THE SPEECH PROCESSING SKILLS OF CHILDREN WITH COCHLEAR IMPLANTS

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requirements for the degree of Master of Speech Therapy
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Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the owner of the copyright thereof (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: December 2008

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To my Heavenly Father – thank you Lord! I was encouraged by the words of Psalm 27:13-14 during this endeavour, *" I'm sure now I'll see God's goodness in the exuberant earth. Stay with God! Take heart. Don't quit. I'll say it again: Stay with God."* Positivity *eventually* pays off.

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Abstract

Title: The Speech Processing Skills of Children with Cochlear Implants

This study aims to describe the speech processing skills of three children ages 6;0, 6;10 and 8; 10, with cochlear implants. A psycholinguistic framework was used to profile each child's strengths and weaknesses, using a single case study approach. Each child's speech processing skills are described based on detailed psycholinguistically-orientated assessments. In addition, retrospective data from 1-2 years post-implantation were examined in the light of the psycholinguistic framework in order to describe each child's development over time and in relation to time of implantation. Results showed each child to have a unique profile of strengths and weaknesses, and widely varying outcomes in terms of speech processing even though all three children had the same initial difficulty (congenital bilateral hearing loss). Links between speech processing and other aspects of development as well as contextual factors are discussed in relation to outcomes for each child. The case studies contribute to knowledge of speech processing skills in children with cochlear implants, and have clinical implications for those who work with children with cochlear implants and their families.

Keywords: cochlear implants in children, speech processing, speech perception, speech production, psycholinguistic profiling, hearing age

Abstrak

Titel: Die Spraakprosseseeringsvaardighede van Kinders met Kogleêre Inplantings

Hierdie studie beoog om die spraakprosseseeringsvaardighede van drie kinders – van 6;0, 6;10 en 8;10 - met kogleêre implantings te beskryf. 'n Psigolinguistiese raamwerk was gebruik om elke kind se sterktes en swakhede to profileer. 'n Gevalsgeskiedenis metodologie was gebruik. Elke kind se spraakprosseseeringsvaardighede is beskryf, nadat gedetaileerde psigolinguistiese evalueering plaasgevind het. Terugwerkende data geneem van 1-2 jaar na inplanting is ook ondersdoek, met verwysing na die psigolinguistiese raamwerk, om elke kind se ontwikkelende profiel te beskryf oor 'n gestipuleerde tydperk, en in verband met tyd van inplanting. Resultate toon dat elke kind in die studie van 'n unieke profiel sterktes en swakhede beskik, en dat hulle spraakprosseseeringsprofiele breë verskille getoon het, selfs het al die kinders dieselfde inisieele problem gehad (kongenitale bilaterale gehoorverlies). Bande tussen spraakprosseseeringsvaardighede en ander aspekte van ontwikkeling, sowel as kontekstuele faktore is bespreek in verband met eindresultate vir elke kind. Die gevalstudies dra by tot kennis van spraakprosseseeringsvaardighede in kinders met kogleêre inplantings, en het kliniese implikasies vir die wat werk met kinders met kogleêre inplantings en hulle families.

Sleutelwoorde: kogleêre inplantings vir kinders, spraakprosesseering, spraakpersepsie, spraakproduksie, psigolinguistiese profileering, gehoorouderdom

Conventions:

In this study the following format is used to refer to children's ages:

- C.A. – chronological age
- 4;6 - 4 years 6 months
- H.A. – hearing age

Other common abbreviations used include:

- C.I. – cochlear implant
- dB HL – decibels hearing loss
- P.A. – phonological awareness
- PCC – percentage consonants correct
- PPC - percentage phonemes correct
- PVC – percentage vowels correct
- H.A. – hearing aid

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CHAPTER 1 : DEVELOPMENT OF AUDITORY PERCEPTION, LANGUAGE, SPEECH AND LITERACY IN CHILDREN WITH COCHLEAR IMPLANTS

In South Africa, hearing loss is the second most common sensory deficit diagnosed (www.statssa.gov.za/publications/statsdownload). Profound bilateral hearing loss, one of the most severe forms, is less common and less treatable since the use of even the most powerful hearing aids are not sufficient to help hearing aid users hear sounds crucial for speech and language development (Goldin-Meadow & Mayberry, 2001). As a result, children with this type of hearing loss may fail to develop linguistic and communicative skills, and this then has significant implications on their education, socio-emotional development and future professional prospects. With the development of cochlear implants, prospects for these children have greatly improved. Now most implanted children can expect similar audiological outcomes to those with moderate to severe loss with hearing aids, under optimal conditions (Snik, Vermeulen, Brokx & Van Den Broek, 1997; Owens, Espeso, Hayes & Williams, 2006). It has even been said that, "No other sensory aid has had the same impact on improving the viability of oral communication for children with profound hearing impairments as have cochlear implants" (Osberger, 1995:231).

Cochlear implants (CI's) are electronic prosthetic devices, which are implanted into humans to directly stimulate the auditory hair cells responsible for conveying sound signals to the brain. The device converts external physical sound to electrical impulses, bypassing the external and middle ears. The basic CI consists of :

1) *a microphone*, which picks up sound, converts it into an electrical signal and transmits it to an external processor. The microphone is usually situated in a behind-the-ear hearing aid casing, or worn on the body of younger child.

2) & 3) *an external processor and transmitter coil*. The external processor converts the electrical signal into a defined code depending on the coding strategy used. This code is then transmitted via radiofrequency, through the skin by the transmitter coil, which is externally held in place by magnets over the receiver-stimulator. The external processor is either housed in the hearing aid casing (where the microphone is), or in a body worn device.

4) a receiver –stimulator receives a digital code and translates this into rapid electrical impulses, which are distributed to the cochlea by the multi-electrode array. In single-channel implants only one electrode is used, but in the multi-channel cochlear implants most commonly used today, an electrode array (5) is inserted into the cochlea so that different auditory nerve fibres can be stimulated at different places in the cochlea, taking advantage of the cochlea's own place mechanism for encoding frequencies. (Eddington & Pierschalla, 1994, Loizou, 1998; RNID, 2003; FDA, 2005, Owens et al, 2006).

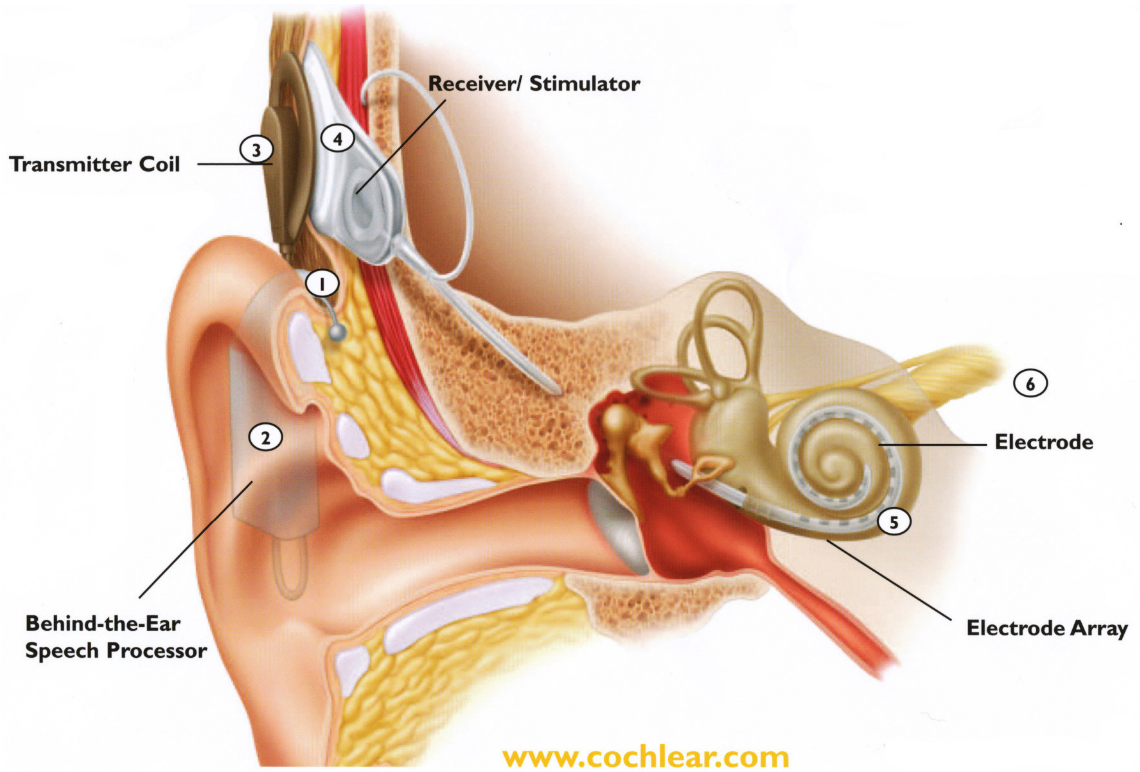


Figure 1.1 Diagrammatic representation of the cochlear implant within the ear.

Although a variety of technologies and variations exist, the basic design system of most CI's consists of the above-mentioned components. The majority of devices are multichannel, and use either a straight or curled electrode array, with transcutaneous transmission. Single-channel devices, which utilise an analogue band-passed signal, are not very commonly used anymore – the electrical stimulation provided at a single site in the cochlear by a singular electrode produced poor results especially for open-set speech perception. In open-set speech perception tests the subject does not know the list of possible word choices, whereas in closed-set tests the possible list of word choices is known (Loizou, 1998).

Multichannel implants however, provide electrical stimulation at multiple sites in the cochlea using an array of electrodes. Since only multichannel implants are utilised currently, the most salient differentiating factor between CI's are the processing strategies used, which ultimately determine the nature of the electrodes' stimulation. The various signal processing strategies can be divided into two main categories: waveform strategies (e.g. CIS, SPEAK and ACE) and feature extraction strategies (e.g. F0/F2, MPEAK). They differ in the way information is extracted from the speech signal and presented to the electrodes. Speech processing strategies aim to extract the maximal energy found in the speech signal and deliver that information in the form of specific frequencies to electrodes corresponding to those frequencies. Research comparing various speech processing strategies shows that in general no one strategy is superior but that newer speech processing strategies provide better speech perception and awareness than the older ones (Loizou, 1998; Geers, Brenner & Davidson, 2000, in Christiaansen, Spencer & Leigh, 2002).

CI's are deemed able to restore partial hearing to the deaf (Loizou, 1998). Not all deaf humans are candidates though – CI's are designed for individuals with bilateral profound to total deafness, who gain almost no benefit from wearing hearing aids. They are also beneficial for the rehabilitation of patients with some residual hearing and some speech comprehension (Ouellet & Cohen, 1999). CI's are especially indicated for use in post-lingually deafened adults, and profoundly hearing impaired children (Eddington & Pierschalla, 1994, Loizou, 1998; RNID, 2003; FDA, 2005, Owens et al, 2006).

Candidacy requirements for cochlear implantation in children include: a confirmed diagnosis of sensori-neural hearing loss > 90 dB at 2000 Hz and 4000 Hz, including a trial period of at least 6 months with hearing aids suited to the hearing loss. Children under 2 years were at one stage excluded as candidates for the procedure because of concerns whether profound hearing loss can be reliably diagnosed in very young children. In addition, there were fears regarding the safety of the procedure and the long-term reliability of the device in a growing child. Subsequently, because these fears were unfounded, children under 2 years are now being considered suitable for implantation (Rubinstein, 2002). Children with multiple handicaps are also considered for implantation – those who are blind and deaf are a priority (The Ear Foundation, 2007). Exclusion criteria include mental retardation, learning disorders, psychiatric disturbances, ossification of the cochlea and congenital anomalies such as absence of the cochlea or auditory nerve (Zwolan, 2000; Linn, 2002; Seeber, 2005).

Benefits from the use of CI's have been reported in post-lingually deafened adults (RNID, 2003), deaf individuals who have poor sentence recognition scores even in best-aided conditions (Loizou, 1998), deaf individuals who obtain little or no benefit from hearing aids (Loizou, 1998; RNID, 2003), as well as in the bilaterally profound paediatric hearing-impaired population (Loizou, 1998; FDA, 2005). It is this last population in particular, on which many research studies have been focused – children fitted with a CI at a young age. Researchers have found that under optimal conditions (i.e. early referral, supportive family environment, adequate access to support staff and therapy), profoundly deaf children implanted at a young age are able to attend mainstream schooling by the age of 5-6 years with continued support from the cochlear implant team. This is regarded as an unlikely achievement had they been wearing hearing aids (Owens et al, 2006).

In addition, cochlear implantation is claimed to enable the vast majority of deaf children to acquire and understand spoken language, speak intelligibly and use the telephone (Blamey, Sarant, Paatsch, Barry, Bow, Wales, Wright, Psarros, Rattigan & Tooher, 2001; Tait, Nikolopoulos, Archbold & O' Donoghue, 2001; Beadle, McKinley, Nikolopoulos, Brough, O' Donoghue & Archbold, 2005) and to have improved literacy and educational attainments (Archbold, Nikolopoulos, O' Donoghue & White, 2006; Stacey, Fortnum, Barton & Summerfield, 2006; Thoutenhoofd, 2006). However, these achievements are not automatic after the switch-on of the cochlear implant – many researchers emphasise the need for intensive aural habilitation, i.e. teaching listening skills to cochlear implant users, before the benefits of having a cochlear implant can be reaped (O'Donoghue, Nikolopoulos, Archbold & Tait, 1999; Ertmer, Strong & Sadagopan, 2003; Ertmer, Young & Nathani, 2007; Archbold & O'Donoghue, 2007; The Ear Foundation, 2007; Nguyen et al, 2008)

For this population, three main areas of development as a result of cochlear implantation have been identified from the research: auditory perceptual development, language development, and speech production development. Furthermore, the literacy development and phonological awareness development in this population will also be discussed, as they are strongly linked to the previously mentioned areas.

1.1 Auditory Perceptual Development in children with cochlear implants

Significant improvements in the auditory perceptual skills of children implanted with cochlear implants have been demonstrated for tasks tapping aided speech detection thresholds (Waltzman, Cohen & Shapiro, 1995; Pulsifer, Salorio & Niparko, 2003), speech perception (Geers & Moog, 1995; Uziel, Reillard-Artieres, Sillon, Vieu, Mondain, Fraysse, Deguine & Cochard, 1995; Pulsifer, Salorio & Niparko, 2003; Connor & Zwolan, 2004; Dillon et al, 2004; Uziel, Sillon, Vieu, Artieres, Piron, Daures & Mondain, 2007), and specifically open-set word recognition (Waltzman, Cohen, Gomolin, Green, Shapiro, Hoffman & Roland, 1997; Loizou, 1998; Waltzman & Cohen, 1999), closed-set word and sentence recognition (Dillon et al, 2004).

Cochlear implant users vs. hearing aid users

Research indicates that the majority of cochlear implant users seem to benefit from increased speech perception skills as a result of cochlear implantation. This benefit appears more obvious when the children with cochlear implants are compared to hearing aid users. Geers & Moog (1995) showed significant gains within different categories of speech perception development for children implanted with cochlear implants over and above gains made by children wearing hearing aids, and children wearing hearing aids and tactile aids.

Kishon-Rabin, Taitelbaum, Segal, Henkin, Tene, Muchnik, Kronenberg, & Hildescheimer (2000) compared the speech perception performance of hearing aid-using children with profound hearing impairments, to the performance of cochlear implant using children (1-6 years post-implantation), on the Hebrew version of the Early Speech Perception Test (ESP). Results indicated that the majority (70%) of the hearing aid users group performance placed them in category 1 of the Hebrew ESP which indicated that they had no auditory/speech perception. The majority of children in the cochlear implant users group (73%) scored in category 4 of the Hebrew ESP – indicating that they were able to differentiate among a closed set of monosyllables differing primarily in vowel sound. Prior to implantation all the children in the cochlear implant users group were scoring in category 1. Thus significant improvements had been made by the cochlear implant group but not by the hearing aid users group.

Within cochlear implant users

When comparing cochlear implant users to themselves, speech perception tests seem to be a favourite with researchers seeking to determine the amount of post-implant gain, in functional terms. O'Donoghue, Nikolopoulos & Archbold (2000: 466) assert that "the primary measure of benefit from cochlear implantation is the ability to perceive speech." Studies have shown that a wide range of speech perception abilities are achieved by implanted children. These findings have been obtained using a wide variety of methods, which have been used to assess speech perception. For example, Tyler, Fryauf-Bertschy, Kelsay, Gantz, Woodworth & Parkinson (1997) measured the performance of 50 children using cochlear implants on several speech perception tests, such as recognition of stress pattern, consonants, vowels and words; audiovisual perception of consonants; sentences in closed-set tests; and open-set tests. Closed-set words are usually easier to identify while open-set words resemble everyday environmental listening conditions more closely (Uziel et al, 1995) and thus can be more valuable in determining real performance. Results from Tyler et al (1997) showed that closed-set word recognition improved within 1 year of implantation, while open-set word recognition only showed slow improvement over time. Large individual differences were observed.

Using a different method to assess speech perception, O'Donoghue, Nikolopoulos & Archbold (2000) assessed 40 children implanted before age 52 months, using connected discourse tracking to measure the mean number of words per minute perceived. Connected discourse tracking (CDT) aims to assess the comprehension of speech without lipreading. Results indicated that the childrens' CDT scores improved significantly from 0 (pre-implantation) to 44.8 words/minute comprehended (5 years after implantation), with a standard deviation of 24.3.

Relying less on lexical knowledge and receptive language abilities, Kishon-Rabin, Taitelbaum, Muchnik & Gehtler (2002) attempted to examine the development of phonological contrasts in children using cochlear implants as a function of device use (since phonological contrasts are minimally influenced by listeners' linguistic knowledge). Their results indicated that the average perception score of the phonological contrasts demonstrate wide variability. They asserted that speech perception performance follows an exponential function and reaches the point of 70%-80% correct discrimination at approximately 4 years of age in the children studied. This is similar to earlier data collected by Kishon-Rabin et al (2000), demonstrating speech perception scores of 90% correct discrimination in normally hearing children at the age of 4 years.

Age at implantation

One of the factors which seems to affect speech perception in children with cochlear implants is age at implantation. Waltzman & Cohen (1999) reported that children who were implanted before their second birthdays developed open-set speech recognition as fast or faster than children who were implanted between 2-5 years of age. Similarly, Svirsky, Teoh & Neuberger (2004) demonstrated that implantation before the age of 2 years resulted in significant speech perception (and language) outcomes. In a ten-year follow-up study of 82 children implanted by mean age 4;8 years with a mean length of device use of 11;7 years, Uziel et al (2007), concluded that children implanted before age 4 had better speech perception outcomes than those implanted later in life.

Holt, Svirsky, Neuburger & Miyamoto (2004) investigated 93 children using cochlear implants to try and discern whether age at implantation made any difference to their speech perception outcomes. Using a modified open-set test of spoken word recognition, children were given instructions on how to assemble a toy and then marked on how many key words in the sentence they could identify. Their results indicated that 1) the average speech perception performance for children implanted at ages between 13-48 months is well below that of typically developing normally hearing children, at least through 6-7 years of age, 2) that speech perception skills improve at the same rate after implantation, regardless of age at implantation, for children implanted between 13-48 months of age, and 3) that speech recognition is enhanced for children implanted earlier than 13 months of age. This study is notable for comparing speech perception performance of cochlear implant using children to that of normally hearing children, to quantify the gains and development brought about by the use of the cochlear implant. However, the speech perception testing method draws heavily on participants' lexical knowledge and receptive language abilities in conjunction with their speech perception abilities, making it difficult to assess their speech perception skills in isolation.

Wide variability exists as to the optimal age for implantation but most studies seem to agree that implantation under the age of 5 is preferable, and that the success of speech perceptual outcomes decreases with later implantation – in the same way in which children's innate ability to learn language decreases with increased age according to the Critical Age Hypothesis

(Moskovsky, 2001). The problem with these group studies however, is that not all the variables have been properly controlled for – there are no allowances made for factors other than age at implantation to affect speech perception skill outcome, e.g. parental involvement, continuous/irregular use of device etc.

In summary, speech perception does seem to increase significantly with cochlear implant usage across the studies shown, but the effect of speech perception on speech and language production is not always straightforward.

1.2 Language Development in children with cochlear implants

Within the realm of language development, significant improvements in the rate of language acquisition (Robbins, Osberger, Miyamoto & Kessler, 1995; Connor & Zwolan, 2004; Dillon et al, 2004; Svirsky, Teoh & Neuberger, 2004;), spoken language development (Nicholas & Geers, 2007) and gains in the area of vocabulary development have been demonstrated for children using cochlear implants (Dawson et al, 1995; Ertmer, Young, Grohne & Mellon, 2002; Peng, Spencer & Tomblin, 2004; Connor, Craig, Raudenbusch, Heavner & Zwolan, 2006; Uziel et al, 2007).

Cochlear implant users vs. hearing aid users

It has been asserted that the language growth for children with cochlear implants is faster than that for children with hearing aids, even though both groups had profound bilateral hearing losses. McConkey-Robbins, Osberger, Miyamoto & Kessler (1995) assessed the language skills of 15 children with cochlear implants (with a mean age at implantation of 5.6 years, mean onset of deafness 0.9 years). They compared the children's expected language level based on maturation with their observed language scores. They found that both receptive and expressive language skills increased with cochlear implant usage over time to a greater extent than would be predicted from maturation alone, and that receptive and expressive language skills showed similar amounts of increases over time. Their findings departed from earlier research findings which suggested that children with profound hearing impairments (wearing hearing aids) demonstrated limited language growth and maturation.

Within cochlear implant users

Historically speaking researchers like Olds, Fitzpatrick, Duireux-Smith & Schramm (2004), have maintained that children with cochlear implants are delayed in the acquisition of speech and language, relative to normally hearing children and children with lesser degrees of hearing loss. However the rate of language development in children with cochlear implants may be significantly faster than predictions based on their unimplanted peers would suggest. At 12 months post-implantation, expressive language scores in a group of children implanted with cochlear implants were shown to be higher than corresponding scores predicted for non-implanted peers. Miyamoto, Svirsky & Robbins (1997) concluded from this that the rate of language growth of the group of children with cochlear implants matched that of *hearing* controls. Other researchers seem to concur with this statement (Ouellet & Cohen, 1999; Geers, Nicholas & Sedey, 2003). This result may have been influenced by the many variables that affect language acquisition – parental input, language stimulation, socio-economic background, etc – variables typically too many to control for. This inability to control for all the influential variables leaves the results of this type of comparative study open to discussion.

Within this population there is a wide variation in language skills among children using cochlear implants. Some children perform within the age appropriate range while others perform more than 3 standard deviations below the average performance of age matched hearing children (Dawson, Busby, McKay & Clark, 2002). More than half the children wearing cochlear implants in Geers' (2003) study, who had average learning ability produced and understood English language at a level comparable with that of their hearing age mates, while in Geers' later study (2004), 43% of the children investigated achieved age appropriate speech and language skills, having been implanted by age 2.

Studies focusing specifically on vocabulary development in children with cochlear implants show significant gains in this area post-implantation. Dawson et al (1995) investigated the post-operative changes in the receptive vocabulary of cochlear implant users undergoing oral training. Using the *Peabody Picture Vocabulary Test* (*PPVT*) (Dunn & Dunn, 1959) as their measurement tool, they tested 32 children and adults. The mean group *PPVT* performance score on the most recent post-operative assessment was significantly greater than the score achieved on the most recent pre-operative assessment. A mean rate of improvement of 0.87 was indicated for the group. The mean post-operative individual rate of improvement was 1.06 (times the rate of development for normally hearing children) which was significantly higher than the mean pre-operative individual rate of improvement. Large inter-subject variability was reported in this study, with age of implantation ranging between 2;5 – 20 years, and length of implant use ranging from 6 months to 7 years 8 months. Similar to other earlier studies, this study demonstrated that cochlear implant users were considerably delayed in their receptive vocabulary development both pre- and post-operatively. However this study noticed significant group improvements that were consistently observed at varying post-operative test periods.

Recent research has also indicated that children who receive a cochlear implant before a substantial delay in spoken language developed were more likely to achieve age appropriate spoken language (Nicholas & Geers, 2007).

Age at implantation

Connor, Hieber, Arts & Zwolan (2000) found that children implanted under the age of 10 years attained significant improvements in receptive vocabulary and expressive spoken/signed vocabulary over time (compared to the expected rate of acquisition had they still been wearing hearing aids), regardless of the communication strategy employed by the school they attended. In addition, they maintain that children wearing cochlear implants attained greater vocabulary and speech scores, on average, than hearing aid users, regardless of the age of implantation, at any given age.

On the other hand, Eisenberg, Kirk, Martinez, Ying & Miyamoto, (2004) found that their hearing aid users group had a significantly higher receptive vocabulary quotient than their cochlear implant users group as measured by the *PPVT* (Dunn & Dunn, 1959). However, the cochlear implant users group was substantially younger than the hearing aid users group, the former had less device experience than the latter, and the mean unaided pure tone average (PTA) threshold for the hearing aid user group was 78.2 dB hearing loss (HL), while the PTA threshold for the cochlear implant users group was 110.2 dB HL. Other measures used in the study which also focused on language such as the *Reynell Developmental Language Scales* (Reynell & Curwen, 1987) and the *Clinical Evaluation of Language Fundamentals* (Semel, Wiig & Secord, 1987) yielded equivalent results for both groups. Thus this study cannot prove that hearing aid users have superior receptive vocabulary skills. The study does show the difficulties involved in comparing cochlear implant users to hearing aid users, since candidacy requirements for the two different devices differ broadly – hearing aid users are fundamentally different to cochlear implant users.

Investigating a single child implanted under the age of three, Ertmer, Strong & Sadagopan (2003) aimed to compile a comprehensive picture of language acquisition in a child implanted with a cochlear implant at a young age by assessing a wide range of language areas (i.e. phonology, morphology, syntax, semantics, pragmatics). A case study was used as the most appropriate way in which these areas could be extensively investigated. The child used in the case study was implanted at 20 months and her initial speech and language progress (post-operatively) was much more rapid than those expected of an infant in the first year of life. This study focused on the speech and language progress during her second to fourth year post-implantation.

Results indicated that this child's rate of development exceeded typical rates of development demonstrated by young deaf children wearing hearing aids. To comment on her rate of language acquisition, the researchers compared her language level to her "hearing age" – the length of time she had been using a cochlear implant – and then compared that to what normally hearing children would achieve in that time. For example, two-word utterances are routinely expected of an 18 month old (Rossetti, 1996), thus at 18 months *hearing age* (C.A. 38 months for this particular child) two-word utterances are regarded as typical of close to normal development. Her levels of performance were then classified as being close to normal, below normal or above normal for the hearing age she was at. Three language behaviours were identified as developing at below normal rates: length of utterance was reduced, use of fewer different words and total words expressively, and decreased speech intelligibility rates. Four language behaviours were identified as developing at close to normal rates: decrease in the frequency of non-words as the frequency of real words increases, receptive vocabulary gains, increase in the frequency of multiword utterances after 2 years implant experience, and increase in Type-Token ratios. The area of language in which she attained above normal rates of acquisition, was language comprehension. She scored age appropriately for her chronological age on the *Assessment of Children's Language Comprehension* (Foster, Giddan & Stark, 1973).

In summary she demonstrated an efficient rate of acquisition for 5/8 of the language areas investigated. The researchers predicted that she would later achieve chronological age appropriate levels for all language areas, especially if therapy was continued (Ertmer, Strong & Sadagopan, 2003). This study highlights an important concept in the terminology of hearing impairment – that of "hearing age". This term is frequently used in studies of children with cochlear implants, as it represents a fair estimate of the gains a child is expected to make in light of their amount of device experience (Ertmer, Strong & Sadagopan, 2003; Nicholas &

Geers, 2007). It must be re-iterated that hearing age refers to the amount of time the child has had the cochlear implant and not the amount of time for which amplification was received, as most children undergo a hearing aid trial prior to being considered for a cochlear implant. To differentiate between the two, Flipsen & Colvard (2006) have coined the term post-implantation age (PIA). Since a candidacy requirement for the cochlear implant is that hearing aids show minimal benefit, PIA is a better gauge of hearing experience. From this point forward, hearing age will be taken to mean PIA.

The methodology used in Ertmer, Strong & Sadagopan's (2003) study is an appropriate one in dealing with this heterogeneous population. The amount of detail generated by this study is atypical of the studies in this area, and valuable, even though the results cannot be generalised to all children.

Szagun (1997) has also used a case study methodology in comparing language results from 2 children with cochlear implants (implanted at or before 3;2) and 2 age-matched normally hearing children. She was able to tabulate detailed differences in the grammatical development of the children with cochlear implants, and concluded that the 2 cochlear implant children differed not only in rate of acquisition relative to each other and the normally hearing children but also in style of acquisition. She further commented that future research should compare children with cochlear implants and those with normal hearing, by making use of in-depth psycholinguistic methods.

Thus, while it appears that children using cochlear implants can definitely progress in language development, they start off their journey with a delay, and large variability exists as to whether they can close the gap or maintain their current rate of progress. This is influenced by variables such as age of implantation, environmental support, innate abilities etc.

1.3 Speech Development in children with cochlear implants

Vocal development is delayed and incomplete in deaf infants (Ertmer & Mellon, 2001) – thus children who receive cochlear implants at a young age are likely to start producing increasingly complex speech-like vocalizations as they are exposed to speech models auditorily (Ertmer et al, 2002). These children's progress in prelinguistic vocal development may be an indicator of implant benefit in children who are still too young to undergo formal speech perception testing.

Cochlear implant users vs normally hearing children

There are several distinctive differences in the vocal development of deaf and normally hearing children – a delayed onset of babbling in the deaf child, restricted formant frequency range, reduced phonetic and syllabic inventories, and the absence of expressive jargon and pre-words (Stackhouse & Wells, 1997; Ertmer et al, 2002; Moeller, Hoover, Putman, Arbataitis et al, 2007a; Moeller, Hoover, Putman, Arbataitis et al, 2007b). After implantation, the type of vocalizations produced can provide an estimate of early speech development, and indirectly auditory perception.

Ertmer, Young & Nathani (2007) investigated the vocal development of 7 children using cochlear implants and found that 6 of the 7 made advancements in vocal development after implantation. Six of the 7 children progressed through the different levels of vocal development in the predicted sequence, and the milestones in vocal development were often achieved with fewer months of hearing experience than observed in typically developing infants and that this seemed to be influenced by age at implantation.

Walker & Bass-Ringdahl (2008) demonstrated that for infants, (with at least 6-9 months device experience) the phonetic complexity of babbling is significantly correlated with receptive vocabulary, articulation abilities and global language skills at age 4. Thus research interest in the babbling of infants with cochlear implants not only seeks to compare the complexity of their babbling with that of normally hearing children, but also to correlate this output with future performance.

Cochlear implant users vs. hearing aid users

Speech feature production in imitation and spontaneous production tasks was assessed in children implanted with cochlear implants and compared to that found in hearing aid using children and children wearing both hearing aids and vibrotactile aids by Tobey and Geers (1995). All 3 groups were measured after 1 and 2 years of use of their respective devices. After 2 years the cochlear implant group's percentage of vowels correctly imitated reached 76%, which was significantly higher than the hearing aid and the hearing aid plus tactile aid groups. They concluded that when a cochlear implant is used in conjunction with intensive auditory-oral instruction, the child's ability to imitate and spontaneously produce a variety of vowels and consonants is positively influenced.

Löhle, Frischmuth, Holm, Becker et al, (1999) used listener judgements and spectrographic analysis of speech productions to rate speech intelligibility. They found that hearing aid users whose aided thresholds fell between 40 -60 dB HL and cochlear implant users implanted between the ages of 2-4 years achieved speech intelligibility ratings of 60-90%, while hearing aid users with aided thresholds between 70-90 dB HL or worse and cochlear implant users implanted between ages 9-14 years obtained speech intelligibility scores under 40%. Spectrographic analyses of the speech samples indicated that only the children in the first group (2-4 years old at time of implantation) were able to exactly imitate prosodic features such as pitch, rhythm, intonation, stress and duration of vowels, within their mothers' or their therapists' speech stimulus. In addition, only this group (cochlear implant users implanted between ages 2-4 years) was shown to develop a natural prosody after implantation.

Within cochlear implant users

Speech production gains in this population display marked increases in the rates of vocal development (Ertmer et al, 2002), speech intelligibility (Osberger, 1995; Dillon et al, 2004; Peng, Spencer and Tomblin, 2004), and speech feature production (Dillon et al, 2004).

With regards to speech intelligibility, researchers have used various methods to objectively measure this phenomenon. Connor et al (2000) used consonant production accuracy scores as their measure of speech intelligibility, and found that significant increases in this measure were seen in children implanted with cochlear implants under the age of 10 years old, regardless of the communication strategy used at the school.

Peng, Spencer & Tomblin (2004) measured speech intelligibility ratings for children with seven years of cochlear implant experience by averaging three listener ratings. The average for their sample was 71.5% intelligibility (standard deviation 29.89). Using linear regression analysis, their study was able to show that two main factors - age at implantation and coding strategy used – contributed to the large variability in speech intelligibility.

Tobey, Geers, Brenner, Altuna, Gabbert (2003) also used multiple measures to measure speech intelligibility including listener ratings, phoneme production accuracy scores, and acoustic analyses of speech among others. Their findings indicated that the average speech intelligibility for key words in their group of children with 4-6 years cochlear implant experience was 63.5%. Accuracy of phoneme production was higher for consonants (68%) than for vowels (61.6%).

Moeller et al (2007a) summarise the apparent trends in speech production by saying that the transition to accurate and intelligible word production appears to progress more slowly in children with hearing loss than children with normal hearing. The same is true for children with cochlear implants.

1.4 Literacy Development in children with cochlear implants

"Literacy is a key to learning in schools. It allows children access to the curriculum. Those children who find reading and writing difficult in the early stages of education often perform poorly on academic measures" (Dodd & Carr, 2003; p128). This statement rings true for most children entering the education system, but even more so for children battling with disabilities. Good academic performance often leads to more career opportunities, and eventually better quality of life. Unfortunately, literacy rates in deaf children typically plateau at third or fourth grade reading and writing levels, and 95% of profoundly deaf school-leavers only reach a reading age of 9 years (Stern, 2001; Paul, 1998, in Nielsen & Luetke-Stahlman, 2002). Nielsen & Luetke-Stahlman (2002) feel that it is of critical importance that children become proficient readers – be they deaf or hearing, whether they are developing normally or experiencing cognitive or learning disabilities – if these children are to participate in contemporary society. Participation and inclusion in society by children with disabilities are some of the goals set out by the South African Department of Health (South African Health Review, 2006).

Cochlear implant users vs. hearing aid users

Connor & Zwolan (2004) report on a study in which 54% of cochlear implant using children between grades 4-12 were reading at or above a fourth grade level, while only 8-14% of similarly aged children using hearing aids, achieved a reading level of at or above a fourth grade level. There was wide variation in the age-appropriacy of the results since a large heterogeneous sample had been chosen. In South Africa, a study was conducted by Stobbart & Alant (2008) which investigated the home-based literacy experiences of severely to profoundly deaf preschoolers (this included hearing aid users and cochlear implant users). The data was collected from questionnaires filled out by the parents of 29 preschool deaf children. Results indicated that, although the children were exposed to literacy-rich home environments, there were limitations in the quality and quantity of text-based interaction between the deaf preschoolers, their hearing parents and their older siblings. In addition, the parents in the study regarded the development of language and communication as being more important than early acquisition of literacy skills, and the parents in this study also assigned the greatest responsibility in teaching literacy skills to teachers. Colin, Magnan, Ecalle & Leybeart (2004) found in their study that deaf and hard-of hearing children acquire reading efficiency more quickly if they enter the first grade with good phonological skills and alphabetic knowledge.

Within cochlear implant users

Connor & Zwolan (2004) examined the effects of multiple variables on the reading comprehension of children using cochlear implants. Ninety-one children with a mean age of 11 years and more than 4 years device experience were used. Variables such as type of cochlear implant device, type of processing strategy, pre-operative speech detection thresholds, post-operative speech detection thresholds, type of educational program, type of reading instruction were controlled for. Data was analysed via path analysis using structural equation modelling to test the hypothesis that multiple factors influence children using cochlear implants reading comprehension. Results indicated that pre- and post-operative vocabulary measures had a significant effect on reading comprehension scores; age at implantation had a direct and negative effect on reading comprehension – children implanted at younger ages demonstrated better reading comprehension skills. Other variables that were significant predictors of reading comprehension were family socio-economic status, i.e. that higher socio-economic status was linked to better literacy outcomes, while communication method was not regarded as a significant variable in this study.

In a study investigating word reading and comprehension levels attained by children implanted by 5 years of age, Geers (2003) hypothesized that the improved speech perception abilities acquired with cochlear implantation would promote phonological coding skills and facilitate the acquisition of beginning reading skills. Three subtests from diagnostic reading assessment batteries standardised on hearing children were administered to 181 children between 8-10 years of age who had 4-6 years device experience. Results indicated that over half the children scored age appropriately on the measures of reading. Reading competence was found to be associated with higher non-verbal intelligence, higher family socio-economic status, female gender and later onset of deafness. Reading outcome was primarily predicted by linguistic competence and secondarily by speech production skill. This statement seems to echo the findings of Connor & Zwolan (2004) linking language/vocabulary development to reading development. Geers (2003) goes on to comment that cochlear implantation is associated with greater use of phonological coding strategies for decoding print, longer working memory spans for short-term storage of phonemes, words and sentences, and accelerated language development for reading comprehension and therefore cochlear implantation should have a facilitative effect on literacy acquisition.

Geers' (2003) hypothesis linking speech perception, phonological coding and early literacy skills has been promoted by many other researchers: Kress, (1997), Stern & Goswami (2000, 2001), Pisoni (2000), Connor & Zwolan, (2004), Geers, (2004), Gillon (2004). According to these reports, the poor reading performance of deaf children can be attributed to two main factors: poor language exposure and poor phonological awareness skills. Since the language development of children using cochlear implants has already been discussed, their phonological awareness will now be examined, firstly because it is said to relate very closely to literacy skills (Stanovich, 1998; Chard & Dickson, 1999; White, 2000; Catts, Fey, Zhang & Tomblin, 2001; Hempenstall, 2003; Gillon, 2004; Puolakanaho, Poikkeus, Ahonen, Tolvanen & Lyytinen, 2004; Heath & Hogben, 2004) and secondly because phonological awareness is a component of speech perception – another extensively studied area in children using cochlear implants.

1.5 Phonological Awareness in children with cochlear implantation

Phonological Awareness refers to the ability to identify, separate and manipulate component sounds/sound segments in a word (Phelps, 2003). Currently phonological awareness (PA) is seen as a dynamic skill following in a typical developmental sequence (Stanovich, 1992, 1993, in Hempenstall, 2003).

PA begins to develop during the preschool and early school-going years, and continues to develop as children are exposed to formal literacy instruction (Phelps, 2003). Initial awareness emerges from broad towards finer distinctions in words, syllables, onsets and rhymes. After exposure to the alphabetic principle (i.e. that graphemes correspond with phonemes) finer distinctions between phonemes become possible (Gillon, 2004).

Phonological awareness is a more global term that includes the earlier stages of rhyme and syllable awareness as well as phonemic awareness (Hempenstall, 2003). Good phonological awareness skills have repeatedly been hailed as a primary predictor of early reading success in children. *Phonemic awareness* is a subset of phonological awareness that is concerned with children's understanding that spoken words and syllables are comprised of specific sequences of individual speech sounds (White, 2000). This is the component that develops most after formal literacy instruction. Phonemic awareness is regarded as being more highly related to learning to read than tests of general intelligence, reading readiness and listening comprehension (Stanovich, 1998; White, 2000). In addition, Share & Stanovich (1995, in White, 2000) hypothesize that phonemic awareness is the most important core and causal factor which separates normal and disabled readers. Some researchers have also commented on the reciprocal relationship between literacy and PA, maintaining that while the later stages of PA, (i.e. phonemic awareness) are only seen after some literacy instruction, awareness of words at a phonemic level is fostered by exposure to the alphabetic rule (Swank & Larrivee, 1998; Gillon, 2004).

PA skills are usually divided into the detection, recognition and identification of three factors: the rhyme factor, syllable factor and phoneme factor. General phonological awareness comprises a large set of skills such as hearing separate words in a sentence, recognition and creation of rhymes, hearing the number of syllables in a word, and listening for words that begin/end on the same sound. Specific phonemic awareness tasks include: blending of phonemes into words/syllables, substitution of phonemes within words/syllables, identification of phonemes from the initial/medial/final position in words, deletion of phonemes from the initial/medial/final position in words, segmentation of words/syllables into phonemes, manipulation of phonemes within words.

PA has been a research focus for many researchers, mainly because of its important role in learning to read and its use in the prediction of reading difficulties in hearing children (Nielsen & Luetke-Stahlman, 2002; Heath & Hogben, 2004). The PA skills of deaf children also need to come under scrutiny if changes in reading level outcomes are desired. Stern & Goswami (2000) claim that hearing impaired (HI) children develop some PA skills even through limited exposure to language, and even when their speech ability and auditory experiences are poor (Stern, 2001), and even though their development may be delayed (Stern & Goswami, 2000). This development resembles that of hearing peers (Nielsen & Luetke-Stahlman, 2002). However, Dodd (1974, 1980; in Nielsen & Luetke-Stahlman, 2002) cautions that the PA skills of the HI child may be underspecified, as not all phonetic distinctions can be perceived.

PA skills in children using cochlear implants vs. those using hearing aids

Gillon (2004) reports on a pioneering study in which the phonological awareness of children using cochlear implants and that of children using hearing aids was investigated using the

Preschool and Primary Inventory of Phonological Awareness (PIPA) (Dodd, 2000). In this study the children using CI's were between 5 and 10 years old, had received their implants prior to beginning formal literacy instruction, were mother tongue English speakers, with no physical or intellectual impairments and were enrolled in mainstream educational settings. All of the children with CI's exhibited delayed receptive and expressive language skills, and a mean of 81.3% accuracy in speech perception tests. Raw scores from the PIPA were transformed into standard scores to enable researchers to compare the participants to normally hearing peers. Results from the PIPA were separated into two groups – scores for the younger group (age 5;0 – 6;11) and scores for the older group (7;0 – 10;11). Within the younger group, only 1 child (who happened to be a good reader) managed to achieve a standard score within the average range on any of the subtests. All the other children in this group showed significant delays compared to norms for the test. None of the children in this group could segment words into phonemes. Within the older group, most of the children showed age equivalent performance to that of a 6;11 year old on the rhyme and alliteration tasks. Scores indicated that they experienced even more difficulty on the phoneme level tasks. All in all most of the children in the study demonstrated patterns of PA development expected of hearing children, i.e. they found phoneme segmentation more difficult than other tasks presented.

James, Rajput, Brown, Sirimanna, Brinton, & Goswami, (2005) compared PA in hearing impaired children using CI's with those using hearing aids. Nineteen CI users, with a mean age of 8.4 years, and two groups of hearing aid users, with mean ages of 9.5 and 7.4 years, were studied. The hearing aid groups consisted of participants with profound hearing loss and severe hearing loss respectively. All three groups scored significantly above chance level on the syllable and rhyme tests, but not on the phoneme tests, where only the severe hearing loss / hearing aid user group scored above chance. The CI users and profound hearing loss / hearing aid users performed similarly on the phoneme and rhyme tests. All three groups performed equivalently on the syllable tasks.

In summary, the researchers suggested that PA skills developed over time in CI users, and in the same sequence as among hearing children. This is in agreement with Stern & Goswami's (2001) findings. They also added that in CI users as in normal hearing users, syllable and rhyme awareness developed before phonemic awareness, and that CI's offer some benefits to the development of PA, mostly at the syllable level (Gillon, 2004).

Summary of Research Findings

- Large individual differences exist among cochlear implant users for the main areas investigated, i.e. language development, speech production, speech perception. These differences may be due to earlier vs. later age at implantation, duration of deafness, pre-implant residual hearing, length of device experience, communication mode employed in the home/school setting, type of device/processor used, level of parental involvement and intra-child variables (Osberger, 1995; Waltzman, 1995; Connor & Zwolan, 2004; Owens et al, 2007).
- In general, earlier age at implantation seems to have a beneficial effect on rates of improvement in the above-mentioned areas
- Cochlear implant users appear to perform equally well or even better than hearing aid users with similar hearing losses, in the above-mentioned areas.
- Cochlear implant users appear to lag behind normally hearing peers in terms of their development in language, speech production and speech perception, but many of them perform appropriately for their *hearing age*.
- Although multichannel cochlear implants provide greatly improved access to spoken language, it is generally accepted that intensive aural habilitation services are needed to optimize the development of speech perception, production and language in children with cochlear implants (who were prelingually deafened) (O'Donoghue, Nikolopoulos, Archbold & Tait, 1999; Ertmer et al, 2002; Ertmer, Strong & Sadagopan, 2003; Ertmer, Young & Nathani, 2007; Archbold & O'Donoghue, 2007; The Ear Foundation, 2007; Nguyen, 2008).
- Speech perception is seen by many researchers, primarily Audiologists, as the most important measure of cochlear implant success.
- Only a small minority of profoundly deaf children learn to read fluently. Some researchers hypothesize that the use of cochlear implants may have a facilitative effect on literacy.
- School aged children with a profound hearing loss can demonstrate above chance PA skills at the syllable, onset-rime and phoneme level.
- Speech perception and phonological awareness are strongly linked to literacy development.

This chapter has highlighted what is known about children with cochlear implants in the areas of auditory perceptual, language, speech and literacy development. However there are many gaps in our knowledge.

The studies are typically focused on assessing one variable at a time, with few studies investigating all four areas (i.e. auditory perceptual, language, speech and literacy development) at once, and even fewer looking into the interaction between the four. Blamey et al (2001) commented on the relationships among speech perception, production, language, hearing loss and age in children with hearing loss, and concluded that speech perception test scores are not only affected by the quality of the listener's hearing but on their language and speech production skills. They urge other researchers to consider that errors in speech perception tasks may in effect be speech production or linguistic errors. Kishon-Rabin et al (2002) also commented on the unavoidably interrelated skills of speech production and speech perception. While some researchers have developed mathematical models trying to explain the amount of influence hearing, lexical and speech production factors have on speech perception numerically (Paatsch, Blamey, Sarant, Martin & Bow, 2004), this does not have any real value for researchers wanting to know why these factors influence each other, or for therapists trying to plan therapy for these children. Nevertheless, researchers have still not been able to successfully or satisfactorily integrate performances in these areas for children using cochlear implants.

Pisoni (2000) commented on this state of affairs by saying that research interest has now started to shift from issues of implant 'efficacy' to questions concerning *how* deaf children encode and process information from a cochlear implant. He maintains that the focus of research on children using cochlear implants needs to change from an emphasis on audiological outcome measures to investigating the underlying neural, psychological, and linguistic processes that mediate speech perception and production. Speech perception and production should be studied together, since these systems develop side by side and are interdependent on each other. Pisoni notes that the information processing approach (of which the psycholinguistic framework is an example) is a suitable framework within which to investigate issues regarding the processes underlying the interrelated areas of speech perception and speech processing. This same author notes the lack of information on the metalinguistic abilities of deaf children using cochlear implants. Since it would relate back to their speech perception and production skills, and since research has shown metalinguistic skills to be a strong predictor of reading success, he questions whether this holds true for deaf children too.

The speech perception and production of deaf children using cochlear implants needs to be analysed within a framework that can attempt to explain how and why they develop as they do.

In addition, the influence of the developing speech perception and production of deaf children using cochlear implants, on their emerging literacy skills needs to be investigated.

The proposed information processing framework used in this study is the Psycholinguistic Framework from Stackhouse & Wells (1997), which will be introduced in the next chapter.

CHAPTER 2: A PSYCHOLINGUISTIC APPROACH TO SPEECH AND LANGUAGE DEVELOPMENT IN CHILDREN

Psycholinguistics has its origins in the two disciplines of psychology and linguistics, and particularly in Noam Chomsky's approach to linguistics. Psycholinguistics was absorbed into mainstream cognitive psychology in the 1970's. Since this time, the approach has been increasingly applied to the clinical understanding of speech and language difficulties, firstly in acquired neurogenic disorders in adults (Coltheart, Bates & Castles, 1994; Patterson & Howard, 1992) and later in children. It is now a well established approach to understanding children's speech and language difficulties (Stackhouse & Wells, 1997; Nathan, Stackhouse & Goulandris, 1998; Vance, Dry & Rosen, 1999; Ebbels, 2000; Wells & Peppe, 2001; Pascoe, Stackhouse & Wells, 2005; Pascoe, Stackhouse & Wells, 2006).

In this approach, the information processing or computational metaphor is used. The central idea postulated is that language and speech tasks can be represented as flow diagrams, in the same way that complex tasks can be represented, before being turned into a computer program. Information processing approaches, such as the psycholinguistic approach, view the mind as being similar to a computer, using rules to translate input such as speech/vision into a symbolic representation. Within this approach, research focuses on describing the sequence of operations, or stages of processing used in a particular task (Pisoni, 2000). Flow diagrams depict several different levels of processing, which are commonly shown to relate to each other. Modern psycholinguistics attempts to break language processing down into its components and show how these components relate to each other (Harley, 2001).

Many different approaches have been used to conceptualize the speech and language difficulties of children. However, they are often problematic because of the heterogeneous nature of this population, and because of the inherent difficulties within the approaches themselves. For example, according to the *medical approach,* speech and language disorders are classified according to a clinical condition, e.g. dyspraxia, hearing loss, or Down's syndrome. These are medical labels used for defining conditions as a result of an observed cluster of deficits. The medical approach to describing speech and language difficulties can be advantageous as it 1) provides information regarding the prognosis of the disorder, 2) sheds light on medical management options for that disorder, and 3) helps define a condition through the identification of commonly occurring symptoms via differential diagnosis. However, the medical approach fails to find the aetiology of speech and language disorders in a number of cases (e.g. children termed as having ‘specific speech and language impairment’ or ‘developmental phonological disorder’), and it also fails to accurately predict the outcomes for speech and language development of children falling within the same medical condition (Stackhouse & Wells, 1997). This approach is then not very useful for therapists devising interventions, since in many cases it does not inform therapists how to manage the presenting difficulties.

On the other hand, the *linguistic approach,* such as Dodd’s subgrouping approach (1995), aims to provide a description of observed behaviour at different levels of linguistic analysis. Terms such as semantic, articulatory, or syntactic difficulties are used to describe children’s speech and language problems irrespective of the aetiology or medical condition associated with the problem. While this approach is more helpful for the therapist in devising treatment strategies, the major shortcoming is that it offers a description rather than an explanation of the presenting disorder (Stackhouse & Wells, 1997). In particular, a linguistic approach focuses on the child’s speech output, but fails to take account of the underlying cognitive processes. Baker, Croot, McLeod & Paul (2001) assert that the psycholinguistic approach aims to move beyond the shortcomings of the medical and linguistic approaches by viewing children’s speech and language problems as being derived from a breakdown at one or more levels of input, output or stored representations according to a specified model. Models allow researchers to move away from mere observation and description of symptoms towards explanation in terms of underlying processing representations and mechanisms. This precise element is deemed missing in the research of children with cochlear implants, according to Pisoni (2000).

Psycholinguistic approaches to investigating language processing in children have been put forward by various researchers (Smith, 1973; Garrett, 1980, 1988; Patterson & Shewell, 1987; Ellis & Young, 1988; Hewlett, 1990; Dodd & McCormack, 1995; Stackhouse & Wells, 1997; Chiat, 2000). Smith’s (1973) model proposed the existence of a single lexicon, which was perceptually based and contained adult-like underlying representations. He put forward the idea that children’s stored representations are modified online (i.e. the modifications occur during the actual production of speech) through the action of phonological rules, thus causing the systematic differences between the child’s perception and production. While this model and similar early single-lexicon models were able to account for the phenomenon in which children are presumed to be able to hear the difference between two minimally-paired words (such as

/maus/ and /mauT/), they still had difficulty explaining the existence of variable pronunciations of the same phoneme in different words (Baker et al, 2001).

Two-lexicon models have also been popular. These consist of an input and an output lexicon, and modifications to adult-like underlying representations are thought to occur offline rather than online. Hewlett's (1990) two-lexicon model is one of these models developed to try and address the shortcomings of previous one-lexicon models. Hewlett proposed that children produce a word via one of two possible speech processing routes – either by accessing an auditory-perceptual feature-based representation from an input lexicon and sending this information to a motor programmer to devise a motor plan for its production, or by accessing an articulatory-based representation from the output lexicon (where the representation has already been established offline via phonological rules to map the perceptual representation onto articulatory feature specifications. Word production via the input lexicon is thought to be more demanding, since it involves online processing while word production via the output lexicon is thought to be more automatic since the motor plan is already entrenched. Within this model feedback and interaction between the various processes and boxes (e.g. input, output, motor programmer) is deemed facilitative of change in the child's articulatory representations in the output lexicon towards more adult-like representations.

A more recent model is the speech processing model put forward by Stackhouse & Wells (1997).They postulate that there is a single lexicon containing one underlying representation (which they call lexical representations) for each lexicon entry (word). This representation is then linked to a series of related processes beginning with audition through to motoric production.

A premise of the psycholinguistic approach put forward by Stackhouse & Wells (1997) is that children's speech and literacy development are the products of an intact speech processing system comprising input, output and storage skills. Although educational, linguistic, medical and psychosocial factors can influence speech and literacy development, any problems with speech and literacy can be traced back to limitations with the speech processing domains of input, output and storage. Therefore an important aspect of the psycholinguistic approach is to develop hypotheses regarding the nature of the child's difficulties and then to test these through specific assessment and intervention tasks (Stackhouse & Wells, 1997). Thus the emphasis is on investigating the processes underlying task success or failure instead of just looking at task outcomes.

The psycholinguistic model devised by Stackhouse & Wells (1997) distinguishes itself from other models in that it is part of a comprehensive psycholinguistic framework which also includes a developmental phase model of speech processing, as well as a speech processing profile. This model specifies various levels of input processing, allowing for a more thorough analysis of a child's processing ability for single words. In addition, this model has been widely utilised in investigations of speech, lexical, and literacy difficulties in children (Constable et al, 1997; Nathan, Stackhouse & Goulandris, 1998; Vance, Dry & Rosen, 1999; Ebbels, 2000; Wells and Peppe, 2001; Pascoe, 2004) and treatment of children with speech and language difficulties (Vance, 1997; Waters, Hawkes & Burnett, 1998; Nathan & Simpson, 2001; Pascoe, 2004). No model however is without its limitations (e.g. it only investigates single word speech processing) – still Corrin (2001) deems this model as one which offers clinicians a systematic, theoretically grounded approach to intervention.

In this thesis, the general term speech processing will be adopted to refer to all the skills included in the understanding and production of speech including peripheral skills such as articulatory ability and hearing. This is in line with the definition used by Stackhouse & Wells (1997) within their model.

The basic elements comprising the psycholinguistic approach to speech processing are 1) an input channel, 2) an output channel, and 3) stored representations, shown in figure 2.1.

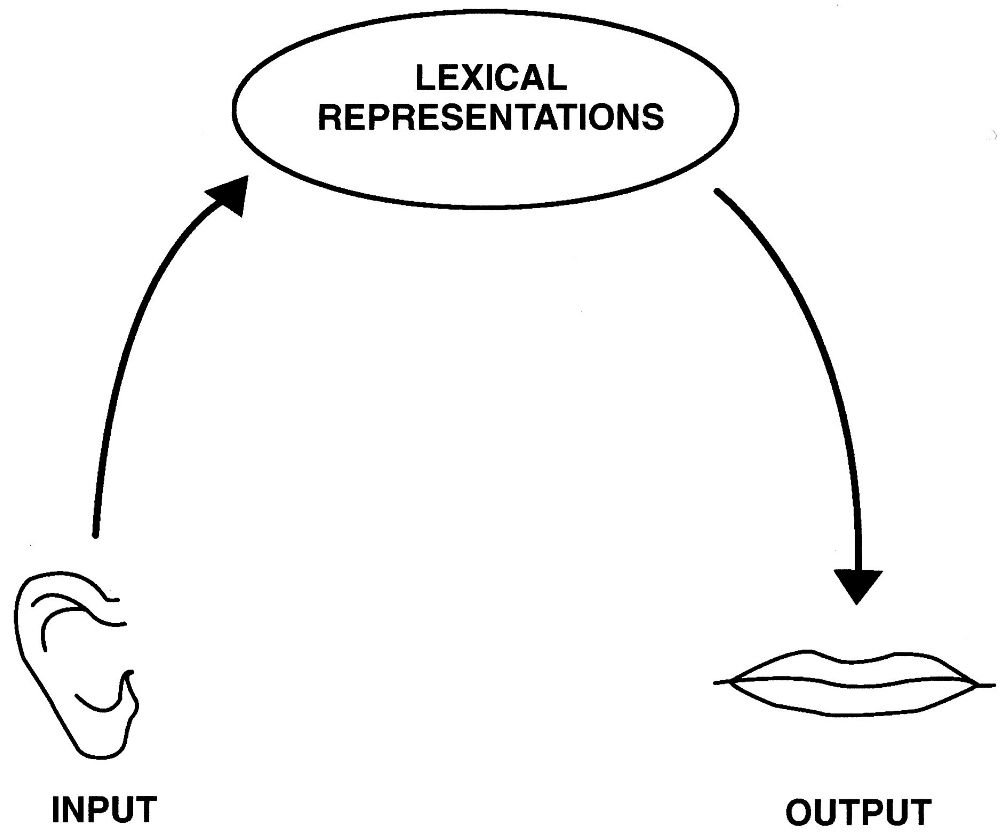


Figure 2.1 – The speech processing chain based on Stackhouse & Wells (1997).

This model essentially assumes that the child/listener receives different kinds of information (e.g. audio/visual) about an utterance via the input channel (represented by the ear in the above diagram). This information is then remembered and stored in a variety of lexical representations within the lexicon (store of words). The child is then able to select words from the lexicon and produce them verbally/ in writing via the respective output channels (represented by the mouth in the diagram above) (Stackhouse & Wells, 1997).

Lexical representations are considered to comprise the following information about a word:

- A semantic representation – information about what the word means, the attributes of that word, what category it is in, e.g. vegetable, animal, etc.
- A phonological representation – information about how the word sounds, allowing discrimination of the target word from other similar words
- A motor programme – a stored set of instructions on how to say the word, i.e. the pronunciation of the word

- A grammatical representation – information about the class of the word, e.g. noun, how it can be used in a sentence, and whether there is a plural form that can be derived from a rule
- An orthographic representation – information about what the word looks like in its written form, thus enabling automatic recognition when reading (Stackhouse, Vance, Pascoe & Wells, 2007)

At the top of the model (in Figure 2.1) lexical representations can be seen which store previously saved information. In psycholinguistic terms, *top-down* processing refers to an activity where previously stored information from the lexical representations are used to complete a task (e.g. automatic recognition of a familiar word , spontaneous naming of a familiar picture). A *bottom-up* processing task is one in which no such prior knowledge is needed and where the task can be successfully completed without accessing the stored linguistic knowledge from the lexical representations (e.g. decoding an unfamiliar word grapheme-by-grapheme, repeating a non-word).

Breakdowns in this speech processing model may result in speech processing difficulties in children. The aim of this psycholinguistic approach is to pinpoint the location of the difficulty (i.e. input side/output side/ lexical representations) and to evaluate how this is affecting speech and literacy development. This type of thinking clearly echoes Pisoni's (2001) views from the previous chapter.

In an attempt to pinpoint specific levels of difficulty in the speech processing system of a deaf child, Ebbels (2000) successfully utilised the psycholinguistic framework. Ebbels presents a case study of a child who exhibits speech and language levels below that which would be predicted from her hearing loss. Although input difficulties are known to exist within this child, Ebbels suggested that additional difficulties on other levels of the speech processing profile existed in order for this child to have developed the type of problems she presents with. One of the strengths of the psycholinguistic framework particularly exemplified in Ebbel's paper is that she is able to 'zoom in' to specific boxes where difficulties exist, and that she is able to link these deficits to specific phonemic contrasts (e.g t/d contrast) and show that these contrasts may be problematic at one level, but not at the other levels. For example, Ebbels eliminates the levels where the problem is not located using different tasks and then comparing performance on them within the same child. She then pinpoints the precise level of difficulty, which would then need to be targeted in therapy specifically for the phonemes identified.

Stackhouse & Wells' (1997) model is used here to evaluate and provide an in-depth profile of the child's speech processing at a single word level, with particular emphasis on input processing to determine the present role of her hearing impairment in her overall profile. TG was 10;4 years old at the time of this study. She was diagnosed with a moderate-severe bilateral sensori-neural hearing loss at age 1;6 and was fitted with bilateral hearing aids. Her aided thresholds fell between 30-40 dBHL. Since her diagnosis, she had been supported by a teacher of the deaf, who then referred her for Speech and Language Therapy at the age of 4;0 years. Her initial assessment showed that she presented with minimal comprehension of single words, and that she used jargon and gesture to communicate. At the time of the study, she was part of the hearing-impaired unit at her school, which integrates into the mainstream class one-third of the time. Her most recent speech and language assessment conducted before this study commenced indicated that she presented with low average comprehension scores, very much below average expressive scores, severe word-finding difficulties and segmental phonological and phonetic errors in her speech.

Ebbels' assessment comprised three stages:

1. a naming test – using the *South Tyneside Assessment of Phonology* (Arnstrong & Ainsley, 1988), and further pictures to test sounds and sound clusters in which errors were made. Mono- and multi-syllabic stimuli were used.
2. single word output tasks with which to compare naming performance – these included real word repetition (with and without lip cues), non-word repetition (with and without lip cues), and reading. The stimuli for these were the words where the correct phonological form was not produced in the picture naming condition. Equivalent non-words were produced by changing the vowels in the corresponding real words, replacing them with vowels comparable in length and state. For the reading task she was shown the written word in isolation and asked to read it aloud.
3. input tests – these included individualised mispronunciation detection tasks where the stimuli were taken from her incorrect productions in 1), and a real word same/different discrimination test, where the incorrect representations of the target word which she identified as correct (in the aforementioned task), were paired with the target word to see whether she could detect a difference between the two.

Results from these assessments indicated that TG had imprecise 'fuzzy' phonological representations for certain words so that she accepted a variety of heard versions of the target. These lead to imprecise motor programmes and therefore output errors. Some of her naming errors were due to difficulty accessing the motor program. This can lead to vowel errors and the addition of consonants. Importantly, it was found that the majority of her faulty phonological representations were not due directly to the hearing impairment, since she could hear the difference between the correct realization and her own faulty production when produced by an adult, but could rather be attributed to lack of awareness of the phonological significance of the sound contrast that she could hear. Certain errors were found to be due solely to faulty motor programs that have not yet been updated, since the phonological representation underlying that motor programme was found to be accurate. In summary TG's output speech processing was found to be age appropriate with no breakdowns. Within her input speech processing, her hearing impairment was found to affect her ability to hear differences between certain sound pairs (e.g. /t/ and /k/), and she failed to give phonological significance to certain sounds where she could hear the difference (e.g. /T/ and /S/). At the level of lexical representations, she was found to have 'fuzzy' representations for certain words, and frequently these were of multisyllabic targets. In some cases she had an accurate phonological representation but an inaccurate motor program.

The assessments conducted demonstrated that there was no single level of breakdown that was the root cause of all her difficulties. However, specific contributing levels at which difficulties were occurring were identified. As a result therapy could be planned at each specific level to treat those difficulties.

While Ebbels (2000) mainly utilised the speech processing profile as a tool for assessing and plotting speech perception development, the psycholinguistic framework of Stackhouse & Wells, (1997) actually comprises three parts:

- A speech processing profile
- A speech processing box and arrow model
- A developmental phase model

In the following sections, each of these components is described.

The Speech Processing Profile

The speech processing profile is a practical instrument for organizing data from an individual child's assessment. The speech processing profile poses a series of questions, which allows data from various assessments to be systematically arranged into a summary profile of the child's strengths and weaknesses.

These questions distinguish between a child's input processing (the skills needed to decode the speech signal) and their output processing skills (the skills needed to encode and produce speech). Input tasks appear on the left of the profile, output tasks on the right. In figure 2.2 below, the Speech Processing profile developed by Stackhouse and Wells (1997) is shown.

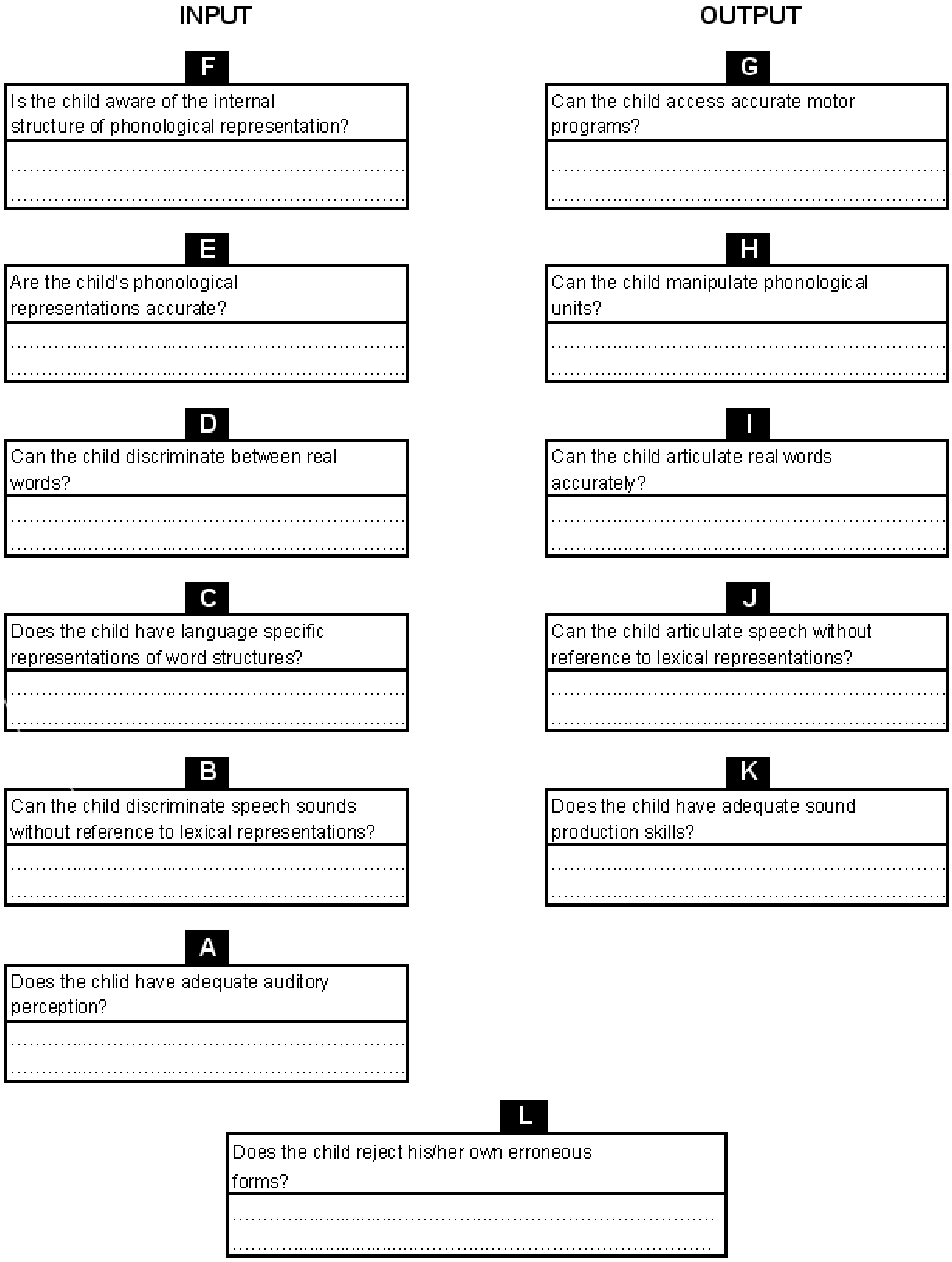


Figure 2.2 Stackhouse & Wells' (1997) Speech Processing Profile.

The framework also distinguishes between tasks that require prior linguistic knowledge for their completion, and those which require manipulation and detection of physical phenomena. Tasks that are dependant on representations appear at the top of the framework, and can be referred to as higher level tasks, while tasks that do not depend on representations appear further down towards the bottom of the framework, and are referred to as lower level tasks. More specifically, the levels of the profile ask the following questions.

Input Processing

Level A: Does the child have adequate auditory perception?

This level of the speech processing profile focuses on the child's hearing acuity or the ability to execute non-speech discrimination tasks.

Level B: Can the child discriminate speech sounds without reference to lexical representations?

This level of the speech processing profile focuses on a child's ability to discriminate between non-words, e.g. whether /vos/ and /vot/ are the same or different. Unlike level A it does involve linguistic stimuli even though the words are unfamiliar to the child.

Level C: Does the child have language specific representations of word structures?

This level of the speech processing profile is not routinely used with monolingual children, but with bi- or multilingual children this level would be used to determine the acceptability of words in a given language.

Level D: Can the child discriminate between real words?

This level of the speech processing profile focuses on a child's ability to discriminate between real words, e.g. whether mat and map are the same or different. It involves linguistic stimuli that are familiar to the child.

Level E: Are the child's phonological representations accurate?

This level of the speech processing profile aims to determine whether the child has stored an accurate internal representation of a word. Tests at this level all involve a stimulus word spoken by the tester which is then matched to a picture. The child is asked to say whether the tester has said the word properly.

Level F: Is the child aware of the internal structure of phonological representations?

This level of the speech processing profile is concerned with children's knowledge about their own stored phonological representations. All tests at this level involve pictures which will trigger the child's own phonological representation, e.g. identifying the 'odd-man out' in a rhyming task.

Output Processing

Level G: Can the child access accurate motor programs?

This level of the speech processing profile investigates whether the child has stored accurate motor programs for particular words. Picture naming tasks are often used at this level.

Level H: Can the child manipulate phonological units?

This level of the speech processing profile taps the child's ability to take a motor program and manipulate it. Tasks at this level typically involve the tester giving the child a stimulus item and requiring him/her to generate, for example, further words that rhyme with it.

Level I: Can the child articulate real words accurately?

This level of the speech processing profile investigates the child's ability to produce real words, without necessarily having to access their own stored representations of the words, most often done using a repetition format.

Level J: Can the child articulate speech without reference to lexical representations?

This level of the speech processing profile investigates the child's ability to repeat non-words, i.e. words that the child will not have produced before and cannot have any stored representations of.

Level K: Does the child have adequate sound production skills?

This level of the speech processing profile is concerned with a child's physical and functional motor execution abilities. It focuses on the child's physical capability to perform non-linguistic tasks, e.g. syllable repetition tasks and oral-motor exercises.

Level L: Does the child reject his/her own erroneous forms?

This level of the speech processing profile taps children's own ability to self-monitor. It is not possible to formally test this level, but clinician's observations of children's responses to their own errors typically yield useful information about the 'feedback loop' that links output and input processing.

The organization of the profile does not denote hierarchical levels of difficulty; therefore a level near the top of the profile is not necessarily more difficult than a lower level. Within each level, different tasks can be designed to tap into different levels of the same skill, e.g. discrimination of CVC real words would be an easier assessment task at level D, than would discrimination of multisyllabic real words at the same level on the profile.

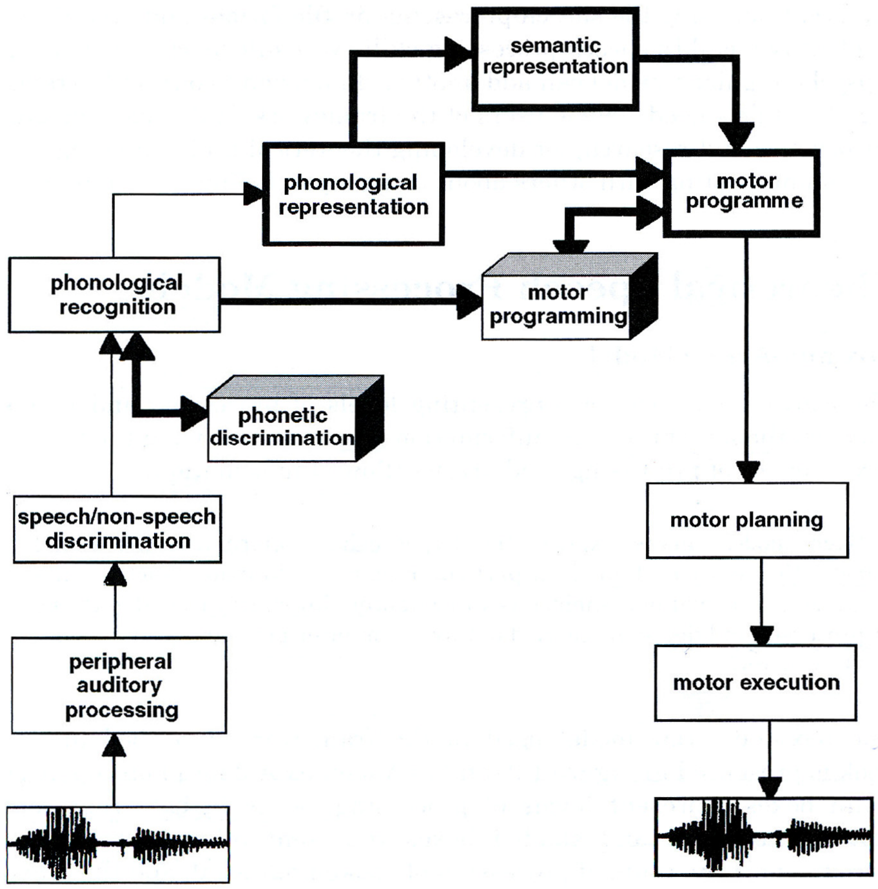
When compiling the profile from assessment data, ticks (√) or crosses (x) are placed at appropriate levels of the profile. Ticks are used to indicate that the child has performed age-appropriately on a particular task, while crosses indicate that they have scored below the expected norm for their age. One cross indicates a score that is more than one standard deviation from the mean for their age, two crosses indicates a score that is two or more standard deviations from the mean for their age, and three crosses indicates a score that is three or more standard deviations from the mean for their age. Mean and standard deviation data are usually provided in the test manuals of published assessments; however for some tests this information is not given. In that case, a qualitative comment can be written in the appropriate box and used to build a picture of the child's own relative strengths and weaknesses, indicated by a tick or cross, according to whether the skill is thought to be age appropriate (√) or not (x).

The Speech Processing Box-and-arrow Model

The psycholinguistic framework also contains a box-and-arrow model of speech processing since the proponents of this framework feel that the model is conventional and helpful in specifying levels of processing and processing routes that are assumed by the framework.

This model, like other box-and-arrow models or information processing models is a visual representation of the processes and components that are thought to be involved when children process and produce speech. Essentially the major aspects of the initial speech processing chain model (input/output/stored representations) are broken down into further levels based on observations and experimental evidence. The speech processing model from Stackhouse & Wells (1997) is presented in Figure 2.3 below.

Figure 2.3 The Speech Processing Box-and-arrow model (Stackhouse & Wells, 1997)



Plain boxes reveal levels of processing while those enclosed with a bold line represent stored knowledge. The shaded boxes – phonetic discrimination and motor programming – indicate 'off-line' processing. These boxes have a role to play in learning over time rather than in the 'on-line' processing of familiar input over time. Similarly the bold arrows indicate the flow of knowledge between boxes as part of an ongoing learning process. Information processing models such as these were originally used to help understand the speech and language processing of adults. Children differ from adults in that they are still learning language, and information processing models for children need to take that into account. Now each of the processing levels on the model will be discussed in turn.

Input Processing

Peripheral auditory processing

This is the lowest level on the input processing side of the speech processing chain model, tapping general auditory ability (as tested by hearing tests) and is usually represented diagrammatically by the ear.

Speech/non-speech discrimination

The ability to separate speech input from other input is assessed at this level.

Phonological recognition

After the child has separated speech from other sounds the next step is to distinguish between the child's own language and other languages. It is at this level, where this process takes place. If the word/s are found to be from a different language, no further processing takes place.

Phonetic discrimination

This shaded box indicates 'off-line' processing. This shows that phonetic processing can be drawn on when needed, e.g. when a child is trying to understand a speaker with a foreign accent.

Lexical representations

This level is indicated in Fig. 2.3 with bold boxes indicating that they are bodies of knowledge built up over time. This box already contains three essential aspects for each word in the lexicon – semantic information, phonological information, and a motor program. Later on, children add to this grammatical information and orthographic information.

Phonological representation

This refers to the stored knowledge of the sound structure of a word. In order to correctly identify a word from a spoken stimulus, the phonological representation must be accessed. The phonological representation of a word must have enough detailed information to be able to distinguish a specific word from other similar sounding ones (e.g. minimal pairs), yet it should not be so specific that the word -produced by speakers of different accents - would not be recognised.

Semantic representation

This refers to the stored knowledge of the meaning of words.

Motor programs

This refers to a series of gestural targets for the articulators needed to produce a specific word, similar to a template for the acceptable production of a word that is compatible with the phonological representation.

Output Processing

Motor programming

This level of processing is responsible for creating new motor programs. It is represented as a shaded box in Fig. 2.3 since it is only called upon when new, unfamiliar words need to be produced.

Motor planning

Once a motor program has been retrieved or created, it is now assembled for production, bearing in mind the contextual influences that will affect production. While the motor program is a template for how to say the word in an ideal world, the motor planning aspect adds to it by determining the speed of the utterance, the intonation and rhythm that is used, the volume and emotion associated with the word, and the influence of neighbouring sounds and words.

Motor execution

This is the lowest level of processing on the output side of the speech processing chain and is represented diagrammatically by the mouth. This level represents the vocal tract and its physical role in producing speech. Motor execution gives rise to an acoustic signal of speech and then completes the speech processing chain.

The Developmental Phase model

The third element of the psycholinguistic framework is the developmental phase model, which outlines phases in the normal development of children's speech. It is presented in Fig. 2.4.

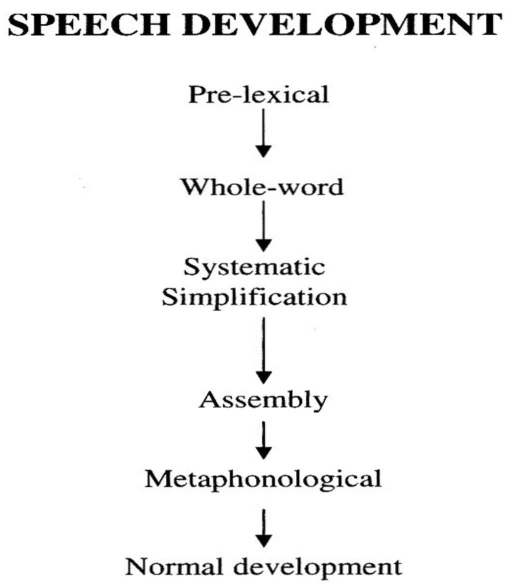


Figure 2.4 Stackhouse & Wells' (1997) Developmental phase model of speech processing.

The first year of a normally developing child's life (0-12 months) is characterised by the *prelexical phase*: the elements of the speech processing system (i.e. input, output, stored representations) are converging, but the child has yet to produce recognizable speech. The child exhibits peripheral auditory processing – speech vs. non-speech discrimination, phonetic discrimination, minimal pairs in syllables discrimination, and shows prosodic feature preferences. The child can recognise some words, but these words are not broken into constituents. Semantic representations exist for these words but they are not linked to a motor program. In terms of output we find motor execution of sounds only – no motor programming.

The next phase of development is the *whole-word phase* in which single words predominate during the second year of life (12-24 months). This phase is marked by variegated babbling and the emergence of first words, which have distinct meanings but a wide range of forms for one target utterance. The child possesses a small vocabulary which is overextended (where one word can pertain to any word within a set category, e.g. 'dog' for all animals), and underextended (where a word is only used to refer to a specific example of a category, e.g. 'Daddy' only refers to the child's Father). There is no evidence of segmentation or simplification of the target words as yet, however sequencing errors and segmental errors occur. Homophony is also characteristic of this stage where different words sound the same. This results from the phonological representation of words being underspecified, which in turn results in the creation of inaccurate motor programs. In addition, the salient acoustic aspect of the word is usually overexagerrated in the child's production. At this stage, there is a marked gap between the child's ability to comprehend language and their ability to produce it.

This phase is followed by the *systematic simplification phase* (±18m – 3 years) in which phonological simplification processes, such as fronting, cluster reduction, stopping, etc. are exhibited. Within this phase regular simplifying processes are displayed and there is less variability in the child's speech, even though the phonological representations are still imprecise. When regular simplifying processes are the dominant feature of the child's speech they have entered this phase and it is within this phase that children learn how to fix these faulty patterns. Homophony is rare within this phase as children have now assigned one sound pattern to one word. Also children are now aware of the syllable within words and have achieved pattern perception. In the beginning of this phase the phonological processes present in children's speech usually affect the whole word (e.g. final consonant deletion) while later in this phase phonological processes which affect individual segments exist (e.g. stopping).

The next phase is known as the *assembly phase* (± 3 years and up) which involves consolidating all the speech processing aspects with single words incorporated into connected speech and used to achieve a range of communicative aims. Within this phase some difficult sounds are usually still problematic (e.g. /r/, /T/) but most phonological processes have disappeared. Children may still have difficulty with consonant clusters but can use intonation in sentences effectively. Greater amounts of dysfluency are also observed during this phase due to the increased demands that syntax and morphology, appropriate intonation and altering phonetic output at word junctions impose.

At early school-age (± 5 years and up) the *metaphonological phase* is entered by normally developing children. Within this phase children develop the ability to reflect on their own speech and to manipulate and understand their own language in a more abstract way. The majority of children at this phase start to be able to consciously segment words and syllables into their constituent parts. Children begin to rhyme and to segment the initial phoneme in words. After exposure to the alphabetic rule children normally begin to be able to segment phonemes in all positions.

Difficulties can occur at any of the phases outlined in the developmental phase model, and arrested development at one phase often has a knock-on effect so that the child may be delayed and move more slowly through all the subsequent developmental phases of speech processing.

Summary

- The psycholinguistic approach is one that has been found useful in answering questions about the processes involved in understanding and producing speech.
- The three key elements of the psycholinguistic framework put forward by Stackhouse & Wells (1997) are the speech processing profile, the box-and-arrow speech processing model and the developmental phase model.
- The speech processing profile is a practical tool that can be used to organise assessment data into appropriate processing levels.
- The box-and-arrow speech processing model shows how speech processing at different levels can be conceptualised.
- The developmental phase model shows which phases children need to pass through in order to develop normal speech processing skills.
- The psycholinguistic framework enables the clinician to be very specific about which skills are really tapped in assessment tasks, and to more accurately identify the level at which a breakdown in speech processing has occurred, so that interventions can be targeted at the correct level.

Stackhouse & Wells framework can be used to account for the process of normal development of speech processing in children – but it has also been widely used as a tool for describing and understanding the difficulties which some children experience during speech acquisition. Each of the components are able to offer slightly different perspectives on a child's strengths and weaknesses, as will be illustrated in the case studies presented in this thesis.

CHAPTER 3: METHODOLOGY

3.1 Purpose of the study

The aim of the study is to investigate the speech processing skills of children with cochlear implants using a psycholinguistic framework. An in-depth and comprehensive assessment of each child's speech processing strengths and weaknesses will be carried out, compared to age norms where appropriate and profiled using psycholinguistic tools.

The specific aims of the study are:

1. To describe the speech processing skills of 3 CI-using children (aged between 4 and 9 years), using psycholinguistic profiling (Stackhouse & Wells, 1997).
2. To make comparisons between the profile and previous speech processing data, for each child, in order to describe the development of speech processing over time, and in relation to time of implant.

3.2 Study Design

This study is descriptive in nature. It employs a non-experimental, ex post facto research design, which combines elements of qualitative and quantitative methodologies within a single case design. A 'snapshot' investigation of the participants' current speech processing skills will be compared with previous assessments.

Three individual case studies were carried out. Single case studies have been used widely in investigations of children's (Tomasello, 1992; Stackhouse & Wells, 1997; Tyler et al, 1997; Ebbels, 2000; Ertmer & Mellon, 2001; Pascoe, Stackhouse & Wells, 2005; Ertmer, Young & Nathani, 2007) and adults' communication difficulties (Ramus, Rosen, Dakin, Day, Castellote, White & Frith, 2003; Fawcett, White, Balcazar, Suarez-Balcazar, Matthews, Paine-Andrews, Seekins, & Smith, 1994; Schachter, Curran, Galluccio, Millberg & Bates, 1996; Martin, Hierson, Herman, Thomas & Pring, 2007; Franklin, Howard & Patterson, 1994). The single case methodology allows for in-depth explanation of an individual's unique weaknesses and strengths, and has been argued by some to be the most appropriate method of investigating individuals with complex language, communication and cognitive deficits (Patterson & Howard, 1992).The use of three single cases provides additional richness of data (Pring, 2005). Each participant is considered separately as an individual rather than comparing them with each other. The case study methodology is particularly suited to populations with speech, language and hearing difficulties as they comprise an extremely heterogeneous group, so that it would be near impossible to control for all variables within an experimental group. While experimental studies establish the efficacy of treatments, case studies allow researchers to understand syndromes and situations more thoroughly (Lindegger, 1999). Case studies also have the advantage of allowing new ideas and hypotheses to emerge from careful and detailed observation.

3.3 Ethical Considerations

The basic tenets of research ethics, guided by the Declaration of Helsinki (1997), the South African Guidelines for Good Clinical Practice, and the Medical Research Council Ethical Guidelines for Research were adhered to. This entailed ensuring compliance with the main tenets of ethical research, which are:

- Autonomy – participants and their parents were fully informed about the purposes and procedures of the research, to enable them to make informed decisions. Participants over 7 years of age were given their own consent form to sign, in addition to their parents signing an informed consent form. See Appendix C for a copy of this.
- Beneficence – in order to maximize benefits and minimize risks for the participants, no invasive testing was done, and a free copy of the assessment results was made available to their families. In addition, there were no transport or other costs involved to the participant as the researcher tested participants in their own homes.
- Equity in subject selection – participants were not unfairly coerced into participating as only those who indicated interest in participating were allowed into the random draw. In addition participants and their parents were made aware that their participation was entirely voluntary, and that they could at any time decline to participate. It was made clear that this would not result in any penalty or prejudiced treatment by the researcher or the Cochlear Implant Centre Staff.
- Participants and their parents were also informed that the current test results, as well as the previous test results from the Cochlear Implant Centre would be confidentially handled. Participants would only be identified by their initials, and the audiotape recordings of certain test results would also be kept in locked storage, to be used exclusively for research purposes.

3.4 Participant selection criteria

Criteria for choosing the participants for this study were as follows:

- All participants should be Cochlear Implant users
- All participants should be aged between 4-9 years. Phelps (2003) suggests that this is the age range within which most phonological and metalinguistic development occurs. In addition, most studies which focus on metalinguistic and beginning literacy development use participants who are on the verge of literacy development (i.e. introduction to the alphabetic principle) or who are in the process of acquiring it (Swank & Larrivee, 1998; Dodd & Carr, 2003; Mann & Foy, 2003; Puolakanaho, Poikkeus, Ahonen, Tolvanen & Lyytinen, 2004; James, Rajput, Brown, Sirimanna, Brinton & Goswami, 2005).
- All participants should have normal intelligence, or normal *non-verbal reasoning scores* as determined from medical, audiological and educational records. This is to ensure that general developmental delays do not further confound any delays observed in speech processing.
- All participants should be mother-tongue English speakers. This will allow the present study to be compared to other studies on CI users, and also because developmental data is available primarily for English-speaking children. Given the diversity of languages used in South Africa, it will be considered acceptable for participants to have exposure to other languages in the home or school, as long as English is their primary language.

Exclusion criteria include:

- Developmental delays as measured by an IQ score of less than 80
- Bi / multilingual participants where English is spoken, but it is not the primary language.
- Less than 12 months cochlear implant use. This will ensure that the participant has had sufficient time to adjust to the new listening conditions imposed by the cochlear implant and that they will have had time to acquire some language. Age at implantation alone is not in and of itself a variable that needs to be controlled for or restricted however, as many other factors also contribute to variability in speech perceptual development (Connor & Zwolan, 2004; Geers, 2004).

3.5 Selection Procedure

Before participants were recruited, a research proposal was submitted and approved by the Committee for Human Research at Stellenbosch University. In addition, permission and co-operation in supplying past test data for the participants was secured from Tygerberg Hospital's

Cochlear Implant Centre. All clients of the Tygerberg Hospital Cochlear Implant Centre, fitting the above-mentioned criteria, were approached to participate in the study. A convenience sample has been used, as the population fitting the above-mentioned criteria is very small. Nine children met the above-mentioned criteria. Introduction and covering letters were sent to each potential participant's family (see Appendix A). Two weeks later telephonic contact was established to ascertain whether parents were interested in participating.

More than three suitable candidates responded favourably. As a result, three participants were then randomly selected, allocating numbers to each family willing to participate, and then selecting three from a hat. Unsuccessful candidates were thanked for their interest and informed telephonically that they were not to be involved in the present study. The three participants' parents were then contacted to set up appointments.

3.6 Participants

The three participants were females between the ages of 6 years,0 months and 8 years,10 months. NG, DP, and BA, (as they will be known for the purposes of this project) are all resident in suburbs of Cape Town. All of them have been exposed to literacy instruction, and all are currently attending schools. Table 3.1 describes the three participants.

Child	Chapter of thesis	Sex	Monaural/ Binaural cochlear implants	CA (years; months at time of testing)	Age at implantation	School level at time of testing	Summary of difficulties based on parental & teacher report
NG	4	F	Monaural	6;0	3;0	Gr R	receptive and expressive language delay
DP	5	F	Binaural	6;10	1;2	Gr 1	receptive and expressive language delay
BA	6	F	Monaural	8,10	2;5	Gr 2	severe speech, receptive and expressive language delay; poor concentration and attention

Table 3.1 Description of child participants

3.7 Data Collection

3.7.1 Materials:

The following materials were used to aid data collection:

3.7.1.1 Data sheet

3.7.1.2 Previous speech, language & hearing test results, taken from the Cochlear Implant Centre folders

3.7.1.3 Speech Processing Profile (Stackhouse and Wells,1997)

3.7.1.1 Data sheet . (see Appendix D).

This sheet was used to record information gathered from the participants' parents. It consists mainly of demographic and hearing performance questions. Data gathering was conducted by the researcher using the participant's parent, as the information source, during a short (5-10 minute) session before/during the assessment.

Questions asked included :

- years of cochlear implant usage,
- age at implantation,
- whether monaural or binaural cochlear implants were being used,
- aetiology of the hearing impairment
- number of years of unaided hearing
- whether or not hearing aids were worn before implantation, and for how many years
- what the home language is, and whether or not any other languages are spoken in the home
- race, perceived socio-economic status, number of siblings
- type of schooling (special or mainstream)
- whether or not speech therapy was/is received, and the frequency thereof

3.7.1.2 Previous speech, language & hearing test results

As part of the Cochlear Implant Centre's fixed management protocol, all clients are tested bi-annually, for two years post-implant and then annually after that. The test battery used differs from child to child according to that child's specific developmental rate, however this battery always includes speech, language, and auditory assessments.

3.7.1.3 Speech Processing Profile, (Stackhouse and Wells,1997).

The speech processing profile is a tool linked to the Psycholinguistic Framework of Stackhouse & Wells (1997). It focuses on Speech processing skills which underpin speech, lexical and literacy development. This profile is a means of systematically organising assessment results in order to provide an overall picture of a child's speech processing skills. It is designed to provide a visual record of a child's strengths and weaknesses, using graded ticks and crosses as a means of indicating how well or poorly a child has performed within each level on the profile, compared to normative data for their age group (Stackhouse & Wells, 1997; Stackhouse, Vance, Pascoe & Wells, 2007). Figure 2.2 shows the speech processing profile.

The profile is ordered in terms of input tasks (left hand side) and output tasks (right hand side), as well as different levels A – L, which tap into different components of speech processing. Each level seeks to answer discrete questions related to speech perception, such as 'Does the child have adequate auditory perception?' (level A), or 'Can the child access accurate motor programs?' (level G). At least one assessment per level of the profile will be conducted. Data from a variety of sources (assessments, case history information, observations) will form the basis for the profiling of speech processing skills. Table 3.2 summarises the input tests used; the level of the psycholinguistic profile they tap into; the nature of the task, as well as a summary of the procedure used in administering the test.

Level	Area to be assessed	Task type	Procedure	Reference
A	Auditory perception	Results from latest audiometric evaluation	Diagnostic audiometrical tests are performed by the audiologists, documented and used.	- Katz, 2002
B	Discrimination of speech sounds without reference to lexical representations	- judgement of non-words in terms of similarity or difference - judgement of non-words in terms of identifying the speaker	- the Tester asks whether two non-words are the same or different, e.g. /ket/ and /ret/ - 2 toys presented, Tester speaks a non-word for each toy from a minimal pair. Participant points to the specific toy that 'said' the word requested by the tester.	- Bridgeman & Snowling, 1988, in Stackhouse, Vance, Pascoe & Wells, 2007 -Stackhouse, Vance, Pascoe & Wells, 2007.
D	Discrimination between real words	- minimal pair auditory discrimination: CVC - auditory rhyme judgement	- words are spoken by Tester, participant has to decide whether they are same/different e.g. /bin/ and /bib/ - Tester presents three words and asks which two words rhyme e.g. /mat/ and /hat/	- Bridgeman & Snowling, 1988, in Stackhouse, Vance, Pascoe & Wells, 2007 - Vance, Stackhouse & Wells, 2004, in Stackhouse, Vance, Pascoe & Wells, 2007
E	Phonological representations	- auditory lexical discrimination task (mispronunciation detection)	- Participant is shown a picture. Tester gives a few possible variants from which participant must judge as correct or incorrect e.g. Target /hen/, also present /hem/, /wen/, etc.	- Nathan et al, 2004, in Stackhouse, Vance, Pascoe & Wells, 2007
F	Internal structure of phonological representations	- picture onset detection - picture rhyme detection	- identification of pictures that begin with the same 'sound', e.g. /pan/, /pot/ - identification of pictures that rhyme, e.g. /sock/, /rock/	- Frederickson, Frith & Reason, 1997. (PhAB subtest: Alliteration part 2) - Vance, Stackhouse & Wells, 2004, in Stackhouse, Vance, Pascoe & Wells, 2007

Table 3.2 Input tasks used in the assessment battery.

Table 3.3 summarises the output tasks used; the level of the psycholinguistic profile they tap into; the nature of the task, as well as a summary of the procedure used in administering the test.

Level	Area to be assessed	Task type	Procedure	Reference
G	Access to accurate motor programs	- Picture description data - Lexical naming tests - Naming accuracy	- Participant is shown a set of 10 pictures and is required to describe the scene in each picture - Participant is shown pictures and is required to name it, according to a standardised test format Phonetic transcription of responses to the above test	- RAPT :Renfrew, 1972; - EOWPVT-R :Gardner, 1990
H	Manipulation of phonological units	- onset string production - Rhyme string production	- Participant is to say as many words as they can that start with a specified sound, e.g. words that start with a /s/ - Participant is to say as many words as they can that rhyme with a specified word, e.g. words that rhyme with /man/	- Frederickson, Frith & Reason, 1997 (PhAB subtest: Alliteration fluency) - Frederickson, Frith & Reason, 1997 (PhAB subtest: Rhyme fluency);
I	Real word articulation	- sound blending of real words - repetition tasks	- word segments are presented verbally, participant must blend to form a word - participant is required to repeat several repetitions of real words	- real word items from the Aston Index, Newton & Thomson, 1982; PAT blending subtest : Robertson & Salter, 1997 - Constable,Stackhouse & Wells, 1997, in Stackhouse, Vance, Pascoe & Wells, 2007
J	Articulation of speech sounds without reference to lexical representations	- Nonword blending - repetition of non-words	- nonword segments are presented verbally, participant must blend to form a word, e.g. /b/+/o/+/f/= /bof/ - participant must repeat a verbally given nonword e.g /kapatila/	- non-word items from the Aston Index :Newton & Thomson, 1982 - Constable, Stackhouse & Wells, 1997, in Stackhouse, Vance, Pascoe & Wells, 2007
K	Sound production skills	- Oral examination of structure and function - Diadochokinetic rates	- assessment of structure and functioning of articulators - repeated imitation of sounds in isolation and in sequences	- Shipley & McAfee, 2004 - Shipley & McAfee, 2004; Fletcher, 1972
L	Rejection of child's own erroneous forms	- Based on Tester's observations of child's behaviour		

Table 3.3 Output tasks used in the assessment battery.

The assessment tasks outlined in Tables 3.2 and 3.3 are discussed in greater detail in this section. Each test used, was scored in relation to detailed guidelines from Stackhouse, Vance, Pascoe and Wells (2007), and in relation to normative data available with the test. The aim was for each individual child's performance to be considered in two ways:

1) in terms of their own profile, i.e. what are their own strengths and weaknesses

2) in relation to normally developing hearing peers (where norms are available).

Test scores can also be used to compare the child to him/herself at different points of time.

Advocates of a psycholinguistic approach strongly recommend comparing test results to normative data (e.g. Stackhouse & Wells, 1997). However, it is important to note that most of these tests have normative data collected on monolingual normally hearing children in the UK, and thus the population involved in the present study is different from that one. The participants in the present study all have been exposed to more than one language, whether at home or at school; they all speak South African English, which in itself has distinctive vocabulary and grammatical structure changes from that of Standard British English. Secondly, no norms are available for hearing impaired children for the above-mentioned tests. Therefore it is important to note that the norms are used as a guideline only, taking the aforementioned factors into account.

<u>INPUT ASSESSMENTS</u>

Level A : this level is concerned with the child's hearing acuity. (Pascoe, Stackhouse & Wells, 2006).

A.1 *Audiometry*. Aided freefield testing measures the sound detection thresholds of participants for frequencies across the speech range. Warble tones are presented via a speaker (0° azimuth, 1m from the participant) utilizing different frequencies (250 Hz, 500 Hz, 750 Hz, 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz, 4000 Hz). The participant indicates each time they hear a sound. The threshold (i.e. softest level) at which they detect a sound at each frequency is recorded and plotted to determine their aided audiogram. The aided pure tone average is calculated by averaging the aided thresholds (in dB HL) at 500 Hz, 1000 Hz and 2000 Hz. For cochlear implant users, the aided pure tone average is usually equivalent to a child with a mild-moderate hearing loss. These tests are done at regular intervals for each cochlear implant user by audiologists at the Cochlear Implant Centre.

Level B : this level focuses on the child's ability to discriminate between non-words. Unlike level A it does involve linguistic stimuli. Two tasks were used to assess level B.

B.1 *Auditory Discrimination of Non-words.*

This was assessed using Bridgeman & Snowling's (1988) Same-Different test, which assesses auditory discrimination of real and non-words (Stackhouse, Wells, Vance & Pascoe, 2007). This is primarily an input task (since the child does not have to give a spoken response – a head nod/shake will also suffice), where the child is required to listen to two non-words presented verbally (e.g. fets vs. fest) and decides whether they are the same or not. There are no lexical representations for these words, as they are non-words. The non-words are formed using CVC, CCVC, CVCC, and CCVCC combinations. The short form used in this assessment battery, comprised 10 non-words. The words were presented verbally using live voice, with the tester's mouth out of the participant's line of sight, to ensure that results are not confounded by the effects of lipreading. Practice items are administered first.

The participants' responses were recorded on a form specially designed for this purpose, which divides responses into categories based on whether the words differed in terms of features/sequences. Three of the response pairs differed in terms of features (e.g. dit – dis), three of the response pairs differed in terms of sequence (e.g. dits – dist), and four of the response pairs were the same. Scores are tallied and then compared to norms for that age group. Where norms for the age group were not available the closest age-group's norms were used.

B.2 *ABX task*

The ABX task developed by Stackhouse et al (2007) was used. It uses non-words and does not tap into any lexical representations. The tester uses two soft toys to each represent one non-word. The tester points to each toy individually and says the non-word associated with it. Hereafter the tester asks the participant which toy said a specific non-word. This task therefore also taps auditory memory. Twenty four pairs of non-words were used. The pairs differed in terms of cluster reduction/place of articulation of one of the consonants/ manner of articulation of one of the consonants/ voicing of one of the consonants/metathesis of one of the consonants (e.g. /faUs/ while showing a house). Practice items are administered first. One repetition of each stimulus pair was allowed. The words were presented verbally using live voice, with the tester's mouth out of the participant's line of sight, to ensure that results are not confounded by the effects of lipreading.

The non-words used varied from 1-3 syllables in length. The tester records the participant's responses (i.e. the toy pointed to) as correct/incorrect on a form specific to this purpose. The total is then calculated out of 24, and incorrect answers can be analysed to see if a particular type of error was consistently made. Scores are tallied and then compared to norms for that age group. Where norms for the age group were not available the closest age-group's norms were used.

Level C was not tested in this study. It is usually reserved for use in determining the ability of bi- or multilingual children to identify the allowable phonetic components of English speech. Since the sample used was chosen to be English mother-tongue speakers, this was not felt to be appropriate for testing.

Level D: this level investigates whether the child is able to discriminate real words from each other. Two tasks were carried out at this level.

D.1 *Auditory Discrimination of Real words*

This was tested using Bridgeman & Snowling's (1988) Same-Different test, which assesses auditory discrimination of real and non-words (Stackhouse et al, 2007). In this input task, the child is required to listen to two words presented verbally and decide whether they are the same or not (e.g. miss vs. mitt). Since real words are used, the participants are likely to have lexical representations for these words. The words used in the test are common words expected to be part of the participants' lexicons.

This task can be performed using either top-down or bottom-up processing routes, whereas non-word discrimination can only be performed using a bottom-up approach, since no previous information stored in the lexical representations can be recalled to help with this task. Thus for non-word discrimination only immediate perceptual information can be used to complete the task, while for real word discrimination, this method as well as comparing two lexical items recalled from the stored representations can be used to complete the task.

The words used comprised CVC (e.g. met), CCVC (e.g. plate), CVCC (e.g. messed), and CCVCC (e.g. placed) combinations. The short form used in this assessment battery comprised 10 pairs of real words. The words were presented verbally using live voice, with the tester's mouth out of the participant's line of sight, to ensure that results are not confounded by the effects of lipreading.

The participants' responses were recorded on a form specially designed for this purpose, which divides responses into categories based on whether the words differed in terms of features/sequences. Three of the response pairs differed in terms of features (e.g. mitt – miss), three of the response pairs differed in terms of sequence (e.g. missed – mitts), and four of the response pairs were the same. Scores are tallied and then compared to norms for that age group. Where norms for the age group were not available the closest age-group's norms were used.

D.2 *Auditory Rhyme Detection*

This was tested using the screening test of rhyme ability (Vance, Stackhouse & Wells, 2004) which assesses both auditory and visual rhyme detection. The tester verbally presents three real words, which the participant must hold in mind, compare to each other, and decide which two rhyme. The participant then has to verbalise the two words thought to rhyme. Thus, this task taps auditory memory as well. One repetition of each stimulus trio was allowed. Practice items are administered first.

The participants' responses were recorded on a form specially designed for this purpose. The form enables the tester to indicate whether mistakes made were due to the participant choosing a semantic or alliterative match instead of a rhyming match. Test stimuli were chosen to be everyday one syllable words likely to be within the participant's lexicon, e.g. nail and whale. Foils were chosen to be either an alliterative (e.g. whale and wall) or a semantic match (e.g. nail and hammer). Thirty stimulus words are used and errors are scored out of ten. An error category where the participant simply did not know the answer was also created to be filled in on the form. Scores are tallied and then compared to norms for that age group. Where norms for the age group were not available the closest age-group's norms were used.

Level E : this level examines whether the child has stored an accurate internal representation of a word.

E.1 *Auditory Detection of Speech Errors*

This was tested using the Auditory Lexical Discrimination Task 1: Mispronunciation detection short form (Nathan et al, 2004 in Stackhouse et al, 2007). This is an input task, which necessitates tapping the lexical representations in order to complete the task. The participant is required to look at a picture and has to decide if the tester has supplied a correct or incorrect version of the name of that picture. A soft toy is used to explain that this particular toy sometimes says words correctly or incorrectly, and that it is the participant's job to determine when that is.

Practice items are administered first. One repetition of each stimulus is allowed and words are presented verbally using live voice, with the tester's mouth out of the participant's line of sight, to ensure that results are not confounded by lipreading. Two to three versions of each picture's name are produced, e.g. brush, /brVs/ . Versions of the target were changed in terms of cluster reduction/place of articulation of one of the consonants/ manner of articulation of one of the consonants/ voicing of one of the consonants/ metathesis of one of the consonants. Twelve items were used in total, and scores out of 24 are obtained.

Incorrect responses are circled and analysed to see if a pattern of difficulty emerges. Scores are recorded on a form specific to this purpose. Certain items are administered but not scored, according to scoring instructions for this test to check for consistency in the child's judgement. Scores are tallied and then compared to norms for that age group. Where norms for the age group were not available the closest age-group's norms were used.

In addition, before testing commences, and to ensure that all of the picture names are within the child's lexicon, the child is asked to name all of them. Responses are recorded and phonetically transcribed to be analysed as part of the naming component (Level G).

Level F: this level is concerned with the child's knowledge about their own stored representations. Two tasks were used to assess this level.

F.1 *Picture Onset Detection*

This was tested using the 'Alliteration with pictures' subtest of the *Phonological Awareness Battery* (PhaB) (Frederickson, Frith & Reason, 1997). This task assesses the visual input channel, taps the participants' lexical representations and cannot be completed without doing so. Firstly the participant has to name all the pictures to ensure that the words feature in their lexicon. Next, three pictures are shown simultaneously to the participant who then has to point to the two that start with the same sound (e.g. road, light, rain). The first half of the test comprises 5 CVC words, while the second half comprises 5 CCVC words. Practice items are administered first.

If the participant fails to score more than 3/5 for the first half of the test, the second part of the test is not done. Responses are recorded on a form specific to this purpose. Scores are tallied and then compared to norms for that age group.

F.2 *Picture Rhyme Detection*

This was tested using the screening test of rhyme ability (Vance, Stackhouse & Wells, 2004) which assesses both auditory and visual rhyme detection. This is an input task as no output other than pointing is required.

Before the test commences, all the pictures are shown to the participant who is required to name them to ensure that the stimuli words are within their lexicon. The participant is thereafter shown a set of three pictures, and has to indicate by pointing which two of them rhyme, e.g. shell, bell, sea. Test stimuli were chosen to be everyday words likely to be within the participant's lexicon. This taps lexical representations as the child is expected to compare stored forms against each other and decide which two of the three rhyme. Foils used are either an alliterative/semantic match with one of the two rhyming stimuli. Practice items are administered first.

The participants' responses were recorded on a form specially designed for this purpose. The form enables the tester to indicate whether mistakes made were due to the participant choosing a semantic or alliterative match instead of a rhyming match. An error category where the participant simply did not know the answer was also created to be filled in on the form. Thirty stimulus words are used and errors are scored out of ten. Scores are tallied and then compared to norms for that age group. Where norms for the age group were not available, the closest age-group's norms were used.

OUTPUT ASSESSMENTS

Level G: this level investigates whether the child has stored representations for particular words, eliciting them via naming. Three tasks were used to assess this area.

Lexical Naming task

G.1 Expressive One Word Picture Vocabulary Test (EOWPVT-R) (Gardner, 1990),

G.2 Renfrew Action Picture Test (RAPT) (Renfrew ,1972),

G.3 Nathan et al's (2004) naming task prior to the mispronunciation detection task (see Level E : auditory detection of speech errors).

Naming is a complex cross-modal task. The participant is required to access their own stored representation of a picture and then produce it, utilizing an existing motor program. This is therefore classed as an output task.

A picture is shown to the participant who then has to name it. Responses are recorded on a form specific to this purpose, in phonetic form (to check accuracy), and also on audio tape to verify transcriptions. EOWPVT-R scoring guidelines indicate that the correct answer needs only to include the root word involved in the picture and need not be phonetically identical to the target. Scores are tallied and then compared to norms for that age group. The RAPT analyses connected speech in terms of vocabulary usage and grammaticality. These language aspects are not specific components of the speech processing profile, but it offers information about the connected speech abilities of the participants. Scores are tallied and then compared to norms for that age group. The other naming test (Nathan et al, 2004) is more informal in nature and does not have any norms. These results were analysed to determine whether any immature phonological processes or articulation difficulties were present.

Level H : tasks at this level tap a child's ability to use an existing motor program and manipulate it. Two tasks were used to assess this level.

H.1 *Onset String Production*

This was assessed using the 'Alliteration fluency subtest' of the *Phonological Awareness Battery* (PhaB) (Frederickson, Frith & Reason, 1997). This task assesses the output channel, and also taps phonological representations of stored words. Participants are required to create as many words as they can starting with the sound the tester gives them within one minute, e.g. /m/ - my, man, mouse, mat, etc. The participants' responses were recorded on a form specially designed for this purpose. Practice items are administered first. One repetition of each stimulus sound was allowed. Scores are tallied and then compared to norms for that age group.

H.2 *Onset Rhyme Production*

This was assessed using the 'Rhyme fluency subtest' of the *Phonological Awareness Battery* (PhaB) (Frederickson, Frith & Reason, 1997). This task assesses the output channel, and also taps phonological representations of stored words. Participants are

required to create as many words as they can rhyming with the word the tester gives them, within one minute, e.g. hat – mat, cat, sat, fat, etc.
The participants' responses were recorded on a form specially designed for this purpose. Practice items are administered first. One repetition of each stimulus word was allowed. Scores are tallied and then compared to norms for that age group.

Level I: this level examines the child's ability to produce real words without necessarily relying on their lexical representations. Two tasks were used to assess this level.

I.1 *Real Word Blending*
This was tested using the 'Blending subtest' of the *Phonological Awareness Test* (PAT) (Robertson & Salter, 1997). This is an output task in which stored representations do not have to be accessed, but may be, since real words are used. The tester verbally produces segments of a word which the participant has to join and produce as one word, e.g. /b/ + /e/ + /d/ = /bed/. This task comprises syllable and phoneme blending sub-tasks. Stimuli for the syllable subtask consisted of 10, 2-4 syllable words. Stimuli for the phoneme sub-task comprised 3 CV words, 3 CVC words, 4 CCVC/CVCC words.

The participants' responses were recorded on a form specially designed for this purpose. Practice items were administered first. One repetition of each stimulus was allowed. Scores are tallied and then compared to norms for that age group.

I.2 *Real Word Repetition*
This was assessed using Constable, Stackhouse & Wells' (1997) real and non-word repetition task. This is an output task which may/may not access the stored representations, since the participant is likely to have a stored motor programme for the stimulus word if it is a real word, and if the participant has already acquired it.. The stimuli comprise 20 real and 20 non-words, of which half have 3 syllables and half have 4 syllables. The stimulus is presented via live voice without obscuring the tester's mouth. The participant is required to repeat the actual stimulus precisely as the tester has said it.

Responses are recorded via audiotape and later transcribed phonetically. The participants' responses were recorded on a form specially designed for this purpose. One repetition of each stimulus word was allowed. No practice items were administered.

Level J : this level investigates the child's ability to repeat non-words. Two tasks were used to assess this level.

J.1 *Non-word Blending*

This was tested using the 'Real and Non-word blending subtest' of the *Aston Index* (Newton & Thomson, 1982). Bottom-up processing is needed to complete this task as stored representations are not accessed when non-words are used. The tester verbally produces segments of a word which the participant has to join and produce as one word, e.g. /p/ + /o/ + /g/ = /pog/. Stimuli consist of 15 real and 5 non-words.

The stimulus is presented via live voice without obscuring the tester's mouth. The participants' responses were recorded on a form specially designed for this purpose. One repetition of each stimulus word was allowed. No practice items were administered.

J.2 *Non-word Repetition*

This was assessed using Constable, Stackhouse & Wells (1997) 'Real and Non-word repetition task'. This is an output task which cannot access the stored representations, since the stimuli are all non-words. Thus new motor programmes have to be constructed for each non-word that is to be repeated.

The stimuli comprise 20 real and 20 non-words, of which half have 3 syllables and half have 4 syllables. There are 10 target lexical items. Two closely matched non-words were derived from each of these items (i.e. 20 nonwords in total). To control for possible response bias, a further 10 real words similar in phonological structure to the targets are included. Non-words were created in 2 ways – either by altering one phoneme at the beginning of the third or final syllable to imitate a perseverative error e.g. escalator – escalacor, or by transposing two phonemes in the word, e.g. escalator – estalacor.

In addition, but separate from this task, a picture identification task was carried out with the 10 target lexical items to ensure that the participant already had the word within a stored representation. The stimulus is presented via live voice without obscuring the tester's mouth. The participant is required to repeat the actual stimulus precisely as the tester has said it.

Responses are recorded via audiotape and later transcribed phonetically. The participants' responses were recorded on a form specially designed for this purpose. One repetition of each stimulus word was allowed. No practice items were administered.

Level K : this level examines the child's physical and functional motor execution abilities. Two tasks were used to assess this level.

K.1 *Oral Peripheral Examination*
This was assessed using Shipley and McAfee's (2004) Oral Facial Examination form, which evaluates the appearance and function of the face, jaw, teeth, lips, tongue, pharynx, hard and soft palate. This is an output task where no speech is required. The tester evaluates the above areas with the participant's co-operation and notes any abnormalities in structure or function.

K.2 *Diadochokinetic Rates*
This was assessed using Shipley and McAfee's (2004) Diadochokinetic Syllable rates worksheet, which requires the participant to complete 20 repetitions of the target syllable in the fastest time they can. Three single syllables as well as one 3-syllable stimulus were targeted. The tri-syllabic stimulus results were used in plotting the profile as it was felt that this more closely resembled fluent speech. This is an output task, that does not access the stored representations.

The tester was required to time the 20 repetitions for each of the four targets. Participants' responses were also audiotaped to help with verification following data collection. The participants' times were then recorded on a form specially designed for this purpose. Scores are tallied and then compared to norms for that age group. No practice items were administered.

Level L: this level of the speech processing profile assesses children's own self-monitoring ability. The Tester's observations of the children's responses to their errors were used since it was not possible to formally test this level.

Figure 3.1 shows the speech processing profile, along with all the tests used to assess each level.

INPUT	OUTPUT
F Is the child aware of the internal structure of phonological representations? PHAB picture alliteration subtest (Frederickson et al, 1997) Picture rhyme detection (Vance, Stackhouse & Wells, 2004)	**G** Can the child access accurate motor programs? EOWPVT-R (Gardner, 1990) RAPT (Renfrew, 1972)
E Are the child's phonological representations accurate? Mispronounciation detection (Nathan et al, 2004)	**H** Can the child manipulate phonological units? PhAB alliteration fluency subtest (Frederickson et al, 1997) PhAB rhyme fluency subtest (Frederickson et al, 1997)
D Can the child discriminate between real words? Real word discrimination test (Bridgeman & Snowling, 1988) Auditory rhyme detection (Vance, Stackhouse & Wells, 2004)	**I** Can the child articulate real words accurately? PAT blending subtest (Robertson & Salter, 1997) Aston Index blending subtest -real words (Newton & Thomson, 1982) Real word repetition subtest (Constable et al, 1997)
C Does the child have language specific representations of word structures? Not tested	**J** Can the child articulate speech without reference to lexical representations? Aston Index blending subtest - non-words (Newton & Thomson, 1982) Non-word repetition subtest (Constable et al, 1997)
B Can the child discriminate speech sounds without reference to lexical representations? Non-word discrimination test (Bridgeman & Snowling, 1988) Auditory discrimination of non-words - ABX task (Stackhouse, Wells, Vance & Pascoe, 2007)	**K** Does the child have adequate sound production skills? Oral-facial examination, Diadochokinetic syllable rates (Shipley & McAfee, 2004)
A Doe steh chlid have adequate auditory perception? Audiometry	

L Does the child rejecthis/her own erroneous forms?
Tester's own observations

Figure 3.1 The Speech Processing Profile from Stackhouse & Wells (1997), with the tests used to assess each level.

In addition, literacy assessments were carried out. The following assessments were used.

Consonant decoding

This was assessed using the consonant section of the grapheme subtest from Robertson and Salter's (1997) *Phonological Awareness Test*. This is an output task that uses visual perception as its input channel. It targets stored representations of the graphemes shown, and participants have to retrieve and use the motor programme for that sound. The participant is shown twenty consonants and has to identify them verbally. The participants' responses are then recorded on a form specially designed for this purpose. Scores are tallied and then compared to norms for that age group. No practice items were administered.

Real word CVC decoding and non-word CVC decoding

This was tested using the CVC word section of the Decoding subtest from Robertson and Salter's (1997) *Phonological Awareness Test*. In addition, since only non-words were used in the aforementioned subtest, a set of matching real words were administered. Examples of non-words and their matching real words are: cag – bag; rop – hop. Real word stimuli were created in order to make comparisons between non-word and real word decoding, even though there are no norms for the real word task. The stimuli were created by changing only one consonant at the onset of the non-word, to change it into a real word that had a high probability of being within a young child's lexicon.

This is an output task that uses visual perception as its input channel. It targets stored representations of the graphemes shown, and participants have to retrieve the sounds for the individual graphemes, blend the sounds, create and use the new motor programme for the non-words that were presented. In the case of the real words, the same route can be followed. However, in some cases, a set of graphemes will have its own stored representation, and its own old motor programme, which can then be used to verbally produce the word.

Participants were shown each word individually. They then had to respond and these responses were recorded on a form specially designed for this purpose. Scores are tallied and then compared to norms for that age group. No practice items were administered.

3.8 Data Collection Procedure

Before testing commenced a pilot study was conducted.

3.8.1 Pilot study

The pilot study was conducted in order to:

- gauge the amount of time needed for each of the tests
- familiarise the tester with all the equipment and procedures
- ensure that the stimuli were appropriate for South African children

The pilot participant was an English-speaking, normally hearing 12 year old. The test battery was administered over two sessions. Even though norms were not available for a child of this age, the child was able to rate tests in terms of those which were very easy, and those which required more concentration. The following information was obtained from the pilot:

- the time needed for each test is short (i.e. 5-10 minutes) but testing should be guided by the participant's concentration levels rather than time constraints
- The vocabulary used in the EOWPVT-R (Gardner, 1990) is American. South African Children might not know a few of the words. As a result these test results were scored more leniently, in that more/other names for items shown were accepted, e.g. picture of a corn cob should elicit the name 'corn', however 'mielie' was also accepted.
- The auditory discrimination tasks should be administered near to the start of testing, when concentration and attention are at their best.

As a result of this information, the order of presentation of the tests was as follows:

B1 Non-word discrimination
B2 ABX task
D1 Real word auditory discrimination
E1 Auditory detection of speech errors
F1 Picture onset detection

F2 Visual rhyme detection

D2 Auditory rhyme detection

G1-G3Naming tests

H1 Onset string production

H2 Rhyme string production

I1 Real word blending

I2 Real word repetition

J1 Non-word blending

J2 Non-word repetition

K1 Oral peripheral examination

K2 Diadochokinetic rates

Consonant decoding

Real word CVC decoding

Non-word CVC decoding

3.8.2 Assessment battery

Testing took place over 1-2 sessions, over 3-5 hours for all the participants. All testing was done in the participant's homes, so that testing took place in a familiar environment for the participants. Signed consent forms were collected and parents were given the opportunity to ask questions before testing commenced. Separate consent forms were used, since for children below the age of 7 years parental consent alone is sufficient, while for children older than 7 years , signed consent from the parents as well as from the child is needed, according to the Ethics Committee (Stellenbosch University). Copies of these forms can be found in Appendix C)

The total estimated time for assessment was between 2-4 hours. It was initially thought that assessment would need to take place over 4-5 sessions, within one week, however after the pilot study was conducted, it was determined that 1-3 assessment sessions at most would be needed. Each session's duration was based on the participant's attention span and concentration levels.

The parent/guardian completed the data sheet either before or during the assessment. The testing procedure was explained to both the participant and the parent/guardian. The various subtests were then administered, participant responses were recorded in writing and on audiotape to enable later analysis, and later mapped onto the speech processing profile (Stackhouse and Wells, 1997).

3.8.3 Retrospective data

This data was used to understand the course of development of the participants' speech processing skills. Files containing past speech, language and hearing test results (from the Cochlear Implant Unit) were used to reconstruct speech processing profiles for each of the participants. However, assessment results slotted in at all levels of the profile were not be possible, since the tests used are different from those used to compile speech processing profiles.

3.9 Data Analysis

Data gathered from the current assessment battery as well as the retrospective data was analysed both quantitatively and quantitatively, in the following ways:

3.9.1 Current Assessment battery

- Each of the 18 tasks were administered and scored according to instructions for that specific task, for each participant.
- Where applicable, audio taped data was phonetically transcribed to enable analysis of phonological processes, and to assist in the compilation of a speech sample, using single word data from the *EOWPVT-R* and connected speech data from the *RAPT*. Ten percent of all recordings were phonetically transcribed by a second, qualified and experienced Speech Therapist, for verification purposes. Point-by-point agreement of the phonetic transcription of the samples was calculated. Cordes (1994, in Guitar, 2006) notes that 80% agreement is thought to be the lower limit for a sample to be considered reliable. The percentage of

agreement between the two therapists for the three samples ranged between 82%-92%. This was done to ensure inter-rater reliability.

- Raw scores were then compared to means, and the standard deviations were calculated for each task, for each participant.
- Ticks or crosses were then allocated, according to the degree of the standard deviation from the mean. One tick indicates a standard score that is between age appropriate performance and one standard deviation greater than the mean. Two ticks indicate a performance that is between one to two standard deviations greater than the mean. One cross indicates a performance that is lower than age appropriate and within one standard deviation lower than the mean. Two crosses indicate a performance that falls between one and two standard deviations lower than the mean. Three crosses indicate a performance that is two standard deviations or more below the mean.
- Speech Processing Profiles were then filled in for each participant, using ticks/crosses, at the levels which corresponded to the task tested.
- Participants' speech processing profiles were then analysed individually to determine:

- areas of strengths, and weaknesses by determining whether the input or the output side is most affected by speech processing difficulties
- whether top-down or bottom-up processing influence the outcomes of tasks

- Performance at different levels on the profile were also compared to each other as this yields relevant information with regards to identifying the level/levels of breakdown.
- Performance on the literacy assessments were also compared to performance on tasks on the profile that are linked to literacy development.

3.9.2 Retrospective Data

Speech, Language and Hearing test data from participants' Cochlear Implant Unit files, were used to profile past speech processing development. All test data gathered one year, and two years post cochlear implantation were used to develop two earlier speech processing profiles, using the above mentioned procedure, so that comparisons could be made between past and current performance. Research from Waltzman, Cohen & Shapiro (1992) indicates that speech perception in implanted candidates improves significantly after 6, 12 and 24 months of implant use. Therefore the retrospective time periods chosen were 1 year and 2 years post implant, since the most improvements are expected in those time periods. While the retrospective profiles were not expected to be as extensively detailed as the current profiles, comparisons between areas of strengths, and weaknesses were made, and hypotheses generated on the basis of similarities and differences seen. Ticks and crosses were assigned differently for the past-performance profiles: one tick represents what is considered age appropriate performance, whereas one cross represents non-age appropriate performance.

In summary, the aims of this research, using the above-mentioned methods, were to:

- describe the speech processing skills of young CI-using children, using psycholinguistic profiling (Stackhouse & Wells, 1997), and to
- make comparisons between the current profiles and previous speech processing data, for each child, in order to describe the development of speech processing over time, and in relation to time of implant.

The three individual children's case studies are presented in the three chapters that follow.

CHAPTER 4 : CASE STUDY - NG

This chapter, which focuses on NG's past and present speech processing skills, will be divided into three main sections:
(A) Current Speech Processing (C.A. 6;0),
(B) Past Speech Processing (C.A. 4;1 & 5;2)
(C) Discussion of Results
Within sections A and B, the following are presented: case history, speech sample, speech processing profile and literacy assessment.

SECTION A – Current Speech Processing (C.A. 6; 0)

4.1 *Case History*

NG was 6 years, 0 months at the time of assessment. She wears a *Nucleus* cochlear implant on the left ear with a SPRINT processor and ACE processing strategy, and has been using it for 3 years. She received the implant when she was 3 years old. Prior to this, she had been wearing a hearing aid (from ages 2 – 3), and before this her hearing was unaided.

The aetiology of NG's hearing loss is unknown. There is a family history of hearing loss: her father is deaf in his right ear, and her father's grandmother is deaf in her left ear. However it is uncertain if there is a genetic component to this impairment. There were no complications before, during or after the birthing process. She was born at term via elective caesarean section, and no hearing abnormalities were suspected until she was 6 months of age. She had her first ear infection at 6 weeks of age, and has had several recurring ear infections thereafter. As a result she had grommets inserted at 6 months, with the hope that this would resolve the hearing problem. Finally, at the age of 1;6, hearing loss was diagnosed as a severe/profound bilateral sensori-neural hearing loss, and shortly thereafter she was fitted with hearing aids.

After a year of wearing hearing aids and progressing minimally with her speech and language development, her audiologist recommended that NG be fitted with a cochlear implant. After the necessary funds had been collected she was implanted in July 2004.

NG is a mother tongue English speaker with no other languages being spoken in the home. The family, originally from Mossel Bay, is of average socio-economic status and consists of NG's mother, father, 8 year old sister, and herself. NG is currently in Grade R at a school for hearing impaired children, in Cape Town. She has been receiving speech therapy once a week since her hearing loss was detected, and is currently receiving therapy in the school setting. Her mother reports that she is excelling at school, and that the staff has suggested she join a mainstream school for Grade 1.

At the time of testing, NG was very co-operative and friendly. She showed appropriate concentration and attention for her age. NG was administered the test battery, and completed the evaluation in one morning over the course of 3 hours, with 2 breaks in between.

4.2 *Speech Sample*

Table 4.1 summarises NG's speech at the time of testing.

Assessment	Comments
Severity Indices	PCC = 95% PVC = 97.2% PPC = 95.8%
Phonological processes analysis (% use)	Developmental processes - liquid gliding /r/ - /w/ (50%), syllable deletion (1.0%) Non-developmental processes – metathesis (2.1%); reduced vowel length (2.1%); perseveration (3.1%); nasalization of /l/ (3.1%); backing (2.1%)
Single word speech sample	[spQntS] for SPONGE ["flaUw@] for FLOWER [tweIn] for TRAIN [bwVS] for BRUSH [glVv] for GLOVE ["dZ@li] for JELLY ["spaId@] for SPIDER ["tr{kt@] for TRACTOR [p@"dZAm@z] for PYJAMAS [p@"gEtsi] for SPAGHETTI ["k{t@p@l@] for CATERPILLAR ["E@r@pleIn] for AEROPLANE
Connected speech sample	[T@ g3lz hVgiN h3 tEdi] for THE GIRL'S HUGGING HER TEDDY [Siz kl@UziN h3 aIz] for SHE'S CLOSING HER EYES [{nd Siz @UldiN hIm] for AND SHE'S HOLDING HIM [mQmIz pUtIN T@ bUts Qn D@ g3lz fit] for MOMMY'S PUTTING THE BOOTS ON THE GIRL'S FEET

Table 4.1 NG's speech at C.A. 6;0.

NG has appropriate speech intelligibility for single words and connected speech. She displayed one phonological process consistently, i.e. liquid gliding, and only for 50% of the time. This could be indicative that this process is being gradually replaced with a more mature articulatory pattern.

4.3 *Test Results & Speech Processing Profile*

Table 1 in Appendix E shows the test results of all 18 tasks carried out. The speech processing profile for NG's current speech processing skills was completed based on these results and is presented in Figure 4.1.

INPUT

F
Is the child aware of the internal structure of phonological representations?
√ - PHAB picture alliteration subtest (Frederickson et al, 1997)
√ - Picture rhyme detection (Vance, Stackhouse & Wells, 2004)

E
Are the child's phonological representations accurate?
x - Mispronounciation detection (Nathan et al, 2004)

D
Can the child discriminate between real words?
√ - Real word discrimination test (Bridgeman & Snowling, 1988)
√ - Auditory rhyme detection (Vance, Stackhouse & Wells, 2004)

C
Does the child have language specific representations of word structures?
Not tested

B
Can the child discriminate speech sounds without reference to lexical representations?
√ - Non-word discrimination test (Bridgeman & Snowling, 1988)
√ - Auditory discrimination of non-words - ABX task
Stackhouse, Wells, Vance & Pascoe, 2007.

A
Does the child have adequate auditory perception?
x - Audiometry (mild hearing loss)

OUTPUT

G
Can the child access accurate motor programs?
√ - EOWPVT-R (Gardner, 1990)
√ - RAPT (Renfrew, 1972)

H
Can the child manipulate phonological units?
√√ - PhAB alliteration fluency subtest (Frederickson et al, 1997)
√ - PhAB rhyme fluency subtest (Frederickson et al, 1997)

I
Can the child articulate real words accurately?
√ - PAT blending subtest (Robertson & Salter, 1997)
√ - Aston Index blending subtest -real words (Newton & Thomson, 1982)
xxx - Real word repetition subtest (Constable et al, 1997)

J
Can the child articulate speech without reference to lexical representations?
√ - Aston Index blending subtest - non-words, (Newton & Thomson, 1982)
xxx - Non-word repetition subtest (Constable et al, 1997)

K
Does the child have adequate sound production skills?
√ - Oral-facial examination,
√ - Diadochokinetic syllable rates (Shipley & McAfee, 2004)

L
Does the child reject his/her own erroneous forms?
Tester's own observations YES

Figure 4.1 –Speech processing profile for NG (6;0)

KEY TO SPEECH PROCESSING PROFILE

√	- age appropriate, i.e. one SD below the mean and up
√√	- one SD above the mean
x	– one SD below the mean or less
xx	– two SD's below the mean or less
xxx	– three SD's below the mean or less

4.4 ***Discussion of Speech Processing Profile***

4.4.1 Overview of the profile

The profile shows four levels of difficulty – level A: auditory perception. It is expected that all the children in this study would have difficulties with this level, as they were selected on the basis of their hearing loss. Level E: phonological representations, level I: real word articulation and level J: non-word articulation were also problematic.

Areas of strength where NG showed above average performance were level D (Auditory rhyme detection) and level H (onset string production).

The output side is more affected by speech processing difficulties, as the greatest degree of below average performances occur on that side. There does not appear to be a pattern with regards to whether she performs better with top-down or bottom-up processing routes.

4.4.2 Input Levels

At level A it can be seen that at NG's last audiometric testing session (6/3/2007), all frequencies tested had thresholds between 30 – 36 dB HL. This is termed her aided hearing threshold and it correlates with a *mild* hearing loss, even though before implantation of the cochlear implant she had had a *severe-profound* loss. Thus only one cross is used to mark the hearing loss on the profile.

From levels B and D we learn that she is able to discriminate both real and non-words accurately. In addition, and also as part of level D, she performed above average for her age in the auditory discrimination of rhyme test, thus receiving two ticks at that level.

However, all the stimulus words used in the auditory discrimination of rhyme test were monosyllabic, and thus it cannot be assumed that her discrimination of real multisyllabic words will be as accurate.

On the other hand, for level E on the profile, she has one cross. In this test (mispronunciation detection/auditory lexical decision) she scored less than one standard deviation from the mean, which is described as below average performance. In this test she accepted too many inaccurate productions of words as correct, e.g. accepting [glVb] as correct when shown a picture of a glove. Figure 4.2 shows a model of how this process works.

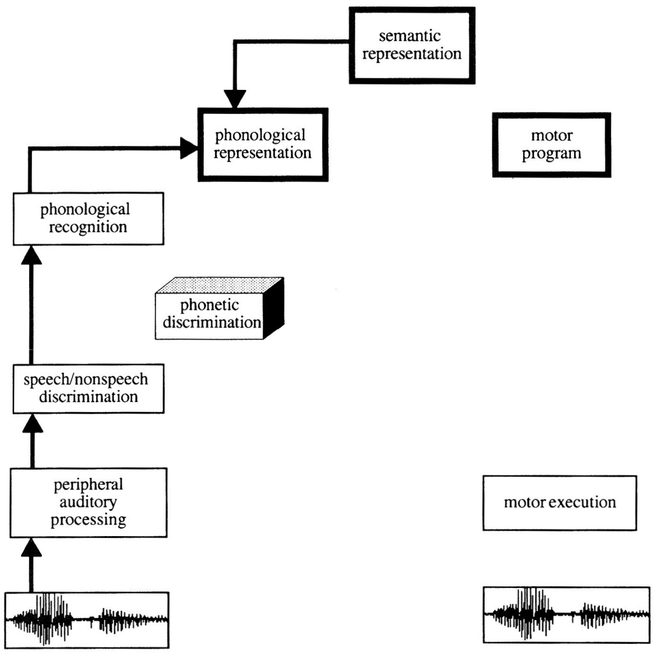


Figure 4.2 Box model of the processing route for the error detection task (Stackhouse & Wells, 2001).

In this task, the stimulus (spoken by the tester) is a possible English word, and so passes through the first three boxes on the left-hand (input) side. This stimulus then has to be compared to the picture the participant is shown. The picture facilitates access to the semantic aspect of the lexical representation, which in turn gives access to the phonological representation. This can now be compared to the form that has been processed auditorily. Therefore the processing route extends to the semantic and the phonological representation within the lexicon.

Poor performance within this level usually indicates that the child's phonological representations of words are 'fuzzy', or ill-defined. Phonological representations store information which allows a word to be identified on the basis of auditory and visual (e.g. lip reading) cues (Stackhouse & Wells, 2001). For her to succeed in this task, NG needs accurate internal phonological representations of each of the pictured items, so that she can compare the spoken form to the stored form she has of the picture shown (Stackhouse & Wells, 2001).

Of the errors made, 80% of the words were mutlisyllabic. This indicates that it is more difficult for her to discriminate correctness/incorrectness with longer words. The types of errors made included:

- those where manner of articulation of the target had been changed (2 errors) (e.g. [glVb] was accepted as correct), from the target *glove*
- where place of articulation had been changed (1 error), (e.g. [E@r@"preIn] was accepted as correct), from the target *aeroplane*
- where voicing of a consonant had been changed (1 error),(e.g. ["dr{kt@] was accepted as correct), from the target *tractor,*
- where metathesis had been used to swap two consonants places' within a word (1 error), (e.g. ["k{p@tIl@] was accepted as correct) from the target *caterpillar*.

Thus there was not one type of error dominating her performance, but word length seemed to be linked to increased errors.

For level F, one tick was given for each task, as she performed within the normal range for both the picture onset detection and picture rhyme detection tasks, which shows that she is aware of the internal structure of phonological representations. Stimuli for both these tasks were monosyllabic.

Summary of Input Speech Processing Performance

NG seems to be processing speech input appropriately, despite difficulties at level A, for all input levels except level E, however her main difficulties here are with multisyllabic words. It appears that the increased length of multisyllabic words increases the processing demands needed to complete tasks successfully. Thus she only has resultant input difficulties at the level of phonological representations. She performs particularly well at the level of real word discrimination, for monosyllabic words, on the input side.

4.4.3 Output Levels

On the output side of the profile, no difficulties were encountered, except for levels I and J. Above average performance was observed at level H.

For level G, she scored within the normal range for both the RAPT (Renfrew, 1972) and the EOWPVT-R (Gardner, 1990), even though those tests are not normed on or designed for English speaking South African children. Therefore, if this test had used South African English vocabulary, she may well have scored above average for her age. This result shows that she can access accurate motor programs. However, phonological analyses of the speech output gathered from this task shows that her articulation accuracy differs according to word length. While 1- and 2-syllable words were between 78%-88% accurate, more errors were made when 3-syllable words were articulated (66.6% accuracy).

For level H NG showed she is capable of manipulating phonological units, as she scored within the normal range for her age on the rhyme string production tasks and scored above average for the onset string production tasks. This shows that she is able to manipulate phonological units.

For level I, for both the Aston Index blending (Newton & Thomson, 1982) and the PAT blending subtests (Robertson & Salter, 1997) she scored within normal limits for her age.

However for the real word repetition component of Constable's real word and non-word repetition task, she scored only 9/20, which is more than 2 standard deviations from the mean and indicates below average performance in this area. This could have been as a result of 1) real word discrimination difficulties that were not tapped in level D (as multisyllabic words were not assessed there); or 2) 'fuzzy', inaccurate phonological representations, as confirmed from level E results; or even as a result of 3) difficulties at level G, with articulation of multisyllabic words.

For level J, she performed within normal limits for non-word blending on the Aston Index blending subtest, which contained mostly monosyllabic words (65%). However, she performed very poorly on Constable et al's (1997) non-word repetition subtest, obtaining a raw score of 2/20, which places her score at more than 2 standard deviations from the mean. This task only uses multisyllabic words. While both real word and non-word repetition scores were low, performance on non-word repetition posed more difficulties than for real word repetition. This suggests that NG may have a difficulty in assembling new motor programs, as well. In addition, non-word discrimination for multisyllabic words was assessed and found to be within normal limits. Thus only output difficulties are influencing non-word articulation performance.

NG has a tick at level K as both her OPE (Shipley & McAfee, 2004) and DDK test (Shipley & McAfee, 2004) results were normal for her age. Thus there is no evidence of articulatory difficulties. It is also unlikely that NG would have poor articulatory skills, as this would then be affecting all speech output, whereas all performances on speech output tasks other than repetition was normal.

At level L, NG was observed to try and correct her own errors at numerous times during assessment. She would then turn to her mother and confirm whether or not she had successfully corrected a word. Thus, she does employ self-monitoring, which can then be applied to change her output, when she has previously been made aware that her articulation is faulty. This also indicates that her speech processing skills on the input side are capable of alerting her to mistakes in her own speech.

Summary of Output Speech Processing Performance

On the output side of the profile NG seems to have most difficulty with real and non-word repetition (levels I and J), particularly with multisyllabic words. In addition, careful analyses of speech output indicate difficulties articulating multisyllabic words.

4.5 *Literacy Assessment*

The three tasks used to assess literacy were: consonant decoding, CVC non-word decoding and CVC real word decoding. Table 4.2 lists the tests used to assess literacy, along with the scores obtained.

Task name:	Raw score	Standard score	Description of performance
Consonant decoding	17/20	102	average
Non-word CVC decoding	7/10	116	above average
Real word match CVC decoding	9/10	no norms available	

Table 4.2 Results of the Literacy assessment

For the first task NG scored within normal limits for her age – this shows that she can access the phoneme from the written grapheme. For the non-word CVC decoding task, she scored 7/10 - in the above average range. This shows that she is capable of decoding phonemes, blending them, creating a new motor program for that word, and then articulating it accurately. In the matched real word CVC decoding task, she scored 9/10. Although there are no norms for the last task it can be seen that she performed better at decoding real words than non-words. This is to be expected according to developmental norms (Ehri & Snowling, 2004).

4.6 *Summary*

NG's speech processing profile reveals a solid foundation of speech processing skills for a child with a hearing loss. Despite the cross at level A, she displays average and above average performance at levels B, D, F, G, J, K and L. She displays difficulty at levels E, I and J, particularly with multisyllabic words since the tasks that she experiences difficulties with at these levels all involved mainly multisyllabic words.

In particular, her strengths were auditory rhyme detection, and onset string production. These tasks tap phonological awareness, and her performance therein (and also her performance in the blending tasks, rhyme fluency tasks, picture onset detection tasks, picture rhyme detection tasks) seems to indicate heightened levels of this. Phonological awareness and specifically phonemic awareness, has been linked to beginning reading success in numerous research studies (Hempenstall, 1993; Heath & Hogben, 1994; Stanovich, 1998; Chard & Dickson, 1999; White, 2000; Stern & Goswami, 2000; Bird, Cleave & McConnell, 2000; Stern, 2001; Nielsen & Luetke-Stahlman, 2002; Cockcroft, Broom, Greenop & Fridjohn, 2003; Phelps, 2003; Puolakanaho, Poikkeus, Ahonen, Tolvanen et al, 2004; Thomas-Tate, Washington & Edwards, 2004). Therefore it was not surprising to see that NG performed appropriately in the literacy tasks as well. In addition, the fact that she is able to monitor and change her own output (Level L) shows that the link between her input and output processing skills is intact.

Her weaknesses included inaccurate phonological representations (Level E), inaccurate real word articulation (Level I) and inaccurate non-word articulation (Level J). In the same way that NG's strengths on the speech processing profile are linked to each other, so also are her weaknesses.

In order to successfully complete a real word repetition task, two methods exist. The first method – top-down processing – assumes that the target word is auditorily discriminated and matched to a word already in the lexicon. Then the existing motor program for that word is accessed and produced. Figure 4.3 shows the speech processing route taken for this task to be completed.

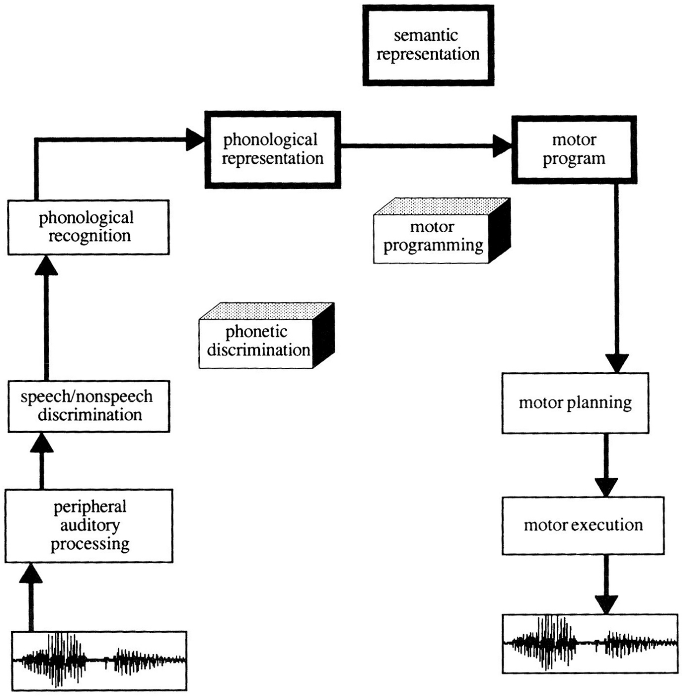


Figure 4.3 Box-and-arrow model depicting the top-down (lexical) route for real word repetition (Stackhouse & Wells, 1997).

However, difficulties have been shown to exist at level E (i.e. inaccurate phonological representations), and thus when the existing fuzzy phonological representations, and its concomitant inaccurate motor programs are used to reproduce words, a word different from the target is produced. Therefore the difficulties at level E could be affecting results at level I, when the top-down processing route is used.

When the second method – bottom-up processing- is used, the target word is auditorily discriminated. It is not matched to an existing phonological representation. A new motor program is created for the target word. This is identical to the route involved in non-word repetition. Figure 4.4 shows the box-and-arrow model depicting the bottom-up route for real word repetition (Stackhouse & Wells, 1997).

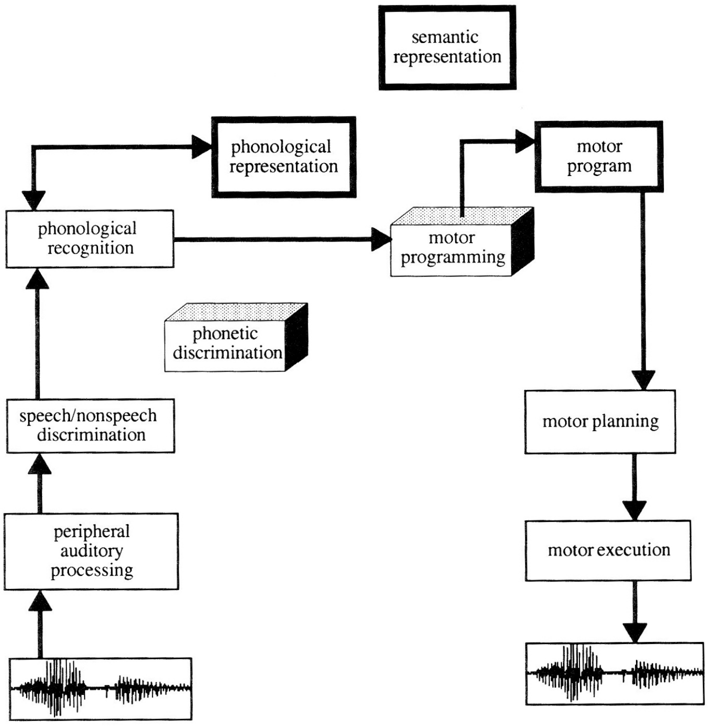


Figure 4.4 Box-and-arrow model depicting the bottom-up (non-lexical) route for real word repetition (Stackhouse & Wells, 1997).

Previously, when discussing NG's non-word repetition performance, it was noted that she struggles with non-word repetition performance because of difficulty creating new motor programs for multisyllabic words. Thus the difficulty situated at the motor programming level is affecting output at Level J, and potentially at Level I. Both methods of completing the real word repetition task are problematic. Method one, the lexical route, is flawed because of inaccurate phonological representations. Method two, the non-lexical route, is flawed, because of motor programming difficulties.

Thus all the levels that have crosses allocated to them influence each other.

Comparison across levels

Real word repetition vs. non-word repetition. Both scores for these tasks were described as being below average (when multisyllabic words were the stimuli). However, non-word repetition performance was poorer than real word repetition performance, indicating that NG has difficulty assembling new motor programs.

Real word repetition vs. naming performance. While real word repetition performance was very much below average, naming performance was within normal limits, and therefore better than real word repetition performance. This may indicate difficulties with auditory perception of the real word target presented verbally. Articulatory difficulties could not be used to explain this phenomenon, as no difficulties were found in level K.

Real word discrimination vs. non-word discrimination. While performance for both these tasks were within normal limits, mono- and multisyllabic non-word discrimination was tested, while only monosyllabic real word discrimination was tested. Therefore some hidden difficulties might exist in the area of multisyllabic non-word discrimination.

In summary, and according to the speech processing profile, NG has:

1. mild auditory perceptual difficulties
2. appropriate non-word discrimination for monosyllabic and multisyllabic words
3. appropriate real word discrimination for monosyllabic words
4. inaccurate/'fuzzy' phonological representations, especially for multisyllabic words
5. appropriate awareness of the internal structure of phonological representations.
6. ease of access to accurate motor programs, with some difficulty naming multisyllabic words
7. appropriate phonological unit manipulation skills
8. appropriate real word blending skills, but poor real word repetition skills
9. appropriate non-word blending skills, but poor non-word blending skills
10. adequate sound production skills
11. the ability to self-monitor and self-correct

SECTION B – Past speech processing results (C.A. 4;1 & 5;2)

In the following section, NG's past test results taken from speech, language and hearing assessments one year post-implantation, and two years post- implantation respectively, will be presented and discussed.

4.7 ***Case history – One year post-implantation*** (C.A. 4;1)

In the year since she had been implanted, NG wore her speech processor conscientiously, attended weekly speech therapy sessions, experienced good parental involvement in the therapy process, and was showing good progress, according to the Speech Therapist. She was assessed in August 2005, at the age of 4;1, after having worn the cochlear implant for 1 year.

At this assessment, the following tests were administered:

- aided hearing thresholds
- *Categories of Auditory Performance* (CAP), a checklist (Nottingham Early Assessment Package, 2004)
- *TAIT video Analysis, a checklist* (Nottingham Early Assessment Package, 2005)
- *Speech Intelligibility Rating*, a checklist (Nottingham Early Assessment Package, 2005)
- *Identifying Early Phonological Needs in Children with Hearing Loss (IEPN).* (Paden & Brown, 1992),
- *Profile of Actual Linguistic Skills* (PALS), a checklist (Nottingham Early Assessment Package, 2005)
- *Reynell Developmental Language Scales* (RDLS), (Edwards, Fletcher, Garman, et al, 1997)

Hearing results

The Speech Therapist reported that NG was at ease with auditory stimulation, and that she seldom made use of visual cues to augment auditory cues. On the *Categories of Auditory Performance* (CAP), (Nottingham Early Assessment Package, 2005) she advanced to level 5 – understanding common phrases without lipreading. She was able to follow short contextualised sentences, on occasion. In addition, her consonant discrimination was reported to be improving – while confusion with regard to discrimination of place of articulation still occurred, discrimination of voicing and manner of articulation cues was age appropriate.

Auditory processing was assessed using the *TAIT video Analysis checklist* (Nottingham Early Assessment Package, 2005). The Speech Therapist reported frequent turn taking without looking at the Speaker, spontaneous imitation, and appropriate responses. Responses were mostly single words and short phrases. Auditory attention was reported to have improved significantly and auditory memory had expanded to 3 items.

Language results

Language was evaluated using the *Reynell Developmental Language Scales*- Third Edition (RDLS-III) (Edwards et al, 1997). For the comprehension scale she obtained an age equivalent score of 2 years 9 months, while for the expressive scale she obtained an age equivalent score of 2 years 5 months. According to the PALS (2004), NG was using everyday communication and receptive language skills on a functional level. Expressive language, voice and speech usage was still in the transitional phase.

Speech results

Speech development was evaluated using *Paden and Brown's (1992) phonological evaluation*. The following phonological processes were found:

- glottal stopping of /k/ and /g/ in medial and final positions, e.g. book - /bU?/, dog - /dQ?/.
- nasalization of /l/, e.g. leaf - /nif/ .
- final consonant deletion (only when /l/ is in final position), e.g. ball - /bO/.

Using the Speech Intelligibility Rating checklist (Nottingham Early Assessment Package, 2005), NG was placed in category 2 – unintelligible connected speech, intelligible speech for single words when context and lipreading clues are available.

In summary, the Speech Therapist reported that while receptive and expressive language scores indicated delays of approximately 16 months, NG's development was 'on par' in light of her hearing age (12 months). She recommended continuing weekly therapy.

4.8 *Speech sample – One year post-implantation* (C.A. 4;1)

Table 4.3 gives a sample of NG's speech at this point in time (i.e. one year post-implantation).

Assessment	Comments
Severity Indices	PCC = 74% PVC = 92.8% PPC = 80.7%
Phonological processes analysis (% use)	Developmental processes -final consonant deletion, only when /l/ is final (15.8%) Non-developmental processes - glottal stopping of /k/ and /g/ (100%);Nasalization of /l/ (25%)
Single word speech sample	/fit/ for FEET /nif/ for LEAF /wQtS/ for WATCH /naIt/ for LIGHT /bOI/ for BOY

Table 4.3 NG's speech sample at C.A. 4;1

The percentage vowels correct was higher than the percentage consonants correct. Most difficulty with intelligibility seems to have stemmed from misarticulation of consonants. Hypernasality of consonants, e.g. /l/-/n/ is commonly seen in deaf children (Nguyen et al, 2008).

4.9 *Speech processing profile* (C.A. 4;1)

From the above-mentioned test results, the speech processing profile for NG was completed retrospectively, and is shown in Figure 4.5.

INPUT

F

Is the child aware of the internal structure of phonological representations?

Not tested

E

Are the child's phonological representations accurate?

Not tested

D

Can the child discriminate between real words?

√ - can discriminate speech sounds without lip-reading (CAP),

x -cannot discriminate with regard to voicing & place of articulation

C

Does the child have language specific representations of word structures?

Not tested

B

Can the child discriminate speech sounds without reference to lexical representations?

Not tested

A

Does the child have adequate auditory perception?

x – Audiometry (mild hearing loss)

OUTPUT

G

Can the child access accurate motor programs?

x - IEPN (Paden & Brown, 1992)

x - SIR category 2

H

Can the child manipulate phonological units?

Not tested

I

Can the child articulate real words accurately?

x - spontaneous imitation has immature phonological processes

J

Can the child articulate speech without reference to lexical representations?

Not tested

K

Does the child have adequate sound production skills?

Not tested

L

Does the child reject his/her own erroneous forms?

Not tested

Figure 4.5 Speech processing profile for NG (C.A. 4;1)

KEY TO SPEECH PROCESSING PROFILE

√ - age appropriate

x - not age appropriate

4.10 ***Discussion of Speech Processing Profile – One year post-Implantation*** (C.A. 4;1)

4.10.1 Overview of the profile

As this profile was compiled retrospectively, information for only a limited number of the levels was available from the assessment. In addition, many of the tests that could be used to give information for the levels were qualitative, and did not have normative data.

The profile shows difficulties on both the input and output sides. The specific levels that were problematic were Level A - auditory perception (as noted previously, it is expected that all the children in this study would have a problem with this level, at every period of time they are tested), Level D – real word discrimination, Level G – naming accuracy, and Level I – real word repetition.

4.10.2 Input Levels

At level A it can be seen that at her last audiometric testing session (March 2005), all frequencies tested had thresholds of approximately 26 dB HL. This is NG's aided hearing threshold and it correlates with a *mild* hearing loss, even though before implantation of the cochlear implant she had had a *severe-profound* loss. Thus only one cross is used to mark the hearing loss on the profile.

For level D (real word discrimination), NG was able to discriminate real words and their meaning in the context of short phrases or common sentences, but she was unable to consistently discriminate consonants, and especially with regard to discrimination of voicing and manner of articulation cues. Thus she was given one cross at this level, as her performance is not regarded as age appropriate.

4.10.3 Output levels

At Level G, one cross was given to show that her performance on Paden and Brown's (1992) Phonological test was not deemed age appropriate. She only produced 74% of the phonemes correctly, and displayed a few immature phonological processes, e.g. final consonant deletion where apple is pronounced as /{p@/.

In addition, she was classed as being in category 2 on the SIR scale – unintelligible connected speech, with intelligible speech developing in single words when context and lipreading cues are available. This also earns her a cross on the profile, as this degree of speech intelligibility is not appropriate for a normally developing four year old child (Bernthal & Bankson, 2004).

The SIR rating holds for naming as well as for spontaneous imitation performance. Thus NG also has a cross at level I, since her spontaneous imitation had the same intelligibility as her naming.

4.10.4 Summary

In summary, and according to the speech processing profile, NG (at C.A. 4;1) had the following profile of difficulties:

1. mild auditory perceptual difficulties
2. inappropriate real word discrimination within words, but could discriminate words and their meanings within phrases/short sentences
3. inaccurate motor programs for words of all lengths,
4. poor real word repetition skills

4.11 *Case history – Two years post-implantation* (C.A. 5;2)

NG was assessed in August 2006, at the age of 5,2, having worn the cochlear implant for 2 years. In the year preceding this assessment, she attended weekly speech therapy sessions. The family moved from Mossel Bay to Cape Town at the start of the second term, to enable NG to attend a special school. She started attending the Carel du Toit school for hearing impaired learners in this year (pre-grade R class), and her parents attended weekly parent guidance classes. Her class teacher reported good progress, and promoted her to Grade R for 2007.

At this assessment, the following tests were administered:

- aided hearing thresholds
- various speech perception tests (i.e. the *Lexical Neighbourhood test*, *Topic centred sentences* (TAPS 5A & 5B, Gardner, 1992), GASP sentences (Erber, 1982)
- *Speech Intelligibility Rating* (SIR) (Nottingham Early Assessment Package, 2005)
- *Goldman-Fristoe Test of Articulation*, (Goldman & Fristoe, 1969)
- *Profile of Actual Linguistic Skills* (PALS), a checklist (Nottingham Early Assessment Package, 2005)
- *Test of Auditory Comprehension of Language* (TACL-3) (Carrow-Woolfolk, 1998)
- *Oral and Written Language Scales* (OWLS) (Carrow-Woolfolk, 1995)
- *Language Assessment, Remediation and Screening Procedure* (LARSP) (Crystal, Fletcher & Garman, 1976).

Hearing results

The audiologist reported that NG was showing good benefit from the implant and that she had made excellent progress in terms of her auditory skills. Her aided hearing thresholds were reported to be between 36 – 38 dB HL across the frequencies tested. The results of the speech perception tests performed were positive. For example, in the *Lexical Neighbourhood test* (Kirk, Pisoni, Osberger, 1995) she was able to correctly discriminate and repeat 76% of the words presented, and 90% of the phonemes presented were correctly repeated within words. Her auditory comprehension was a relative strength with her comprehension of the *Topic centred sentences* (TAPS 5A & 5B) (Gardner, 1992) tasks scoring 100% and 90% respectively.

Language results

NG's language was evaluated using the *TACL-3* (Carrow-Woolfolk, 1998), *OWLS* (Carrow-Woolfolk, 1995), and the *LARSP* (Crystal, Fletcher & Garman, 1976). Her receptive language scores ranged from age equivalent scores of 3;10 – 4;4 according to the Speech Therapist assessing her. She was reported to have an average receptive language delay of 13 months. NG's expressive language scores were reportedly on the level of a 3;5 month old child, showing an expressive language delay of approximately 21 months. This was verified with the use of the LARSP profile where most of her utterances were reported to be in stage V (3 years 0 months – 3 years 6 months).

Speech results

The Therapist reported that all NG's suprasegmental skills in speech had been established, e.g use of rhythm in words, use of rhythm in connected speech, use of spoken English intonation contrasts, etc. Furthermore, all speech sounds were developing within her phonetic and phonemic repertoire, except for the /v/, /m/, /N/, and the /sl/ cluster. She was observed to be using the phonological process of consonant addition, e.g. [rwiN] for ring. Her speech intelligibility was rated as falling within category 4 – her connected speech is intelligible to a listener who has little experience of a deaf person's speech.

4.12 ***Speech sample – Two years post-implantation*** (C.A. 5;2)

Table 4.4 gives a sample of NG's speech two years post-implantation.

Assessment	Comments
Severity Indices	PCC = 89.3% PVC = 96.4% PPC = 91.5%
Phonological processes analysis (% use)	Developmental processes: Final consonant deletion, only when /l/ is final (16.7%); Stopping of /g/ (60%) Glottal stopping of /k/ (11%) Non-developmental processes - nasalization of /l/ (12.5%) nasalization of fricatives (4.65%), consonant addition (2.1%)
Single word speech sample	/"b{kium/ for VACUUM /"snipiN/ for SLEEPING /rwiN/ for RING /"O4IndZ/ for ORANGE /fInd@/ for FINGER

Table 4.4 NG's speech sample at C.A. 5;2.

While an overall improvement in severity can be seen when the speech sample from one year post-implantation is compared to the speech sample from two years post-implantation, there are also new phonological processes which were not present before, e.g. fronting of /g/. It is hypothesized that this process emerged as a result of therapy aiming to rectify glottal stopping of /g/ and /k/. Also, while the percentage occurrence of nasalization of /l/ has increased, this seems to be due to lesser occurrences of that phoneme in the sample analysed, rather than a true increase in the occurrence of that phonological process. In addition mention must be made of the fact that two lists of utterances were used to compile the speech sample. The first list consisted of only monosyllabic words – for which NG obtained 90% correct phoneme production, while the second list contained mono- , bi- and tri-syllabic words. For the second list, she obtained only 63% correct phoneme production. Thus it appears that she was able to produce monosyllabic words more accurately than multisyllabic words, which is a normally occurring phenomenon in children. This finding was also found in her results at C.A. 6;0.

4.13 ***Speech processing profile*** (C.A. 5,2)

From the above-mentioned test results, the speech processing profile for NG's speech processing skills was completed retrospectively, and is presented in Figure 4.6.

INPUT

F

Is the child aware of the internal structure of phonological representations?

Not tested

E

Are the child's phonological representations accurate?

Not tested

D

Can the child discriminate between real words?

√ - can discriminate speech sounds in the form of commands, and comprehend them - TAPS Listen and Do test

C

Does the child have language specific representations of word structures?

Not tested

B

Can the child discriminate speech sounds without reference to lexical representations?

Not tested

A

Does the chlid have adequate auditory perception?

x - Audiometry
(mild hearing loss)

OUTPUT

G

Can the child access accurate motor programs?

√ - SIR category 4
x - Goldman Fristoe Test of Articulation

H

Can the child manipulate phonological units?

Not tested

I

Can the child articulate real words accurately?

x - GASP sentence repetition test
√ - Lexical Neighbourhood test

J

Can the child articulate speech without reference to lexical representations?

Not tested

K

Does the child have adequate sound production skills?

Not tested

L

Does the child reject his/her own erroneous forms?

Not tested

Figure 4. 6 Speech Processing Profile for NG (C.A. 5;2)

KEY TO SPEECH PROCESSING PROFILE
√ - age appropriate
x - not age appropriate

4.14 ***Discussion of Speech Processing Profile – Two years post-Implantation*** (C.A. 5;2)

4.14.1 Overview of the profile

As this profile was compiled retrospectively, information for only a few of the levels was available from the assessment. In addition, many of the tests that could be used to give information for the levels were qualitative, and did not have normative data.

The profile shows difficulties on both the input and output sides. The specific levels that were problematic were Level A - auditory perception, Level G – naming accuracy, and Level I – real word repetition.

Areas that show improvement relative to the one year post-implantation profile are level D: real word discrimination, level G: naming, and level I: real word repetition.

4.14.2 Input Levels

At level A it can be seen that at her last audiometric testing session (26/07/2006), all frequencies tested had thresholds of approximately 36 dB HL. Thus only one cross is used to mark the hearing loss on the profile.

For level D (real word discrimination), NG was able to discriminate real words and their meaning out of the normal context, and perform the appropriate responses. She was given one tick at this level, as this ability is regarded as age appropriate, and shows an improvement from one year post-implantation scores, where she could only comprehend short phrases in context.

4.14.3 Output levels

At Level G, one cross was given to show that her performance on Goldman & Fristoe's Test of Articulation was not deemed age appropriate. She only produced 63% of the phonemes correctly, and still displayed immature phonological processes, e.g. final consonant deletion, fronting. As previously mentioned, this test contains stimuli of different syllabic lengths.

However, NG's speech intelligibility had significantly improved so that she was then classed as being in category 4 on the SIR scale – connected speech is intelligible to a listener who has little experience of a deaf person's speech. Thus she earned a tick for that performance.

NG also has a tick at level I, for her performance in the Lexical Neighbourhood Test (Kirk, Pisoni & Osberger, 1995), where she had to repeat several monosyllabic words, since she performed well in that test. Conversely, she received a cross for her performance on the GASP (Erber, 1982), a sentence repetition test.

4.14.4 Summary

In summary, and according to the speech processing profile, NG (at C.A. 5;2) had the following profile:

1. mild auditory perceptual difficulties
2. appropriate real word discrimination
3. improving motor programs for real words, with monosyllabic words articulated better than multisyllabic words
4. improving real word repetition skills, which are better on a single word level than on sentence level.

SECTION C – Discussion of results

In this section past and current results will be discussed and compared in order to elucidate the developmental progression of NG's speech processing skills, in order to understand her current results more clearly.

NG's most recent profile (C.A. 6;0) shows that:

- input processing is a relative strength at all levels except for level E – this was deemed due to indistinct phonological representations mainly for multisyllabic words.
- output processing is also a relative strength for all levels except for levels I and J – multisyllabic real word and non-word repetition was deemed a weakness, due to indistinct phonological representations for multisyllabic real words causing inaccurate real-word output and/or difficulty assembling new motor programs for multisyllabic non-words causing inaccurate non-word output.
- the link between her output and input processing skills was found to be intact and active, since she monitors her own output and is able to modify it well.
- the literacy results obtained which demonstrated average and above average performance in the tasks tested link well with the age appropriate results obtained in the levels of the profile that tap phonological awareness-type tasks.

Weaknesses pinpointed by the profile include the indistinctness of her phonological representations for multisyllabic words, and her difficulty with the creation of new motor programs for multisyllabic words. These would need to be targeted in therapy in order to rectify and strengthen these areas.

NG's most recent results (CA 6;0) were compared to results obtained one, and two years post-implantation. At the time of testing (CA 6;0) she was three years post-implantation. Thus it was logical to compare the current results with the one- and two years post-implantation results to develop a retrospective longitudinal perspective of the changes in her speech processing. In addition, one year in terms of communication development is a significant amount of time, since this is the common age at which children produce their first meaningful word (Rossetti, 1996; Bernthal & Bankson, 2004). Two years too is a significant amount of time in terms of communication development, as most normally developing children have developed and established the use of two-to three word utterances by this time (Rossetti, 1996;Bernthal & Bankson, 2004), which is a significant increase from one word utterances. In addition, research from Waltzman, Cohen & Shapiro (1992), and Tobey & Geers (1995) indicates that speech perception in implanted children improves significantly after 6, 12 and 24 months of implant use. Therefore the retrospective time periods chosen were 1 year and 2 years post implant, since the most improvements are expected in those time periods.

While it was not possible to monitor NG's speech processing development over these three time frames using the same tests, results from the different tests used confirm that development is occurring between testing times. For example, the speech samples taken at each testing period were analysed in terms of severity indices, and the improvement for each index can be seen in Table 4.5 and Figure 4.7 below.

	T1	T2	T3
	CA 4;1	**CA 5;2**	**CA 6;0**
	2005	2006	2007
PVC %	74	89.3	95.3
PCC %	92.8	96.4	98.4
PPC %	80.7	91.5	96.5

Table 4. 5 Severity Indices for NG's speech samples C.A. 4;1-6;0.

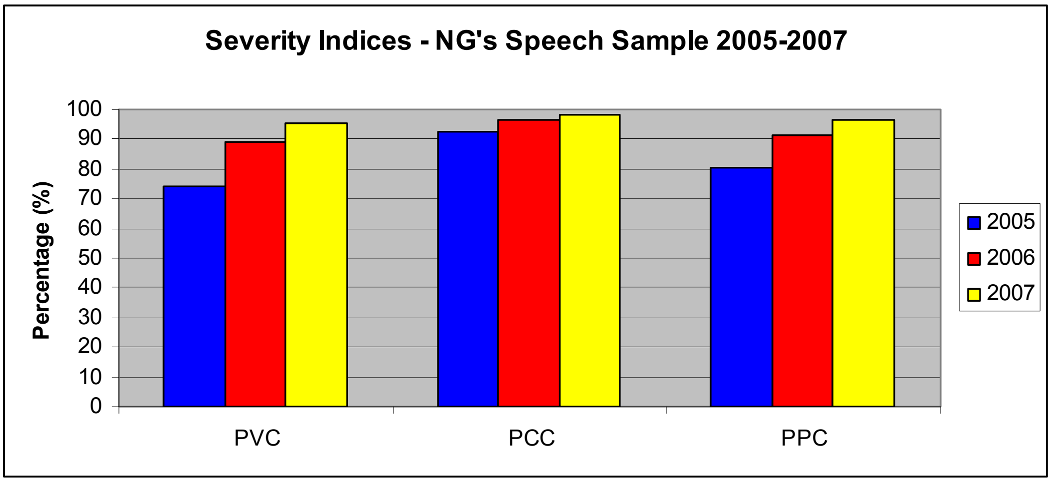


Figure 4.7 Severity indices – NG's speech samples C.A. 4;1-6;0

The increase in each severity index can be seen. Percentage vowels correct (PVC) displayed the greatest increase from 74% to 95.3% correct.

Within the respective speech processing profiles, improvement over the three time periods is also shown. On the input side, level A (auditory perception) has remained the same, but level D (real word discrimination) has improved/developed from below average performance to above average performance.

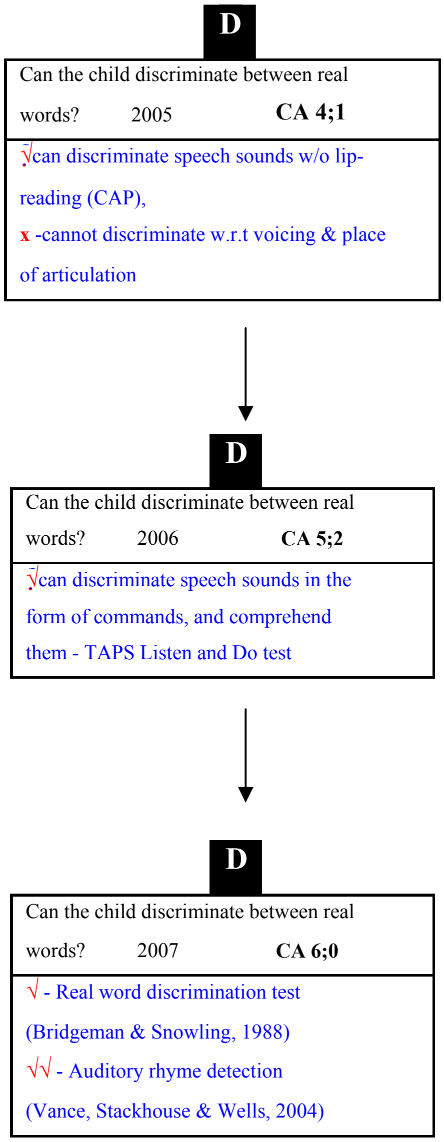


Figure 4.8 Development within level D from C.A. 4;1-6;0.

On the output side of the profile, levels G (naming) and I (real word repetition) have gone from areas of weakness to areas of strength. However within levels G and I, higher levels of the same task are still problematic, e.g. multisyllabic real word repetition results are below average while monosyllabic word repetition is age appropriate.

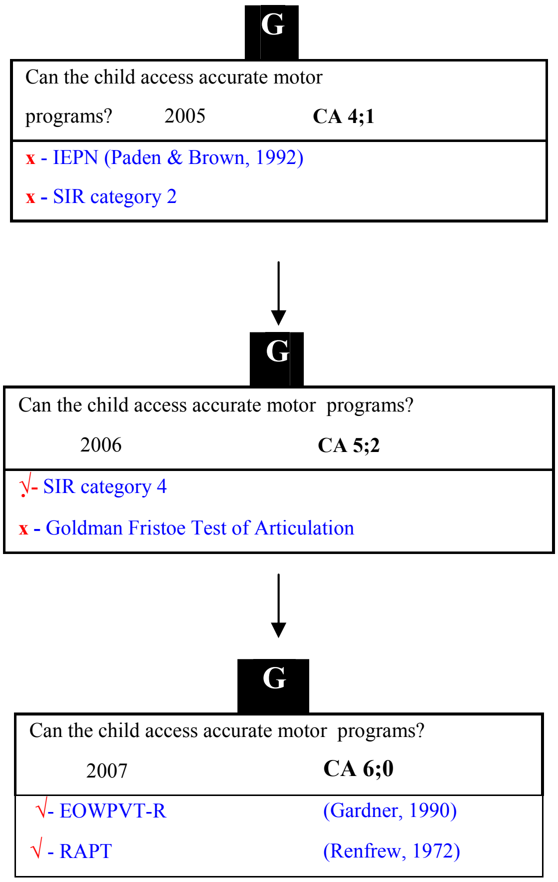


Figure 4.9 Development within level G from C.A. 4;1-6;0.

In the same way, level I (real word repetition), has shown successive improvements/developments.

From the changes in the severity indices (Table 4.5) and from the changes in the speech processing profile (Figures 4.8-4.9) it can be seen how NG's speech processing system has undergone developmental changes.

The developmental changes that have occurred in the period from C.A. 4;1-6;0 can be explained and analysed using a developmental phase model (Stackhouse & Wells, 1997; see Figure 2.4).

Based on the results obtained at the above-mentioned ages Table 4.6 was compiled to show the ages at which NG entered the stages of the model. Also the ages at which normally hearing children enter these stages are given allowing for a comparison between the normal developmental age guidelines and NG's own ages at those phases of speech processing development.

Time of assessment in relation to implant	pre-implant	1 year post-implantation	2 years post-implantation	3 years post-implantation
C.A.	**3;0**	**4;1**	**5;2**	**6;0**
Speech processing developmental phase	Whole word	Systematic simplification	Systematic simplification	Metaphonological ?plus
Normal ages for this phase	**12-18** months	**18-36** months	**3** years upward	± **5** years upward
Hearing age	0	1;0	2;0	3;0

Table 4.6 NG's speech processing development in phases.

At the time before she was implanted, NG's speech processing development was arrested at the whole word phase, since she had 6 words within her expressive vocabulary at the pre-implantation assessment. All deaf children have arrested development at the prelexical phase since the auditory input they receive is compromised and this delays them from developing the necessary skills needed to progress into the next developmental phase. However, she was able to progress into the whole word phase even before implantation.

At one year post-implantation a great deal of development had taken place. She already showed signs of having entered the systematic simplification phase. She had much less variability in her production of words, was displaying regular patterns of word simplification e.g. nasalization of /l/, glottal stopping of /k/ and /ɡ/, and had good pattern perception. Normally hearing children operate within this phase between the ages of 18 - 36 months, however she had managed to enter into it at 49 months.

At 2 years post-implantation the previous rate of development had not been duplicated. She was still operating within the systematic simplification phase since she was still showing regular phonological simplifying processes, as can be seen in Table 4.7 below.

Phonological Processes at C.A. 4;1	**Phonological Processes at C.A. 5;2**
Final consonant deletion, only when /l/ is final (15.8%)	Final consonant deletion, only when /l/ is final (16.7%)
Glottal stopping of /k/ and /g/ (100%)	Stopping of /g/ (60%)
	Glottal stopping of /k/ (11%)
Nasalization of /l/ (25%)	Nasalization of /l/ (12.5%)
	Nasalization of fricatives (4.65%)
	Consonant addition (2.1%)

Table 4.7 Comparison of phonological processes in NG's speech at 4;1 and 5;2.

Most of the phonological processes presented with reduced frequency of occurrence at C.A. 5;2 and seemed to be in the process of resolving. However, she had been using intonation effectively, which is a characteristic of the assembly phase. Thus she could have been close to transitioning into the assembly phase at 2 years post-implantation.

A 3 years post-implantation, the only phonological process which occurred frequently was liquid gliding (50%), and this also seemed to be resolving. The other processes occurred very rarely (i.e. less than 5%). In the assembly phase most processes have disappeared, although children may still have difficulty with /r/ or /T/, as is the case for NG. Another characteristic of the assembly phase is the ability to produce consonantal sequences. This NG could do with accuracy for most but not all words, e.g. 'spider' was pronounced correctly but 'spaghetti' was pronounced [p@gEtsi]. Thus it seems as though NG is operating within the assembly phase here. However when the results of her performance on the literacy tasks are evaluated, it is clear that she must be operating either within the metaphonological phase of her speech processing development or beyond into the normal phase, since not only is she able to segment words and syllables into parts but she can blend phonemes into words successfully, from verbal and written stimuli, in an age-appropriate way. This is in accordance with Kaderavek & Pakulski's (2007) statement that children, regardless of their functional hearing ability are able to acquire reading skills commensurate with their hearing peers.

Figure 4.10 shows how Stackhouse & Wells (1997) predict which speech difficulties arise from arrested development at any of the developmental phases.

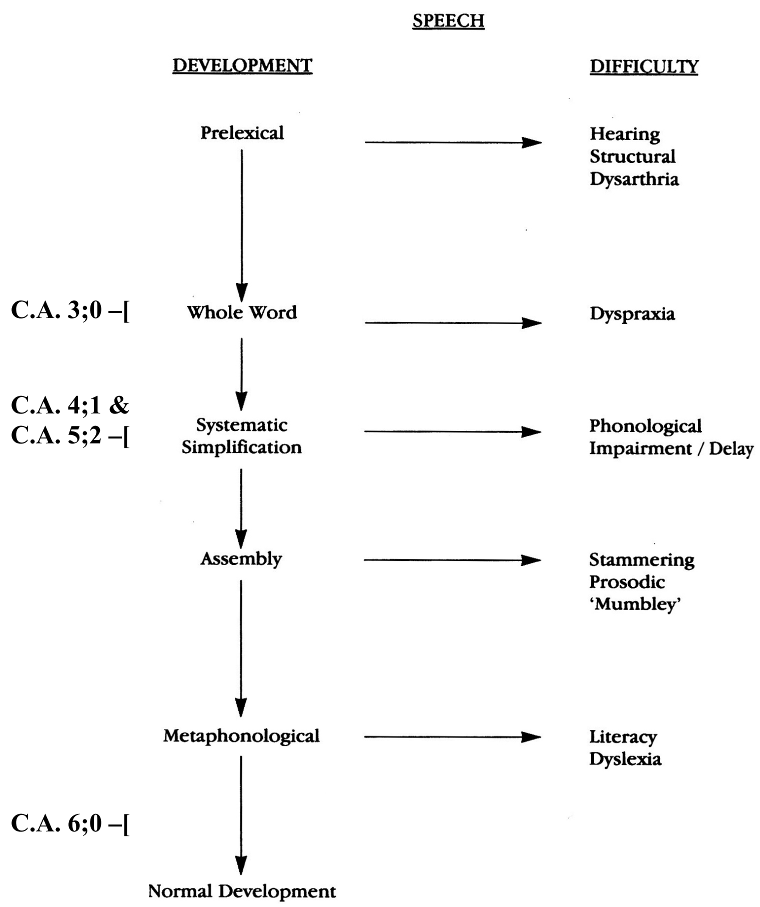


Figure 4.10 Stackhouse & Wells' developmental phase perspective on speech difficulties (Stackhouse & Wells, 1997), modified to indicate the chronological ages within which NG displayed characteristics particular to the speech processing developmental phases.

Thus for NG who does not have arrested development at the metaphonological phase and is thought to be transitioning into the final phase, no further speech difficulties are predicted. This concurs with her teacher's, and speech therapists's recommendation at 3;0 post-implantation that she is ready to attend a mainstream school.

Even though she may be ready to attend a mainstream school, NG's profile uncovered that she has difficulty producing multisyllabic words. At her last assessment, (C.A. 6;0) it emerged that she could only name 3-syllable words accurately 66% of the time, and that 80% of the errors she made on the Mispronunciation detection task (level E) were on multisyllabic words. However, she performed better on the ABX task than the Mispronunciation detection task, indicating that her multisyllabic non-word discrimination is intact, and that the difficulty lies with the accuracy of her phonological representations for multisyllabic real words (Vance, 1995).

In addition, she performed below average for both real and non-word repetition tasks (both multisyllabic). Real word repetition failure may be linked back to the inaccurate phonological representations but since no such representations exist for non-words, another process must be at fault.

NG's non-word repetition (NWR) scores were poorer than her real word repetition (RWR) scores. This pattern is found in normally developing hearing children where RWR scores are usually 10% higher than NWR scores (Vance, 1995). However, the difference between NG's RWR and NWR scores was 35%. Therefore a significant discrepancy exists between NG's RWR and NWR abilities and this points to a specific difficulty with the motor programming of non-words, since the difficulty appears to lie in producing novel phonological patterns (Dillon et al, 2004).

The task of NWR is expected to be especially difficult for children with hearing impairments (Briscoe, Bishop & Norbury, 2001; Dillon et al, 2004). The following processes need to be intact for the successful completion of this task:

a) perception of a completely novel sound pattern in auditory-only mode without the aid of speech-reading, pragmatic context, or semantic context
b) retention and verbal rehearsal of the novel sound pattern in immediate phonological memory
c) reassembly and translation of the novel perceived sound pattern into an articulatory program to produce speech.

All three of these components need to be completed rapidly with some minimum level of accuracy (Dillon et al, 2004). NG's test results on the ABX task at C.A. 6;0 demonstrated that she could perceive the novel sound pattern adequately, therefore only b) and/or c) may have been problematic for her. Vance (1995) suggests that the difficulty is rooted in the reassembly and translation of the novel speech pattern into an articulatory program (i.e. motor programming), while Dillon et al (2004) maintain that verbal rehearsal speed is the strongest contributor to variation in the non-word repetition performance of children with cochlear implants in their study.

In terms of addressing these areas it would be beneficial to use NG's strengths as described by the profile (e.g. good non-word discrimination, good awareness of the internal structure of phonological representations) to help facilitate learning in the areas where she experiences difficulties. For example, a concentrated effort on phonological awareness training to refine existing phonological representations for multisyllabic words is suggested. In addition, new vocabulary learning linked to ongoing themes at school, wherein NG is encouraged to reflect on the structure of words, and to produce it syllable by syllable, is recommended. Word segmentation games, which teach chunking strategies to facilitate effective subvocal rehearsal and production are also suggested (Stackhouse & Wells, 1997, 2001).

<u>Summary</u>

NG is a 6 year old girl with a congenital profound bilateral hearing loss, who was implanted with a cochlear implant at age 3. She comes from a supportive family and attends a special school for learners with hearing losses. She has developed normal speech processing and production, literacy and phonological awareness commensurate with normally developing six year olds. Multisyllabic word processing reveals some residual difficulties in her speech processing system and these should be specifically addressed and monitored to ensure that they do not cause ongoing difficulty in her speech, reading or spelling.

CHAPTER 5 : CASE STUDY - DP

This chapter, which focuses on DP's past and present speech processing skills, will be divided into three main sections:

(A) Current Speech Processing (C.A. 6;10),

(B) Past Speech Processing (C.A.2;2 & 3;2,)

(C) Discussion of Results

In sections A and B, the following are presented: case history, speech sample, speech processing profile and literacy assessment.

SECTION A – Current Speech Processing (C.A. 6;10)

5.1 *Case History*

DP was 6;10 at the time of assessment. She wears a *Nucleus 24 Contour* cochlear implant on both ears, using a 3G processor in the right ear and a Freedom processor in the left ear, and utilizes the ACE processing strategy in both processors. She received the first implant at the age of 1;2 , on the right ear, and then at the age of 5;0 she received the cochlear implant for the left ear. Thus she had been wearing the right cochlear implant for 5 years 8 months and the left cochlear implant for 1 year 10 months at the time of testing. Prior to receiving her first cochlear implant she had been wearing hearing aids bilaterally (i.e. from 0;6 to 1;2). Prior to this her hearing had been unaided.

DP's hearing loss has been ascribed to congenital rubella. Her hearing loss was first suspected when she failed the in-hospital neonatal hearing screener, and then confirmed at the age of 6 months by an audiologist. The hearing loss has been described as bilateral profound and sensori-neural. There were no other complications before, during or after the birthing process, however she also presented with a congenital cataract on the left eye, and a heart defect as a result of the congenital rubella.

After 6 months of wearing hearing aids and progressing very little with her speech and language development, the audiologist recommended that DP be fitted with a cochlear implant. After the necessary funds had been collected she was implanted in October 2001.

DP is a mother tongue English speaker with exposure to Afrikaans and Hindi, as these languages are also spoken in the home. The family is of average socio-economic status and consists of DP's mother, father, 12 year old brother, and herself. DP is currently in grade 1 at a school for hearing impaired children, in Cape Town. She has been receiving speech therapy once a week since her hearing loss was detected, and is still currently receiving therapy in the school setting. She also receives occupational therapy once a week as she was diagnosed as having low muscle tone.

At the time of testing, DP was co-operative and engaging. She showed appropriate concentration and attention for her age. DP was administered the test battery, and completed the evaluation in two days over the course of 4 hours, with 2 breaks in between.

5.2 ***Speech Sample***

Table 5.1 summarises DP's speech at the time of testing.

Assessment	Comments
Severity Indices	PCC = 97% PVC = 97.8% PPC = 97.3%
Phonological processes analysis (% use)	No consistent processes observed, isolated examples of errors noted, e.g. ["QksrItS] for OSTRICH, ["trVkt@] for TRACTOR
Single word speech sample	[haUs] for HOUSE [frut] for FRUIT ["trVkt@] for TRACTOR ["h{m3] for HAMMER ["sk3l@t@n] for SKELETON ["k{t@pIl@] for CATERPILLAR
Connected speech sample	[T@ "lItl g3l is "hVgiN h3 "tEdi] for THE LITTLE GIRL IS HUGGING HER TEDDY [{nd Siz "wE@riN kl@UDz] for AND SHE'S WEARING CLOTHES [{nd DEn Si lVvz h3 "tEdi I"lQt] for AND THEN SHE LOVES HER TEDDY A LOT [DIs mQm iz pUtiN T@ tSaIld sVm buts] for THIS MOM IS PUTTING THE CHILD SOME BOOTS

Table 5.1 DP's speech at C.A. 6;10

DP has very high intelligibility for single words and connected speech. In addition there were no observed repeated errors that could be attributed to phonological processes.

5.3 *Test Results & Speech Processing Profile*

Table 2 in Appendix E shows the test results of all 18 tasks carried out. The speech processing profile for DP's current speech processing skills was completed based on these results.

INPUT

F

Is the child aware of the internal structure of phonological representations?

x -PHAB picture alliteration subtest (Frederickson et al, 1997)

√ - Picture rhyme detection (Vance, Stackhouse & Wells, 2004)

E

Are the child's phonological representations accurate?

√ - Mispronounciation detection (Nathan et al, 2004)

D

Can the child discriminate between real words?

√ - Real word discrimination test (Bridgeman & Snowling, 1988)

√√ - Auditory rhyme detection (Vance, Stackhouse & Wells, 2004)

C

Does the child have language specific representations of word structures?

Not tested

B

Can the child discriminate speech sounds without reference to lexical representations?

√ - Non-word discrimination test (Bridgeman & Snowling, 1988)

- Auditory discrimination of non-words

√ - ABX task (Stackhouse, Wells, Vance & Pascoe, 2007).

A

Does the child have adequate auditory perception?

x -Audiometry (mild hearing loss)

OUTPUT

G

Can the child access accurate motor programs?

√ - EOWPVT (Gardner, 1990)

xx - RAPT (Renfrew, 1972)

H

Can the child manipulate phonological units?

x - PhAB alliteration fluency subtest (Frederickson et al, 1997)

x - PhAB rhyme fluency subtest (Frederickson et al, 1997)

I

Can the child articulate real words accurately?

√ - PAT blending subtest (Robertson & Salter, 1997)

x - Aston Index blending subtest -real words (Newton & Thomson, 1982)

xxx - Real word repetition subtest (Constable et al, 1997)

J

Can the child articulate speech without reference to lexical representations?

x - Aston Index blending subtest - non-words (Newton & Thomson, 1982)

xxx - Non-word repetition subtest (Constable et al, 1997)

K

Does the child have adequate sound production skills?

√ - Oral-facial examination,

√ - Diadochokinetic syllable rates (Shipley & McAfee, 2004)

L

Does the child reject his/her own erroneous forms?

Yes- Tester's observations observations

Figure 5.1 –Speech processing profile for DP (C.A. 6;10)

KEY TO SPEECH PROCESSING PROFILE

√	- age appropriate, i.e. one SD below the mean and up
√√	- one SD above the mean
x	– one SD below the mean or less
xx	– two SD's below the mean or less
xxx	– three SD's below the mean or less

5.4 *Discussion of Speech Processing Profile*

5.4.1 Overview of the profile

DP's profile appears to have strengths and weaknesses on both the input and output sides of the profile. The output side seems to have the most below average performances, while the input side has the only above average performance. In addition some levels have mixed performances for different tests within that level.

Levels which appear to be problematic are - level A: auditory perception (it is expected that all the children in this study would have a problem with this level, as they were selected on the basis of their hearing loss), level F : awareness of the internal structure of phonological representations, level G : naming, level H : manipulation of phonological units, level I : real word articulation, and level J : non-word articulation. Thus she presents with widespread difficulties.

There does not appear to be a pattern with regards to whether she performs better with top-down or bottom-up processing routes.

5.4.2 Input Levels

At level A it can be seen that at her last audiometric testing session (17/5/2007), all frequencies tested had thresholds between 26 – 34 dB HL. This is termed her aided hearing threshold and it correlates with a *mild* hearing loss, even though before implantation of the cochlear implant she had had a *severe-profound* loss. Thus only one cross is used to mark the hearing loss on the profile.

At level B, for both the non-word discrimination tests she scored within normal limits. However for the ABX task she scored in the low average range for her age. This may be explained by either of two reasons: firstly the ABX task has a slightly more difficult auditory memory component than the non-word discrimination task, and secondly the ABX task comprises multisyllabic stimuli whereas the non-word discrimination task only contains monosyllabic stimuli.

On closer inspection, the ABX task comprised 8 stimuli of the monosyllabic, bisyllabic and trisyllabic type respectively, yet DP scored similarly for these different stimuli. Table 5.2 explains how she scored for this test.

	Monosyllabic Stimuli (n=8)	**Bisyllabic stimuli (n=8)**	**Trisyllabic stimuli (n=8)**
Example:	[snaIk]/ [naIk]	[drektI]/ [trektI]	[{fIlQnt]/ [{lIfQnt]
RAW SCORE:	6/8	6/8	5/8

Table 5.2 DP's scores for the ABX task

DP's pattern of performance in this task seems to support the first hypothesis rather than the second. If multisyllabic words were more difficult for her to discriminate, this would have been seen on the scores for the ABX task, yet she scored the same for mono- and bisyllabic words, and only slightly less for trisyllabic words. Therefore the scores for the ABX task being lower than the non-word discrimination tasks may be better explained by the increased demand on auditory memory that the ABX task requires.

From level D it can be seen that she is able to discriminate between real words. In addition, and also as part of level D, she performed above average for her age in the auditory discrimination of rhyme test, thus receiving two ticks at that level. However, all the stimulus words used in the auditory discrimination of rhyme test were monosyllabic, and thus it cannot be assumed that her discrimination of real polysyllabic words will be as good.

At level E, one tick was given as she was able to accurately detect errors in speech. This suggests that her phonological representations for these words are accurate.

At level F, mixed results are observed. She has one cross for her performance in the picture alliteration subtest, while she has a tick for her performance in the picture rhyme detection. This may mean that her awareness of the internal structure of phonological representations is still developing. She has proven (at level D) that she can recognise rhyme appropriately, thus it might be expected of her to also perform age appropriately on the picture rhyme detection task, which indeed she has. However, in the realm of phonological awareness development, rhyme detection usually develops in children before initial phoneme detection (Nadler-Nir, 1997; Gillon, 2004). Therefore if she can do the former and not the latter, it means that her schema of how phonological representations are structured is still developing. Still, initial phoneme detection is expected in children by the age of 6 years (Vance, 1995; Nadler-Nir, 1997). Thus her awareness of the internal structure of phonological representations is not age appropriate.

Summary of Input Speech Processing Performance

Despite difficulties at level A, DP seems to be processing input at an age appropriate level for all input levels except level F. She performs particularly well at level D, for the task of auditory rhyme detection. Memory difficulties affect her performance at the level of non-word discrimination.

5.4.3 Output Levels

On the output side difficulties were encountered at every level, except level K.

For level G mixed results were obtained. She scored age appropriately for the EOWPVT, earning a tick on the profile, even though this test is not normed on or designed for English speaking South African children. Therefore, if this test had used South African English vocabulary, she may well have scored above average for her age. In contrast she scored two crosses on the profile for her performance on the RAPT. The RAPT is scored in terms of information given and grammaticality of utterances, according to a prescribed set of norms, thus she could be marked down for a variety of reasons not related to naming. This seems to be the case as her raw grammar score for the RAPT was 19, while the expected mean for her age group was 28. An error analysis revealed difficulties with the use of past and future tense, she did not use possessive markers (e.g. girl's), and used incorrect forms of irregular plurals (e.g. mices). In addition, there were no appreciable articulation errors that were found when analysing her utterances from the RAPT. She scored poorly as a result of syntactical and morphological errors, not as a result of poor naming in connected speech.

In analysing her responses to the EOWPVT, only 6/46 errors were found. Of these 6 errors, 5 were found in multisyllabic words. However this sample is too small to be conclusive. Her scores for the EOWPVT which assesses naming in isolation was age-appropriate. Thus for the naming section, level G of the profile she is deemed as performing at an age-appropriate level, since grammar and syntax are not customarily assessed within this profile.

Figure 5.2 shows that naming is concerned with tapping the semantic representations and then the accompanying motor programs. No further additional aspects of the connected utterance, such as grammar or syntax (or even prosody or fluency) are regarded within this profile.

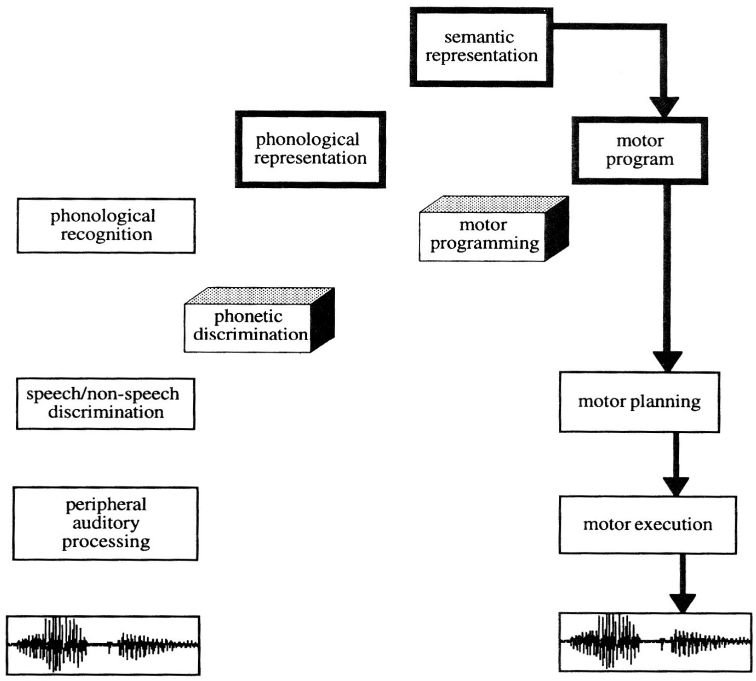


Figure 5.2 The speech processing route for naming as proposed by Stackhouse & Wells (1997).

At level H both test performances scored a cross on the profile. DP scored below average for both the alliteration fluency subtest, and the rhyme fluency subtest. These results show that she cannot manipulate phonological units yet. This result seems to confirm the assertion that her phonological awareness skills are still developing according to the normal sequence, where segmenting and blending skills are acquired before the skill of manipulation of phonemes (Nadler-Nir, 1997; Chard & Dickson, 1999; Hempenstall, 2003). However, according to normal developmental expectations she is supposed to have developed this skill by now (Frederickson, Frith & Reason, 1997; Nadler-Nir, 1997). In addition, in the rhyme fluency subtest she had to be reminded of what the stimulus word was. This could indicate that auditory memory difficulties, as encountered at level B could also be affecting her performance here.

Level I also shows mixed results. Her performance on the PAT blending subtest earned her a tick on the profile, but her performance on the real word blending on the Aston Index blending subtest earned her a cross on the profile. Although the task demands are identical, the stimuli used are not. The PAT used mainly monosyllabic stimuli (e.g. boy) with one bisyllabic stimulus (e.g. slipper), while the Aston Index subtest used more multisyllabic stimuli (i.e. 33.2% multisyllabic stimuli in Aston Index vs. 10% multisyllabic stimuli in PAT). Thus the Aston Index may have been more challenging because of the more complex stimuli it used. In addition, she scored three crosses for the real word repetition component of Constable's real word and non-word repetition task. In this task she obtained a raw score of 12/20, which is more than 2 standard deviations from the mean and indicates well below average performance in this area. This subtest uses only multisyllabic stimuli of 3 and 4 syllables. The length of the stimuli seems to have influenced results. Results from an analysis of the utterances used to compile her speech sample seem to agree with this statement. Results show that DP's articulation accuracy differs according to word length. While 1 syllable words were accurately articulated 97.4% of the time, and 2-syllable words were accurately articulated 85.7% of the time, more mistakes were made when 3-syllable words were articulated (62.5% accuracy). Thus it seems that DP has difficulty articulating and repeating real multisyllabic words. Within normal development it is expected that children master monosyllabic words first and that longer more complex words are mastered later (Bernthal & Bankson, 2004). In the context of her difficulty with auditory memory, and with the tasks used to assess real word repetition being auditory only, this may also have had an effect on her performance.

Both tests at level J showed non age-appropriate outcomes. Non-word blending on the Aston Index blending subtest scored a cross on the profile, as she performed below average for her age. This task only used 1- and 2-syllable words. DP earned three crosses on the profile for her performance on the non-word repetition component of Constable's real word and non-word repetition task. She obtained a raw score of only 5/20, which is rated as well below average performance on this test. This test comprised of stimuli which had three and four syllables. These results indicate that DP cannot articulate speech without reference to lexical representations. While both real word and non-word repetition were poor, performance on non-word repetition was much worse than for real word repetition. This suggests that DP may have a difficulty in assembling new motor programs. Her aforementioned difficulties with auditory memory may have influenced results in these tests as well, as the stimuli were presented auditorily only. In Figure 5.3, the memory difficulties are thought to affect speech processing at the level of retrieval of the motor program, as indicated by the red arrow.

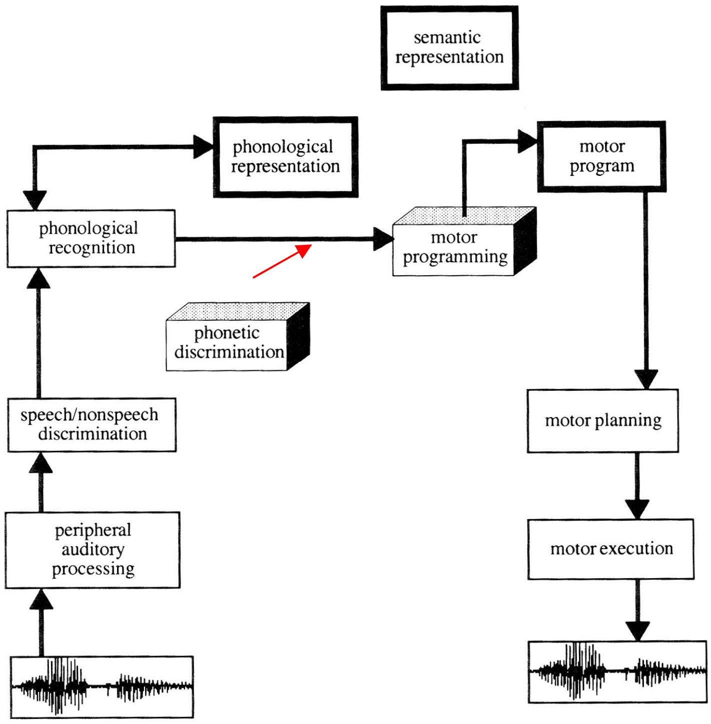


Figure 5.3 The speech processing route for non-word repetition as proposed by Stackhouse & Wells (1997) with an arrow indicating where auditory memory difficulties are thought to affect processing.

At the point where auditory memory difficulties are thought to interfere with the normal sequence of events, it results in an inaccurate motor program being assembled. This then results in inaccurate output.

At level K, she earned ticks for both tests, as both her OPE and AMR test results were within the normal limits for her age. Thus there is no evidence of articulatory difficulties.

Even though she has been diagnosed as having low tone, this seems not to have affected her articulatory capacity.

At level L, DP was observed trying to correct her own errors at some times during the assessment, e.g. on repetition of the word *rhinoceros* she initially said /raInQs@sIp/, then changed her production to the target production. Thus, she does employ limited self-monitoring, which can then be applied to change her output, when she has previously been made aware that her articulation is faulty. This also indicates that her speech processing skills on the input side are capable of alerting her to mistakes in her own speech as well.

Summary of Output Speech Processing Performance

DP has difficulty on all the output levels except level K (sound production skills). In addition, careful analyses of speech output indicates difficulties articulating multisyllabic words, which may be due to difficulties assembling new motor programs and/or auditory memory difficulties. In effect, the difficulties with assembling new motor programs may even be due to the auditory memory problems, in that if she has difficulties holding the spoken model in auditory memory, a degraded/inaccurate model of the target word is used to construct a new motor program, which would then be faulty.

5.5 *Literacy Assessment*

The three tasks used to assess literacy were: consonant decoding, CVC non-word decoding and CVC real word decoding. Table 5.3 lists the tests used to assess literacy, along with the scores obtained.

Task name:	Raw score	Standard score	Description of performance
Consonant decoding	19/20	106	average
Non-word CVC decoding	2/10	91	average
Real word match CVC decoding	5/10	no norms available	

Table 5.3 Results of the Literacy assessment

For the first task DP scored within normal limits for her age – this shows that she can access the phoneme from the written grapheme. For the non-word CVC decoding task, she scored 2/10 - in the average range. Although this performance is described as average for her age, it shows that she was not capable of decoding phonemes, blending them, creating a new motor programme for more than 2 words out of 10. In the matched real word CVC decoding task, she scored 5/10. Although there are no norms for the last task it can be seen that she performed better at decoding real words than non-words. This is to be expected according to developmental norms (Ehri & Snowling, 2004).

5.6 ***Summary***

For a child with a primary input disability, DP's speech processing profile shows most difficulties on the output side. This means that she may have had output difficulties even without a hearing loss or that her input difficulties have resulted in other system-wide difficulties even though her hearing loss has now been addressed. Despite the cross at level A, she displays average and above average performance at levels B, D, E, and K. She displays mixed performances at levels F, G and I. She displays difficulties at levels H and J.

In particular, her strength was auditory rhyme detection (level D). It is assumed that this was targeted extensively during therapy, as she performed normally for the visual rhyme detection condition as well, and seemed to enjoy the rhyme detection tasks more than any of the others in the assessment. However, she performed below average for the PhAB rhyme fluency subtest. While she clearly understood what was expected of her in the task, she only produced one rhyming word for one of the task stimuli, and none for the other. She seemed to forget the stimulus word as she kept asking to be reminded of it. This may point to difficulties with auditory memory, as also indicated by her performance in the ABX task (level B), or difficulties with creating new motor programs.

Her weaknesses included her performance on the RAPT (Level G), inability to manipulate phonological units (Level H), inaccurate real word articulation (Level I) and inaccurate non-word articulation (Level J).

For her performance on the RAPT, it was previously attributed to grammatical errors, which did not really impact on how she accessed accurate motor programs. The Speech Processing Profile (Stackhouse & Wells, 1997) does not take into account the syntactic component of language, but focuses on the articulatory, phonetic, phonological and semantic aspects of single word processing and production. This could be problematic for a population such as this (i.e. the hearing impaired population), where speech perception and syntactic development are linked. For example, deaf children frequently struggle hearing high frequency sounds, often failing to hear the sound /s/ in speech and therefore failing to comprehend and use morphemes such as the plural 's', possessive 's' or even the third person singular verb ending 's' (Lewis & Penn, 1989). Their output will reflect the absence of these morphemes, but there is no way to indicate this kind of problem using the profile of Stackhouse & Wells as there is no scope for indicating the overlap between the closely related areas of morphology and phonology.

In the case of DP, as she was not performing poorly in terms of accessing accurate motor programs, she should earn a tick at this level on the profile. Yet, in terms of her syntax and morphology, she is not performing age appropriately.

Below average performance at level H on the PhAB alliteration fluency subtest links to below average performance on the PhAB picture alliteration subtest (level F) as detection of initial phoneme similarities usually precedes production of words with the same initial phoneme (Chard & Dickson, 1999). Thus if she could not detect the same initial phoneme in pictures (PhAB picture alliteration subtest), it is expected that she would not be able to produce words with the same initial phoneme yet (PhAB alliteration fluency subtest). In addition, as previously explained it is hypothesized that DP's phonological awareness development has not yet progressed to the phoneme level. This is supported by her literacy assessment results, where she could only successfully decode, blend, and articulate 2/10 non-words, despite being in the middle of grade 1 at the time of testing.

Test results for levels I and J show that DP has difficulty articulating and repeating real multisyllabic words, as well as multisyllabic non-words indicating that she may have difficulties assembling new motor programs.

Comparison across levels

<u>Real word repetition vs. non-word repetition</u>.

Both scores for these tasks were described as being very much below average (when multisyllabic words were the stimuli). However, the raw score for non-word repetition performance was poorer than real word repetition performance, indicating that DP may have difficulty assembling new motor programs.

<u>Real word repetition vs. naming performance</u>.

While real word repetition performance was very much below average, naming performance was within normal limits, and therefore better than real word repetition performance. This may indicate difficulties with assembly of new motor programs for words (as described above) not within the lexicon or not often used. All stimuli elicited during the naming task are found in the lexicon, while stimuli for the real word repetition task, may have been unfamiliar to DP. In addition, this may indicate difficulties with auditory perception of the real word target presented verbally. Articulatory difficulties could not be used to explain this phenomenon, as no difficulties were found at level K.

<u>Rhyme detection (level D) vs. rhyme production (level H)</u>

When performance in rhyme judgement tasks are adequate but the child is unable to produce rhyming responses in a rhyme production task, especially when the child is older than 6;0, Vance (1995) asserts that there is a phonological processing difficulty that mitigates against fluent and flexible rhyme production. Such is the case for DP. Similar patterns of rhyme detection vs. rhyme production have been found for dyslexia (Stackhouse & Wells, 1991, in Vance, 1995).

Real word discrimination vs. non-word discrimination.

Although auditory discrimination of real words was not problematic (level D), the stimuli used for both tests at that level were monosyllabic, thus hidden difficulties might exist in the area of multisyllabic real word discrimination. While DP scored in the low average range for one of the tests within level B: non-word discrimination, it has been explained that this result seems to have more to do with auditory memory demands than actual discrimination skills.

In summary, and according to the speech processing profile, DP has:

1. mild auditory perceptual difficulties
2. appropriate non-word discrimination for monosyllabic and multisyllabic words
3. appropriate real word discrimination for monosyllabic words
4. appropriate and well-defined phonological representations
5. developing awareness of the internal structure of phonological representations.
6. ease of access to accurate motor programs, but poor use of syntax and grammar
7. poor phonological manipulation skills
8. appropriate blending skills for monosyllabic real words, but poor blending skills for multisyllabic real words.
9. difficulty assembling new motor programs for new multisyllabic words
10. poor real word and non-word repetition skills
11. adequate sound production skills
12. the ability to self-monitor and self-correct occasionally

SECTION B – Past speech processing test results (C.A. 2;2 & 3;2)

In the following section, DP's past test results taken from speech, language and hearing assessments 1 year post-implantation, and 2 years post- implantation respectively, will be analysed and discussed.

5.7 ***Case history – One year post-implantation*** (C.A. 2;2)

In the first year since she was implanted, DP attended weekly speech therapy sessions, experienced good parental involvement in the therapy process, and showed good progress, according to the Speech Therapist. She was described as verbally and vocally interactive by the Speech Therapist. She reportedly had a short attention span and was easily distracted. During the day she was cared for by the family's nanny as she was still too young for special placement. She was assessed in November 2002, at the age of 2;2, after having worn the cochlear implant for 1 year.

At this assessment, the following tests were administered:

- aided hearing thresholds
- phoneme detection test (US TBH Cochlear Implant Unit)
- IT- MAIS parent questionnaire (Nottingham Early Assessment Package, 2005)
- The MacArthur Communicative Developmental Inventory (Fenson, Dale, Reznick, Thal, et al, 1994).
- adapted TAIT video Analysis, a checklist (Nottingham Early Assessment Package, 2005)
- Profile of Actual Linguistic Skills (PALS), a checklist (Nottingham Early Assessment Package, 2005)
- SPICE-objects (assessment of early vocal development), (Moog, Biedenstein & Davidson, 1995)
- Communicative Intention Inventory (Coggins & Carpenter, 1981)
- Westby symbolic play scale (Westby, 1980)
- Communication Promoting behaviours checklist (Cole, 1992)
- US TBH Phonetic and Phonological Inventory : spontaneous language, Voice rating scale, Speech Intelligibility Rating (SIR), (Nottingham Early Assessment Package, 2005)

Data for this assessment was reportedly collected via video analysis of parent-child interaction, parental report and clinical observation during therapy sessions.

Hearing results

In both the phoneme detection task and IT- MAIS parent questionnaire, DP scored at ceiling as she could identify and repeat all consonants and vowels tested (phoneme detection task), and was reported as always displaying the listening behaviours targeted in the IT- MAIS parent questionnaire.

The Speech Therapist reported that DP consistently responded to speech and environmental sounds and enjoyed music activities. She was reportedly able to discriminate between fast/slow and loud/soft during these activities. According to the Speech Therapist's report she could identify tone of voice and everyday environmental sounds, her distance hearing had improved, and she demonstrated consistent pattern perception. However, she reportedly struggled with two-item memory listening tasks.

Language results

DP's receptive single word vocabulary was reported to be rapidly expanding, and she was able to relate two named objects, since two-word utterances were emerging in her expressive repertoire. She was reportedly finding object selection tasks difficult, even from a set of two objects. This result may be linked to her short attention span. She was able to comprehend the questions "where?" and "what?"

Her expressive language was age equivalent to that of an 18 month old child. She communicated mostly with single words, routine expressive phrases and a few two-word utterances, using a variety of early intentional communication phrases. She used speech as a primary means of everyday communication.

Speech results

According to the Speech Therapist her vowel and consonant systems were developing, but the accurate production of bisyllabic words was not yet established, as she often only produced the first or final syllable of these words, however no examples were given. She had acceptable speech resonance and had established pitch control. In addition, vowel deviations were noted in specific words (once again no examples were given).

In summary, her language and speech skills showed a mild delay. Continued speech and language therapy and Parent Guidance were recommended.

5.8 ***Speech sample – One year post-implantation*** (C.A. 2;2)

The test results and report do not include a transcript of words/utterances produced by DP during the assessment, thus it was not possible to compile a speech sample, for this period.

5.9 ***Speech processing profile*** (C.A. 2;2)

From the above-mentioned test results, the speech processing profile for DP's speech processing skills was completed retrospectively, and is shown in Figure 5.4.

INPUT	OUTPUT
F Is the child aware of the internal structure of phonological representations? Not tested	**G** Can the child access accurate motor programs? x - cannot produce bisyllabic words, word specific vowel deviations
E Are the child's phonological representations accurate? Not tested	**H** Can the child manipulate phonological units? Not tested
D Can the child discriminate between real words? √ - consistent pattern perception √ - phoneme detection 100% x - object selection tasks	**I** Can the child articulate real words accurately? Not tested
C Does the child have language specific representations of word structures? Not tested	**J** Can the child articulate speech without reference to lexical representations? √ - phoneme detection task - repetition of phonemes heard
B Can the child discriminate speech sounds without reference to lexical representations? Not tested	**K** Does the child have adequate sound production skills? Not tested
A Does the child have adequate auditory perception? x -Audiometry (mild hearing loss)	

L
Does the child reject his/her own erroneous forms?
yes — Tester's observations

Figure 5.4 Speech Processing Profile of DP (C.A. 2;2)

KEY TO SPEECH PROCESSING PROFILE

√ - age appropriate

x - not age appropriate

5.10 ***Discussion of Speech Processing Profile – One year post-Implantation*** (C.A. 2;2)

5.10.1 Overview of the profile

As this profile was compiled retrospectively, information for only a few of the levels was available from the assessment. In addition, many of the tests that could be used to give information for the levels were qualitative, and did not have normative data.

The profile shows difficulties on both the input and output sides. The specific levels that were problematic were Level A - auditory perception (it is expected that all the children in this study would have a problem with this level, at every period of time they are tested) and Level G – naming accuracy. Level D showed mixed results, and level J showed a positive result.

5.10.2 Input Levels

At level A it can be seen that at her last audiometric testing session (November 2002), all frequencies tested had thresholds of approximately 26 dB HL. This is termed her aided hearing threshold and it correlates with a *mild* hearing loss, even though before implantation of the cochlear implant she had had a *severe-profound* loss. Thus only one cross is used to mark the hearing loss on the profile.

At level D, DP demonstrated consistent pattern perception and phoneme detection skills which are age appropriate and earned one tick respectively on the profile, while her performance in object selection tasks was below average and earned her a cross on the profile. She struggles with consistently selecting a specific object from a set of two objects. She also had difficulty with two-item memory listening tasks. The Speech Therapist who assessed her related this to her short attention span, and decreased parental expectations.

5.10.3 Output levels

At level G one cross was given since her naming performance is below average. She could not name any bisyllabic words – either deleting the initial or final syllable, and specific words contained vowel deviations.

At level J she earned a tick, since she could correctly repeat all the phonemes heard in the phoneme detection test. However, this does not necessarily mean she could repeat all those phonemes in words.

5.10.4 Summary

In summary, and according to the speech processing profile, DP had:

1. mild auditory perceptual difficulties
2. appropriate real word discrimination but poor functional use of this skill
3. inaccurate motor programs for bisyllabic words,

5.11 ***Case history – Two years post-implantation*** (C.A. 3;2)

DP was assessed in November 2003 at the age of 3; 2 after having worn the cochlear implant for 2 years. She was still being looked after by the nanny during the day. Her use of the cochlear implant was described as excellent by the audiologist.

At this assessment, the following tests were administered:

- aided hearing thresholds
- various speech perception tests (i.e. the open set monosyllables & phonemes, Listen & Do test)
- IT- MAIS parent questionnaire
- US TBH Phonetic and Phonological Inventory : spontaneous language, Voice rating scale, Speech Intelligibility Rating (SIR)

- Profile of Actual Linguistic Skills (PALS), a checklist (Nottingham Early Assessment Package, 2004)
- Reynell Developmental Language Scales (RDLS), (Edwards, Fletcher, Garman, et al, 1997)
- Westby symbolic play scale
- Communication Promoting behaviours checklist (Cole, 1992)

Data for this assessment was collected via video analysis of parent-child interaction, as well as through direct test administration.

Hearing results

According to the audiologist, DP's results showed good speech sound discrimination, which enabled her to follow conversational speech without lipreading. Her IT-MAIS results again were at ceiling while she scored 100% on the open set monosyllables task results, and 90% for the Listen & Do test. She was reportedly making good use of the auditory information provided by the implant to develop her verbal communication skills.

Language results

DP's age equivalent score for the comprehension scale of the RDLS was 2 years 6 months. She demonstrated comprehension of a variety of single words, understood agent-action relationships, early attributes and prepositions.

Expressively she made use of three word clause and phrase structures, and had started using the conjunction 'and' to join her three word syntactic structures. Her expressive syntactic and morphological development was reportedly on a 2;0-2;6.

Speech results

DP's speech intelligibility was reported to have improved greatly, as a result of her phonetic inventory expanding, and becoming more complete. The volume of her speech (i.e. very soft), however influenced intelligibility negatively. The accuracy of her speech productions improved with direct and delayed imitation. She still presented with a number of age appropriate phonological processes, such as gliding of liquids (e.g. blow - /bw@U/), stopping (e.g. jump - /dVmp/, cluster reduction (e.g. pretty - /p@ti/).

Thus DP's speech and language skills were developing, albeit with a small delay compared to her chronological age.

5.12 ***Speech sample – Two years post-implantation*** (C.A. 3;2)

Assessment	Comments
Severity Indices	PCC = 79.5% PVC = 98.7% PPC = 86.8%
Phonological processes analysis (% use)	Developmental processes: cluster reduction (55.5%), final consonant deletion (30%), stopping (25%) Weak syllable deletion (16.6%) gliding of liquids (14.3%)
Single word speech sample	[iN] for RING [n@Uz] for NOSE [tIk@n] for CHICKEN [l@l@U] for YELLOW [bQt@] for BOTTLE [b@nAn@] for BANANA

Table 5.4 DP speech sample C.A. 3;2

Table 5.4 shows a number of phonological processes in use, however all of them were described as age appropriate by the Speech Therapist assessing her. When related to her *hearing age* of 2;0 all these processes are definitely still age- appropriate, but when related to her chronological age of 3;2, Stoel-Gammon and Dunn (1985 in Bernthal & Bankson, 2004) maintain that weak syllable deletion and final consonant deletion should have disappeared. The soft volume of her speech was regarded as affecting intelligibility more than these processes by the Speech Therapist. Volume of speech in children with cochlear implants has not received a lot of attention in the literature – it is suggested that DP's soft volume may have rather been an extension of her personality.

5.13 ***Speech processing profile*** (C.A. 3;2)

DP's speech processing profile at C.A. 3;2 is presented in Figure 5.5.

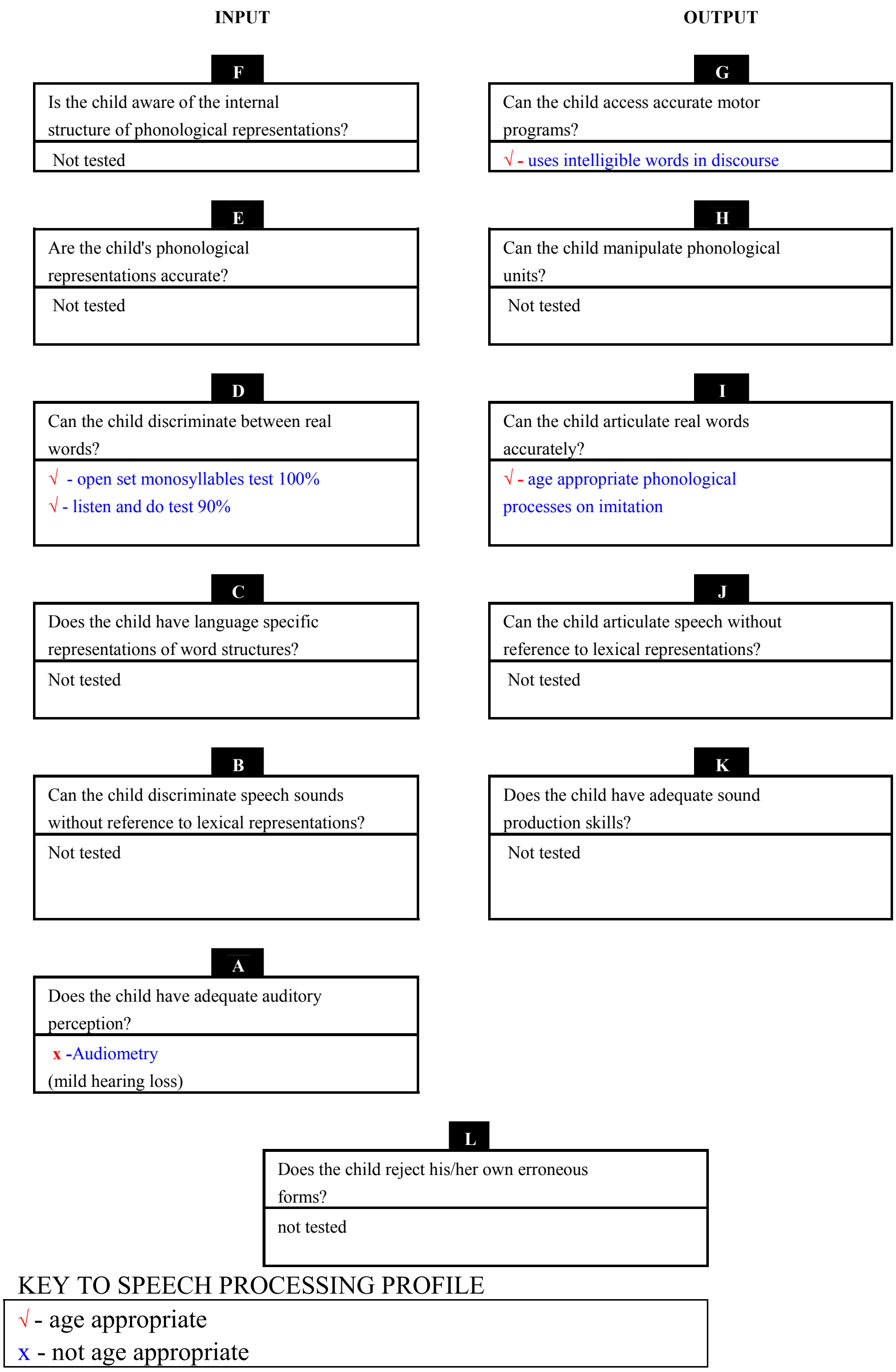


Figure 5.5 Speech Processing profile of DP (C.A. 3;2)

5.14 ***Discussion of Speech Processing Profile – Two years post-Implantation*** (C.A. 3;2)

5.14.1 <u>Overview of the profile</u>

As this profile was compiled retrospectively, information for only a few of the levels was available from the assessment. In addition, many of the tests that could be used to give information for the levels were qualitative, and did not have normative data.

The profile shows difficulties on only the input side. The specific level that was problematic was Level A - auditory perception, and as noted before, it is expected that all the children in this study would have a problem with this level. Information on all the other levels (i.e. levels D, G, I) indicated age appropriate performance.

5.14.2 <u>Input Levels</u>

At level A it can be seen that at her last audiometric testing session (December 2003), all frequencies tested had thresholds of approximately 28-32 dB HL. This is her aided hearing threshold and it now correlates with a *mild* hearing loss, even though before implantation of the cochlear implant she had had a *severe-profound* loss. Thus only one cross is used to mark the hearing loss on the profile.

At level D, she earned two ticks for her performance in the open set monosyllables set and the “Listen and Do” test respectively. She obtained 100% correct in the former and 90% correct in the latter. Her performance in the “Listen and Do” test is noteworthy, since she reportedly had difficulties with functional real word listening tasks, such as this at her last assessment.

5.14.3 <u>Output levels</u>

At level G she earned a tick for using intelligible words in discourse, which is age appropriate. Her speech sample also shows that her utterances are mostly intelligible despite the amount of phonological processes present in her speech.

These processes were also observed on imitation of real words. As these processes are still age appropriate, she earns a tick at level I – real word repetition.

5.14.4 Summary

Thus according to this speech processing profile DP only has difficulties with auditory perception. However, not all the levels were tested, and the tests that were employed may have been too easy for her age level.

SECTION C – Discussion of results

In this section past and current results will be discussed and compared in order to elucidate the developmental progression of DP's speech processing skills, in order to understand her current results more clearly.

DP's most recent profile (C.A. 6;10) shows that:

- input processing is a relative strength at all levels except for level F – she displayed less than age appropriate awareness of the internal structure of phonological representations. This area is thought to be developing in the normal sequence but at a slower rate, since normally developing children acquire the ability to detect rhyme before the ability to detect similar onsets (Nadler-Nir, 1997). Similarly, Stern & Goswami (2000:621) assert that, "In deaf children, as in hearing children, phonological awareness at the syllable level appears to precede phonological awareness at the phoneme level."
- output processing demonstrated mixed results. Levels G and K were definite strengths, while levels H (phonological unit manipulation), I (real word repetition) and J (non-word repetition) were regarded as relative weaknesses. Difficulties with phonological unit manipulation are hypothesized to be linked to her immature awareness of the internal structure of phonological representations, but may also be due to her difficulties with assembling new motor programmes, and/or her auditory memory difficulties as demonstrated in her performance in levels I and J. In addition, her ability to detect rhyme coupled with her inability to

produce it is reminiscent of patterns of phonological awareness shown by children with dyslexia.

- the link between her output and input processing skills was found to be intact and active, since she monitors her own output at times and is then able to modify it.
- the literacy results obtained demonstrated average performance in the tasks tested. These link satisfactorily with the age appropriate results obtained in levels of the profile that tap certain phonological awareness-type tasks. However her phonological awareness skills are not age appropriate yet – she displays emerging phoneme level phonological awareness only. This can be seen in her speech processing performance and in her limited ability to decode non-words.
- Limited auditory memory seems to be a theme that runs through her performance in many of the tests. Although it was not formally tested it was evidenced in her requests to repeat stimuli, her superior performance when visual stimuli was present, and from the tester's observations. It was also alluded to in her earlier assessments.

Weaknesses pinpointed by the profile include immature phonological awareness, limited auditory memory and difficulty constructing new motor programs. These will need to be targeted in therapy in order to rectify and strengthen these areas.

DP's current results (CA 6;10) were compared to results obtained one, and two years post-implantation. At the time of testing (CA 6;10) she was 5 years 8 months post-implantation (on the right ear, and 1 year 10 months post-implantation on the left ear.). It was logical to compare the current results with the one- and two years post-implantation (of the right ear) results to develop a longitudinal perspective of the changes in her speech processing. In addition, as previously noted, one year and two years respectively are significant amounts of time in terms of communication development (Rossetti, 1996; Bernthal & Bankson, 2004). Studies have indicated that speech perception in implanted candidates improves significantly after 6, 12 and 24 months of implant use (Waltzman, Cohen & Shapiro,1992; Tobey & Geers, 1995), also showing that 1- and 2-year periods after cochlear implantation are significant time periods in implantee's development.

Therefore the retrospective time periods chosen were 1 year and 2 years post implant, since the most improvements are expected in those time periods.

While it was not possible to monitor her speech processing development over these three time frames using the same tests, results from the different tests confirm that development occurred between testing times. For example, the speech samples taken at each testing period were analysed in terms of severity indices, and the improvement for each index can be seen in Table 5.5 and Figure 5.6 below.

	T2	T3
	C.A. 3;2	C.A. 6;10
	2003	2007
PCC	79.50%	97%
PVC	98.70%	97.80%
PPC	86.80%	97.30%

Table 5.5 Speech sample severity indices for C.A. 3;2 and C.A. 6;10

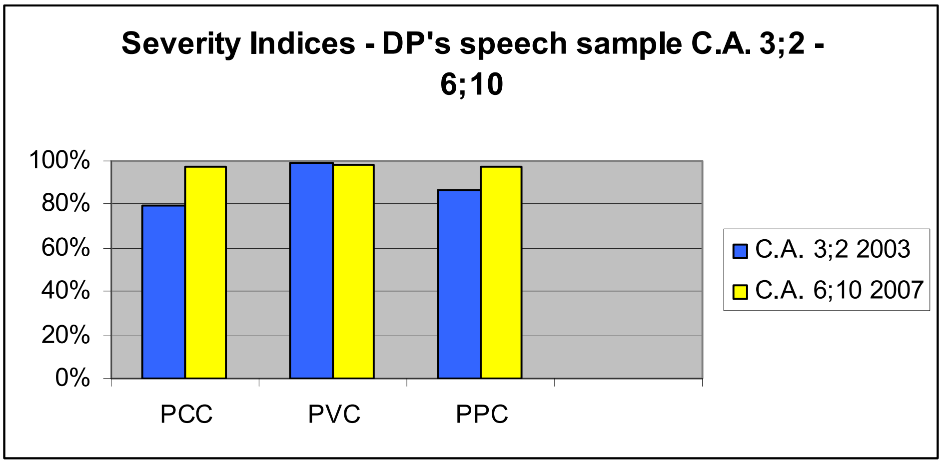


Figure 5.6 Severity Indices – DP's speech samples at C.A. 3;2 and 6;10.

Even though there are only 2 speech sample tables to compare, the increases and improvements are clear. Percentage consonants correct (PCC) was seen to show the biggest increase (i.e. from 79.5% to 97%) from the first time period to the second.

Within the respective speech processing profiles, improvement over the three time periods is also shown. On the input side, level A (auditory perception) has remained the same, but level D (real word discrimination) has improved/developed from below average performance to above average performance. It seems as if the effect of having the cochlear implant (at level A) cascades most dramatically to level D.

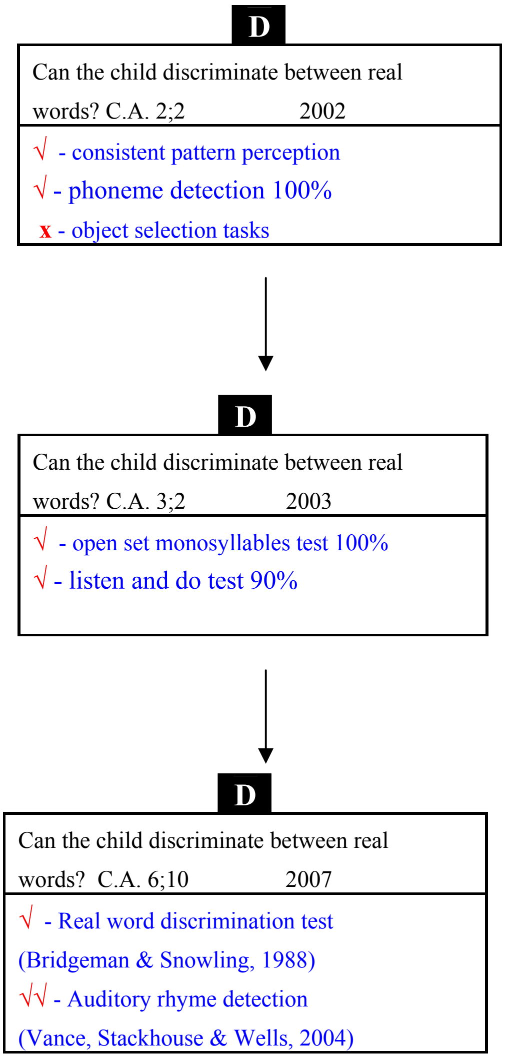


Figure 5.7 Improvements in the speech processing profile for level D

In Figure 5.7 it can be seen how DP's performance improved – from obtaining mixed results in 2002, to age appropriate results in 2003, to above average results in 2007. Real word discrimination can now be regarded as one of DP's strengths.

On the output side of the profile, level G (naming) has also shown some development. While it was assigned a cross at C.A. 2;2 , current results show age appropriate performance. Figure 5.8 below shows this.

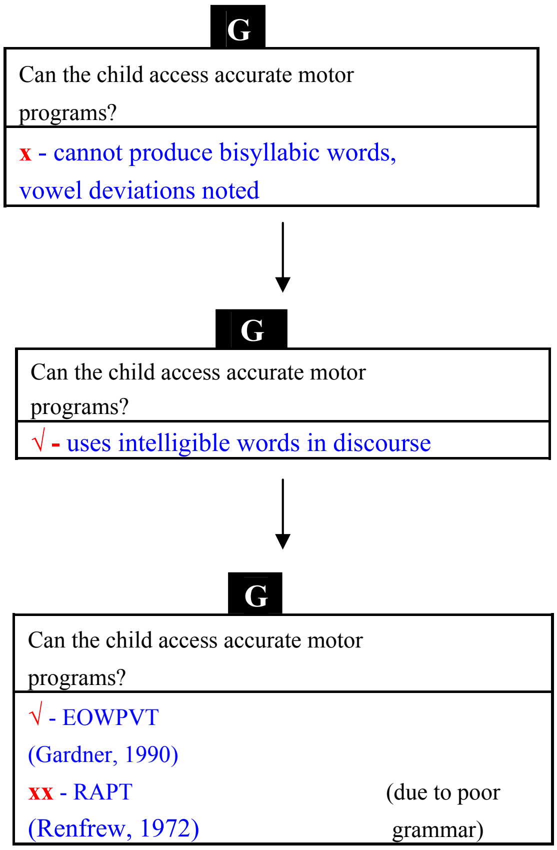


Figure 5.8 Improvements in the speech processing profile for level G

Thus we can see from the changes in the severity indices and from the changes in the speech processing profile how DP's speech processing system undergoes developmental changes.

The developmental changes that have occurred in the period from C.A. 2;2 - 6;10 can be explained using a developmental phase model (Stackhouse & Wells, 1997), shown in Figure 2.4.

Based on the results obtained at the above-mentioned ages Table 5.6 was compiled to show the ages at which DP entered the stages of the model above. Also the ages at which normally hearing children enter these stages are given allowing for a comparison between the normal developmental age guidelines and DP's own ages at those phases of speech processing development.

Time of assessment in relation to implant	pre-implant	1 year post-implantation	2 years post-implantation	5;8 years post-implantation
C.A.	**1;2**	**2;2**	**3;2**	**6;10**
Speech processing developmental phase	Prelexical	Whole word	Systematic simplification	Metaphonological
Normal ages for this phase	**0-12 months**	**12-18 months**	**18 months - 3 years**	**± 5 years upward**
Hearing age	0	1;0	2;0	5;8

Table 5.6 DP's speech processing development in phases.

At the time before she was implanted, DP's speech processing development was arrested at the prelexical phase. All deaf children have arrested development at the prelexical phase since the auditory input they receive is compromised and this delays them from developing the necessary skills needed to progress into the next developmental phase. Pre-implantation all she produced were vocalisations with gestures – she had no real words yet.

At one year post-implantation some development had taken place. She showed signs of having entered the whole word phase. Her receptive language skills were far superior to her expressive language skills which consisted of a few single words and some routine 2-word phrases. She produced the first syllable only of bisyllabic words, probably since this is the most acoustically salient part of the word. This pattern fits with the phase she was in. There were no regular phonological processes noted. Since children are expected to enter this phase between 12-18 months, she displayed a slight delay. However, in terms of her hearing age (12m) she was developing appropriately.

At 2 years post-implantation DP's speech processing skills demonstrate that she is in the systematic simplification phase. Here phonological processes dominate her speech output and there is less variability in production. Normally, children enter this phase between 18 months and 3 years, however she is past 3 years and still in this phase. This indicates a delay. However, in terms of her hearing age (24m) she was developing appropriately.

At the most recent assessment (5 years 8 months post-implantation on the right ear, 1 year 10 months post implantation on the left ear) DP was deemed as being in the metaphonological phase, the second last phase of speech processing development, since she had all the characteristics needed for the assembly phase plus the beginnings of phonological awareness. However, she had been exposed to the alphabetic rule for approximately 1½ years and still she had only developed the basics of phonological awareness. Her development may be delayed at this level.

Stackhouse & Wells (1997) predict which speech difficulties arise from arrested development at any of the developmental phases. Figure 5.10 shows Stackhouse & Wells' developmental phase perspective on speech difficulties, modified to show the chronological ages at which DP performed within the developmental phases.

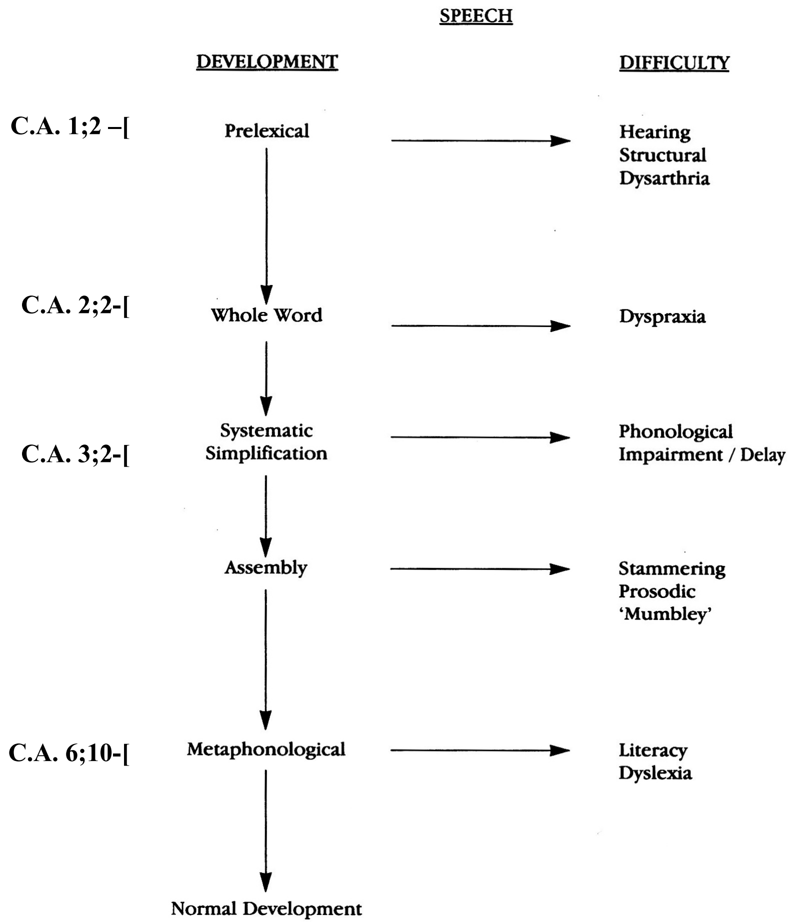


Figure 5.9 A developmental phase perspective on speech difficulties (Stackhouse & Wells, 1997), modified to show the chronological ages at which DP displayed characteristics particular to the speech processing developmental phases.

From this model it can be seen that DP is at risk of developing literacy difficulties, since she is delayed at the level of metaphonological development. This links with Vance's (1995) earlier assertion that the pattern of phonological awareness skill deficits DP shows is seen in children with dyslexia.

All in all her post-implantation outcomes show good progress through the speech processing developmental stages, with the exception of the delay in the metaphonological phase. Her specific weaknesses in the areas of auditory memory/attention, and motor program retrieval relating to phonological awareness, and the possible impact of bilateral cochlear implantation will be discussed next.

Phonological awareness is defined as the ability to reflect on and manipulate the sound structure of words separate from their meaning, and includes an awareness of sounds at the syllable, onset-rime and phoneme levels (Nielsen & Luetke-Stahlman, 2002). Phonemic awareness refers specifically to the phonological awareness skills at the phoneme level, e.g. sound identification, sound blending, segmenting, and sound manipulation (Friedman Narr, 2006).

DP's most current phonological awareness results (at C.A. 6;10) indicate that she scored age appropriately for phonological awareness tasks such as :

- Auditory Rhyme Detection (better than average performance)
- Visual Rhyme Detection (average performance)
- Word and phoneme blending (average performance)

However she performed below levels expected for her age on tasks such as:

- Rhyme fluency
- Alliteration fluency
- Picture Alliteration (Onset Detection)

Therefore it can be seen that she performed better at the level of onset-rime than at the phonemic level and that the area of phonemic awareness is still emerging. Her performance is regarded as delayed, since phonological awareness shows a developmental progression towards awareness of smaller units of words (Gillon, 2004), which she has not yet fully achieved. This specific area of weakness needs to be addressed.

A variety of studies have already confirmed the predictive power of phonological awareness in relation to literacy success (Catts, Fey, Zhang & Tomblin, 2001; Gillon, 2004; Heath & Hogben, 2004). Phonemic awareness in particular in kindergarten (grade R) children has emerged as a strong predictor of reading and spelling in grade 2 (Lundberg et al, 1980; Bradley & Bryant, 1983, in Gillon, 2004). Gillon (2004) also urges monitoring of the phonological awareness development of children with diagnosed impairments that place them at risk for developing reading disorder (such as hearing loss), during the early preschool years, with a view as to whether or not the child shows an accelerated rate of phonological awareness development during the ages of 3-4 years as is shown by normally developing hearing children. If this is not the case, specific interventions to improve phonological awareness development before the child starts school would be appropriate (Swank & Larrivee, 1998; Gillon, 2004). In DP's case, prior to the assessment at C.A. 6;10 phonological awareness had never been assessed. It is suggested that the assessment battery of children implanted with cochlear implants should include assessments of phonological awareness since this population is at risk for developing reading difficulties. Nielsen & Luetke-Stahlman (2002) recommend using the *Phonological Awareness Test* (Robertson & Salter, 1997) which assesses segmentation, blending, substitution, rhyming, isolation and deletion skills, for hearing impaired children.

Factors that have affected the phonological awareness development of DP need to be investigated in order to remediate difficulties found. Nielsen & Luetke-Stahlman (2002) report on three decades of research correlating phonological awareness with hearing acuity in deaf readers, but providing poor details on aided hearing thresholds in those reports. One study that was able to link the amount of hearing acuity to the amount of phonological awareness development in children, was that of James et al (2005), who found that: 1) syllable awareness of cochlear implant users was equivalent to that of children with severe hearing loss using hearing aids and better than that of children with profound hearing loss using hearing aids, and that 2) rime and phonemic awareness of cochlear implant users was similar to that of children with profound hearing loss using hearing aids. However, the cochlear implant using children in this study had a mean device experience of 3;8, whereas DP had 5;8 device experience on the right ear and 1;10 device experience on the left ear. Thus better performance for DP than those reported above could possibly be predicted from longer device experience. In addition, the hearing acuity of a child optimally mapped with a cochlear implant is expected to exceed, in many cases, that of a child optimally fitted with hearing aids (Davidson, 2006; Mildner, Sindija, Vrban Zrinski, 2006; The Ear Foundation, 2007).

Linked to hearing acuity, speech perception has been identified, along with vocabulary and articulation skills, as being correlated with phonological awareness in children (Rvachew , 2006). Rvachew developed a model, adapted from a linear structural equation model of test scores obtained after assessing all the above in preschoolers with speech-sound disorders, to try and describe relationships between these variables. Figure 5.11 shows this model.

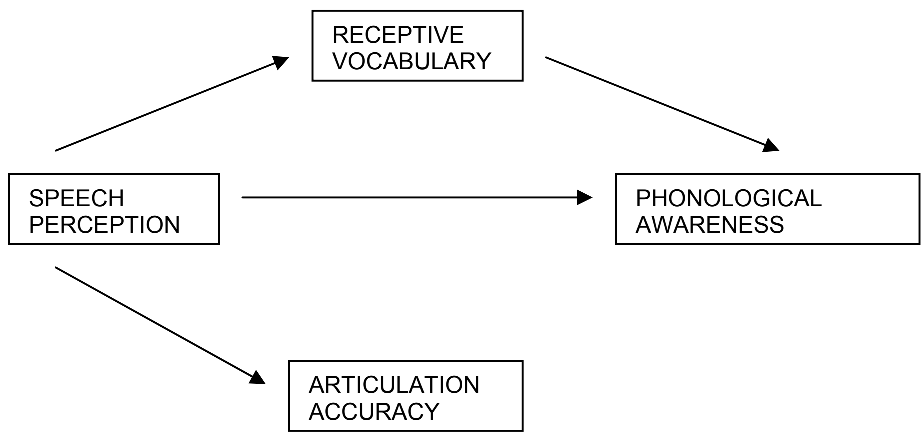


Figure 5.10 Rvachew's (2006) model linking speech perception, vocabulary, articulation accuracy and phonological awareness.

This model suggests that speech perception has a direct effect on phonological awareness, *and* an indirect effect on phonological awareness because speech perception skills support vocabulary learning which in turn supports phonological awareness development. She also hypothesized that articulation skills have no direct effect on phonological awareness. According to this model, speech perception has a direct effect on phonological awareness and therefore delays in speech perception development (e.g. arrested development at the metaphonological phase) are expected to influence phonological awareness development negatively. However, DP's vocabulary is not expected to negatively influence her phonological awareness development. Her expressive vocabulary is age appropriate (performance on the *EOWPVT* at C.A. 6;10) and therefore it is expected that her receptive vocabulary would be age appropriate too.

Other factors deemed important to phonological awareness development are:

- The influence of reading and spelling experiences, which are reported as having a reciprocal relationship with phonological awareness (Swank & Larrivee, 1998; Gillon, 2004)
- Letter/Alphabet Knowledge (Nielsen & Luetke-Stahlman ,2002; Gillon, 2004)
- The influence of underlying phonological representations. Friedman Narr (2006) maintains that inadequately developed internal representations lead to weak phonological awareness skills. Internal representations are defined as mental images of the sounds within words – similar to Stackhouse & Well's (1997) phonological representations. Gillon (2004) also supports this statement saying that the distinctness of the child's phonological representations for a word influences the child's explicit awareness of the word's phonological structure. To be able to break a word down into its individual segments a child needs a distinct phonological representation for the target word stored in memory as well as the ability to access this representation in a conscious manner. DP appeared to have distinct phonological representations for the words investigated at level E since she performed age appropriately on the Error Detection Task. Thus the difficulty seems to lie, not in the phonological representation itself but in the conscious accessing/utilising of this phonological representation.

  Earlier on in this chapter it was hypothesized that auditory memory difficulties may affect retrieval of the motor program after the phonological representation is retrieved. Marschark (1993, in Nielsen & Luetke-Stahlman ,2002) suggested that young readers may need to store phonological representations, such as strings of letters or syllables in the working memory temporarily while phonologically assembling or sounding out a word. However if the working memory itself is problematic, then sounding out of a word becomes even more difficult. For example, if a word is to be manipulated, that word is retrieved from the phonological representation and sent to the working memory while operations (deletion/substitution/addition) are carried out on it. From there on the completed new word is sent on to motor programming to create the motor program and output it. However if a glitch occurs at the level of the working memory, then the correctly retrieved phonological representation is not where the difficulty lies. Other researchers in deaf education (Hanson, 1986; Hanson et al, 1984; Locke & Locke, 1971, all in Nielsen & Luetke-Stahlman, 2002) have found that working memory capacity is a strong predictor of reading achievement for deaf readers, even stronger than degree of hearing loss.

- Early language experience and lexical growth leads to more distinct, specified organizational frameworks for storing similar sounding words in the lexicon (Stern & Goswami, 2000; Kaderavek, Pakulski, 2007)

Thus for DP difficulties with auditory/working memory rather than hearing acuity, vocabulary, articulation, letter knowledge or indistinct phonological representations, may be a component in her phonological awareness delay and may put her at risk for reading difficulties.

Still, researchers Friedman Narr (2006) & Nielsen & Luetke-Stahlman (2002) assert that phonological awareness can be developed in children with hearing impairments through explicit, systematic and structured strategies and that it should be multidimensional, involving sound-grapheme skills, articulation-to-spelling skills, speechreading-to-spelling skills, and the writing of grammatically correct English words, phrases and sentences. Auditory memory also should be included in assessment batteries when phonological awareness is tested.

In addition, in therapy, the focus for DP should be on promoting the development of her phonological awareness in the natural sequence in which it emerges in normally developing children, i.e. syllable, onset/rime, phoneme; promoting vocabulary growth but using known vocabulary when working on phonological awareness tasks; using the written form of words to help improve her understanding of the internal structure of phonological representations (James, 2005); facilitating her ability to manipulate phonemic units using concrete representations of speech-sound units (e.g. coloured blocks) (Swank & Larivee, 1998); facilitating access to nursery rhymes, story book telling and singing in a meaningful and developmentally appropriate context (Kaderavek & Pakulski, 2007)

There is another factor particular to DP's case which may/may not be affecting her outcomes – that of bilateral cochlear implantation. DP was implanted at 1;2 on the right ear and at 5;0 on the left ear. Thus there was a gap of 3;10 between the two implantations.

Bilateral cochlear implants are recommended because of the widely documented advantage of hearing with both ears (Galvin, Mok & Dowell, 2007; Peters, Litovsky, Parkinson & Lake, 2007; Papsin & Gordon, 2008). Binaural hearing (be it with two hearing aids, two cochlear implants or with one of each) leads to improved localization of sound, better speech perception in noise and better subjective quality of sound (Galvin, Mok & Dowell, 2007; Papsin & Gordon, 2008). Bilateral cochlear implants are recommended to:

1) ensure auditory input in the event of device failure in the one ear
2) allow children to obtain/maintain binaural hearing resulting in better localization of sound and speech perception in noisy environments such as the classroom. (Galvin, Mok & Dowell, 2007; Peters, Litovsky, Parkinson & Lake, 2007; Papsin & Gordon, 2008).

Thus there are several established reasons for bilateral implantation that promise improved outcomes for the child.

Papsin & Gordon (2008) argue that simultaneous bilateral implantation or sequential implantation within 1-2 years after the first implantation is preferable, so that there is not too much of a difference between the auditory processing abilities between the two ears. Studies have shown that unilateral implant use leads to mismatched timing of the brainstem activity evoked by either ear (Cone-Wesson, Ma & Fowler, 1997, in Papsin &

Gordon, 2008; Gordon, Valero & Papsin, 2007). This unbalanced timing in the auditory brainstem resolves in children who had brief periods (6-12 months) of unilateral implant use, by about 9 months, but persists in children with more extended unilateral implant use. Papsin & Gordon (2008) maintain that a period of delay between the first and second implant might slow/compromise the development of binaural processing. Therefore in DP who has had an implant interval of 3;10, binaural processing delays may have resulted.

Factors mediating successful outcomes for bilateral implantees include:

1) increased device experience in the binaural condition (more than 6 months experience needed before positive effects start to show) (Galvin, Mok & Dowell, 2007).
2) Decreased age at implantation (Galvin, Mok & Dowell, 2007; Peters et al, 2007; Papsin & Gordon, 2008)
3) Decreased time period between the first and second implantation (Galvin, Mok & Dowell, 2007; Peters et al, 2007; Papsin & Gordon, 2008).
4) Specific auditory habilitation to develop listening skills in the second implanted ear (Galvin, Mok & Dowell, 2007).

DP benefits from increased device experience (1;10 binaural experience at C.A. 6;10), and decreased age at implantation (1;2) but she also experienced an increased period of delay between the first and second implantation. In addition, it is not known whether she received specific habilitation for the second ear, since it was not mentioned in her Cochlear Implant Centre folders. Therefore, if binaural processing delays had resulted from the delayed implantation of the second cochlear implant, and if no specific habilitation was given, then the bilateral implantation itself could have been a limiting factor in DP's speech processing development. This information must be regarded in the light that her speech processing development was on target for her hearing age at 1- and 2-years post-implantation (before she received the second implant) but is currently delayed. In contrast to this, research asserts that bilateral sequential implantation of cochlear implants in children leads to open-set speech discrimination in the second ear, even for children receiving their second implant as late as 13:0, and that a significant binaural advantage in noise is demonstrated (Galvin, Mok & Dowell, 2007; Peters et al, 2007). Therefore it is believed that this area should be more thoroughly investigated in DP, with an emphasis on the speech perception abilities of the ear that was implanted last. If deficits are found, remediation would be needed specifically for that ear.

Summary

DP is a 6 year, 10 month old girl with a congenital profound bilateral hearing loss, who was implanted with her first cochlear implant at age 1;2 and her second cochlear implant at age 5;0. She attends a special school for learners with hearing losses. DP presented with output processing difficulties, her phonological awareness is delayed, she is at risk for developing literacy problems, her auditory memory appears limited, and she may have a possible binaural processing delay. However she presented with age appropriate input processing for all but one of the levels on the speech processing profile, and her self-monitoring abilities are intact. All of these factors contribute to her current speech processing abilities. Ongoing remediation and monitoring of the weak areas of her profile is recommended, utilising the age appropriate areas of her profile as a facilitative aid.

CHAPTER 6 : CASE STUDY - BA

This chapter, which focuses on BA's past and present speech processing skills, will be divided into three main sections:

(A) Current Speech Processing (C.A. 8;10),

(B) Past Speech Processing (C.A. 3;5, 4;5)

(C) Discussion of results

In sections A and B, the following are presented: case history, speech sample, speech processing profile and literacy assessment.

SECTION A – Current Speech Processing (C.A. 8;10)

6.1 *Case History*

BA was 8 years 10 months at the time of assessment. She wears a *Nucleus 24 Contour* cochlear implant on the right ear which has a SPRINT processor and utilises the ACE processing strategy. She had been using it for 6 years 5 months at the time of the assessment. She was implanted when she was 2 years 5 months old. Prior to this, she had been wearing a hearing aid (from age 5 months onward), and before this, her hearing was unaided.

The aetiology of BA's hearing loss is ascribed to exposure to Rubella in utero. In addition she also had chronic otitis media as a baby. As a result she had grommets inserted a total of 3 times. There is no family history of hearing loss. There were no complications before, during or after the birthing process. She was born at term via normal vaginal delivery and no hearing abnormalities were suspected until she was 3 months of age. At the age of 5 months her hearing loss was diagnosed as a profound bilateral sensori-neural hearing loss, and shortly thereafter she was fitted with hearing aids. BA and her parents started attending a Parent Guidance Programme, offered by a school for hearing impaired learners, focusing on teaching parents communication enhancing strategies, from the age of 8 months onward.

After 2 years of wearing hearing aids and progressing very little in terms of her speech and language development, the audiologist recommended that BA be fitted with a cochlear implant. After the necessary funds had been collected she was implanted in January 2001.

BA's primary language is English, however Afrikaans is also spoken in the home by the adults. The family is of average socio-economic status and consists of BA's mother, father, 14 year old brother, and herself. BA's parents are divorced. BA lives with her father and brother in a "granny flat" behind her father's parents home. It could not be ascertained how much contact BA still has with her mother. BA is cared for by her grandparents after school until her father arrives home from work in the evening. Speech Therapy and Audiology reports all mention that it was very difficult for BA's parents to accept and come to terms with her hearing loss, and that the extended family (who are very involved in BA's life) initially rejected the idea that BA was to receive a cochlear implant.

BA is in Grade 2 at a school for hearing impaired children. She received speech therapy irregularly for 2 years at tertiary level hospital, and is still currently receiving therapy in the school setting. At school, BA is described as a friendly little girl who is trying hard and making some progress. She requires a great deal of repetition to remember things, her progress in reading is slow, and she finds it difficult to follow a logical sequence when things are explained to her.

At the time of the assessment, BA was co-operative and friendly. She did not show appropriate concentration and attention for her age, and had to be refocused to the task at hand on several occasions. BA was administered the test battery, and completed the evaluation in two mornings over the course of 6 hours, with 1 break in between, on each morning.

6.2 *Speech Sample*

Table 6.1 gives an indication of BA's speech at the time of testing.

Assessment	Comments
Severity Indices	PCC = 83.7% PVC = 93.9% PPC = 87.3%
Phonological processes analysis (% use)	Developmental processes - liquid gliding (71%), cluster reduction (35%), Non-developmental processes - final consonant deletion of /s/ or /z/ (4%), vowel deviations (6%), voicing/devoicing (2%), nasalization of /l/ (4%)
Single word speech sample	[spQnz] for SPONGE ["flaUw@] for FLOWER [tweIn] for TRAIN [wVS] for BRUSH [lVb] for GLOVE ["dZ@ni] for JELLY ["teIb@l] for TABLE [twVk] for TRACTOR [p@"dZAmIs] for PYJAMAS [mI"tEti] for SPAGHETTI ["k{t@pIl@] for CATERPILLAR ["{w@pleIn] for AEROPLANE
Connected speech sample	[mQmi "putiN in D@ but] for MOMMY PUTTING IN THE BOOT [D@ dQg iz "puSiN] for THE DOG IS PUSHING [D@ hOs "dZVmpiN] for THE HORSE JUMPING [hOs "dZVmpiN lQN] for HORSE JUMPING LONG

Table 6.1 BA's speech at C.A. 8;10

BA's PCC score of 83% places her in the category of mild-moderately impaired intelligibility (Shriberg & Kwiatkowski, 1982 in Bernthal and Bankson, 2004). However, this percentage is below that which is expected of a typically-developing 8 year old. In addition, she still presents with many phonological processes which are not age appropriate, e.g. cluster reduction, liquid gliding, final consonant deletion, etc. She also demonstrates nasalization of /l/, which is commonly seen in the speech of deaf children (Nguyen et al, 2008).

6.3 *Test Results & Speech Processing Profile*

Table 3 in Appendix E shows the test results of all 18 tasks carried out with BA. The profile for BA's current speech processing skills was completed based on these results and is presented in Figure 6.1.

Figure 6.1 –Speech processing profile for BA (C.A. 8;10)

KEY TO SPEECH PROCESSING PROFILE

√	- age appropriate, i.e. one SD below the mean and up
√√	- one SD above the mean
x	– one SD below the mean or less
xx	– two SD's below the mean or less
xxx	– three SD's below the mean or less

6.4 *Discussion of Speech Processing Profile*

6.4.1 Overview of the profile

BA's profile shows difficulties with every level investigated, on both the input and output sides of the profile. Her difficulties are pervasive and severe. There does not appear to be a pattern with regards to whether she performs better with top-down or bottom-up processing routes. She scored within the age-appropriate range for one test, at level K – the oral-facial examination, where it was found that her oral structures are normal and functional.

6.4.2 Input Levels

At level A it can be seen that at her last audiometric testing session (20/3/2007), all frequencies tested had thresholds between 22 – 26 dB HL. This is termed her aided hearing threshold and it correlates with a *mild* hearing loss, even though before implantation of the cochlear implant she had had a *severe-profound* loss. Thus only one cross is used to mark the hearing loss on the profile.

At level B she performed poorly on both tests used. She scored below average for the non-word discrimination task, earning her three crosses on the profile. In particular, she could only correctly discriminate the difference between the phonemes /s/ and /t/ in final position in words, 33% of the time. Also she struggled to discriminate between the consonant clusters /st/ and /ts/ in final position in words, 40% of the time.

BA scored below average for the ABX task, earning her two crosses on the profile. In the cases where she failed to correctly discriminate between the non-words, the nature of the contrast between the two words was mainly place of articulation or metathesis, e.g. [{fIlQnt]/ [{lIfQnt] . In addition, this task requires the participant to correctly identify the non-words associated with 2 respective toy figures. BA did not pay full attention to the toy figures when non-words were being allocated to them, as she did not look at them. Thus poor attention might have been an influential factor in the outcome of this test.

Her performance at level D was poor. For the Real Word Discrimination test she performed below average (three crosses on the profile), and her raw score for this test was lower than her raw score for the equivalent non-word version of this test. This is atypical since real word discrimination is usually better than non-word discrimination in normally developing children (Stackhouse & Wells, 1997). Once again she failed to discriminate the difference between the phonemes /s/ and /t/ in final position in words, (e.g. /miss/ vs. /mitt/) 33% of the time. Also she struggled to discriminate between the consonant clusters /st/ and /ts/ in final position in words, 40% of the time.

For the Auditory Rhyme Detection task BA performed well below average, earning three crosses on the profile. Her raw score for this task was 8/12, indicating that she can detect rhyming words, but that her performance, when compared to normally developing 7 year olds, was not age appropriate. Since she scored above chance level it can be inferred that she knows what rhyme is and how to detect it, but that other factors are interfering with her consistently recognising it. These may include momentary inattention, or poor auditory discrimination of the words spoken by the tester. Figure 6.2 shows one of the routes that can be taken when an auditory rhyme detection task is performed, according to Stackhouse & Wells (1997).

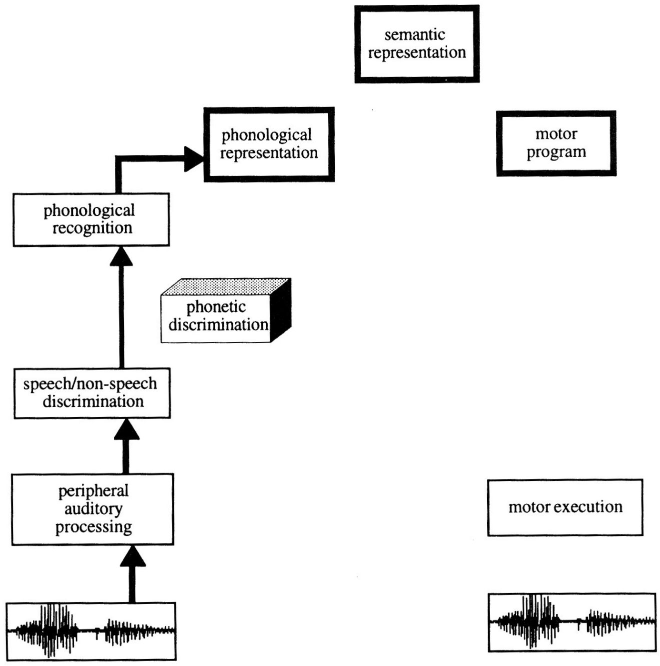


Figure 6.2 Box-and-arrow model of the bottom-up processing route for Auditory Rhyme Detection (Stackhouse & Wells, 1997).

In Figure 6.2, the process within which the phonological representations of the three words verbally presented by the Tester are retrieved and compared to each other, without accessing the semantic representations of these words, is shown. However, in the analysis of the errors BA made in this task, 75% of errors were semantic in nature, i.e. where she said 2 words rhymed based on their semantic relation to each other (e.g. spoon and knife were said to rhyme). This may mean that she is in fact accessing semantic representations, and using a different route to the one described above.

At level E BA performed below average on the Mispronunciation Detection task, earning her two crosses on the profile. Here an error analysis reveals that she accepted many incorrect versions of target words as correct, and rejected many correct forms of the target word as being incorrect. For example, for the target *sponge,* /spVndz/ was accepted as being correct, while /spVndZ/ was rejected once, and accepted once on different occasions. This points to her lexical representations of words being ill-defined, since even the same version of a word is considered correct at one time, and then considered incorrect at another time. This is also linked to her difficulty in discriminating real words - since dissimilar words are judged as being similar due to the imprecise, ill-defined nature of her phonological representations. Both the difficulty discriminating real words and the imprecise nature of her phonological representations may also be linked to her difficulties with attention.

BA performed well below average for both tests in level F, earning three crosses for each test on the profile. She could not identify, above chance level, the pictures that start with the same sound in the Picture Alliteration task. While her raw score for the Picture Rhyme Detection task was above chance (i.e. 8/12), indicating that she can visually detect rhyming words, her performance, when compared to normally developing 7 year olds, was not age appropriate. From these results it can be seen that she does not have sufficient awareness of the internal structure of phonological representations of words for her age. Unlike the Auditory Rhyme Detection task, the participant can only rely on their own phonological representation linked to the semantic concept of the pictures shown to help them decide which two of the three words rhyme. Figure 6.3 shows the route taken to complete the Visual Rhyme Detection task according to Stackhouse & Wells (1997).

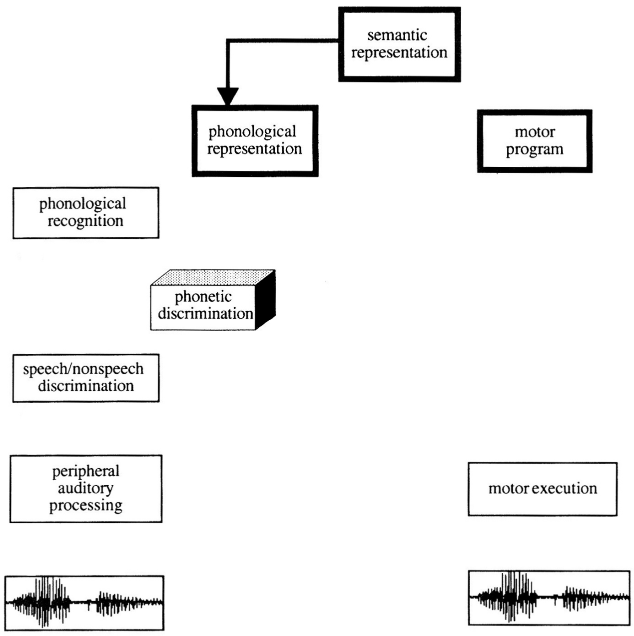


Figure 6.3 Box-and-arrow model of the processing route for Visual Rhyme Detection.

From this figure it can be seen how semantic representations are accessed before phonological representations are. From the number of semantic errors made in the auditory rhyme detection task, it seems plausible the route shown in Figure 6.3 is also used during the auditory rhyme detection task, i.e. phonological representations are accessed after semantic representations are accessed.

Summary of Input Speech Processing Performance

BA struggled at all levels on the input side of the profile. It is difficult to try and pinpoint one or two levels as being most affected. Level A (auditory perception), seems to be the least affected level, however severe problems earlier at this level may have had a knock-on effect, leading to the wide-spread problems seen on this side of the profile.

6.4.3 Output Levels

Results at Level G show well below average performance for both tests, earning her three crosses respectively at that level. On the *EOWPVT-R* (Gardner, 1990) her utterances included articulation errors 65.6% of the time, and her age equivalent score for this test was 3 years, 5 months. On the *RAPT* (Renfrew, 1972) her utterances were semantically and grammatically deficient, causing her scores for that test to be very low, however she did not make many articulation errors. Typically, connected speech is less intelligible than single words, in children with speech difficulties (Bernthal & Bankson, 2004). This may due to differing task demands. The *EOWPVT-R* is more confrontational in its naming approach, where only one target word will suffice for the answer, whereas the RAPT allows for the use of synonyms for the target word with which the child is more familiar in terms of speech production. Therefore it appears that BA has difficulty with confrontation naming of picture stimuli.

At level H BA performed well below average for both the Alliteration Fluency subtest and the Rhyme Fluency subtest. From her performance on the Auditory – and Visual Rhyme Detection tasks, as well as the Picture Alliteration tasks, it was clear that BA had difficulty doing tasks that require intra-syllabic segmentation. Thus it would be expected that she would not yet be able to produce words that start with the same sound age appropriately, since detection precedes production in a normally developing phonological awareness hierarchy. However, rhyme production is usually evident from a young age (before age three – Nadler-Nir, 1997) in normally developing children therefore other factors may have contributed to the performance, e.g. limited vocabulary from which to draw rhyming words from, poor attention.

At level I BA was unable to perform age appropriately on any of the tests used. She earned one cross for her performance on the real word component of the Aston Index Blending subtest, two crosses for her performance on the PAT Blending subtest and three crosses for her performance on the real word repetition subtest. On the real word component of the Aston Index blending subtest, she was only able to blend one CVC real word (from verbalized phonemes).This is far below chance performance. For certain CVC phoneme combinations she answered with guesses, e.g. /b-eI-b-i/ became "bicycle". In another task that taps blending, the PAT blending subtest, she scored two crosses. This task looked at syllabic blending (raw score 4/10) and phonemic blending (raw score 0/10). BA seems to be able to blend syllables better than she can phonemes. This pattern is typically seen in younger children, where syllabic blending is achieved earlier than phonemic blending (Nadler-Nir,1997) .

In the Real Word Repetition subtest, only 2/20 real words could be correctly repeated. These two words were among the few known to be within her receptive vocabulary. Errors on the remaining 18 words included metathesis (35% of the total number of errors), e.g. /"k{lt@keIl@/ for *calculator*, cluster reduction (25% of the total number of errors), e.g. /"kQk@daIl/ for *crocodile*, syllable reduction (20% of the total number of errors), e.g. /"reIdit@/ for *radiator*, schwa insertion (20%), e.g. /"Qk@t@p@s/ for *octopus*, final consonant deletion (15% of the total number of errors), e.g. /pOkju"ba/ for *porcupine,* and voicing (10% of the total number of errors), e.g. /pOkju"ba/ for *porcupine.* Her performance on this test is influenced by many factors including real word discrimination, reliability of stored representations and motor programming, which have all been identified as being problematic. Thus it can be assumed that BA cannot articulate all real words accurately.

BA's performance on both tests at level J showed that, in general, she cannot articulate speech without reference to lexical representations. For her performance on the non-word component of the Aston Index Blending subtest (Newton & Thomas, 1982) she earned two crosses – she was unable to blend any non-words. On the real word component she was able to blend one word. One reason that might account for this, was that she employed guessing as a strategy during both components, but it only "paid off" during the real word component. With regards to her performance on the Non-Word Repetition subtest, she earned three crosses as she could not successfully repeat any non-words. Figure 6.4 illustrates the route taken for Non-Word Repetition tasks, and where difficulties exist at other levels that might influence performance on this level. Difficulties present at other levels are indicated with a red cross.

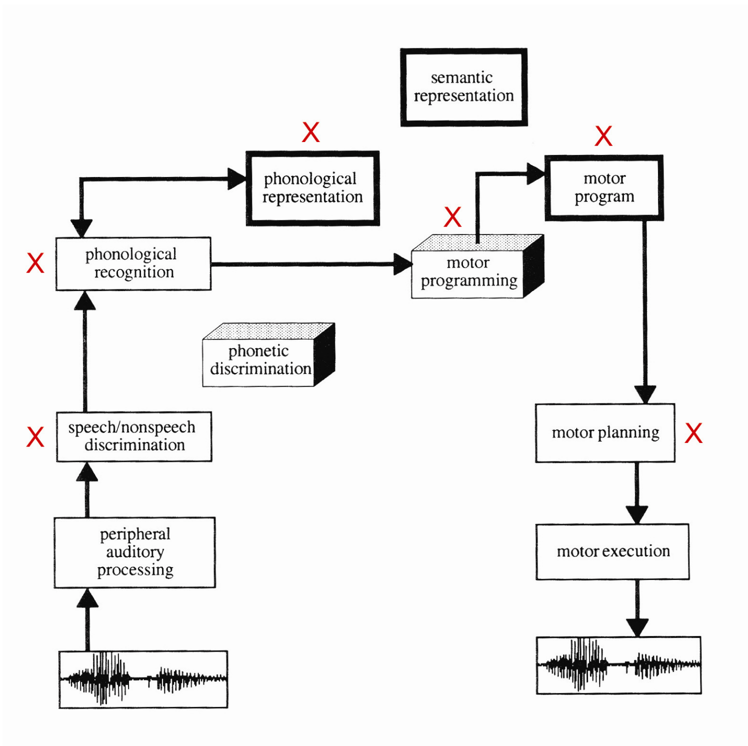


Figure 6.4 Box-and-arrow model of the processing route for Non-Word Repetition (Stackhouse & Wells, 1997).

At level K, she earned a tick for her performance on the Oral-Facial Examination, but earned two crosses for her performance on the diadochokinetic rates test, as her rate of repetition was greater than 2 standard deviations slower than the mean. This points to difficulties with articulation at a peripheral level, which could have affected the results of all output tests at higher levels on the profile.

At level L, BA was observed trying to correct her own errors at some times during the assessment. For example, for the target *alligator* her first repeated output was /{lit@/, which she then changed to /{lIgeIt3/. Thus, she does employ limited self-monitoring, which can then be applied to change her output, when she has previously been made aware that her articulation is faulty.

Summary of Output Speech Processing Performance

BA struggled at all output levels of the profile. Each assessment's scores earned her at least two crosses on the profile, except for the oral-facial examination, where she earned a tick for age appropriate performance. The articulatory difficulties found at level K are hypothesized to affect all output levels of the profile.

6.5 *Literacy Assessment*

The three tasks used to assess literacy were: consonant decoding, CVC non-word decoding and CVC real word decoding. Table 6.2 lists all the tests used to assess literacy, along with the scores obtained.

Task name:	Raw score	Standard score	Description of performance
Consonant decoding	13/20	< 47	below average
Non-word CVC decoding	1/10	< 48	below average
Real word match CVC decoding	1/10	no norms available	below average

Table 6.2 Results of the Literacy assessment (C.A. 8;10)

This table shows poor performance for all areas of literacy tested. BA is already in grade 2 and should have mastered all the above tasks. In effect these results tell us that she cannot read - even with the simplest of CVC words. Also, these results tie in with her aforementioned poor blending skills (levels I & J on the speech processing profile) – she cannot blend sounds heard to form a word, and she cannot blend sounds from graphemes to form a word.

6.6 ***Summary***

BA's speech processing profile is affected at every level of the profile, on both the input and output sides. There were few levels that could be deemed areas of strength: the only test where she earned a tick on the profile was the oral facial examination (level K).

The level that seems least affected is level A – auditory perception. However, research has shown that lower hearing thresholds do not automatically mean better speech processing ability (Blamey et al, 2001; Paatsch et al, 2004), as has happened here with BA. The two and a half years of suboptimal hearing before she was fitted with her cochlear implant, seem to have had a deleterious effect on the speech processing development of this child. In addition, she was reported to not wear the cochlear implant consistently after it had been implanted. There are other factors, which will be discussed later, that may have been influential in the poor speech processing outcome of this child.

BA's literacy results were poor. She is struggling to decode simple CVC words and has not yet made phoneme-grapheme associations for all the letters in the alphabet. This result ties in with research showing that speech processing development is linked to literacy development (Stackhouse & Wells, 1997; Kaderavek & Pakulski, 2007). These researchers predict that where speech processing development (and especially phonological awareness development) is delayed, literacy development will be too, and reading difficulties may result.

Comparison across levels

Real word repetition vs. non-word repetition

Both scores for these tasks were described as being well below average. However, the raw score for non-word repetition performance was poorer than real word repetition performance, indicating that BA may have difficulty assembling new motor programmes.

Real word repetition vs. naming performance.

Both scores for these tasks were described as being well below average. Both performances are affected by input processing difficulties, and articulation difficulties on the output side. Thus it is difficult to assess whether her naming is better than her repetition.

Real word discrimination vs. non-word discrimination.

Both these tasks had three crosses on the profile indicating poor performance. This indicates all speech is being poorly discriminated. This results in ill-defined phonological representations, inaccurate motor programmes and imprecise articulations.

In summary, and according to the speech processing profile, BA has:

1. mild auditory perceptual difficulties
2. poor non-word discrimination
3. poor real word discrimination
4. ill-defined, ‘fuzzy’ phonological representations
5. poor awareness of the internal structure of phonological representations.
6. difficulty accessing accurate motor programmes
7. poor phonological manipulation skills
8. poor blending skills for real and non-words
9. difficulty assembling new motor programs for new words
10. poor real word and non-word repetition skills
11. inadequate sound production skills
12. adequate oral-motor competence

13. the ability to self-monitor and self-correct occasionally

SECTION B –Past speech processing results

In the following section, BA's past test results taken from speech, language and hearing assessments 1 year post-implantation, and 2 years post- implantation respectively, will be analysed and discussed.

6.7 ***Case history – One year post-implantation*** (C.A. 3;5)

In the year since she had been implanted, BA attended weekly speech therapy sessions, and was showing some progress, according to the Speech Therapist. The therapist commented that BA's parents were not creating an optimal language learning environment for her at home, that they did not provide a structured routine for her at home and that they were unable to give accurate feedback on a weekly basis regarding her progress for that week.

BA reportedly had difficulty maintaining auditory and visual attention, and quickly lost interest in activities during the assessment. Nevertheless, her attention and concentration span had increased since her last assessment. During the day she attended a special crèche for hearing impaired children. She only wears her cochlear implant at creché and takes it off at home. She was assessed in February 2002, at the age of 3;5 after having worn the cochlear implant for 1 year.

At this assessment, the following tests were administered:

- aided hearing thresholds
- IT- MAIS parent questionnaire, (Nottingham Early Assessment Package, 2004)
- Westby symbolic play scale (Westby, 1980)
- Communicative Intention Inventory (Coggins & Carpenter, 1981)
- Communication Promoting behaviours checklist (Cole, 1992)
- adapted TAIT video Analysis, a checklist (Nottingham Early Assessment Package, 2004)

- US TBH Phonetic and Phonological Inventory:spontaneous language, Voice rating scale, Speech Intelligibility Rating (SIR), (Nottingham Early Assessment Package, 2004)

Data for this assessment was reportedly collected via video analysis of parent-child interaction, parental report and clinical observation during therapy sessions.

Hearing results

The Audiologist was unable to test soundfield responses at the different frequencies due to poor co-operation, however she reported that BA responded to speech sounds at 34 – 38 dB. She also felt that BA was making very slow progress with regard to adapting to her implant.

On the IT-MAIS questionnaire it was found that she never responded to her name being called in noisy situations. However she showed consistent awareness of environmental sounds and presented with clear signs of auditory processing during play interaction in the form of auditory only verbal imitation and specific eye contact responses to speech. The therapist reported that she could perceive patterns in speech, as she could accurately imitate a speaker's intonation pattern and length of multisyllabic words. However there were many instances of final syllable deletion found in her speech sample, which could indicate her pattern perception skills were inconsistent.

Language results

BA was reported as having a very limited receptive and expressive vocabulary (10 -12 words). She responded to and used single words and sound-object associations without the aid of visual/contextual clues or prompting. She could not accurately select a known object from a set of 3 objects.

Information from the Communicative Intention Inventory (Coggins & Carpenter, 1981) showed that she communicated intentionally with her parents on a preverbal and early verbal communication level. She still relied heavily on gestures, vocalizations and body language to initiate conversations. These behaviours are not at all age appropriate and would be more appropriate for a 9-12 month old child (Rossetti, 1996). However, one should consider that 12 months is the time period for which BA had had the cochlear implant for.

Speech results

The therapist reported that she presented with an incomplete phonetic inventory.

Her spontaneous vocalizations and imitated productions consisted of bilabial plosive phonemes, glides and back vowels. She could imitate alveolar phonemes in specific CV combinations, certain diphthongs, high frequency phonemes (e.g. /s/, /f/, /t/) in word initial and word final position. She frequently produced differing realisations of the same word.

Thus in summary her language and speech showed a marked delay, but there had been definite progress.

6.8 ***Speech sample – One year post-implantation*** (C.A. 3;5)

Assessment	Comments
Severity Indices	PCC = 42% PVC = 13.6% PPC = 30.9%
Phonological processes analysis (% use)	Processes: vowel deviations (81%), final syllable deletion (28.5%)
Single word speech sample	[p] for PULL [@f], [@m] for OFF [pO], [mO] for POUR [wa:] for WATER [b@b@] for BABY [a:p] for OPEN

Table 6. 3 BA's speech sample at C.A. 3;5

It can be seen that BA's speech was very unintelligible at this point in time. In addition, her productions were inconsistent – this can be seen in that some words have more than one articulation, e.g. [pO], [mO] for *pour*. This is far from what is expected from a child of 3 years and 5 months, and closer to what is expected from a child of 12-18 months. From the sample it can be seen how the most salient acoustic aspect of the word is reproduced in her speech, e.g. the onset is always present. However the vowel is frequently inaccurate – this can be seen from the PVC score of 13.6% (lower than PCC and PPC), and from the frequent vowel deviations occurring within words. Usually consonants are more affected than vowels in normally or delayed developing speech. In a recent study, Moeller et al (2007) identified low vowel accuracy as an atypical marker of vocal development in children fitted with cochlear implants, and suggested that it may indicate problems other than vocal development delay due to hearing loss. Also her PCC score of 42% is regarded as a severe handicap in intelligibility by Shriberg & Kwiatkowski (1982, in Bernthal & Bankson, 2004).

6.9 ***Speech processing profile*** (C.A. 3;5)

From the above-mentioned test results, the speech processing profile for BA's speech processing skills was completed retrospectively, and is shown in Figure 6.5.

INPUT

F

Is the child aware of the internal structure of phonological representations?

Not tested

E

Are the child's phonological representations accurate?

x - does not consistently imitate correct syllable length

x - several phonetically different versions of the same target word found in speech

D

Can the child discriminate between real words?

x - inconsistent pattern perception

x - phoneme detection 80%

x - object selection tasks

C

Does the child have language specific representations of word structures?

Not tested

B

Can the child discriminate speech sounds without reference to lexical representations?

Not tested

A

Does the child have adequate auditory perception?

x -Audiometry

(mild hearing loss)

OUTPUT

G

Can the child access accurate motor programs?

x - cannot name words accurately due to incomplete phonetic inventory

H

Can the child manipulate phonological units?

Not tested

I

Can the child articulate real words accurately?

x - very unintelligible speech. Only 30.9% of phonemes correct in speech sample

J

Can the child articulate speech without reference to lexical representations?

Not tested

K

Does the child have adequate sound production skills?

Not tested

KEY TO SPEECH PROCESSING PROFILE

√ - age appropriate

x - not age appropriate

Figure 6.5 Speech Processing profile for BA at C.A. 3;5

6.10 *Discussion of Speech Processing Profile – One year post-Implantation* (C.A. 3;5)

6.10.1 Overview of the profile

As this profile was compiled retrospectively, information for only a few of the levels was available from the assessment. In addition, many of the tests that could be used to give information for the levels were qualitative, and did not have normative data.

The profile shows difficulties on both the input and output sides. The specific levels that were problematic were Level A - Auditory Perception, Level D – Real Word Discrimination, Level E – accuracy of phonological representations, Level G – Naming Accuracy, and Level I – Real Word Repetition.

6.10.2 Input Levels

At level A it can be seen that at her last audiometric testing session (C.A. 3;4), all frequencies tested had thresholds of approximately 34 -38 dB HL. This is termed her aided hearing threshold and it correlates with a *mild* hearing loss, even though before implantation of the cochlear implant she had had a *severe-profound* loss. Thus only one cross is used to mark the hearing loss on the profile.

For level D (Real Word Discrimination), BA was not able to consistently perceive patterns in speech, or select objects in simple object selection tasks. She could only correctly perceive consonants 80% of the time. She was given one cross for each respective task as these performances are not age appropriate.

At level E, it was demonstrated that her phonological representations were not accurate since she could not consistently imitate correct syllable length in words, and she produced several phonetically different versions of the same target word. This could have been as a result of her poor auditory discrimination skills.

6.10.3 Output levels

At level G, one cross was given as BA could not name objects accurately, probably due to a) inaccurate phonological representations, and b) an incomplete phonetic inventory.

At level I she had difficulty articulating real words accurately, as she had very unintelligible speech. This could be as a result of all the problematic input factors, or even as a result of difficulties at levels not tested. She was given one cross for this level.

6.10.4 Summary

In summary, and according to the speech processing profile, BA has:

1. mild auditory perceptual difficulties
2. poor real word discrimination
3. ill-defined 'fuzzy' phonological representations
4. questionable accuracy of motor programs
5. poor real word repetition skills

6.11 ***Case history – Two years post-implantation*** (C.A. 4;5)

BA was assessed in February 2003 at the age of 4 years 5 months after having worn the cochlear implant for 2 years. She was attending a special crèche for hearing impaired children during the day. She still had a short attention and concentration span, but had become more involved in group activities within the classroom over the past few months. However, she tended to 'tune out' in one-to-one therapy situations. She was reported as having behavioural problems at home, a lack of parental support, and had only worn her cochlear implant full-time for the past six months. In addition, the Speech Therapist reported that her listening skills seem to have deteriorated since the previous assessment at C.A. 3;11.

At this assessment, the following tests were administered:

- US TBH Phonetic and Phonological Inventory : spontaneous language, Voice rating scale, Speech Intelligibility Rating (SIR)
- Profile of Actual Linguistic Skills (PALS), a checklist (Nottingham Early Assessment Package, 2004)
- Reynell Developmental Language Scales (RDLS), (Edwards, Fletcher, Garman, et al, 1997)
- Westby symbolic play scale
- The MacArthur Communicative Developmental Inventory: Words and Gestures (Fenson, Dale, Reznick, Thal, et al, 1994) (completed by her current and past class teachers)
- adapted TAIT video Analysis, a checklist (Nottingham Early Assessment Package, 2004)
- Communicative Intention Inventory (Coggins & Carpenter, 1981)
- GAEL-P objects (assessment of early verbal development on a word level)

Data for this assessment was reportedly collected via video analysis of parent-child interaction, as well as through direct test administration.

Hearing results

BA was reportedly not responding consistently to environmental sounds anymore. No device problems were reported. The most recent audiological results (August 2002, C.A. 3;11) showed that she responds consistently to speech sounds at 30-35 dB, but that she could still not be tested in the sound field as is customary for children her age. The Audiologist reported that her progress was very slow. Instead of never responding to her name being called in noise (as she did in 2002), she reportedly could now respond occasionally.

Language results

Her receptive and expressive language was assessed using the Reynell Developmental Language Scales (Edwards, Fletcher, Garman, et al, 1997), and both were found to be at the level of an 18 month old typically hearing child. Within receptive language her vocabulary was very limited, and she could relate two named objects, actions and agents when known vocabulary was included in the task.

Expressively, she used single words and unintelligible two word utterances. She now had difficulty imitating two word utterances, whereas at C.A. 3;11, she could imitate three to four word utterances. She was able to answer yes/no questions correctly and to repeat a simple instruction (one word) to check with a conversation partner whether or not she correctly heard the instruction.

Speech results

Her speech was reported as being highly unintelligible as her vowel and consonant systems were limited. Phonological processes, e.g. final consonant deletion, occurred in her speech as a result of her limited phonetic inventory. The quality and accuracy of her single word speech productions did not improve with imitation.

BA’s ability to monitor her own speech auditorily was reported as poor, resulting in poor voice quality. She was reported as producing all her vowels with a retracted tongue and wide open mouth, altering only intonation to differentiate between vowels.

In summary, BA presented with a severe delay in her speech, receptive and expressive language at C.A. 4;5. Her progress in terms of verbal communication development was described as limited and slow. Possible reasons for this suggested by the Speech Therapist included lack of parental support, exposure to a mainly Afrikaans environment, emotional issues (her parents were recently divorced) and inconsistent use of the cochlear implant.

6.12 ***Speech sample – Two years post-implantation*** (C.A. 4;5)

Assessment	Comments
Severity Indices	PCC = 63.5% PVC = 53.6% PPC = 59.1%
Phonological processes analysis (% use)	Processes: vowel deviations (46.3%), final consonant deletion (31.8%) cluster reduction (85%)
Single word speech sample	[pI] for PEEP [ma:] for MORE [wVS] for WASH ["d{d@] for DADDY ["mQmI] for MOMMY ["sEpI] for SLEEPING

Table 6.4 BA's speech sample at C.A. 4;5

Table 6.4 shows a higher percentage of consonants, vowels and phonemes correct than the previous speech sample (C.A. 3;5). Phonological processes are still being used frequently, but with less regularity than before, showing that learning has taken place. Her speech is still very unintelligible taken out of context. None of the phonological processes she presents with are age-appropriate, except when taking her hearing age into account (i.e. 2;0). Her PVC score has increased by a large margin in comparison to 1 year post-implantation, but it is still the lowest of the three severity indices. The PCC score also shows an improvement from the previous year and would now be regarded in the category of a moderate-severe handicap by Shriberg & Kwiatkowski (1982, in Bernthal & Bankson, 2004).

6.13 ***Speech processing profile*** (C.A. 4;5)

Figure 6.6 shows BA's speech processing profile at C.A. 4;5.

INPUT

F

Is the child aware of the internal structure of phonological representations?

Not tested

E

Are the child's phonological representations accurate?

√ - consistently produces correct syllable length

√ - phonological representations more defined, consistent production of target

D

Can the child discriminate between real words?

√ - consistent pattern perception

√ - can listen without lipreading

C

Does the child have language specific representations of word structures?

Not tested

B

Can the child discriminate speech sounds without reference to lexical representations?

Not tested

A

Does the child have adequate auditory perception?

x -Audiometry

(mild hearing loss)

OUTPUT

G

Can the child access accurate motor programs?

x - cannot name words accurately due to incomplete phonetic inventory

H

Can the child manipulate phonological units?

Not tested

I

Can the child articulate real words accurately?

x - very unintelligible speech. Only 59.1% of phonemes correct in speech sample

x - overarticulation

x - imitated speech not better than naming

J

Can the child articulate speech without reference to lexical representations?

Not tested

K

Does the child have adequate sound production skills?

Not tested

L

Does the child reject his/her own erroneous forms?

Not tested

Figure 6.6 BA’s speech processing profile C.A. 4;5

KEY TO SPEECH PROCESSING PROFILE

√ - age appropriate

x - not age appropriate

6.14 ***Discussion of Speech Processing Profile – Two years post-Implantation*** (C.A. 4;5)

6.14.1 Overview of the profile

As this profile was compiled retrospectively, information for only a few of the levels was available from the assessment. In addition, many of the tests that could be used to give information for the levels were qualitative, and did not have normative data.

The profile shows difficulties on both the input and output sides. The specific levels that were problematic were Level A - Auditory Perception (it is expected that all the children in this study would have a problem with this level, at every period of time they are tested), Level G – Naming Accuracy, and Level I – Real Word Repetition.

Areas that show improvements relative to the one year post-implantation profile are level D: real word discrimination, and level E: accuracy of phonological representations.

6.14.2 Input Levels

At level A it can be seen that at her last audiometric testing session (February 2003, C.A. 4;5), all frequencies tested had thresholds of approximately 30 - 35 dB HL. This is termed her aided hearing threshold and it correlates with a *mild* hearing loss, even though before implantation of the cochlear implant she had had a *severe-profound* loss. Thus only one cross is used to mark the hearing loss on the profile.

For level D (real word discrimination), BA was able to listen without lipreading, and consistently perceive patterns. She was given one tick at this level, as this ability shows an improvement from one year post-implantation scores.

At level E she also demonstrated an improvement from the previous year's profile. She earned one tick respectively for being able to consistently produce the correct syllable length in words, and for being able to produce a target more consistently.

6.14.3 Output levels

At Level G, one cross was given to show that she could not name objects accurately, possibly due to an incomplete phonetic inventory.

At level I, BA earned a cross for her performances in the informal speech sample collection process since she had a) very unintelligible speech, b) overarticulation, and c) her imitated speech was not better than her naming.

6.14.4 Summary

In summary, and according to the speech processing profile, BA has:

1. mild auditory perceptual difficulties
2. appropriate real word discrimination
3. appropriately defined phonological representations
4. poor motor programmes for real words
5. poor real word repetition skills, which are better on a single word level than on sentence level.

SECTION C – Discussion of results

In this section past and current results will be discussed and compared in order to elucidate the developmental progression of BA's speech processing skills.

BA's most recent profile (C.A. 8;10) shows that:

- input processing is a weakness for all input levels of the profile; auditory processing (level A) seems to be the least affected
- output processing is a weakness for all output levels of the profile, except for her performance in the oral-facial examination where no muscular weakness or dysfunction of the articulators was found.
- the link between her output and input processing skills was found to be intact but underutilised since she monitors her own output and modifies it infrequently.

- The poor literacy results obtained seem to link well with the poor awareness of the internal structure of phonological representations she displayed on the input and output sides of the profile.

Weaknesses pinpointed by the assessment include poor attention and concentration in addition to the difficulties mentioned above. In particular the articulation difficulties found at level K appear to affect all output levels.

BA's most recent results (CA 8;10) were compared to results obtained one, and two years post-implantation. At the time of testing (CA 8;10) she was 6 years, 5 months post-implantation. Thus it was logical to compare the current results with the one- and two years post-implantation results to develop a longitudinal perspective of the changes in her speech processing. As previously mentioned in chapters 4 and 5, one year in terms of communication development is a significant amount of time, since this is the common age at which children produce their first meaningful word (Rossetti, 1996; Bernthal & Bankson, 2004). Two years too is a significant amount of time in terms of communication development, as most normally developing children have developed and established the use of two-to three word utterances by this time (Rossetti, 1996; Bernthal & Bankson, 2004), which is a significant jump up from one word utterances. In addition, research from Waltzman, Cohen & Shapiro (1992), and Tobey & Geers (1995) indicates that speech perception in implanted candidates improves significantly after 6, 12 and 24 months of implant use. Therefore the retrospective time periods chosen were 1 year and 2 years post implant, since the most improvements are expected in those time periods.

While it was not possible to monitor her speech processing development over these three time frames using the same tests, results from the different tests used confirm that development is occurring between testing times. For example, the speech samples taken at each testing period were analysed in terms of severity indices, and the improvement for each index can be seen in the table and the figure below.

	T1	T2	T3
	C.A. 3;5	**C.A. 4;5**	**C.A. 8;10**
	2002	2003	2007
PCC	42%	63.5%	83.7%
PVC	13.6%	53.6%	93.9%
PPC	30.9%	59.1%	87.3%

Table 6. 5 Severity Indices for BA's speech samples C.A. 3;5-8;10.

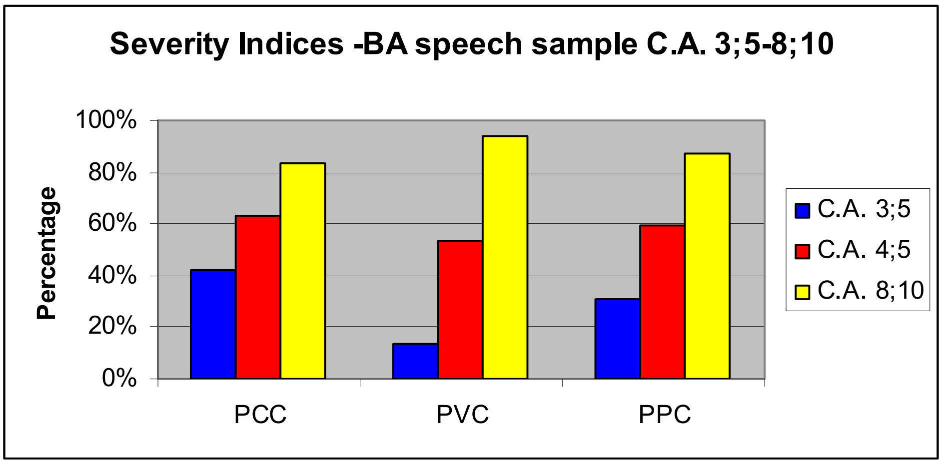


Figure 6.7 Severity indices – BA's speech samples C.A. 3;5-8;10

Percentage vowels correct displayed the biggest increase from 13.6% to 93.9% correct. Percentage consonants correct increased from 42% (severe intelligibility handicap) to 83.7% (mild-moderate intelligibility handicap) (Shriberg & Kwiatkowski,1982 in Bernthal & Bankson, 2004).

The developmental changes that have occurred in the period from C.A. 3;5-8;10 can best be explained and analysed using a developmental phase model (Stackhouse & Wells, 1997). See Figure 2.4 depicts the developmental phase model of Stackhouse & Wells (1997).

Based on the results obtained at the above-mentioned ages, Table 6.6 was compiled to show the ages at which BA entered the phases of the developmental model. Also the ages at which normally hearing children enter these phases are given allowing for a comparison between the normal developmental age guidelines and BA's own ages at those phases of speech processing development.

Time of assessment in relation to implant	pre-implant	1 year post-implantation	2 years post-implantation	6 years, 5 months post-implantation
C.A.	**2;5**	**3;5**	**4;5**	**8;10**
Speech processing developmental phase	Prelexical	Whole word	Systematic simplification	Assembly
Normal ages for this phase	**0-12** months	**12-18** months	**18-36** months	**3** years upward
Hearing age	0	1;0	2;0	6;5

Table 6.6 BA's speech processing development in phases.

At the time before she was implanted, BA's speech processing development was arrested at the prelexical phase. All deaf children have arrested development at the prelexical phase since the auditory input they receive is compromised and this delays them from developing the necessary skills needed to progress into the next developmental phase. Before she was implanted BA used facial expressions, gestures and repetitive babble patterns when communicating. She had no words in her expressive vocabulary.

At one year post-implantation some development had taken place. She displayed signs of having entered the whole word phase since she was using single word utterances, produced inconsistent productions for the same word, and exaggerated the most salient acoustic aspect of the word. Also since her phonetic inventory had expanded she was able to produce variegated babbling instead of only repetitive babbling as seen in the previous assessment. In terms of her hearing age, it was appropriate to enter the whole word phase at this point in time, however when her chronological age is considered this performance is delayed.

At 2 years post-implantation BA's speech processing skills display signs of her being in the systematic simplification phase. She displays regular simplifying processes (e.g. final consonant deletion, cluster reduction) and there is reduced variability in production. Once again this phase is age appropriate for her hearing age (2;0) since normally developing children are expected to enter this phase from 18 months onward. However, when her chronological age is considered, this phase is not age appropriate.

At the most recent assessment (6 years 5 months post-implantation) BA was deemed as being in the assembly phase, since most of her phonological processes had disappeared, and her main speech difficulties included articulating liquids and consonant clusters. She displays arrested development at this phase, and as a result she cannot make use of literacy instruction as her speech processing development and her phonological awareness development specifically is too limited. In addition, being in grade 2, she has had almost three years of exposure to the alphabetic rule and yet she struggles to identify consonant phonemes from graphemes more than 65% of the time.

Figure 6.9 shows Stackhouse & Wells' (1997) developmental phase perspective on speech difficulties, which predict which speech/literacy difficulties arise from arrested development at any of the developmental phases, which has been modified to include the ages at which BA performed within the developmental phases.

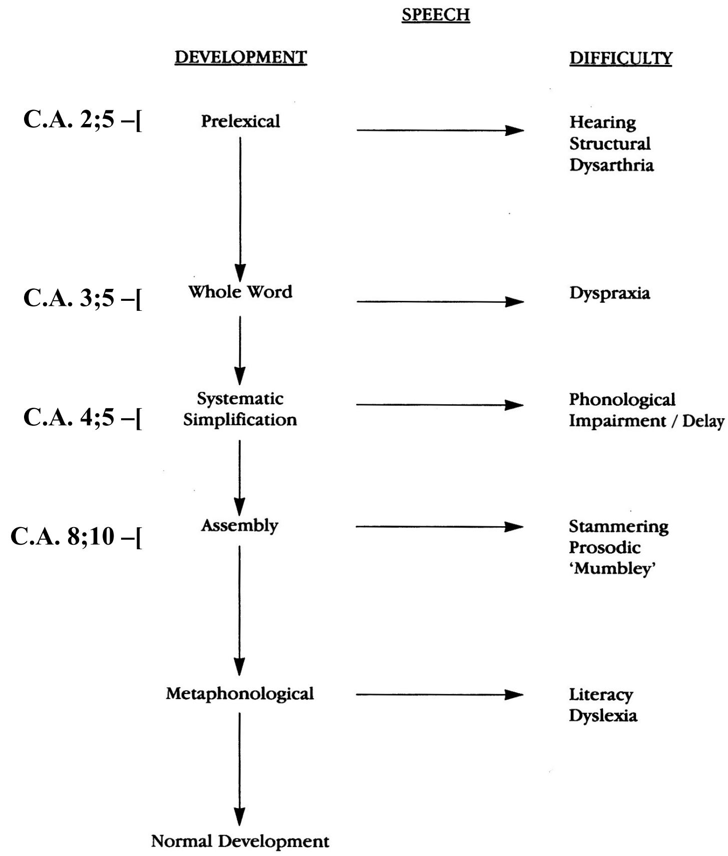


Figure 6.8 Stackhouse & Wells' developmental phase perspective on speech difficulties (Stackhouse & Wells, 1997), modified to indicate the chronological ages within which BA displayed characteristics particular to the speech processing developmental phases.

From this figure it can be seen that BA may be at risk for difficulties with prosody, stuttering and 'mumbley speech'. Furthermore, being delayed at this phase also puts her at risk for developing literacy difficulties when she eventually moves on to the metaphonological phase. However, it is not certain when of even if she will move into the metaphonological phase. According to the critical age hypothesis (Bishop & Adams, 1990) children who have speech difficulties that persist to the point at which they need to use phonological skills for learning to read are at high risk for reading problems. Stackhouse & Snowling (1992, in Nathan, Stackhouse, Goulandris & Snowling, 2004) are of the opinion that the risk is even greater for children with pervasive speech problems which affect both input and output processing. They conclude that children with persisting speech difficulties at 6;9 are particularly vulnerable to deficits in reading-related processes. Therefore BA may struggle to acquire phonological awareness and may have difficulty accessing the phoneme-grapheme code as a result.

BA seems to have attained relatively poor outcomes post-implantation – in terms of speech perception, speech production and literacy skills, all of which are delayed relative to her chronological age and her hearing age. Even though she was implanted at an early age (2;5), other factors seem to have influenced her poor outcomes post-implantation. These factors include 1) inconsistent wearing of the cochlear implant, 2) sub-optimal language and literacy exposure and facilitation in the home environment, and 3) attention and memory difficulties.

One factor that may have played a role in BA's post-implantation outcomes is that she did not wear the cochlear implant consistently. A recent study by Moeller et al (2007(a)) showed that children who used hearing amplification inconsistently demonstrated slower than expected speech progress because their hearing age did not accurately reflect their amount of auditory experience. In BA's case the Speech Therapist reported (at the 1 year post-implantation assessment, C.A. 3;5) that she only wore the cochlear implant to crèche and switched it off at home. At the 2 years post-implantation assessment the Speech Therapist reported that she had only been wearing the implant full-time for 6 months. Therefore her hearing age does not truly reflect her level of auditory experience, since she had only been receiving auditory information for 5-6 hours per day for the first one-and-a-half years post-implant. In addition, at C.A. 8;10, for the most recent assessment, BA's grandmother reported that she still switches off the cochlear implant when she arrives home from school. In addition, there were no reported attempts from the family's side to encourage/enforce longer hours of wearing the cochlear implant. The reasons for this are not known but the impact it has had is evident. During the early intervention years O'Donoghue, Nikolopoulos, Archbold & Tait (1999:426) maintain that to "ensure the continued use of the implant system during this period appears imperative". However, this was not the case for BA. Other researchers have also emphasized the importance of consistent device usage (Sarant, Blamey, Dowell, Clark & Gibson, 2001; Chute & Nevins, 2003)

One suggestion for the lack of consistent use of a cochlear implant put forward by Archbold & O'Donoghue (2007) is that non-use or ineffective use results from inavailability of appropriate support to enable the cochlear implant user and their parents to meet the challenges in the community. These challenges may arise from a mismatch between the cultures of the family of the cochlear implant wearer and the culture of the service-provider, which may lead to issues of miscommunication and not asking for help when it is required. Tyler et al (1997) also posit reasons for non-use of a cochlear implant. They claim that inadequate device fitting, poor motivation for using the cochlear implant, and limited parental support may lead to non-use of the cochlear implant.

Another factor which may have influenced outcomes for BA is the suboptimal language and literacy facilitating environment reported within her home. The Speech Therapist's report at C.A. 3;5 indicated that BA's parents were not creating the most favourable language learning environment in the home (especially since she was allowed to switch off the device at home), and that they could not give feedback regarding BA's progress at home. In an early intervention therapy situation a large amount of "homework" is typically given for parents to work on within a specified amount of time, with their child (Rossetti, 1996).If they could not give feedback on the progress of the tasks given them, it may indicate a decreased level of involvement during those activities. The Speech Therapist's report at C.A. 4;5 also indicated a lack of parental support for BA. Truy, Lina-Granade, Jonas, Martinon, Maison, Girard, Porot & Morgon (1998) observed that parent commitment to rehabilitation was identified as a main factor mediating cochlear implant outcomes in their study. The Speech Therapist also mentioned in her report at C.A. 4;5 that BA's parents had recently divorced and that BA was emotionally influenced by the family situation. BA was living with her father and his parents, in an Afrikaans home-language environment at that time. This situation also did not help to provide her with the rich English language stimulation she needed at that time.

In a recent South African study, Stobbart & Alant (2008) reported that although the preschool deaf children they studied were exposed to literacy-rich environments, the quantity and quality of text-based interactions between parents and their deaf children were poor, and that parents assigned the greatest responsibility in teaching literacy skills to teachers and regarded development of language and communication as more important than early acquisition of literacy skills. This finding was confirmed by one mother of a cochlear implant user (aged 13) who, on being questioned why her daughter had never heard of children's classic tales like Cinderella/Little Bo-Peep, reported that at the age when normally hearing children are enjoying these stories she was focusing on basic communication skills and not literacy.(personal communication) .

Most researchers agree on the pivotal role of parental involvement for language and literacy facilitation. Archbold & O'Donoghue (2007) maintain that parents of children with cochlear implants need appropriate early support to help them develop early communication skills with their child, in order to achieve successful outcomes. In addition, Stobbart & Alant (2008) assert that there is a need for a triadic approach to early literacy, which includes the parent, the child and the educational context (teachers and therapists). Continuation between these different environments is pivotal in facilitating acquisition of literacy skills by the deaf child. It seems that in BA's case the triadic approach of support, and the continuation between home and school was not effectively applied. It may be that additional factors not related directly to BA's cochlear implant and not identified by the rehabilitation team influenced parental compliance and co-operation. These factors may include psychotherapeutic, social and financial needs – parental needs identified by Yucel, Derim & Celik (2008) in their study of the needs of hearing-impaired children's parents who attended an auditory verbal therapy-counselling program.

In addition to the above-mentioned factors, poor attention and memory also seem to have affected BA's post-implantation outcomes. At C.A. 3;5 difficulties maintaining auditory and visual attention were reported by the Speech Therapist assessing her, while at C.A. 4;5 short attention and concentration span were noted during that assessment. At C.A. 8;10 the assessment indicated that her attention and concentration were not age-appropriate, and the latest school report indicated that BA required much repetition to remember instructions, and that she struggled to follow logical sequences of instructions. Therefore it appears that BA has had ongoing difficulties with attention and memory and that these difficulties are still persisting.

Attention – the state of alertness or arousal that allows an individual to focus on a selected part of the environment, in preparation for learning or problem solving (Kanhneman, 1973 in Bukatko & Daehler, 2004) - and memory – the ability to store information encountered at a given time for potential future recall- are hypothesized to interact with speech processing in the following way. The ability to sustain and direct attention to sounds is termed auditory attention and it includes the ability to select relevant stimuli from a background of irrelevant stimuli and to continue to attend selectively to this stimulus for an appropriate length of time (Oakland & Williams, 1971, in Sanders, 1977). Auditory attention to speech is deemed an aspect of language processing (Sanders, 1977). Baddeley & Hitch (1974, in Harley, 2001) view auditory attention as one of the processes involved in the *working memory*. According to them the *working memory* comprises a central executive (where auditory attention operates), a visuo-spatial sketch pad (for short-term storage of spatial information and a phonological loop. The central executive and the phonological loop play an important role in language processing – the central executive is critical in semantic integration and comprehension of incoming information, while the phonological loop plays a role in phonological processes in language. The phonological loop is posited to comprise a passive phonological store that is linked with speech perception, and an articulatory control process linked to speech production, which can maintain and operate on the contents of the phonological store. The effectiveness of the phonological loop is measured by means of auditory short term memory tasks, such as digit recall and word span recall. Gillon (2004) reports that children with a hearing impairment often exhibit reduced auditory short term memory skills. Generally this may be seen to affect language comprehension but specifically this impairment of the phonological loop affects the ability to repeat words and particularly non-words.

This was precisely the case for BA at the latest assessment (C.A. 8;10) where repetition scores were very poor and non-word repetition scores were worse than real word repetition scores. Thus the impact of BA's poor attention and memory may be most evident in the tasks which tap auditory short term memory such as real word and non-word repetition. However, auditory short term memory impairment influences language function as well – an auditory memory span reduced to just one or two items (from the usual 5-9) can have profound consequences for language processing including single word processing. This means that difficulties discriminating, recognising, and understanding even one word at a time may exist for an individual with such a reduced auditory short term memory. At spans reduced to two to three items, single word processing is still intact but performance on longer sequences of words can be impaired (Harley, 2001). Although auditory short term memory was not assessed formally for BA at the latest assessment (C.A. 8;10) it now seems as though it should have been. Her attention and memory problems seem to be deeply entangled with her speech processing outcomes.

BA appears to need help with input and output speech processing, phonological awareness and literacy development. The first priority however, lies with the family and getting lines of communication and co-operation going between them and the Cochlear Implant Centre facilitators. In addition an individualised educational service plan needs to be set up by the educators, family and Cochlear Implant Centre facilitators in collaboration with each other since BA's speech, language and literacy problems will start impinging on her academic progress. A plan needs to be drawn up and parents/family/BA herself need to be made accountable for sustained cochlear implant usage. In terms of improving specific speech, language and literacy skills, the following are recommended:

- Listening to similarities and differences between familiar and unfamiliar words, using pictures of items at first to scaffold the development of this skill
- Audio and video tapes/CD's of nursery rhymes should be introduced to increase awareness of popular rhymes. Selected rhymes could then be used to work on

rhythm and gap filling tasks. Gradually identifying rhyming words through picture cards could be introduced.

- Segmentation at the word and syllable level initially, gradually advancing to the phoneme level
- Auditory discrimination targeted specifically at her difficulties with liquid gliding and cluster reduction. Once this is achieved, aim for facilitating change in the phonological representations of the words that contain those phonological processes
- Letter knowledge activities and especially those that overtly link the phoneme to the grapheme, in auditory and written formats
- 'flooding' her with high-quality children's literature written specifically for children, utilising the dialogic reading method on a daily basis as part of a routine.

Summary

BA, an 8 year old girl who was implanted at the age of 2 years 5 months, because of a congenital bilateral profound hearing loss, presented with both input and output speech processing difficulties. These included auditory perceptual difficulties, poor word discrimination, poor phonological awareness skills, difficulty assembling new motor programs, poor repetition skills, and inadequate sound production skills. In addition her literacy skills were not age appropriate. The hypothesized reasons for these poor outcomes are inconsistent usage of the cochlear implant, poor language and literacy stimulation in the home environment, and attention and memory difficulties. Her strengths were limited to normally functioning oral motor muscles. Intensive remediation and monitoring of all areas related to speech processing is needed, along with specific training in phonological awareness and letter knowledge, to try and improve BA's outcomes for speech and literacy.

CHAPTER 7 – DISCUSSION

The specific aims of the study were:

1) to describe the speech perception skills of 3 children with cochlear implants using the psycholinguistic speech processing profile, and
2) to make comparisons between the profile and previous speech processing data, for each child, in order to describe the development of speech processing over time and in relation to the time of implantation.

Case studies of three children between the ages of 6-9 years old, with cochlear implants have been presented. The children's speech processing and literacy skills were assessed from a psycholinguistic perspective and results were mapped onto the speech processing profile of Stackhouse & Wells (1997). The same was done for results of assessments taken from their Cochlear Implant Centre folders for 1- and 2-years post-implantation. From these profiles, each child's strengths and weaknesses in individual speech processing areas could be judged relative to the performance of normally developing hearing children. In addition, their current phase of speech processing development, as well as the developmental phase from their assessment at 1- and 2-years post-implantation could be identified according to the developmental phase model of speech processing of Stackhouse & Wells (1997). Relevant contributing factors to each child's outcomes were discussed and suggestions for therapy directions were made.

The three children studied were similar in many ways – all three of them were girls, all had congenital hearing loss, all were implanted by age 3, all attended a special crèche for hearing-impaired children that had an auditory-verbal approach, were mother-tongue English speakers, had IQ's within the average range, and had 3 years or more of cochlear implant experience. However, their speech processing profiles were very different and demonstrated varying rates of development through the phases of typical speech processing development. This serves to underscore the finding of many researchers on the variability of outcomes for children with cochlear implants (Dawson, McKay, Busby, Grayden & Clark; 2000; Pyman, Blamey, Lacy, Clark, Dowell, 2000; Ertmer, Strong &

Sadagopan, 2003; James et al, 2008,). The population is a heterogeneous one, even when an attempt is made to study children who meet specific criteria. This is one of the main reasons a case study methodology was chosen for this study. The psycholinguistic framework has previously been used in the assessment of children with the same diagnosis, e.g. dyspraxia (Stackhouse, 1992), phonological impairment (Pascoe, Stackhouse & Wells, 2006), to show how they can have very different underlying difficulties. This study contributes to this body of literature by showing how hearing impaired children with cochlear implants can have very different underlying profiles.

7.1 Summary of results

NG (implanted by 3;0) displayed good outcomes for speech processing and literacy. Her speech processing profile at 6;0 showed age appropriate performance for all but two speech processing areas: indistinct multisyllabic word phonological representations, and difficulties with new word motor programming for multisyllabic words. At the most recent assessment (C.A. 6;0) she was performing within an age appropriate developmental phase (i.e. the final phase on the developmental phase model of Stackhouse & Wells, 1997) and it was not anticipated that she would have any literacy difficulties. Previous assessment results suggested that she moved smoothly through the developmental phases with no delays when compared to her hearing age. Suggestions were made for therapy to improve her phonological representations' specificity and accuracy, and to improve her motor programming for multisyllabic words.

DP, the only child with bilateral cochlear implants who was initially implanted at 1;2, displayed fair outcomes for speech processing and literacy. Her speech processing profile at 6;10 showed more age appropriate performances on the output side than on the input side of the profile. She struggled with some of the tasks used in the assessment. These performances revealed difficulties with phonological awareness, motor programming and auditory memory and attention. At C.A. 6;10 on the developmental phase model she displayed arrested development at the metaphonological phase, which puts her at risk for literacy difficulties. From test results at 1- and 2-years post-implantation, DP's progression through the developmental phases of speech processing had moved smoothly with no delays relative to her hearing age, apart from the initial delay at the prelexical phase – which all children with congenital hearing losses are expected to undergo.

BA (implanted at 2;5) displayed poor outcomes for speech processing and literacy. Her speech processing profile at 8;10 displayed deficits in all areas of the profile, except for oral-motor functioning. Her input and output processing skills were well below age appropriate levels, as were her literacy skills. Poor attention and concentration, and poor articulatory skills were thought to affect performance on all levels of the profile (and especially so for the output levels). In terms of developmental phases, her speech processing development had been arrested at the assembly phase. Even though her development at 1- and 2-years post-implantation saw her moving through the developmental phases smoothly, the rate of development was not maintained. Currently, as a result of her arrested development she is at risk for a number of speech, language and literacy difficulties.

7.2 Using a case study methodology

The case study methodology has been utilized/ recommended by a few researchers dealing with children with cochlear implants (Tyler et al, 1997; Ertmer & Mellon, 2001; Ertmer, Strong & Sadagopan, 2003; Ertmer, , Young, & Nathani, 2007) because this type of methodology is able to produce far richer qualitative information than traditional experimental approaches. Historically, some notable discoveries have come from the in-depth examination of a single child or just a few children (Bukatko & Daehler, 2004). If more case studies of children implanted with cochlear implants were available in a database, therapists might find it easier to compare their clients with the existing ones in the case studies, and extract useful information from the database. Evidence-based practise is concerned with matching current clients to reported clients in the research base so that treatment methods can be selected that provide a good 'fit' based on what has been previously documented. A computerised database of children with cochlear implants could be useful for systematically applying the evidence. Furthermore, analyses could be conducted to determine the influence of issues such as age at implantation, IQ, SES, etc. and how such variables interact.

Researchers like Pisoni (2000) feel that it is of paramount importance to study the individual differences among users, and especially for those users who experience high levels of success after cochlear implantation. This should be done in order to determine what characteristics/ variables/ behaviours contributed to their outcomes, to enable therapists to extend these factors to average or under-performing cochlear implant users. Only the case study methodology generates enough detail on individual differences to enable this type of analysis. The cases presented in this study add to this database.

Pisoni (2000) also foresees the shift in research emphasis from researching issues of implant efficacy to researching questions surrounding what the child is learning via the cochlear implant and how the cochlear implant works in a functional way to control behaviour in a specific information processing task. The case study methodology is able to zoom in on such specific issues in a detailed manner in order to provide answers to questions of how and why speech/language processing is successful in certain candidates and unsuccessful in others.

7.3 Measuring outcomes in children using cochlear implants

In the previous chapters issues pertaining to outcomes centred specifically around speech processing and literacy outcomes for the three children studied. However, outcomes measurement should not only be restricted to those two aspects of the child's overall development. A broader approach is needed to consider whether the child's outcomes are being holistically evaluated and measured. For example, self-esteem and social adjustment are important aspects closely tied to communicative abilities, that were not directly evaluated in this study.

This leads to the question of *how* outcomes for children with cochlear implants are defined. Pisoni (2000:72) notes that " the study of demographic variables and the focus on traditional audiological outcomes measures in these children are only a small part of the story of what is actually going on under the surface". The traditional approach to issues of efficacy of the cochlear implant are largely based on the medical model of health and very limited in its scope of causal and contributing factors to any health related situation.

One measure of outcomes that is widely recognised by speech therapists is the Therapy Outcomes Measurement Scale (TOMS) as devised by Enderby (1997, in John, Enderby & Hughes, 2005). This approach utilises the World Health Organisation's (WHO) International Classification of Functioning (ICF) conceptual framework. Therapists are required to answer questions relating to the client in a rating scale format in order to quantify the amount of impairment, disability, handicap and well-being of the client. These scores are then used to determine the amount of functional gain from therapy. Although different versions of the TOMS have been developed for a variety of speech/language disorders (e.g. voice, dysphagia), a version for paediatric cochlear implantees has not yet been developed.

In an attempt to fill this gap, Lin, Ceh, Bervinchak, Riley, Miech & Niparko (2007) have developed the Functioning After Paediatric Cochlear Implantation Instrument (FAPCI). Using the conceptual framework of the WHO's ICF, the FAPCI takes into account the two interrelated components of body functions/structures and activities/participation. It further divides communication into communicative capacity and communicative performance and takes note of the effect of environmental and personal factors which affect performance in spite of capacity. This comprehensive evaluation of verbal communicative performance focuses on the child's behaviours at home and therefore incorporates the child and the family's perspective. This is in contrast to using results from tests of speech perception, speech production and language, which may not fully reflect a child's communicative functioning in everyday life (Lin et al, 2007). However, this tool was designed for use with children from 2-5 years old and therefore cannot be used in conjunction with the outcomes for the children in this study.

A model that has been put forward by Frattalli (1998) as one which integrates the medical and social models of health is that of Wilson & Cleary (1995). A conceptual model is proposed which categorises measurement of patient outcome according to the underlying health concepts they represent. Different specific causal relationships between different health concepts are proposed. According to this model, measures of health can be thought of as existing on a continuum of increasing biological, social and psychological complexity. At one end of the continuum, are biological measures, on the other end are more complex and integrated measures such as functioning and general health perceptions. Dominant causal associations with each level are specified. Figure 7.1 below show the Wilson & Cleary (1995) Conceptual Model of Patient Outcomes.

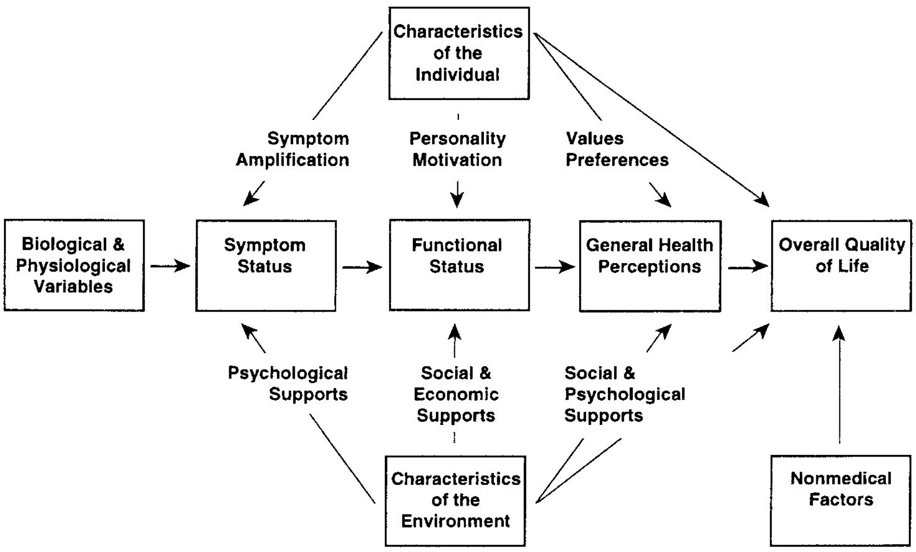


Figure 7.1 Wilson & Cleary's Conceptual Model of Patient Outcomes (1995, in Frattalli, 1998).

The five levels of the model are described in the following way:

1. Biological and physiological variables – these include the functioning of cells, organs and organ systems. Measures include those of physiological function and

physical examination findings. For this project, the main finding for the children assessed, may be congenital cochlear damage.

2. Symptom status – the organism as a whole is assessed. The assessments focus on physical, psychological and emotional symptoms (e.g. speech difficulty, fear, learning difficulty). Thus a symptom is a patient's perception of an abnormal physical, emotional or cognitive state. For this project, all the children studied presented with bilateral sensori- neural hearing loss as a result of cochlear damage. At this level characteristics of the individual, such as symptom amplification, or characteristics of the environment, such as psychological supports can either ameliorate or negatively impact the symptom status.
3. Functional status - this looks at a patient's ability to perform particular defined tasks. Four domains of functioning are included: physical functioning, social functioning, role functioning, and psychological functioning. Functional status can vary depending on personality and motivation (e.g. determination to be self-sufficient), as well as social and economic support (e.g. supportive family, access to care). Thus two individuals with similar conditions may function very differently. This was clearly demonstrated in the case studies, where all 3 candidates had congenital bilateral sensori-neural hearing loss, yet the personality, motivational, social support and economic support factors differed, and therefore the outcomes for each candidate differed.
4. General Health Perceptions – these are a subjective rating representing an integration of previous health care concepts, discussed above, as well as others such as mental health. Variations in the health perceptions are associated with individual values and preferences, as well as psychological and social supports. An example of a general health perception could be the assignation of whose responsibility it is to ensure that a child consistently wears their cochlear implant – educators may feel it is the parents responsibility, while parents may feel it is the teacher's responsibility alone.
5. Overall quality of life – this is a subjective measure of a patient's well-being, which often assesses how happy/satisfied respondents are with their life as a whole. This too is associated with individual values and preferences, social and

psychological supports. For the children in this study, parental views of quality of life for their children would also be an important factor to evaluate as they often can see more of the 'big picture' than the clinician/therapist. It would also be interesting and valuable to interview the children with cochlear implants themselves, to determine their own perceptions of of their communication skills and challenges.

This model seems capable of dealing with all the biological/physiological variables, such as age at implantation, aetiology of hearing loss, etc, and then adding on each child's unique personality factors, and the factors they bring with them because of the family they form part of. It reminds us of the vast number of factors that contribute to outcomes – for clients with communication challenges generally – and in this case as specifically applied to children with cochlear implants

However, it should be considered that all three children investigated in this study also attended schools, and here more variables come into play. Chute & Nevins (2003) assert that outcomes for children with cochlear implants in educational settings should be thought of in relation to 5 crucial aspects:

- ***acoustic challenges***, e.g. classroom size, distance from teacher
- ***academic challenges***, e.g. the child's own innate language learning ability, development of literacy
- ***attention challenges***, e.g. coping with the short term memory deficits often found in children with hearing loss, being able to attend to speech amidst background noise. BA was a child for whom this factor played an important role.
- ***associative challenges***, e.g. social development, development of a cultural identity via communicating and establishing relationships with peers
- ***adjustment challenges***, e.g. adjusting to what the cochlear implant can and cannot do, adjusting to the implications of their hearing loss and how they can facilitate listening via the cochlear implant.

In summary, we are not just dealing with a child with an amplification device – we (Speech therapists and Audiologists) are participants in the evolution of a 'cochlear implant culture' (Chute & Nevins, 2003). All aspects of the child as a functioning human being need to be taken into account during our interaction with them. While Speech therapists focus mainly on a small part of the child's ultimate development (i.e. their communication), it must be remembered that communication ultimately touches on every other aspect of their lives. Chute & Nevins (2003: 66) propose that "success with a cochlear implant is a distinctly relative concept. What may be success for one child may be considered failure for another. Children who receive a cochlear implant bring with them certain traits that may/may not support its use and fulfil its potential." Therefore the idea of successful outcomes needs to be broad-based and individualised for each specific client.

In looking at factors influencing 'success' in cochlear implant outcomes, NG (chapter 4) is taken as a particular example. Echoing Pisoni (2000), it is important to identify factors which contribute to success in specific individuals, so that they may be extrapolated and extended to other children.

- Age at implantation has been hailed by many researchers (Sarant, Blamey, Dowell, Clark & Gibson, 2001; Sharma, Dorman & Spahr, 2002; Nicholas & Geers, 2007) as an indicator of future performance, however, NG was the last to receive a cochlear implant among the three candidates, at age 3;0, which is not considered particularly young.
- Timeous identification of the hearing loss is described as important by various researchers as it minimises the length of auditory deprivation (O' Donoghue et al, 1999, Kaderavek & Pakulski, 2007). Yoshinago – Itano (2000 In Kaderavek & Pakulski, 2007) asserts that children identified by 6 months of age had significantly increased language abilities when reaching school age. However, NG was only diagnosed by the age of 1;6.
- Receiving consistent high quality audiological management is deemed a priority in the case of children with hearing loss by many in this field (Sharma, Dorman &

Spahr, 2002; Kaderavek & Pakulski, 2007; Nicholas & Geers, 2007). In NG's case, she consistently wore hearing aids best suited to her type of hearing loss, but when too little communicative progress was made she received the cochlear implant and used this consistently too.

- Researchers (Truy et al, 1998; Geers, Nicholas & Sedey, 2003; Tobey, Geers, Brenner, Altuna & Gabbert, 2003; Archbold & O'Donogue, 2007; Kaderavek & Pakulski, 2007) re-iterate the importance of receiving intense auditory intervention on a regular basis. NG received speech therapy weekly from the time she was diagnosed, and attended a special crèche and preschool which is geared towards teaching hearing impaired children via the auditory-verbal approach.
- Chute & Nevins (2003) and Kaderavek & Pakulski (2007) emphasize the value of a high quality linguistic environment. For NG this was shown in variety of ways – both her parents and her older sister are oral communicators (thus providing good speech and language models), the family only speaks English in the home (thus eliminating language confusion), NG's mom's didactic style of interaction was commended by the Speech Therapist in previous reports, the quality of the linguistic environment was recreated at her preschool.

Therefore factors which appear to have positively influenced NG's outcomes include consistent audiological management, intense auditory intervention, and high quality linguistic environments at home and at school. Conversely, factors which appeared to influence outcomes negatively , from the case study of BA, seemed to be inconsistent device usage, infrequent auditory habilitation/therapy, and the poor quality of the linguistic environment at home.

7.4 The Psycholinguistic Framework

The psycholinguistic framework used in this study consists of three main components:

7.4.1 The speech processing profile

7.4.2 The box-and-arrow model

7.4.3 The developmental phase model

7.4.1 The speech processing profile

The speech processing profile of Stackhouse & Wells (1997) is able to delineate the different speech processing skills of hearing impaired children in a way that makes it easy to see their strengths and weaknesses, in terms of input and output processing skills. In the present study, it was possible to show the development of speech processing skills over time, and in relation to each child's hearing age and chronological age by comparing profiles compiled at different stages of the child's development. The profile therefore facilitates intra-child comparisons over time. The profile also encourages Therapists to think about the connectedness of the input and output speech processes and how they influence each other. By investigating processes instead of only focusing on test results a deeper understanding of where difficulties are occurring and why, is fostered. The profile is also helpful in that it gets therapists/researchers see which levels of speech processing may not have been assessed.

However, the profile only assesses single word processing. It does not explicitly examine speech perception or production in connected speech, which is the level all the children studied are communicating in. It is possible for a child to have good real word and non-word discrimination for single words, but yet to struggle discriminating words in sentences, or to be helped by the semantic context of the sentence. There are too many variables differing between single and connected word processing to assume that if one is developing normally that the other one is too. Phonology and articulation are the main emphases of this approach. Syntax and morphology in particular are areas in which hearing impaired children struggle (Lewis & Penn, 1989), however this assessment is not able to integrate that information into its levels of speech processing.

7.4.2 The box-and-arrow model

The box-and-arrow model allows for task comparison, across levels and is useful for understanding processing routes for different tasks. However, it is focused on speech and not on language. In addition, it could account for single word speech processing and but not connected speech processing. Another critique relates to where general cognitive skills which affect performance on speech processing tasks, such as attention and memory, would fit in on this model.

7.4.3 The developmental phase model

This model in particular helps therapists to establish which phase of speech processing development their clients are in, and helps expose which speech/literacy difficulties their clients may face as a result.

The developmental phase model was very useful in conceptualising the developmental trajectory over time, of the children studied. This model should be used more often, especially in cases where the child's hearing age versus their speech and language age are important factors to consider. This model seemed more capable than the profile, or the box-and-arrow model of linking speech and language behaviours. It is interesting to note that of all components of Stackhouse & Wells' Psycholinguistic framework, the developmental phase model has been used the least (Pascoe, Stackhouse & Wells, 2005). However, shortcomings of this model included:

- criteria for classifying children in the phases were mostly output based. Especially in the early phases, e.g. prelexical and whole word phase, more input processing based criteria (of the type that audiologists assess at young ages) should be included in the criteria. For example, an additional criteria for the prelexical phase could be that the child recognises their name and/or turns to face the speaker, since this is generally expected of normally developing hearing children before 12 months (Rossetti, 1996; Bukatko & Daehler, 2004), however it is not always seen in children with input processing difficulties, such as hearing loss. To improve on this area it is suggested that Audiologists are consulted and fully involved in setting up new phase level criteria that have more input processing based items as well.
- The metaphonological phase should ideally be divided into 2 sub-phases: the rhyming phase and the phonemic awareness phase. While all phonological awareness skills are thought of as existing on a continuum (Chard & Dickson, 1999; Hempenstall, 2003; Phelps, 2003; Gillon, 2004), and as overlapping with

each other, phonemic awareness is regarded as the one type of phonological awareness skill that responds differentially/shows the most growth after exposure to specific alphabetic instruction (Snow, Burns & Griffin, 1998, in Chard & Dickson, 1999; Hempenstall, 2003; Gillon, 2004). Therefore a child who is developing at a normal rate should enter the rhyme phase before entering the phonemic awareness phase, and should enter the phonemic phase after some kind of exposure to the alphabetic principle. This could also differentiate children with specific phonological awareness problems if, after some exposure to alphabetic instruction, they still do not show age appropriate phonemic awareness skills. An example of the revised developmental phase model is shown in Figure 7.2.

SPEECH DEVELOPMENT

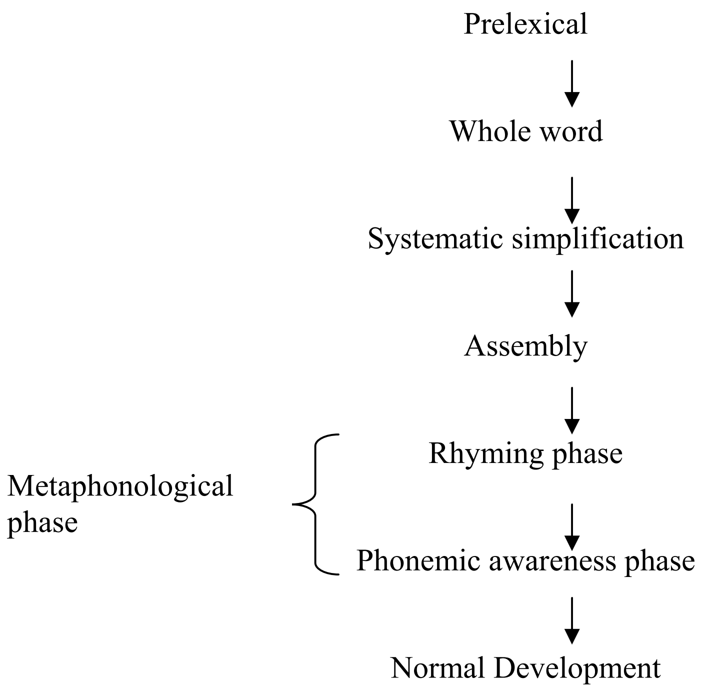


Figure 7.2 Stackhouse & Well's (1997) developmental phase model, modified by expanding the metaphonological phase to include two categories.

All in all, this model although little used in the literature to date, appears to have a lot of promise and there may be many future applications for it, especially for use with hearing impaired children. Additionally it shifts the focus off deficit-thinking to focusing on what the children can do.

A last comment on the psycholinguistic framework is that while strengths and weaknesses in speech processing are pointed out, it does not shed light on how the specific problem can be remediated (Chiat, 1994, in Stackhouse & Wells, 2001) and does not grapple with issues of therapy. Therapists have to work out for themselves how and if a certain intervention will work to counteract an identified weakness. Authors like Stackhouse & Wells (2001), and Baker et al (2001), however have argued that the approach is closely linked to therapy, and that goals for therapy are easily delineated based on the weaknesses and strengths found in the profile. This approach does not offer readymade pre-planned programmes exactly because the need for tailor-made individualised interventions, based on individual profiles are asserted. This may make it difficult for the new/inexperienced therapist to plan effective therapy, however, later books by Stackhouse, Wells and other authors (2001; 2006) address this very topic of therapy planning.

7.5 Clinical Implications

The use of the psycholinguistic framework for assessment has proved useful in this study for investigating children with similar diagnoses, i.e. profound congenital bilateral hearing loss, while producing distinctive speech processing profiles, which identified specific strengths and weaknesses for individual children. The strengths and weaknesses identified should be the focus of ongoing therapy for these children. Therapists are urged to continue profiling these children using future speech perception and production testing, and comparing those results to the ones obtained in this study. Future testing at all levels of the profile, using tests created and normed for this purpose is recommended. Audiologists as well as speech therapists should be involved in the speech processing profiling, and the use of phonological awareness tests in the speech and language battery of the Cochlear Implant Centre is deemed crucial.

Regular use of the device and regular speech therapy/auditory habilitation are two extremely important aspects in the speech and language development of children with cochlear implants. Parents should know this in advance, i.e. pre-implantation, and should be prepared to make the commitment to have their children wear the device all their waking hours, and attend therapy regularly.

A third aspect which differentiated NG (chapter 4) from BA (chapter 6) was the level of parental support. The triadic approach to intervention as advocated by Stobbart & Alant (2008) which involves communication and co-operation between the school (teachers and therapists), the parents and the child, which emphasises the continuity of intervention in all environments is felt to be a necessary component for successful outcomes. This should entail acknowledgement of cultural differences in parenting styles/family set-ups, and should promote the use of different strategies to obtain desired outcomes for the child. This should also involve parental empowerment , and education of the broader family support structure.

7.6 Limitations of the study

The main limitation relates to the generalisability of the findings: individual children were studied, therefore results cannot be generalised to other children. However it must be acknowledged that the study originally did not aim for widespread generalisability of its findings but rather aimed for rich data collection to enable deeper levels of qualitative analysis than is usually possible in experimental studies.

Another limitation relates to the limited retrospective data that could be used to create past speech processing profiles. The assessments used at those times were carried out without a psycholinguistic perspective in mind. In addition only 2 time periods in the past were chosen for analysis – as a result a limited longitudinal picture composed of a few ‘snapshot’ measurements was obtained. However, ongoing speech processing development could still be monitored over time.

7.7 Future Research Directions

Future research documenting the frequency of occurrence of non-use of the cochlear implant, looking into causes and contributing factors, and also speech and language outcomes for those children is needed. In addition, data generation with regards to strategies to overcome causes and contributing factors is needed.

Research investigating speech and language interventions for children with cochlear implants is needed. It is generally known what types of problems they present with – now approaches to management, and interventions with documented success are required in the literature.

Research detailing broader communication outcomes for children with cochlear implants, including aspects such as social adaption, self-esteem, functional use of language for learning, etc. would be a valuable addition to the knowledge base regarding speech and language difficulties in children with cochlear implants.

7.8 Conclusion

In this study the present and past speech processing profiles of three children wearing cochlear implants was presented, using a case study methodology. Intra-child comparisons of present and past results were done to investigate development over time. Assessment was guided by the psycholinguistic framework (Stackhouse & Wells, 1997) – results were mapped onto a speech processing profile, performances at different levels were compared using box-and-arrow models, and speech processing development over time was plotted onto the developmental phase model. Finally aspects which were thought to influence successful outcomes for children with cochlear implants were discussed and factors which are thought to affect outcomes negatively were considered. Theoretical implications with regard to the use of the case study methodology and the psycholinguistic framework are presented along with clinical implications for the children studied, their therapists, and the Cochlear Implant Centre.

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PERSONAL COMMUNICATIONS:

Annamaria Capatti (mother of a 13 year old child wearing a cochlear implant)

APPENDICES:

A – Information letter to parents
B – Ethics approval
C – C1:Informed consent form
(Parents),
C2: Informed consent form
(children over 7 years old)
D – Data sheet
E – E1: NG Test results
E2: DP Test results
E3: BA Test results

APPENDIX A

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

1 May 2007

Dear Parent,

My name is Candice Randall. I am currently completing my Masters degree in Speech-Language Therapy at the University of Stellenbosch. The purpose of my research is to profile the Speech Processing performances of children with cochlear implants, to see if and how they differ from children with normal hearing, and to see how Speech Perception performance is related to Phonological Awareness performance. These measures are in turn linked to later reading performance in most research studies. A battery of 10-12 tests will be performed which measures different aspects of Speech Processing.

The results of the study will ultimately help to design future testing and profiling methods, and may help to inform therapy for your child and others.

For this purpose, I require children such as your child who wear cochlear implants and who :

- speak English as their main language
- are between 5 – 9 years of age
- have average/higher than average intelligence,

Should you agree to allow your child to partcipate:

1) your child will be administered the full battery of Speech Processing tests, which are similar to tests of Speech and Language. This test lasts between 10 - 30 mins each and testing will take place over 2-3 days.
2) you as the parent will be asked to complete a short questionnaire pertaining to your child's hearing and use of the implant; and
3) Previous Speech Processing results from your child's Cochlear Implant Centre folder will also be retrieved and analysed for the purposes of the research.

This study has already obtained approval from the Ethics Committee of the University of Stellenbosch. All that remains is to recruit willing participants. All information gathered will be treated as strictly confidential, and parents will have access to all their children's test scores and interpretations thereof.

I will contact you telephonically to determine whether you agree to participate or decline to participate. If you agree, an appointment will be made, at your earliest convenience to test your child.

Thank you for your co-operation,

Candice Randall, *BscSpeech Language Pathology (UCT)*

Fakulteit Gesondheidswetenskappe • Faculty of Health Sciences

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Dissipline van Spraak-Taal- & Gehoorterapie • Discipline of Speech-Language and Hearing Therapy

Posbus/PO Box 19063 • Tygerberg 7505 • Suid-Afrika/South Africa

APPENDIX B

UNIVERSITEIT-STELLENBOSCH-UNIVERSITY
jou kennisvennoot • your knowledge partner

28 May 2007

Mrs C Randall
Division of Speech-Language and Hearing Therapy
Dept of Interdisciplinary Health Sciences

Dear Mrs Randall

RESEARCH PROJECT: "THE SPEECH PROCESSING SKILLS OF PRESCHOOL CHILDREN WITH COCHLEAR PLANTS"
PROJECT NUMBER : N07/04/082

At a meeting of the Committee for Human Research that was held on 2 May 2007 the above project was approved on condition that further information that was required, be submitted.

This information was supplied and the project was finally approved on 28 May 2007 **for a period of one year from this date**. This project is therefore now registered and you can proceed with the work. Please quote the above-mentioned project number in all further correspondence.

Please note that a progress report (obtainable on the website of our Division) should be submitted to the Committee before the year has expired. The Committee will then consider the continuation of the project for a further year (if necessary). Annually a number of projects may be selected randomly and subjected to an external audit.

Patients participating in a research project in Tygerberg Hospital will not be treated free of charge as the Provincial Government of the Western Cape does not support research financially.

Due to heavy workload the nursing corps of the Tygerberg Hospital cannot offer comprehensive nursing care in research projects. It may therefore be expected of a research worker to arrange for private nursing care.

Yours faithfully

CJ VAN TONDER
RESEARCH DEVELOPMENT AND SUPPORT (TYGERBERG)
Tel: +27 21 938 9207 / E-mail: cjvt@sun.ac.za
CJVT/cjvt

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Fakulteit Gesondheidswetenskappe • Faculty of Health Sciences

Verbind tot Optimale Gesondheid • Committed to Optimal Health
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APPENDIX C1

PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM

TITLE OF THE RESEARCH PROJECT:

The Speech Processing Skills of Children with Cochlear Implants

REFERENCE NUMBER:

PRINICIPAL INVESTIGATOR: Candice Randall

ADDRESS: Tygerberg Hospital, Bellville

CONTACT NUMBER: (021) 9384825

You are being invited to take part in a research project. Please take some time to read the information presented here, which will explain the details of this project. Please ask the study staff any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research entails and how you could be involved. Also, your participation is **entirely voluntary** and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

This study has been approved by the **Committee for Human Research at Stellenbosch University** and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki, South African Guidelines for Good Clinical Practice and the Medical Research Council (MRC) Ethical Guidelines for Research.

What is this research study all about?

- This project aims to assess the Speech Processing skills and Speech Processing development of children with Cochlear Implants. Speech Processing refers to how we listen to,identify and understand sounds we hear. Speech perception and Phonological Awareness fall under Speech Processing. Speech Perception (SP) is a type of listening skill, and is routinely measured by the Cochlear Implant Team, as you may well know. Another type of listening skill is called Phonological Awareness (PA). This looks at whether a child can identify, separate and manipulate sounds in a word. Some researchers predict, that good PA skills help children learn how to read. Also, the child's strengths and weaknesses in PA are compared with their Speech Perception scores. This research may help us understand how children with Cochlear Implants develop PA skills, the relationship between children's PA and their SP skills, and how their development compares to that of normally hearing children.
- The project's testing procedures are to be conducted either at Tygerberg Hospital, or at the partcipant's homes, according to the preference of the partcipants' parents. Three children are needed for this study, which involves in-depth profiling of each child's Speech Processing development over time. Each child will be individually assessed.
- All parents of participants will need to fill in a data form giving us more background data on the participant. This takes approximately 5 minutes.
- A battery of tests specific to different areas of PA and SP will be administered. The battery contains 10-12 tests, and is administered in a manner consistent with most speech and language tests. Each of the 10-12 tests looks at a different aspect of SP and PA. The

participants will be required to perform certain tasks such as clapping, verbalizing answers and pointing to the correct picture during these tests.

➢ The total estimated time for assessment will be between 2-3 hours. Assessment would need to take place over 4-5 sessions, within one week, and each session is guided by the participant's attention span and concentration levels.

➢ The tests will be administered by a trained Speech Therapist, and all responses are to be recorded via audio cassette, and on a test record form. All data collected including audiotapes will be kept in locked storage, and be used exclusively for research purposes. Your own Speech Therapist will also be informed of your child's participation in this study.

➢ If more participants than are needed respond favourably, the required number of participants for the study will be chosen randomly from the willing participants, by drawing numbers from a bag corresponding to a child's name.

Why have you been invited to participate?

➢ You and your child have been invited to participate as you meet all the criteria for selection of participants, for this study, i.e.

- All participants must be Cochlear Implant users
- All are to be aged between 4-8 years
- All must have normal intelligence
- All are English mother tongue-speaking

What will your responsibilities be?

1. Completion of this consent letter
2. Arrival on agreed date and time for testing/availability on mutually agreed date and time for your child to be tested in your home
3. Completion of data form
4. Your child's participation in the testing session.

Will you benefit from taking part in this research?

➢ This research may benefit all children with Cochlear Implants some day. Personally you will receive a free profile of your child's PA skills, if you so wish, which you can discuss with your own Speech Therapist. There are no additional costs involved to the parent or remuneration for participation in this study.

Are there risks involved in your taking part in this research?

➢ There are no foreseen risks. All procedures are the same or similar to standard speech, language and audiological testing.

If you do not agree to take part, what alternatives do you have?

➢ You may decline to participate, or to withdraw at any time during testing. The assessment does not take the place of or interfere with your routine testing by the Cochlear Implant Unit. Declining to take part will in no way negatively affect your treatment or assessment with the Cochlear Implant Unit.

Who will have access to your medical records?

➢ The information collected will be treated as confidential and protected. If it is used in a publication or thesis, the identity of the participants will remain anonymous. Only the research team and the Cochlear Implant Unit will have access to the information.

Declaration By Participant's Parent/Legal Guardian

By Signing below, I............................... agree for my child to take part in a research study entitled:- <u>The Speech Processing Skills of Children with Cochlear Implants</u>

I declare that:

- I have read or had read to me this information and consent form and it is written in a language with which I am fluent and comfortable.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is **voluntary** and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- I may be asked to leave the study before it has finished, if the study doctor or researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.

Signed at (*place*)..............................on (*date*) 2007

....
Signature of Participant's Parent/ Legal Guardian Signature of Witness.

Declaration By Investigator

I (name) ....declare that:-

- I explained the information in this document to ....
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I did not use a translator.

Signed at (*place*)..............................on (*date*) 2007

....
Signature of Investigator Signature of Witness.

Declaration By Partcipant

I (name) ....declare that:-

I agree to take part in this study, after everything was explained to me.

....
Thumbprint or cross of Participant Signature of Witness.

Signed at (*place*)..............................on (*date*) 2007

In case of any uncertainty regarding this project please contact Candice Randall at: 021 9384825 or 0834202017.

APPENDIX C2

PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM (FOR PARTICIPANTS OLDER THAN 7 YEARS)

TITLE OF THE RESEARCH PROJECT:

<u>Phonological Awareness Skills in Cochlear implant children</u>

PRINICIPAL INVESTIGATOR: Candice Randall
ADDRESS: Tygerberg Hospital, Bellville
CONTACT NUMBER: (021) 9384825

You are being invited to take part in a research project. The Researcher will explain all the details of this project. Please ask the researcher any questions about any part of this project that you do not fully understand. It is entirely up to you if you want to take part in this project.

The researcher will provide information as set out in the original consent form, relating to the following topics:

- ☐ What is the research study all about?

  We're going to listen to the sounds in words and play some games
- ☐ How long it will take?

  This will take you as long as 2-3 hours. Assessment would need to take place over 4-5 sessions, within one week.
- ☐ What is the procedure?

  You'll sit here and I'll tell you what to do
- ☐ Why have you been invited to participate?

  All the children from the Cochlear Implant centre between age 4-8 were invited
- ☐ What will your responsibilities be?

  You need to listen carefully, and try your best to do the task I set you
- ☐ Will you benefit from taking part in this research?

  This will help us find out how well you play with sounds in words
- ☐ Are there in risks involved in your taking part in this research?

  It's the same as when you're tested at the clinic
- ☐ If you do not agree to take part, what alternatives do you have?

  If you feel like you don't want to take part, that's ok
- ☐ Who will have access to your medical records?

  Only will know how you do on the test, but your parents can ask for the results as well

Declaration By Participant

By Signing below, I............................... (Child's name) agree to take part in a research study entitled:- <u>Phonological Awareness Skills in Cochlear Implant children</u>

I declare that:

- I have had read to me this information and consent form and it is written in a language with which I am fluent and comfortable.

Version 1, dated 13 May 2005

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- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is **voluntary** and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be penalized or prejudiced in any way.
- I may be asked to leave the study before it has finished, if the researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.

Signed at (*place*)................................on (*date*) 2006

....

Signature of Participant   Signature of Witness.

Declaration By Investigator

I (name) ....Candice Randall.......................................declare that:-

- I explained the information in this document to ....
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I did not use a translator.

Signed at (*place*)................................on (*date*) 2006

....

Signature of Investigator   Signature of Witness.

In case of any uncertainty regarding this project please contact Candice Randall at: 021 9384825 or 0834202017.

APPENDIX D

DATA SHEET

Assessment date: ....
Tester: ....

Participant's name:	Years of CI usage: ....
Reference no.:	Age at implantation: ....
Date of birth:...	Monaural/binaural CI's: ....
Age:..	

Aetiology of hearing impairment:

No. of years of unaided hearing: ....

Were H/A's worn before implantation? ....

For how many years? ....

Aided thresholds before implantation? ....

Unaided thresholds before implantation? ....

Years of unaided hearing experienced? ....

Demographics:

Home language: ....

Other languages spoken in the home: ....

Race:.................................

Socio-economic status: low [ ] average [ ] hig

No. of siblings: ....

Schooling: special [ ] mainstream [ ] priva

Grade: ....

Has he/she received or are they receiving any Speech Therapy? YES | NO

If yes, when? ....

How often? ....

Where is/was therapy received? ....

APPENDIX E.1

Test:	OPE results	DDK results			Aud Discrim test			ABX		
		RAW	SD	Descript	RAW	SD	Descript	RAW	SD	Descript
Participant:		p? =5.9s	+ 2SD	slower	17/20	+ 0SD	normal	19/24	+ 0SD	normal
NG	normal structure &	t? =?	N/A	N/A	80%					
	function	k? = 6.5s	+ 1SD	slower	90%					
	of articulators	ptk = 7.5s	- 1SD	normal						

Error detection			Rhyming			EOWPVT			
RAW	SD	Descript	RAW	SD	Descript	RAW	SS	SD	Descript
			11/12 (V)	SD	normal				
38/48	- 1SD	below	12/12 (A)	+ 1SD	above	48	100	+ 0SD	normal
		average			average				

(V) = visual
(A) = auditory

RAPT			PhaB				PAT			
RAW	SD	Descript	RAW	SS	SD	Descript	RAW	SS	SD	Descript
I = 35.5	+ 0SD	normal	1. 7/10	87	- 0SD	normal	1. 6/10	96	- 0SD	normal
G = 29	+ 0SD	normal	2. 8/10	102	+ 0SD	normal	2. 17/20	102	+ 0SD	normal
			3. 7/10	115	+ 1SD	above ave	3. 7/10	116	+ 1SD	normal

Subtest 1 = Alliteration with pictures
Subtest 2 = Rhyme fluency
Subtest 3 = Alliterative fluency

Subtest 1 = Blending
Subtest 2 = Grapheme recognition
Subtest 3 = CVC word decoding

Aston Index blending		Constable's repetition task		
RAW	Descript	RAW	SD	Descript
6/10	above mean	RW=9/20	> 2SD	below
		=45%		average
		NW=2/20	> 2SD	below
		=10%		average

RW = real word
NW = non-word

APPENDIX E.2

Test:	OPE results	DDK results			Aud Discrim test			ABX		
		RAW	SD	Descript	RAW	SD	Descript	RAW	SD	Descript
DP	Normal function	p? = 7.4	+ 2.5SD	slower	18/20	+ 0SD	normal	17/24	- 1SD	below
	and anatomy of	t? = 5.9	+ 1SD	slower	100% NW					average
		k? = 6.1	+ 0.5SD	normal	80% RW					
		ptk = 10.4	+ 0SD	normal						

EOWPVT				Error detect			Rhyming		
RAW	SS	SD	Descript	RAW	SD	Descript	RAW	SS	PR
59	105	+ 0SD	normal	44/48	+ 0SD	normal	11/12 (V)	+ 0SD	normal
							12/12 (A)	+ 1SD	above
									average

(V) = visual
(A) = auditory

RAPT			PhaB				PAT			
RAW	SD	Descript	RAW	SS	SD	Descript	RAW	SS	SD	Descript
I = 24.5	- 2SD	below ave.	1. 5/10	79	- 1.4 SD	below ave.	1. 15/20	94	- 0SD	normal
G = 28	- 2.2SD	very much	2. 1	77	- 1.5 SD	below ave.	2. 19/20	106	+ 0SD	normal
		below ave.	3. 4	79	- 1.4 SD	below ave.	3. 2/10	91	- 0SD	normal

Subtest 1 = Alliteration with pictures
Subtest 2 = Rhyme fluency
Subtest 3 = Alliterative fluency

Subtest 1 = Blending
Subtest 2 = Grapheme recognition
Subtest 3 = CVC word decoding

Aston Index		Constable's repetition task		
RAW	SS	RAW	SD	Descript
4.5/10	below	RW=14/20	- 1SD	below
	mean	= 70%		average
		NW=2/20	> 2SD	VMBA
		= 10%		

RW = real word
NW = non- word

APPENDIX E.3

Test:	OPE results	DDK results			Aud Discrim test			ABX			Error detect		
		RAW	SD	Descript	RAW	SD	Descript	RAW	SD	Descript	RAW	SD	Descript
BA	Normal	p? = 3.5	- 1SD	faster	9/20	- 4SD	very much	15/24	- 2SD	below	36/48	- 8SD	very
	functioning	t? = 4.4	+ 0SD	normal	50%		below			average			below
	and anatomy	k? = 4.7	+ 0SD	normal	40%		average						average
	of articulators	ptk =	+ 4.6SD	slower									

Rhyming			EOWPVT				RAPT		
RAW	SD	Descript	RAW	SS	SD	Descript	RAW	SD	Descritp
8/12 (V)	- 13SD	VMBA	23	69	- >2SD	very much	I = 20	- 5.7SD	VMBA
8/12 (A)	- 4SD	VMBA				below	G = 6	- 6.6SD	VMBA
						average			

(V) = visual
(A) = auditory

PhaB				PAT				Aston Index		Constable's real & Non		
RAW	SS	SD	Descript	RAW	SS	SD	Descript	RAW	Descript	RAW	SD	Descript
1. 2/10	69	> 2SD	VMBA	1. 4/20	< 50	> -2 SD	VMBA	0.5/10	below	RW=2/20	> 2SD	VMBA
2. 0	69	> 2SD	VMBA	2. 13/20	< 47	> -2SD	VMBA		mean	=10%		
3. 3	69	> 2SD	VMBA	3. 1/10	< 48	> -2 SD	VMBA			NW=0/20	> 2SD	VMBA
										=0%		

Subtest 1 = Alliteration with pictures
Subtest 2 = Rhyme fluency
Subtest 3 = Alliterative fluency

Subtest 1 = Blending
Subtest 2 = Grapheme recognition
Subtest 3 = CVC word decoding

RW = real word
NW = non- word