<th>Infant</th>
<th>Chronological Age (months)</th>
<th>Hearing Age (months)</th>
<th>Grammatical Age (months)</th>
<th>Equivalent to CA, HA or CIA</th>
<th>Typical Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant 1</td>
<td>28</td>
<td>21</td>
<td>&lt; 24</td>
<td>HA or CIA ?</td>
<td>≤2 years</td>
</tr>
<tr>
<td>Infant 2</td>
<td>26</td>
<td>23</td>
<td>12</td>
<td>Hearing age</td>
<td>2;0 – 2;6 years</td>
</tr>
<tr>
<td>Infant 3</td>
<td>25</td>
<td>22</td>
<td>&lt; 24</td>
<td>Hearing age, Cochlear implant age</td>
<td></td>
</tr>
<tr>
<td>Infant 4</td>
<td>26</td>
<td>23</td>
<td>12</td>
<td>Hearing age, Cochlear implant age</td>
<td></td>
</tr>
<tr>
<td>Infant 5</td>
<td>30</td>
<td>24</td>
<td>24</td>
<td>Hearing age</td>
<td>3 years</td>
</tr>
<tr>
<td>Infant 6</td>
<td>21</td>
<td>20</td>
<td>&lt; 24</td>
<td>CA, HA or CIA?</td>
<td></td>
</tr>
<tr>
<td>Infant 7</td>
<td>28</td>
<td>21</td>
<td>30</td>
<td>Chronological age</td>
<td></td>
</tr>
<tr>
<td>Infant 8</td>
<td>22</td>
<td>20</td>
<td>&lt; 24</td>
<td>CA, HA or CIA?</td>
<td></td>
</tr>
</tbody>
</table>

<sup>o</sup> Not available for assessment

<sup>?</sup> Difficulty determining level of development. The ages in question were below 2 years, when limited grammatical development has occurred

Grammatical Development: Chronological Age

At the assessment 12 months post-cochlear implantation, only one infant (Infant 7) had grammatical development equivalent to her chronological age. At the 18-month assessment the grammatical development of three infants (1, 6 and 7) was appropriate for their chronological age.

Grammatical Development: Hearing Age

Two infants (Infants 3 and 5) had grammatical development equivalent to their hearing age, 12 months post-cochlear implantation. It is possible that Infant 1’s development was also progressing at a rate consistent with her hearing age. However, this possibility was difficult to
confirm because her development was at an approximate age equivalent of less than 2 years and both hearing age and cochlear implant age were below 2 years. At the 18-month assessment, the development of Infant 5 was appropriate for her hearing age.

Table 5.6: Grammatical development 18 months post-implantation, based on chronological age, hearing age, and cochlear implant age.

<table>
<thead>
<tr>
<th>Chronological Age (months)</th>
<th>Hearing Age (months)</th>
<th>Grammatical Age (months)</th>
<th>Equivalent to CA, HA or CIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant 1</td>
<td>34</td>
<td>27</td>
<td>30-36</td>
</tr>
<tr>
<td>Infant 2</td>
<td>34</td>
<td>27</td>
<td>12-18</td>
</tr>
<tr>
<td>Infant 3</td>
<td>31</td>
<td>29</td>
<td>12-18</td>
</tr>
<tr>
<td>Infant 4</td>
<td>32</td>
<td>29</td>
<td>12-18</td>
</tr>
<tr>
<td>Infant 5</td>
<td>37</td>
<td>31</td>
<td>24-30</td>
</tr>
<tr>
<td>Infant 6</td>
<td>30</td>
<td>29</td>
<td>30-36</td>
</tr>
<tr>
<td>Infant 7</td>
<td>34</td>
<td>27</td>
<td>36</td>
</tr>
<tr>
<td>Infant 8^</td>
<td>(months)</td>
<td>(months)</td>
<td>(months)</td>
</tr>
</tbody>
</table>

^ Not available for assessment

? Difficulty determining level of development. The ages in question were below 2 years, when limited grammatical development has occurred

Grammatical Development: Cochlear Implant Age

Infant 4 had grammatical development equivalent to his cochlear implant age 12 months post-cochlear implantation. Another two of the infants (Infants 6 and 8) had chronological age, hearing age and cochlear implant age all under 2 years. As there is no specific information on typical grammatical development prior to 2 years, their grammatical development could not be appropriately assessed relative to age. At the 18-month assessment, the grammatical development of three infants (2, 3 and 4) was equivalent to their cochlear implant age. However, it is possible that their development was more delayed than this, as they did not demonstrate any grammatical structures in their spontaneous language, whereas grammatical structures do appear in the language of typically developing children prior to 2 years of age.
Parent Questionnaire – Vineland Adaptive Behavior Scales: Overview

The results for each infant for receptive and expressive language development for each assessment over the 2 years of the study are presented in Figure 5-D on the following page.

**VINELAND RECEPTIVE & EXPRESSIVE LANGUAGE**

Vineland Receptive Language Pre-cochlear Implantation: No infant had typical receptive language development for the entire pre-implant period. The receptive language skills for four infants (Infants 1, 3, 4 and 5) were delayed throughout the entire pre-implant period. The remaining three infants (6, 7 and 8) moved in and out of the normal range.

Vineland Receptive Language Post-cochlear Implantation: The results of the Vineland receptive language scale post-implantation showed that four infants (Infants 1, 2, 7, and 8) had typical receptive language development throughout the post-implant period. (Note that Infant 2 had no data for the assessment 12 months post-implantation and Infant 8 had no data for assessments 3 months and 18 months post-implantation.) Infant 4 had delayed receptive language throughout the entire post-cochlear implant period. The remaining infants (3, 5 and 6) moved in and out of the normal range for receptive language skills during this time.

Vineland Expressive Language Pre-cochlear Implantation: All infants in the study had normal expressive language skills as measured by the Vineland for most if not all of the pre-cochlear implant period, with the exception of Infant 8.

Vineland Expressive Language Post-cochlear Implantation: No infant was able to maintain typical expressive language development as measured by the Vineland, throughout the entire post-implantation period. Three infants (Infants 6, 7, and 8) demonstrated normal expressive language skills during most of the post-implant phase of the study. (Note there are not data for Infant 8, 3 and 18 months post-implantation.) Infant 3 demonstrated normal expressive language to 6 months post-cochlear implantation, but completed the study with delayed skills. The remaining infants (1, 2, 4, and 5) had delayed expressive language throughout most of the post-implant period.
Figure 5-D: Receptive and expressive language development as measured by the Vineland Adaptive Behavior Scales, pre- and post-cochlear implantation: a two year period
Figure 5-D: Receptive and expressive language development as measured by the Vineland Adaptive Behavior Scales, pre- and post-cochlear implantation: a two year period
Vineland Receptive and Expressive Language compared with Chronological Age, Hearing Age and Cochlear Implant Age

Each infant’s performance for expressive and receptive language on the Vineland at 12 and 18 months was analysed relative to the chronological age (see Table 5.7), hearing age (see Table 5.8), and cochlear implant age (see Table 5.9). Where an infant was performing at a level consistent with his or her chronological age, development was not considered for hearing age or cochlear implant age as chronological age represented the highest level of expected performance.

Vineland Receptive and Expressive Language: Chronological Age

12 months post-cochlear implantation, the receptive language development for five of the seven infants (Infants 1, 3, 6, 7 and 8) was equivalent to their chronological age. At the 18-month assessment five of the seven infants (1, 2, 3, 5 and 7) had receptive language skills developing equivalent to their chronological age.

Two (Infants 7 and 8) of the seven infants had expressive language skills developing consistent with their chronological age, 12 months post-implantation. Three infants (1, 6 and 7) had expressive skills equivalent to their chronological age, 18 months post-implantation (see Table 5.7).

Table 5.7: Receptive and expressive language development results from the Vineland Adaptive Behavior Scales, 12 and 18 months post-cochlear implantation compared to chronological age.

<table>
<thead>
<tr>
<th>Infant</th>
<th>Receptive Language</th>
<th>Expressive Language</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12 months</td>
<td>18 months</td>
</tr>
<tr>
<td>Infant 1</td>
<td>above average</td>
<td>average</td>
</tr>
<tr>
<td>Infant 2</td>
<td>average</td>
<td>average</td>
</tr>
<tr>
<td>Infant 3</td>
<td>average</td>
<td>average</td>
</tr>
<tr>
<td>Infant 4</td>
<td>very delayed</td>
<td>delayed</td>
</tr>
<tr>
<td>Infant 5</td>
<td>delayed</td>
<td>average</td>
</tr>
<tr>
<td>Infant 6</td>
<td>average</td>
<td>delayed</td>
</tr>
<tr>
<td>Infant 7</td>
<td>average</td>
<td>average</td>
</tr>
<tr>
<td>Infant 8</td>
<td>average</td>
<td>average</td>
</tr>
</tbody>
</table>

Not available for assessment
**Vineland Receptive and Expressive Language: Hearing Age**
The receptive language of Infant 5 was equivalent to her hearing age, 12 months post-cochlear implantation. The expressive language development for three infants (Infants 1, 5 and 6) was equivalent to their hearing age 12 months post-cochlear implantation. No infant had expressive language development commensurate with hearing age 18 months post-implantation.

<table>
<thead>
<tr>
<th>Infant 1</th>
<th>Infant 2</th>
<th>Infant 3</th>
<th>Infant 4</th>
<th>Infant 5</th>
<th>Infant 6</th>
<th>Infant 7</th>
<th>Infant 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receptive Language</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 months</td>
<td>average</td>
<td>delayed</td>
<td>delayed</td>
<td>average</td>
<td>delayed</td>
<td>delayed</td>
<td>delayed</td>
</tr>
<tr>
<td>18 months</td>
<td></td>
<td></td>
<td></td>
<td>delayed</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.8: Receptive and expressive language development results from the Vineland Adaptive Behavior Scales, 12 and 18 months post-cochlear implantation compared to hearing age.

**Vineland Receptive and Expressive Language: Cochlear Implant Age**
Infant 4 had receptive language skills equivalent to his cochlear implant age, 12 months post-implantation. At the 18-month assessment, two infants (4 and 6) had receptive language development equivalent to their cochlear implant age.

Two infants (Infants 3 and 4) had expressive language development equivalent to their cochlear implant age at the 12-month assessment. At the 18-month assessment four infants (2, 3, 4 and 5) had expressive language equivalent to their cochlear implant age. See Table 5.9 on the following page.
Table 5.9: Receptive and expressive language development results from the Vineland Adaptive Behavior Scales, 12 and 18 months post-cochlear implantation compared to cochlear implant age.

<table>
<thead>
<tr>
<th>Infant 1</th>
<th>Infant 2</th>
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VINELAND COMMUNICATION DOMAIN

Figure 5-E on the following pages, presents the result of the infants’ communication skills using the Vineland Communication Domain, over the entire period of the study. The results marked by the brown line represent the infants’ skills compared to hearing peers or chronological age. Over the course of the study the infants moved in and out of the normal range for communication development. The trend appeared to reflect a decline in communication skills relative to typically developing peers as the infants progressed through the post-cochlear implant phase. Two infants (Infants 7 and 8) were within the normal range over the entire course of the study. Only Infant 4 demonstrated delayed communication skills throughout both the pre- and post-cochlear implantation periods. At the final assessment 18 months post-implantation, three of the seven infants (1, 6 and 7) had communication developing commensurately with their chronological age.
Figure 5-E: Vineland communication development (combined receptive, expressive and written language) pre- and post-cochlear implantation based on chronological age, hearing age and cochlear implant age.
Figure 5-E: Vineland communication development (combined receptive, expressive and written language) pre- and post-cochlear implantation based on chronological age, hearing age and cochlear implant age.
Vineland Communication Domain Pre-cochlear Implantation:
Figure 5-E demonstrates that prior to cochlear implantation, six (Infants 2, 3, 5, 6, 7 and 8) of the eight infants had communication skills developing consistent with their chronological age, throughout the entire pre-cochlear implant period. Two infants (1 and 4) had delayed communication development during the pre-cochlear implant phase.

Communication Domain Post-cochlear Implantation: Three infants (Infants 6, 7, and 8) had normal communication development throughout the post-implantation phase of the study. Infant 1 began the post-implantation period with delayed communication skills, but by 6 months post-cochlear implantation was within the normal range. Four infants (2, 3, 4 and 5) had delayed communication development for most (Infants 2 and 3) or all (Infants 4 and 5) of the post-cochlear implant period of the study.

Vineland Communication Domain Results compared with Chronological Age, Hearing Age, and Cochlear Implant Age

Figure 5-E presents the data obtained from the Vineland compared with each child’s chronological age (brown line), hearing age (orange line) and cochlear implant age (green line).

Communication Development: Chronological Age
Three infants (Infants 1, 7 and 8) had communication development equivalent to their chronological age, 12 months post-cochlear implantation. At 18 months post-cochlear implantation, three (1, 6 and 7) of the seven infants available for assessment had communication development equivalent to their chronological age.

Communication Development: Hearing Age
Three infants (Infants 3, 5 and 6) had communication development equivalent to their hearing age at the 12-month assessment. The communication development of Infant 5 continued to be equivalent to her hearing age at the 18-month assessment.
Communication Development: Cochlear Implant Age
The communication development of Infant 4 was equivalent to his cochlear implant age, 12 months post-implantation. At the 18-month assessment, three infants (Infants 2, 3 and 4), had communication development delayed relative equivalent to their cochlear implant age.

Summary of Vineland Results
Analysis of the results of the Vineland Scales showed that throughout the course of the study the infants moved in and out of the normal range for receptive, expressive and communication development. By 18 months post-implantation, two infants (Infants 1 and 7) had all areas developing consistent with their chronological age. For Infant 5 the receptive, expressive and communication areas assessed were developing consistent with her hearing age. Three infants (Infants 2, 3 and 4) showed development equivalent to their cochlear implant age. Their rate of development was slower than that of the other infants in the group.

Standardised Assessments
At 12 months post-implantation, five of seven infants (Infants 1, 5, 6, 7 and 8) were assessed using the RDS-III, with two other infants (3 and 4) being assessed with the PLS-3. Four infants (1, 5, 6 and 7) were assessed with the RDS-III at the 18-month assessment and three infants (2, 3 and 4) were assessed with the PLS-3. The results for each infant on the expressive language assessments at 12 and 18 months post-implantation are presented in Figure 5-F. Results indicated that few infants had typical language skills as assessed on standardised assessment.

STANDARDISED ASSESSMENT – RECEPTIVE LANGUAGE
Figure 5-F shows the infants’ receptive and expressive language results on standardised assessment compared with typically developing peers. Infant 6 had receptive language developing within the normal range 12 months post-implantation. For the remaining infants receptive language was delayed. At the next assessment, 18 months post-cochlear implantation, Infant 7 had normal receptive language skills. For the remaining six infants, receptive language development was delayed relative to their chronological age.
STANDARDISED ASSESSMENT – EXPRESSIVE LANGUAGE

Three of the seven infants (Infants 6, 7 and 8) had expressive language skills within the normal range 12 months post-implantation. The expressive language development of the remaining four infants (1, 3, 4 and 5) was delayed. At the next assessment, 18 months post-implantation, Infant 7 had normal expressive language skills. The expressive language development of all other infants was delayed.

![Graph showing expressive language development](image)

**Figure 5-F:** Results of standardised assessments for receptive language (RL) and expressive language (EL) at 12 months and 18 months post-implantation based on chronological age of infants

**Standardised Language Assessment Results compared with Chronological Age, Hearing Age and Cochlear Implant Age**

The infants’ receptive and expressive language results were analysed relative to chronological age and hearing age. The results for chronological age were discussed in the previous section and presented in Figure 5-F. Results compared with hearing age are presented in Figure 5-G and discussed below. Results were not compared to the infants’ cochlear implant age. This is because most of the infants were assessed with the RDS-III, which does not have normative data for ages 12 and 18 months. Therefore, their results could not be compared to their cochlear implant ages 12 and 18 months post-cochlear implantation. In addition, where infants were performing at a level consistent with their chronological age, their performance was not considered for hearing age. This was for the reason that chronological age represented the highest level of expected competence.
Figure 5-G: Results of standardised assessments for receptive language (RL) and expressive language (EL) at 12 months and 18 months post-implantation based on hearing age of infants. The transparent bars indicate that development was commensurate with the infant’s chronological age.

**Standardised Receptive Language: Chronological Age**
Infant 6 had receptive language development equivalent to his chronological age 12 months post-implantation. Infant 7 had receptive language development equivalent to her chronological age 18 months post-cochlear implantation.

**Standardised Expressive Language: Chronological Age**
The expressive language development of three infants (Infants 6, 7 and 8) was equivalent to their chronological age 12 months post-implantation. At the next assessment, 18 months post-implantation, Infant 7 was the only infant who had expressive language skills equivalent to her chronological age.

**Standardised Receptive Language: Hearing Age**
The receptive language skills of three infants (Infants 1, 5 and 7) were equivalent to their hearing age, 12 months post-implantation. For the remaining three infants (3, 4 and 8), receptive language development was delayed relative to their hearing age. At the 18-month assessment, the receptive language development of Infant 1 was equivalent to her hearing age.
For five infants (2, 3, 4, 5 and 6), receptive language skills were delayed relative to their hearing age (see Figure 5-G).

**Standardised Expressive Language: Hearing Age**

The expressive language development of two infants (Infants 3 and 5) was equivalent to their hearing age 12 months post-cochlear implantation. For the remaining two infants (1 and 4) expressive language was delayed relative to their hearing age. At the 18-month assessment the expressive language development of two infants (1 and 5) was equivalent to their hearing age. Four infants (2, 3, 4 and 6) had expressive language skills delayed relative to their hearing age (see Figure 5-G).

**Summary of Language Results**

The language results were variable throughout the study. An overview of the infants’ language development 12 and 18 months post-implantation is provided in Table 5.10 and Table 5.11 respectively.

At 12 months post-cochlear implantation, three infants (Infants 6, 7 and 8) had many aspects of language developing commensurate with their chronological age. (Note that Infant 2 was not available for assessment 12 months post-cochlear implantation) This is evident in the table below.

At the 18-month assessment only Infant 7 had language development commensurate with her chronological age, with two infants (1 and 6) having typical development in some areas of language development. The language development of the remaining infants was commensurate with either their hearing age or chronological age. (Note Infant 8 was not available 18 months post-cochlear implantation.)
Table 5.10: An overview of the infants’ language development – all areas were compared to chronological age, hearing age and cochlear implant age 12 months post-implantation

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Table 5.11: An overview of the infants’ language development – all areas evaluated were compared to chronological age, hearing age and cochlear implant age 18 months post-implantation

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Standardised Assessment

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Comparison of Assessment Tools
The assessment tools provided comprehensive information across several areas of receptive and expressive language development. One interesting finding was that all the infants who could not cope with the Reynell-III scored language age equivalents on the PLS-3 below the minimum starting age of the Reynell-III, that is, less than 21 months. This suggests compatibility between the two tests. At the assessment 18 months post-cochlear implantation most language results were comparable. However, there were two interesting discrepancies between assessment tools over the course of the study.

Two infants (Infants 1 and 6) had grammatical development commensurate with their chronological age and an MLU consistent with their cochlear implant age, 18 months post implantation. An additional unexpected finding was that many of the infants’ Vineland receptive language scores were not equivalent to other receptive language findings. Most infants had Vineland receptive language age equivalents much higher than the receptive language score from the standardised assessment. See Figure 5-H on the following page. Extreme examples of this were noted in two infants (2 and 3). These two infants were consistently the poorest performers of the group in many areas of language development. However, according to their Vineland results, they were deemed to have normal receptive language at one or both assessments 12 and 18 months post-implantation. Conversely, the age equivalents for all expressive language scores 18 months post-implantation, including the Vineland, were similar.

Improvement in Language Development versus Rate of Progress
Figure 5-H shows the age equivalents for each infant on all language assessments, 12 and 18 months post-cochlear implantation. For the six infants (Infants 1, 3, 4, 5, 6 and 7) available for both assessments, all showed progress or an increase in age equivalence between 12 and 18 months post-implantation. That is, their language skills improved or developed between the two assessments. The only language measure not to show improvement in skills for all the infants was MLU. MLU remained stable for Infant 5 and decreased between the 12- and 18-month assessments for two infants (3 and 4). Overall, although the infants made progress shown by an increase in age equivalence of skills, the rate of progress for some of the infants was not sufficient to develop or maintain normal or typical language development.
Figure 5-H: Age equivalence graphed over a 6-month period using age equivalence 12 and 18 months post-cochlear implantation of all language assessments. Graphs show progress over this time and compare age equivalent results of language assessments.
Figure 5-H: Age equivalence graphed over a 6-month period using age equivalence 12 and 18 months post-cochlear implantation of all language assessments. Graphs show progress over this time and compare age equivalent results of language assessments.
Discussion
At the commencement of the study the infants were aged from 4 to 12 months of age. All had been fitted with hearing aids and received auditory intervention between 1 and 7 months of age. The youngest to receive a cochlear implant was 8 months and the oldest was 16 months. Their language development was followed from the prelinguistic stage prior to cochlear implantation to 18 months post-cochlear implantation when all the infants were verbal.

The results for the infants’ language were analysed in terms of general language skills, mean length of utterance and grammatical development. This was done through functional assessment (videotaped interaction), parent questionnaire and standardised language assessment. Where possible the infants’ development was compared to their chronological age, hearing age (time from hearing aid fitting) and cochlear implant age (time from cochlear implant activation). The results largely focus on oral language development 12 and 18 months post-cochlear implantation.

Language Results
Three of the eight infants (Infants 6, 7 and 8) in general demonstrated typical language development 12 months post-implantation (see Table 5.10). That is, their development was commensurate with their chronological age. This finding was based on the results of MLU, the Vineland and standardised testing for Infant 6; grammatical development, Vineland and receptive language on standardised assessment for Infant 7; and MLU, Vineland and expressive language on standardised assessment for Infant 8. Two of these infants (6 and 8) were the youngest in the study, receiving their hearing aids prior to 6 months of age and cochlear implant at 12 months of age or younger. That the youngest infants in the study had normal language development 12 months after implantation supports the suggestion by Svirsky et al. (2000) that earlier cochlear implantation should result in a reduction in language delay. However, Infant 7 was one of the oldest of the group, and although diagnosed with hearing loss and in early intervention prior to 6 months of age did not receive hearing aids until 7 months of age or a cochlear implant until 16 months of age.
One of the youngest infants (Infant 6) did not show a normal rate of development when assessed 18 months post-implantation. At an age where typically developing children have rapid growth in their language this infant with a cochlear implant did not show this rate of language development despite having optimal and early intervention. (Note that Infant 8, who was also implanted at 8 months, was not available for assessment 18 months post-cochlear implantation and therefore no comparison can be made.) This contradicts the findings of other studies that once children receive a cochlear implant their language development develops at a rate comparable to hearing peers (Novak et al., 2000; Svirsky et al., 2000). However, it should be noted that these studies were conducted on older children using either oral language or TC to communicate, so direct comparisons cannot be made.

Infant 7 had language skills developing consistent with her chronological age 12 months post-implantation. She maintained typical language development at 18 months post-implantation (see Table 5.11). Infant 7 was female and the oldest of the group. Infants 1 and 6 also had several language results developing consistent with their chronological age. Infant 1 was female and one of the oldest in the subject group. Infant 6 was male and the youngest of the group. These findings provide no clear indicators that may predict an infant’s language development.

For the remaining infants (Infants 2, 3, 4 and 5) at the 18-month assessment, language skills were delayed relative to chronological age on all language assessment measures. While one infant (5) had most areas developing consistent with her hearing age, the remaining infants (2, 3 and 4) had development further delayed than this. It is, however, worth noting that even the most delayed infants in the study developed oral language skills. This includes Infant 4 who was diagnosed with a developmental delay. Moreover, none of the infants demonstrated overall language development delayed relative to their cochlear implant age. This suggests that cochlear implantation had a positive effect on language development for these infants. It may also suggest that comparing infants’ language development to their cochlear implant age is a low standard of expectation.

Although it is the hope of many parents that their infant with profound hearing loss attains normal language skills, this achievement may not be possible for all children, even with early
auditory stimulation using hearing aids and changing to a cochlear implant at 12 months of age. These results demonstrate that it is difficult for many infants to achieve typical language development by 18 months post-implantation. According to Calderon & Naidu (2000), “The early intervention years are possibly are too brief for many of these children to ‘catch up’ on everything: language, auditory, and speech production skills” (p.68). This is a consideration for the group of infants in this study. In summary, the results of this investigation revealed variable outcomes and no clear trends on each of the language assessment measures.

**FACTORS IMPACTING ON LANGUAGE DEVELOPMENT**

As described in the previous chapters, there were three infants (Infants 2, 3, and 4) whose development was slower than that of the other infants in the study. For each of these infants there were factors contributing to their slower progress. In summary, Infant 2 had required re-implantation 12 months after her original cochlear implant surgery, due to infection at the cochlear implant site. The second implant was put into the contralateral ear. The time between surgeries (when no signal was available) and a new signal in the opposite ear may have affected her progress during the time of the study.

Infant 3 also showed minimal progress or regression in language between the 12- and 18-month assessments in some areas of language development. During this period she had been exposed to social and emotional trauma which may have affected her language development. This hypothesis is supported in the literature (Allen & Wasserman, 1985; Augoustinos, 1987; McFayden & Kitson, 1996). Another infant who showed little progress was Infant 4. This infant was diagnosed with a developmental delay and this may have affected his language development. Developmental delay is also demonstrated to affect language development (Brady, Marquis, Fleming, & McLean, 2004; Paul, 1995c).

Recognition of these factors (re-implantation, social emotional trauma and developmental delay) may assist in predicting or flagging slow progress in infants with profound hearing loss who receive cochlear implants. Professionals need to be aware of factors that may affect the language outcomes of infants who receive cochlear implants, and to be able to counsel parents accordingly.
**IMPROVEMENT IN LANGUAGE DEVELOPMENT VERSUS RATE OF PROGRESS**

All infants available for both the 12- and 18-month assessments showed progress in language development in most if not all areas assessed. That is, there was an improvement in age equivalency on assessments between the 12- and 18-month assessments. However, the rate of progress for most infants was not sufficient to develop or maintain typical language development. This may be due to the low level of expectation for language development on assessment measures in the first 18 months compared with the sudden increase in expectation after 18-24 months of age. For example, on the Vineland, the expected early behaviours include “turns eyes to sound”, “understands at least 10 words”, “listens to the caregiver”, “understands yes or no”, “points to body parts”, “says yes or no”, and “imitates one syllable words”. Around 24 months of age, typically developing children are expected to use more grammatical structures and begin to put two words together (Owens, 1992; Paul, 1995b). In addition, they are expected to know many concepts, have a developed vocabulary and be able to follow simple directions (Owens, 1992). It may be that cochlear implantation did not occur early enough to give the infants enough foundation for age-appropriate development at 18-24 months of age. Further longitudinal studies would provide data as to whether the children catch up or continue to display delayed development.

**Early Auditory Stimulation and the Development of Receptive and Expressive Language: The Effect of Hearing Aids and Cochlear Implantation**

All infants in the study had been identified with a hearing loss, fitted with hearing aids and had received auditory stimulation by 7 months of age. The Vineland results (the only language measure pre-cochlear implantation) demonstrated that most of the infants had delayed receptive language development for most if not all of the pre-implantation phase of the study. Receptive language behaviour listed in the Vineland and expected from the infants at these early ages included simple tasks of turning to sound, and understanding words such as “up”, “yes”, “no” and “sh”. Due to their profound hearing loss, most of the infants did not have these skills, suggesting that early diagnosis, fitting of high-powered hearing aids and early auditory stimulation was not effective in the development of early language skills. This supposition is supported by the literature (Sininger et al., 1999; Tibussek et al., 2002; Tsao et al., 2004).
The fact that all the infants developed oral language after cochlear implantation suggests that for infants with a profound hearing loss, auditory stimulation for language development is more effective when using a cochlear implant. This assumption is also supported by the current literature (Novak et al., 2000; Svirsky, 2000; Svirsky et al., 2000; Tomblin et al., 1999).

Another aspect of language demonstrating the effectiveness of auditory stimulation using a cochlear implant was the infants' grammatical development. Three infants (Infants 1, 6, and 7) had typically developing grammar and one infant (Infant 5) had grammatical development commensurate with her hearing age. These infants were using grammatical structures that most infants with a profound hearing loss would not hear without a cochlear implant, including plurals, possessive –s, copulas in the contracted form, and unstressed structures such as articles (Stelmachowicz et al., 2004). However, the use of these structures cannot be attributed to the cochlear implant alone. If infants with profound hearing impairment are not taught to use their cochlear implant they may have difficulty hearing these unstressed grammatical markers and therefore not use them in their speech. The fact that the infants in this study were using these structures in their spontaneous speech at an appropriate age appears to be a result of learning language through listening. This surmise is supported by the observation of Geers, Nicholas et al. (2003), who considered that one of the positive factors associated with linguistic outcomes was an educational emphasis on speech and auditory skills. The initial development of grammar at this early stage of language development is essential if infants are to have an opportunity to develop good oral language skills. In addition, it provides the platform for further acquisition of grammar.

Overall, with the exception of Infant 7, the remaining infants were delayed in most if not all aspects of language development. This included MLU development and receptive and expressive language development as reflected in both parent questionnaires and standardised assessment. There may be several reasons for this delay in most aspects of language development. One reason may be that infants with a profound hearing loss may never achieve typical language development. Catching up in auditory receptive language and oral expressive development may be too high an expectation of infants with cochlear implantation. However, this supposition is not supported by observation: we see many infants and young children reaching typical language development after cochlear implantation in our clinics. There is also some research now to show children can develop typical oral language skills in auditory-verbal programs (Rhoades, 2001; Rhoades & Chisholm, 2000). While the children in the
study by Rhoades (2001) used either hearing aids or a cochlear implant, the author stated that typical oral language development occurred regardless of device used.

Another reason for delay in language for infants in this study may be that the infants were not studied long enough to see them catch up in their language skills. Again this theory is supported by (Calderon & Naidu, 2000; Rhoades, 2001), who found the longer the children were in therapy, the better the outcomes. During the time frame of this study these infants were progressing through many language, motor and cognitive developmental phases. The time frame to 18 months post-cochlear implantation may be too short to determine the benefit or otherwise of cochlear implantation. This notion would also support Calderon and Naidu’s (2000) suggestion that the early intervention years are too short a time for the infants to catch up. It has been suggested that it takes at least 18 months for pre-verbal children to attain functional language after cochlear implantation (Allen & Dyar, 1997). In fact, in Allen and Dyar’s study, the infants showed greater language abilities 3 years after cochlear implantation. In typically developing infants, the greatest language explosion occurs between the ages of 2 to 5 years (Paul, 1995b). If the infants in this study had been followed to 3 or 4 years post-cochlear implantation, we may have seen more infants catch up. Alternatively, the infants may have had delayed language because they used hearing aids for most if not all of the first year of life. As auditory stimulation did not appear to be effective using hearing aids, it may be that the infants required a cochlear implant at an earlier age. These infants may not have been able to take advantage of the early speech perception development that occurs in the first year of life and lays the foundation for typical language development (Kuhl, 2004; Tsao et al., 2004). While Infant 7, who received her cochlear implant at 16 months, had typical development from 12 months post-cochlear implantation, she was the exception rather than the rule. Further longitudinal research on the language outcomes of infants who receive cochlear implants under the age of 12 months is required.

**Assessment Tools**
The assessment tools in general provided descriptive information across several areas of receptive and expressive language development. However, there was disagreement between the functional measures. Two infants (Infants 1 and 6) had grammatical skills consistent with their chronological age, but their MLU development was at a level consistent with their
While it is possible that the infants’ grammatical development may have been a predictor for an increase in MLU, this cannot be confirmed. Although this discrepancy occurred with only two of the infants in the study, it supports the suggestions made by Klee, Schaffer, May, Membrino, and Mougey (1989) and Miller and Chapman (1981). Klee et al. (1989) suggested that MLU was not a sensitive measure of language development beyond sentence length itself. Moreover, Miller and Chapman (1981) cautioned that clinical decisions should not be based on MLU alone. This is because MLU is a general indicator of structural development and is a calculated average. Children with an MLU of two are sometimes using three- and four-word utterances and therefore further analysis should accompany MLU calculations. This caution is pertinent to this study, as analysis of the infants’ utterances showed that several demonstrated age-appropriate grammatical development (or at least developing well), even though their MLU was delayed.

An additional unexpected finding was that the Vineland receptive language scores were not equivalent to other receptive language findings. Most infants had Vineland receptive language age equivalents much higher than the receptive language score from the standardised assessment. This discrepancy may have occurred because the assessments were not compatible or because the parents overestimated their child’s receptive language abilities. An alternative explanation is that parents were reporting skills observed at home which their child had yet to consolidate. That is, when the context was removed the infant was not able to understand the language. Ultimately the reason for the discrepancy between parent reports and standardised tests for receptive language is unknown. However, these results are consistent with the findings of Thal et al. (1999) that parent reports for receptive language did not correlate with standardised measures of receptive language. These results emphasise the need to use different types of assessments and to use caution in characterising the child’s language as typical or not.

From the discrepancies described, it is concluded that using a single assessment to evaluate the language development of infants who receive cochlear implants is not ideal. This assertion is supported by Yoshinaga-Itano (1994) who suggested that a range of assessments should be used to accurately evaluate language development, and in particular that videotaped parent-child interactions and parent report should be used as part of any battery evaluating the language development of infants with a hearing loss. A protocol was used that contained a
battery of assessments to evaluate the infants’ language development, which provided broad data on the acquisition of language skills of the infants with a profound hearing loss who use a cochlear implant. Moreover, it appears to have yielded an accurate, holistic picture of language development.

Limitations of Study
There were several limitations to this study. Firstly, the subject sample was small. Further research with a larger subject sample may provide information on group trends in this population. As a result, professionals and parents would have an outline of appropriate expectations for language outcomes for infants who receive a cochlear implant. Such an outline would be a useful clinical tool to determine whether an infant’s progress was appropriate following cochlear implantation.

Another limitation pertains to the length of the study. Tracking the acquisition of language to 18 months post-cochlear implantation represents a relatively short time in an infant’s life. It seems that 18 months was not long enough for most of these infants to achieve age-appropriate language skills. Although it is not known whether they would develop normal language skills, tracking their development over a longer post-implant period would address this question. It would also allow documentation of changes in language skills over time. Tracking their development through to their final preschool year would allow investigation of the impact of early cochlear implantation on eventual school readiness.

While the assessment protocol used in the study provided a good description of the infants’ skills, it could be improved upon. The toys were chosen to conform with a consistent method, but age needs to be a determining factor. As described in Chapter 3, the toys used for videoed parent-child interaction to 6 months post-implantation were not suitable for the entire 1- to 6-month post-implantation phase. Toys that are appropriate for older children may have facilitated different interactions. Rather than selecting toys for the different phases of data collection, toys should be selected relative to the infants’ ages and interests (Schwartz & Heller Miller, 1988). The impact on the language outcomes of using the toys from the original protocol is not known, but toys that take further take into consideration infants’ age and interests may yield different results.
Finally, the standardised language assessment selected for future research protocols should be considered. The importance of using a range of assessment tools with infants who receive cochlear implants has been demonstrated, however, it would be preferable that only one standardised assessment be used within such a protocol. It is recommended that the PLS-3 be the preferred standardised assessment within future assessment protocols for infants who receive cochlear implants. Firstly, it evaluates language from 1 month of age through to 6 years 11 months, and therefore the infants’ language can be evaluated from infancy through to the preschool years (or pre- and post-cochlear implantation). Such longitudinal standardised measures would offer more objective information to supplement subjective measures, completing a holistic picture of the infants’ language skills from the pre-implant phase to the end of the preschool years. In addition, the PLS-3 was shown to be an accurate measure of receptive and expressive language skills when the results were compared with the RDS-III. That is, the infants who were unable to complete the initial tasks of the RDS-III had language ages on the PLS-3 below the starting age of the RDS-III (21 months).

Conclusions
In-depth longitudinal data has been provided on the oral language development of infants who were diagnosed, fitted with hearing aids and received early auditory intervention before 7 months of age, and who then changed to a cochlear implant near their first birthday. It appears that this is one of the first studies to produce such comprehensive data on this population. It has been demonstrated that there will be variability in language outcomes of infants who receive cochlear implants. While it is not unrealistic to have high expectations of this population with regard to language outcomes, not all children are going to have an ideal oral language result within the first 18 months following cochlear implantation. The language delay may be reduced or eliminated, compared with children who receive cochlear implants at an older age. However, it cannot be assumed that this gap will remain small or that the infant will maintain normal language development. The language outcomes of this study demonstrated that cochlear implantation at an early age does not eliminate the ongoing input of the infants, parents and professionals.

The fact that auditory stimulation did not appear to be effective in the development of early auditory comprehension or oral language for the infants with a profound hearing loss until
they received a cochlear implant is an important consideration. Knowing that delaying cochlear implantation possibly delays the onset of auditory comprehension and oral language development for most infants with a profound hearing loss, the question arises: should such infants change to a cochlear implant at an earlier age than those in this study?

The methodology employed provided information on the acquisition of oral language with this population and a base from which research can continue. The results provide a general indication of what can be expected in terms of oral language development in infants who receive cochlear implants, who are in auditory-verbal programs. In addition, the results provide some insight into factors that affect progress. Further research is required into the oral language development of infants who receive a cochlear implant, with larger numbers of participants and more participants receiving cochlear implants before the age of 12 months.
CHAPTER SIX

Concluding Remarks
Extensive data have been accumulated over the past decades on speech and language outcomes of children who receive cochlear implants (Allen & Dyar, 1997; Blamey et al., 2001; Ertmer, Strong, & Sadagopan, 2003; Geers & Brenner, 2003; Geers, Brenner et al., 2003; Geers et al., 2002; Higgins et al., 2003; Houston et al., 2003; Lutman & Tait, 1995; McConkey Robbins, 2003; McDonald Connor et al., 2000; Novak et al., 2000; Robinson, 1998b; Schauwers et al., 2004; Serry & Blamey, 1999; Svirsky, 2000; Svirsky et al., 2000; Tait & Lutman, 1997; Tye-Murray et al., 1995; Uchanski & Geers, 2003; Waltzman & Cohen, 1998). Over time, the studies on children with cochlear implants have reported on increasingly younger children; however, to date, there are only a few studies of infants (12 months of age) with cochlear implants (Dettman et al., 2005; Houston et al., 2003; Schauwers et al., 2004).

Data that is both longitudinal and comprehensive is presented in this thesis that describes the speech and language development in a small sample of infants with a profound hearing loss who received a cochlear implant and oral intervention from a young age. The stages of acquisition of early communication skills of infants are included, from the period before implantation and through the changes that occur post implantation. Previous studies of speech and language skills of infants with a hearing loss have used cross-sectional data collection methods (Calderon & Naidu, 2000; Geers, Nicholas et al., 2003; Geers et al., 2002; Mayne, Yoshinaga-Itano, & Sedey, 2000; Mayne, Yoshinaga-Itano, Sedey et al., 2000; Miyamoto et al., 2003; Obenchain et al., 2000; Svirsky et al., 2000; Yoshinaga-Itano & Apuzzo, 1998). Findings of these studies have demonstrated speech and language development at one moment in time; usually at a particular age or following a number of years of cochlear implant usage. In contrast, the longitudinal data collection method in this study has documented the infants’ development of early speech and oral language skills over time and the impact of cochlear implantation on the development of those skills.

Assessment Tools
The use of a wide range of measures to evaluate the infants’ prelinguistic and early speech and language development adds significantly to our current knowledge of the development and changes that occur in infants post-implant. To date most findings published on communication development of infants with profound hearing loss have focused on single measures of speech and language thereby limiting the evaluation of "communication skills"
to one aspect of development (Calderon & Naidu, 2000; Ertmer et al., 2002; Houston et al., 2003; Mayne, Yoshinaga-Itano, & Sedey, 2000; Miyamoto et al., 2003; Novak et al., 2000; Obenchain et al., 2000; Schauwers et al., 2004; Svirsky et al., 2000).

To adequately describe the acquisition of communication development of infants with hearing loss, multiple assessments tools need to be used (Yoshinaga-Itano, 1994) because no single assessment captures a representative sample of communication skills (Paul, 1995c). The combination of a longitudinal methodology and the assessment of a number of communication skills including communicative intention (types; forms; rate), pre-speech, speech (phoneme inventories and acquisition; phonological processes; speech intelligibility) and language (MLU; grammar; general skills) provide a comprehensive and realistic picture of prelinguistic and early communication acquisition of infants with profound hearing loss developing their auditory and oral capacity. In addition, the outcomes reflect the complexity of this development. While the findings do not comprehensively challenge the theory that earlier cochlear implantation is better, the findings lend caution to the claim that earlier cochlear implantation for infants facilitates typical early language development (Dettman et al., 2005; Houston et al., 2003; Schauwers et al., 2004). These studies included infants who received cochlear implants at very young ages (up to 16 months of age), however all studies used a single holistic measure to evaluate one aspect of prelinguistic development (pre-word learning and babble respectively) or early language development. They reported that the infants within their subject sample who were implanted before 12 months of age demonstrated typical development in the area assessed. However, because of the limited measures used and the lack of developmental data these studies provide only limited and indirect support for the benefits of early implantation.

The retrospective study by Dettman, Briggs, and Dowell (2005) in particular reports normal language development within a year of implantation, if the infant receives a cochlear implant prior to 12 months of age. The language measure used was the Rossetti Infant Toddler Language Scale (Rossetti, 1990). The Rossetti is a widely used clinical assessment tool as it is simple to administer and provides general information on language development. However, these data based solely on a criterion referenced parent questionnaire are of limited value in describing the infants’ speech and language development. Indeed, they found later when the infants were subsequently assessed using standardised measures that the infants did not
necessarily have better long-term language outcomes if implanted before the age of 12 months. The authors concluded that maturational factors may have complicated a demonstration of the earlier is better hypothesis.

The results of the present study emphasise that infant communication development is complex and such complexity has not been reflected in the methodology used in many of the studies. Therefore, the conclusion that cochlear implantation before 12 months of age will facilitate typical communication development in infants with profound hearing loss, needs to be regarded with caution and researched further. The findings of the current study also underline the need for intensive habilitation and early intervention for infants with hearing loss. Even with early cochlear implantation intensive intervention needs to be maintained to ensure communication skills continue to develop (Calderon & Naidu, 2000; Rhoades, 2001).

**Development of Oral Communication**

Many studies on children with profound hearing loss, have included children who used signing as well as audition for communication (Calderon & Naidu, 2000; Mayne, Yoshinaga-Itano, Sedey et al., 2000; Yoshinaga-Itano & Apuzzo, 1998; Yoshinaga-Itano et al., 1998). These studies have not necessarily reflected the outcomes of infants and children using auditory-oral/verbal communication. The infants in the present study had all received early auditory-verbal intervention which was focused on developing their auditory ability and capacity as a basis for their auditory-oral communication. They did not receive any exposure to signing to facilitate their language development but were solely reliant on auditory/oral input. The results of the present study therefore provide data about a more homogeneous population than previous studies (Coerts & Mills, 1995; Ertmer et al., 2002; Knutson, Boyd, Reid, Mayne, & Fetrow, 1997; Mayne, Yoshinaga-Itano, & Sedey, 2000; Mayne, Yoshinaga-Itano, Sedey et al., 2000; Moeller, 2000; Obenchain et al., 2000; Yoshinaga-Itano, 2000; Yoshinaga-Itano & Stredler-Brown, 1992) and provide significant new findings about the acquisition of early oral communication skills from the prelinguistic stage to verbal communication post-cochlear implantation.

While specific milestones in oral communication development following cochlear implantation could not be delineated due to the variability in skills across the infants, some
common factors were found across the infants. It was evident that the infants’ prelinguistic development was limited, and for some infants nonexistent, until they received their cochlear implant. This finding supports the literature demonstrating that infants with profound hearing loss have difficulty developing speech and oral communication skills when using hearing aids (Obenchain et al., 2000; Oller & Eilers, 1988; Oller et al., 1985; Stoel-Gammon, 1988; Yoshinaga-Itano & Stredler-Brown, 1992). This finding also suggests that early implantation (providing a better auditory signal) in conjunction with auditory intervention can help infants with profound hearing loss to develop their auditory and oral capacity. Together the evidence suggests that the benefits for the infants with profound hearing loss of an improved auditory signal through the cochlear implant, support further research into early cochlear implantation; however we need to be cautiously optimistic and realistic about the results. While there were some positive early communication outcomes, most of the infants in this study struggled to attain typical development in several key areas of early communication by 18-months post-implantation despite early cochlear implantation. It is not known whether the infants would catch up over time; however it should be kept in mind that little is expected with regard to early speech and language development at the age at which these infants were studied. If the infants maintain a typical rate of development after cochlear implantation, as has been found in previous studies (Novak et al., 2000; Svirsky et al., 2000) then the infants may continue to be delayed. The infants need to experience an accelerated rate of development (more than one year’s development for one year of learning) to catch-up to their peers. This is not impossible as demonstrated by one of the infants, however it may not be a realistic outcome for all infants with profound hearing loss who receive a cochlear implant.

For some infants there were obvious factors that affected their acquisition of communication skills such as developmental delay, reimplantation and social/emotional trauma. For the remaining infants, the inability to develop typical skills across all areas of speech and oral language development demonstrates that early diagnosis of hearing loss and early cochlear implantation do not eliminate the need for ongoing intensive therapy to develop communication skills (Calderon & Naidu, 2000; Rhoades, 2001). It also reflects the complex nature of communication acquisition. Calderon and Naidu (2000) state “the early intervention years possibly are too brief for many of these children to ‘catch up’ on everything: language, auditory, and speech production skills” (p. 68). This may be the case. It may also be the case that the infants did not receive their cochlear implants early enough to take full advantage of
early speech perception development and in turn attain typical development in all areas of oral communication. It is possible that the 8-16 months of auditory deprivation (age at implantation), or limited access to the entire speech signal, is still too late for optimal speech perception development and in turn prelinguistic, and speech and oral language development. Such speculation indicates that further study on the prelinguistic and early communication development of infants with profound hearing loss who receive a cochlear implant is urgently required.

**Clinical Implications**

The findings of the present study demonstrate the benefits of access to the entire speech signal as all infants demonstrated similar patterns of development after cochlear implantation, regardless of age at implantation. In addition, the outcomes provide hearing professionals with insight into what may be expected from infants with a profound hearing loss pre- and post-cochlear implantation. The results of early speech and oral language acquisition of the infants following device activation (discussed in chapters 3-5.) suggest professionals can expect good development in terms of early vocal, speech and verbal skills following cochlear implantation. However, they should be mindful that infants with profound hearing loss who receive a cochlear implant between the ages of 8-16 months are not likely to achieve age appropriate development in all, or even most, areas of communication by 18-months post-implantation.

The infants, while demonstrating typical patterns of development in a number of communication areas, had considerable delays across both speech and language areas relative to typically developing children. These findings indicate that early cochlear implantation does not replace the need for ingoing intervention services that enable children with profound hearing loss to attain good speech and oral language skills. The need for a early and on-going intervention is an important aspect of language outcomes in children with hearing loss (Calderon & Naidu, 2000; Moeller, 2000; Prendergast, Nelson Lartz, & Casson Fiedler, 2002; Yoshinaga-Itano, 2000). The delays found in several key areas of speech and language development also suggest that infants with profound hearing loss may benefit from a cochlear implant before the age of 12 months so that the period of auditory deprivation is minimised. Earlier implantation may lead to increased stimulation of the auditory pathway at an earlier
age and may assist early speech perception development through provision of a signal that
gives infants access to a wider range of speech sounds than is possible with a hearing aid

Future Research
Suggestions regarding future research have been discussed in Chapters 3-5. It is increasingly
easier to obtain larger cohorts of infants who have been diagnosed with a hearing loss due to
hearing screening programs (Samson-Fang et al., 2000). Consequently large scale prospective
studies of infants with hearing loss should be conducted, with some research addressing
whether there are additional significant benefits to implanting infants before the age of 12
months. While a study of a large population of infants receiving a cochlear implant under the
age of 12 months may continue to be difficult, research should be conducted in clinics where
teams of audiologists and therapists are capable of evaluating infants for cochlear
implantation and skilled surgeons are implanting infants under 12 months of age. Studies
should focus on the development of prelinguistic and early communication development in
infants who receive a cochlear implant before 12 months, using a comprehensive battery of
assessments such as that used in this study. The findings of such research may clarify whether
cochlear implantation in the first year of life in conjunction with auditory intervention results
in improved rate of communicative intention, phoneme acquisition and language development
and warrants a re-consideration of the current age guidelines for implantation.

Summary
This is one of the first studies of its kind to comprehensively evaluate the early
communication skills of infants who receive a cochlear implant. It is particularly relevant
today with the increase in number of infants diagnosed with hearing loss, as a result of hearing
screening programs being established around the world. The findings indicate that early
auditory intervention has minimal impact on the development of pre-speech and early oral
communication skills for infants with a profound hearing loss when using hearing aids, as
they have limited access to sound. The impact of 8-16 months of a limited auditory signal on
the development of prelinguistic and early communication development was evident in the
outcomes of this study as were the benefits of cochlear implantation. While it was apparent
that even with early intervention, catching-up in all areas of communication before the infants
reach their preschool years was difficult, there were very positive findings for verbal
development and speech production following cochlear implantation in this young population.
It remains unclear if earlier implantation (before 12 months of age) will assist in infants
achieving typical oral communication development. Further research with larger groups of
infants studied over a longer period of time would likely answer this question.


APPENDICES
Appendix A: Aided Audiograms

Key

- Sound field (two ears aided)
- Right Ear aided
- Left Ear aided
- No response
Key
△ Sound field (two ears aided)
H Right Ear aided
V Left Ear aided
▼ No response
### Appendix B Communicative Intention Inventory

The Communicative Intention Inventory Coggins and Carpenter (1981)

**COMMENT ON ACTION**: Direction of the listener’s attention to some observable referent. An intentional behaviour that appears to call the listener’s attention to the movement of some object rather than the object per se.

<table>
<thead>
<tr>
<th>Gestural or Gestural-Vocal</th>
<th>Frequency Tally</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Looks at an entity in action; points toward an entity in action; or is involved with an entity in action; may vocalise.</td>
<td></td>
</tr>
<tr>
<td>Verbal</td>
<td>Frequency Tally</td>
</tr>
<tr>
<td>a. Looks at an entity in action; points toward an entity in action; or is involved with an entity in action and produces words.</td>
<td></td>
</tr>
</tbody>
</table>

**REQUEST FOR ACTION**: Solicitation of services from a listener where child awaits a response. An intentional behaviour that directs the listener to act upon some object in order to make the object move. The child’s interest appears to be in the action of the object rather than in the object per se.

<table>
<thead>
<tr>
<th>Gestural or Gestural-Vocal</th>
<th>Frequency Tally</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Looks at an object that has stopped moving, has the potential to move or be moved; reaches or leans toward entity; may fuss or whine.</td>
<td></td>
</tr>
<tr>
<td>b. Looks toward entity that has ceased moving, has the potential to move or be moved; and makes ritual gesture.</td>
<td></td>
</tr>
<tr>
<td>Verbal</td>
<td>Frequency Tally</td>
</tr>
<tr>
<td>a. Looks at an object that has stopped moving, has the potential to move or be moved may point toward entity or adult; may give entity to adult and produce a word or word combination</td>
<td></td>
</tr>
</tbody>
</table>

**COMMENT ON OBJECT**: Direction of the listener’s attention to some observable referent. An intentional behaviour that appears to call the listener’s attention to some object identified by the child.

<table>
<thead>
<tr>
<th>Gestural or Gestural-Vocal</th>
<th>Frequency Tally</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Extends an arm or shows entity already in hand; may vocalise.</td>
<td></td>
</tr>
<tr>
<td>b. Picks up an entity and immediately shows it to an adult; may vocalise.</td>
<td></td>
</tr>
<tr>
<td>c. Points to, looks toward or approaches entity; may vocalise.</td>
<td></td>
</tr>
<tr>
<td>Verbal</td>
<td>Frequency Tally</td>
</tr>
<tr>
<td>a. Extends an arm or shows entity already in hand and produces a word.</td>
<td></td>
</tr>
<tr>
<td>b. Picks up an entity and immediately shows it to an adult and produces a word.</td>
<td></td>
</tr>
<tr>
<td>c. Points to, looks toward or approaches entity and produces a word or word combination</td>
<td></td>
</tr>
<tr>
<td>d. Produces a word or word combination that refers to an entity not existent in the immediate environment (generally the word/word combination will either have or require a form of the copula or the word have).</td>
<td></td>
</tr>
</tbody>
</table>

**REQUEST FOR OBJECT**: Solicitation of services from a listener where a child awaits a response. An intentional behaviour that directs the listener to provide some object for the child; is usually out of reach due to some physical or spatial barrier.

<table>
<thead>
<tr>
<th>Gestural or Gestural-Vocal</th>
<th>Frequency Tally</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Stretches hand toward entity; whines or fusses while leaning toward the entity.</td>
<td></td>
</tr>
<tr>
<td>b. Stretches hand toward entity with ritual gesture; may vocalise.</td>
<td></td>
</tr>
<tr>
<td>Verbal</td>
<td>Frequency Tally</td>
</tr>
<tr>
<td>a. Looks at or touches entity; pints to or reaches toward entity and produces word/s.</td>
<td></td>
</tr>
<tr>
<td>b. Produces a word or word combination that directs the listener to furnish entity not existent in immediate environment.</td>
<td></td>
</tr>
</tbody>
</table>
**REQUEST FOR INFORMATION:** Solicitation of services from a listener where a child awaits a response. An intentional behaviour that directs the listener to provide information about an object, action or location.

<table>
<thead>
<tr>
<th>Gestural or Gestural-Vocal</th>
<th>Frequency Tally</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Looks at and/or points toward an entity, movement or location; picks up or touches entity; may vocalise (possibly accompanied by rising intonation).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Verbal</th>
<th>Frequency Tally</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Looks at adult and requests additional input about a referent; gesture may accompany request (generally a 'wh' word initiates the request possibly accompanied by rising intonation).</td>
<td></td>
</tr>
</tbody>
</table>

**ANSWERING:** Responding to a request for information with semantically appropriate data.

<table>
<thead>
<tr>
<th>Gestural or Gestural-Vocal</th>
<th>Frequency Tally</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Responds to adult’s query with affirmative head nod; may vocalise.</td>
<td></td>
</tr>
<tr>
<td>b. Responds to adult’s query with negative head nod; may vocalise.</td>
<td></td>
</tr>
<tr>
<td>c. Provides obligatory gestural response to adult’s query where the answer is visually apparent in the immediate environment; may vocalise.</td>
<td></td>
</tr>
<tr>
<td>d. Provides gestural response to adult query where the answer is not apparent in the immediate environment; may vocalise.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Verbal</th>
<th>Frequency Tally</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Responds to adult’s query with affirmative verbal response; may imitate part of adult’s preceding question.</td>
<td></td>
</tr>
<tr>
<td>b. Responds to adult’s query with negative verbal response; may imitate part of adult’s preceding question.</td>
<td></td>
</tr>
<tr>
<td>c. Provides a verbal response to adult’s query where the answer is visually apparent in the immediate environment; may imitate part of the adult’s preceding question.</td>
<td></td>
</tr>
</tbody>
</table>

**ACKNOWLEDGING:** providing notice that a previous gesture or utterance was received.

<table>
<thead>
<tr>
<th>Gestural or Gestural-Vocal</th>
<th>Frequency Tally</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Child spontaneously imitates the immediately preceding adult gesture and/or vocalisation and awaits response.</td>
<td></td>
</tr>
<tr>
<td>b. Child nods his head to agree / disagree with the adult’s immediately preceding action request (Can you give me a kiss?) or attention request (Did you hear me?).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Verbal</th>
<th>Frequency Tally</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Child spontaneously imitates the immediately preceding adult utterance and awaits response. Child does not add any new information or modify word order.</td>
<td></td>
</tr>
<tr>
<td>b. Child Verbally agrees (OK yeah) with the adult’s immediately preceding action request (Shall we draw daddy?) or attention request (Do you see him?).</td>
<td></td>
</tr>
</tbody>
</table>

**PROTESTING:** Expressing disapproval of the speaker’s action or utterance.

<table>
<thead>
<tr>
<th>Gestural or Gestural-Verbal</th>
<th>Frequency Tally</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Adult initiates activity (not question) that the child rejects/ declines. Child may turn away from the adult; may fuss; may push adult’s hand away or strike out at adult; may scream or vocalise.</td>
<td></td>
</tr>
<tr>
<td>b. Adult initiates activity (not question) that the child rejects/ declines. Child uses ritualised gesture to indicate disapproval or disagreement (shake head etc.) may vocalise.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Verbal</th>
<th>Frequency Tally</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Adult initiates activity (not question) that child rejects/declines. May shake head push hand away; says words.</td>
<td></td>
</tr>
</tbody>
</table>
Appendix C: Parent Information Sheet

The Children’s Cochlear Implant Centre

The University of Sydney

Pre-linguistic communicative intention and vocalisation/speech development of infants with a profound hearing loss, pre and post cochlear implantation.

Who are the investigators?

a) Ms Maree Wright, a speech pathologist at the Children’s Cochlear Implant Centre (NSW), The New Children’s Hospital Westmead (off site at the Old Gladesville Hospital). Masters student at the University of Sydney, School of Communication Sciences and Disorders.

b) Ms Alison Purcell, an honorary speech pathologist at The New Children’s Hospital Westmead and lecturer at the University of Sydney, School of Communication Sciences and Disorders.

c) Professor Vicki Reed, Head of Department at the University of Sydney, School of Communication Sciences and Disorders.

What is the purpose of the study?

This study forms part of a Masters degree being undertaken by Maree Wright. The Children’s Cochlear Implant Centre (NSW) has been providing cochlear implants for children with a profound hearing loss (loss greater than 90dB) since 1987. During 1998, 7 children commenced attending the centre aged 12 months and younger, with the youngest implanted at 9 months of age and the oldest at 15 months. This began a new phase in the work at the Children’s Cochlear Implant Centre (CCIC). For the staff, new challenges arose, in terms of what we should expect from these children in the way of normal pre-linguistic development. Other issues included, the fact that four of the seven infants implanted in 1998 had slower than expected gross motor development and what impact this might have on their speech development? As the number of infants being referred to CCIC is increasing, it is of vital importance to have answers for some of these questions.
Given the fact that only a few babies with a hearing impairment have been diagnosed or studied in the first year of life, there is sparse information about their social or communicative development during this period (Wood et al., 1986).

The aim of this study is to document the prelinguistic communication of infants with a profound hearing impairment, before and after cochlear implant surgery.

**Who will be included in the study?**
We are looking for infants with a profound hearing impairment who have presented at The Children’s Cochlear Implant Centre for Candidacy Evaluation. The children are to be 13 months or less at the beginning of the evaluation period.

**What will my child have to do?**
Your child will be video taped four (4) times at monthly intervals during the Candidacy Evaluation period and six (6) times after cochlear implantation and his/her prelinguistic skills will be documented. This will take approximately 15 minutes and will be a part of your normal Candidacy Evaluation or habilitation session. It is possible that the videotape will be used in workshops and for teaching purposes.

Your child will also be required to undergo a cognitive assessment by the centre’s psychologist. This is a part of every child’s programme. Participation in the study will in no way effect the length of the evaluation period nor have any bearing on recommendations made regarding cochlear implantation. It will also not extend your time at CCIC in the post-operative phase of management unnecessarily.

**What will I have to do?**
If you agree to your child participating, you will need to complete a questionnaire. The Vineland Adaptive Behavior Scale will be administered three (3) times in Candidacy Evaluation (over 12 weeks) and twice post cochlear implantation (at the three and six month mark). This is a questionnaire that looks at your child’s language, social and motor development. Again the results will not have any bearing on recommendations made regarding cochlear implantation or have any impact on the post operative phase. The time frame is no longer or shorter that other infants who attend the programme at the Centre with a congenital, profound hearing loss.

**Are there any risks involved?**
No. The procedure is non-invasive and there are no dangers associated with the procedure of recording the data. All measures will be taken to ensure your and your child’s privacy. The investigators will ensure confidentiality of all information obtained from the tape recordings. Information obtained will be coded so there is no identifying data available.

**What are the benefits of this study?**
The results of the study will:
- Expand our knowledge of the prelinguistic (pre-language) development of infants with a profound hearing impairment.
- Enable us to develop more appropriate assessment and habilitation procedures for speech pathologists and teacher of the deaf who work with infants with a profound hearing impairment.
Although we hope to develop a battery of assessment tools that will aid parents, speech pathologists and teachers of the deaf, this study will not directly benefit your child.

Participation in this project is voluntary and if you decide not to take part or decide to withdraw at any time this will not otherwise affect your child’s care at The Children’s Cochlear Implant Centre (NSW)

If you have concerns about the conduct of this study, please do not hesitate to discuss them with Maree Wright (Ph: (02) 9871 0011), Ms Alison Purcell (Ph: (02) 9351 9335) or with Dr Anne O’Neill (Ph: 9845 3037); the secretary of the Ethics committee who has approved this project.

If you are willing to have your child participate in this study, please sign the attached consent form and return it to the address below.

Ms Maree Wright  
Speech Pathologist  
The Children’s Cochlear Implant Centre (NSW)  
The Old Gladesville Hospital  
P.O. Box 188  
Gladesville NSW 1675  

Yours sincerely  

Maree Wright, Alison Purcell & Professor Vicki Reed
Appendix D: Toys used in the Study

Toys used pre-cochlear implantation to six months post-cochlear implantation
1 rattle
1 rolling toy
2 duck shaped animals
1 plastic train
1 toy telephone receiver
1 set of nesting cups
Pop-up-friends (four pop-up animals activated by turning or pushing a button)
A fluffy toy inside a clear Tupperware container with a lid
One shape sorter

Toys used 12 and 18 months post-cochlear implantation

Play Scenes
Tea Party: teddy; container of plastic food; teapot; large and small frying pan (small one with a lid); three cups, saucers, spoons and forks; small plastic cooker/stove

Farm: green Duplo® board; two red Duplo® houses with white doors; a big and small Duplo® cow, duck, pig and horse; two Duplo® sheep, chickens and one dog; Duplo® fence pieces; Duplo® people man, woman, baby and little girl.

Transport: Fisher Price® Little People Garage; plastic container of Matchbox® and plastic cars, trucks, planes.

Nurture: Female baby; clothes (jumper, booties, pants); blanket; towel; powder; brush; bottle; Crib/ Cot
### Appendix E: Phonological Process Definitions

#### Consonant Processes

<table>
<thead>
<tr>
<th>Process</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final Consonant Deletion</td>
<td>Deletion of the final single consonant of a word (dog → do)</td>
</tr>
<tr>
<td>Initial Consonant Deletion</td>
<td>Deletion of the initial single consonant of a word (cat → at)</td>
</tr>
<tr>
<td>Other Consonant Deletion</td>
<td>Deletion of a single consonant (speckle → spe’el)</td>
</tr>
<tr>
<td>Stopping</td>
<td>Fricative sounds such as /ʃ/, /θ/ or /s/ are replaced by a stop sound such as /t/ or /d/ (shoe → do)</td>
</tr>
<tr>
<td>Assimilatory Processes</td>
<td>Phoneme takes the characteristic of another sound (tag → kag)</td>
</tr>
<tr>
<td>Gliding</td>
<td>Substituting one glide for another (red → wed)</td>
</tr>
<tr>
<td>Nasalisation</td>
<td>An oral consonant is replaced by a nasal consonant (boat → moat)</td>
</tr>
<tr>
<td>Velar Fronting</td>
<td>Velar sounds such as /k/ and /g/ are replaced by sounds produced at the front of the mouth such as /t/ and /d/ (cat → tat or goose → doose)</td>
</tr>
<tr>
<td>Other Fronting</td>
<td>A consonant is replaced by a more anterior consonant excluding velar fronting or palatal fronting (car → par)</td>
</tr>
<tr>
<td>Voicing</td>
<td>A voiceless consonant is replaced by a voiced consonant (toe → doe)</td>
</tr>
<tr>
<td>Other Backing</td>
<td>A consonant is replaced by a more anterior consonant excluding alveolar backing (pip → lip)</td>
</tr>
<tr>
<td>Devoicing</td>
<td>A voiced consonant is replaced by a voiceless consonant (gold → cold)</td>
</tr>
</tbody>
</table>

#### Universal Processes

<table>
<thead>
<tr>
<th>Process</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syllable Deletion</td>
<td>Deletion of a syllable in a word (shivering → shivring)</td>
</tr>
<tr>
<td>Reduplication</td>
<td>A word is replaced by two or more identical syllables (cupboard → cubcub)</td>
</tr>
</tbody>
</table>

#### Vowel Processes

<table>
<thead>
<tr>
<th>Process</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vowel Reduction</td>
<td>A vowel is replaced by a schwa (apple → /æpt/)</td>
</tr>
<tr>
<td>Monophthongisation</td>
<td>A diphthong is replaced by a monophthong (mouth → moth)</td>
</tr>
<tr>
<td>Substitution</td>
<td>Phoneme change not covered by any enabled phonological processes (car → shar)</td>
</tr>
</tbody>
</table>

#### Cluster Processes

<table>
<thead>
<tr>
<th>Process</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster Reduction</td>
<td>Reduction in the number of consonants in a cluster (trickle → tickle)</td>
</tr>
<tr>
<td>Cluster Deletion</td>
<td>Deletion of an entire cluster in a word (flower → ower)</td>
</tr>
</tbody>
</table>
## Appendix F: Developmental Vocal Assessment

Paul (1995)

<table>
<thead>
<tr>
<th>Stage 1 (Birth –2 months)</th>
<th>Occurrence</th>
<th>Stage 4 (6-10 months)</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crying with sudden pitch shifts, extremely high pitch.</td>
<td></td>
<td>Canonical repetitive or reduplicated babbling (CV or CV-CV like structure) begins to appear. [mama], [dada] and [nAnA]</td>
<td></td>
</tr>
<tr>
<td>Fussing or discomfort</td>
<td>Consistent variation of intonational contours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetative sounds (burps, sounds accompanying feeding)</td>
<td>Early non-repeated CV sequences appear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutral sounds (grunts sighs)</td>
<td>Parent may report hearing first word around 10 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vowel like sounds [i, I, æ, u, U, a]</td>
<td>Utterances produced with full stop consonant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utterances produced with full stop consonant</td>
<td>Short exclamations such as ‘ooh!’ begin to appear</td>
<td></td>
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</tbody>
</table>

### Stage 2 (2-4 months)

Vowels sounds predominate, but a few consonants emerge (velars and glottals)

| Marked increase in crying (after 12 weeks) | Variegated babbling (successive syllables not identical) appears |
| Begins consonant plus vowel; mostly ‘coo’ and ‘goo’. | Variety of CV and CVC combinations with sentence like intonation |
| Begins to produce pleasure sounds, such as ‘mmmmm’ | Syllables other than CVs produced |

### Stage 3 (4-6 months)

Consistent production of vowel (CV) combinations

| Imitation of sounds on back-and-forth babbling games with others | Approximations of meaningful single words; phonological processes may operate on word approximations |
| More variations in vowel production | Notes |
| Number of consonant segments increases to include front stops and nasals | |
| Laughter emerges (around 16 weeks) | |
| Front sounds begin to predominate, including blowing ‘raspberries’, bilabial trills (lip smacks) | |
| Begin variation of intonation contours often when playing alone with toys | |
| Extreme pitch glides such as yells squeals and low pitched growls | |
Appendix G: Australian Vowel Profile
(Mannell & Cox, 2005)

<table>
<thead>
<tr>
<th>Height of Tongue</th>
<th>Back</th>
<th>Mid</th>
<th>Front</th>
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</thead>
<tbody>
<tr>
<td>High</td>
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<tr>
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<th>Front</th>
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<th>Front</th>
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<table>
<thead>
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<table>
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<th>Height of Tongue</th>
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Appendix H: Method for Parent Interaction Analysis

Parent Interaction
Most infants with a hearing loss are born to hearing parents and when there is a gap between hearing status of parent and infant, interaction can be difficult (Gallaway, 1998). It was for this reason that the parents’ interactions with their child was analysed. Parent interaction can be measured for many clinical purposes including planning intervention, evaluating outcomes and determining parent control over the interaction (Aspland & Gardner, 2003). To analyse the parents’ interactions with their child in this study, the Parent Interaction Rating Scale was used (Talbott, 1998). This rating scale has not been used in previous studies. It was used because it was developed by a Certified Auditory-Verbal Therapist® for parents to evaluate their own interactive behaviours. As parent training is a central to AVT (Caleffe-Schenck et al., 1991), the development of a parent interaction tool by someone in the field was deemed most suitable for this study. The intention was not to extensively report the findings, but use in the interpretation of findings in the areas of communication should there appear to be an unusual result in any of the areas studied.

Procedure for Parent Interaction
The Parent interaction Rating Scale is on the following page. Every video-taped interaction was analysed using this tool. Each interaction of the parent was placed into one of the following categories: comments, elaboration/rephrasing, pausing, question, repetition, command e.g. “Give me that” “Say…”. The first three behaviours are considered as facilitative and the latter three are considered as controlling. At the end of the video-taped section, the number of behaviours was tallied with the number of facilitative interactions being compared with the number of controlling interactions. If most of the interactions fall into the facilitative category, the parent’s interactions with the child were deemed to be appropriate. If the parents interactions were largely controlling, the parents were deemed to be falling into the performance trap and therefore not producing the best interactions for the child’s language development (Talbott, 1998). If the number of interactions were similar between the two groups, the parent is deemed to be on the edge of the performance trap.

Reliability of Parent Interaction
Online consensus agreement was used between the author and a second independent rater.
**The Performance Trap Test**

Tape record a ten-fifteen minute sample of your interaction with the child. As you review the tape, tally each of your utterances into one of the categories below.

<table>
<thead>
<tr>
<th>Type of Interaction</th>
<th>Number of Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Facilitative Interactions</strong></td>
<td></td>
</tr>
<tr>
<td>Pause</td>
<td></td>
</tr>
<tr>
<td>(any pause long enough to catch your attention)</td>
<td></td>
</tr>
<tr>
<td>Elaboration / Rephrasing (saying the same message in a different way)</td>
<td></td>
</tr>
<tr>
<td>Comment</td>
<td></td>
</tr>
<tr>
<td>Adult Controlled Interactions</td>
<td></td>
</tr>
<tr>
<td>Command (Any statement requesting action or response) i.e. “give me that”, “Say..”</td>
<td></td>
</tr>
<tr>
<td>Repetition (exact repetition of your previous utterance)</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td></td>
</tr>
</tbody>
</table>

**Parent Interaction Rating Scale**

*Tops in Auditory-Verbal Therapy*

Pamela Talbot M.Ed., CCC-SLP, C.ED