The acquisition of verbal morphology in coclear-implanted and specific language impaired children

Hammer, A.

CHAPTER 2

Introducing hearing and language-impaired children

1. Introduction

This chapter gives an overview of the three clinical groups that are central in this dissertation. These groups are 1) children with Cochlear Implants (CI), 2) children with classical Hearing Aids (HA) and 3) children with Specific Language Impairments (SLI).

This chapter starts with a short overview of the normal functioning of the cochlea and how we perceive speech. The hearing-impaired children in this study all have a sensorineural hearing loss. We discuss the effects of sensorineural hearing loss on speech perception followed by a description of the rehabilitation devices (i.e. hearing aid and cochlear implant) in section 2.

The primary aim of rehabilitation devices is to improve the quality of auditory (speech) input. By optimizing auditory speech input, oral language development is stimulated. For children with a severe to profound hearing loss, qualitatively better auditory speech input is obtained with the advent of cochlear implantation as compared to conventional HAs. In chapter 1, we have already indicated that, for CI recipients, major improvements in language development have been reported. In section 3 of this chapter, we will summarize some of the most recent findings with respect to the language development of CI children and in particular the grammatical morphology.

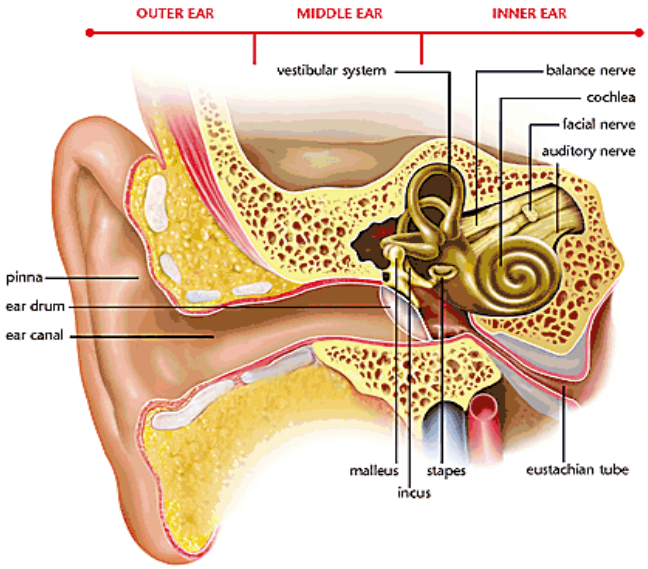
This chapter will end with the description of the SLI children and the accounts that have been given to explain their language difficulties (section 4).

2. Hearing impairment and intervention

2.1 Anatomy of the ear

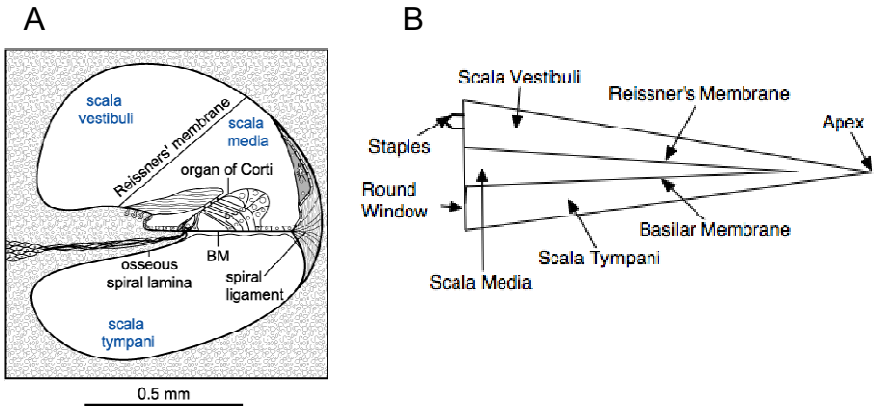
The ear can be divided into three sections, which include the outer, middle and inner ear (see Figure 1). The outer ear is made up of the ear flap (pinna) and the ear canal which is approximately 3 cm in length. The middle ear consists of the tympanic cavity, which starts with the ear drum (tympanic membrane). The sound waves that are directed through the ear canal cause the ear drum to vibrate. This vibration is passed on to a chain of three small bones (ossicles) behind the ear drum. The first bone is attached to the ear drum and is called the hammer (malleus). The hammer attaches to the anvil (incus) and the anvil is attached to the stirrup (stapes). The stirrup is attached to the oval window of the inner ear. The three bones act as a series of levers to reduce the loss of energy when transmitting the vibration from the air to the rather stiff fluid of the inner ear. The Eustachian tube is also a part of the middle ear. This tube connects the middle ear to the throat to keep the air pressure in the middle ear equal to the pressure of the outside ear. The inner ear consists of the semicircular canals (vestibular system), that assist in keeping our balance, and the cochlea. The cochlea is the sensory organ of the hearing system. The cochlea is a 35mm tube coiled into a spiral.

Figure 1. Anatomy of the ear (retrieved from: www.ncbegin.org/audiology/hearing_system.shtml)



A cross-section of the cochlea is given in Figures 2 A and B. The two membranes in the cochlea, which are the basilar membrane (BM in Figure 2) and Reissner's membrane, divide the cochlea into three compartments. These compartments are the scala vestibuli, the scala medio (cochlear duct) and the scala tympani. The scala vestibuli and scala tympani contain the perilymph fluid and the scala medio the endolymph fluid. The scala vestibuli abuts the oval window from which the perilymph is set in motion. The waves move towards the helicotrema (near the apex, see Figure 2B), where the scala vestibuli merge with the scala tympani. The fluid waves continue in the perilymph of the scala tympani. The scala tympani ends in the round window, which provides pressure relief as the perilymph is an incompressible fluid.

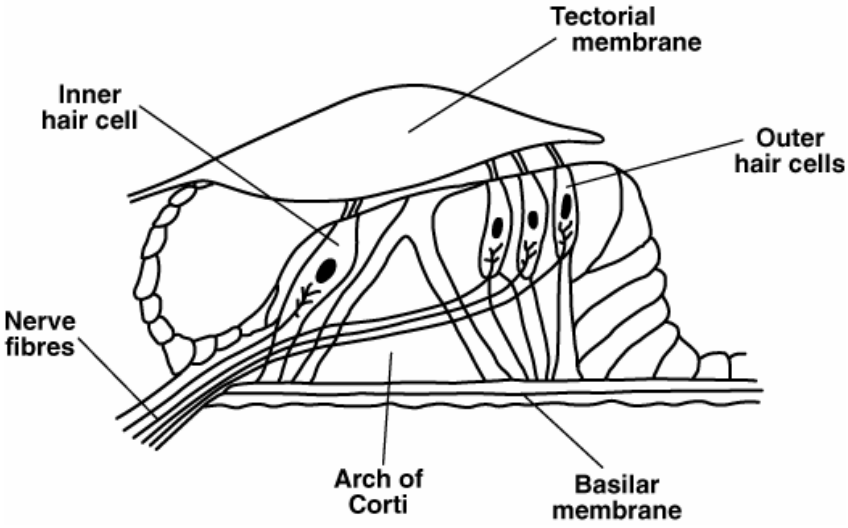
Figure 2. Cross section of the cochlea. Panel A shows the three compartments, which are divided by the basilar membrane (BM) and Reissner's membrane (retrieved from: *www.bai.ei.tum.de/research*). Panel B shows a schematized unrolled cochlea (retrieved from: *www.postaudio.co.uk/education/acoustics/ear.html*).



2.2 Auditory perception

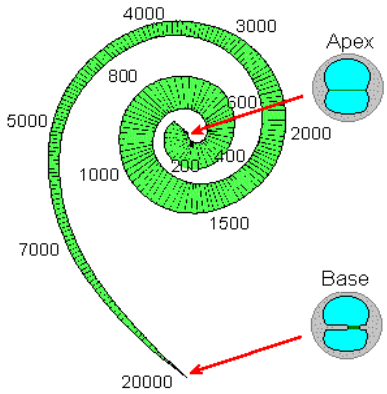
The waves in the scala tympani are transmitted to the endolymph in the scala media. As a result, the basilar membrane starts to vibrate. Subsequently, this causes the organ of Corti to move. The organ of Corti has one row of Inner Hair Cells (IHC) and three rows Outer Hair Cells (OHC) (see Figure 3). These cells have stereocilia or 'hairs' that protrude. When the basilar membrane is set in motion, the stereocilia bend back and forth against the tectorial membrane. The deflection of the stereocilia of the IHCs lead to a flow of electric current. Subsequently, this leads to the generation of action potentials in the neurons of the auditory nerve. The OHCs have a mechanical function which influences the response of the basilar membrane to sound (Moore, 2003). The details of this mechanical function are not yet fully understood.

Figure 3. The organ of corti (retrieved from: http://cobweb.ecn.purdue.edu/~ee649/notes/figure/innder_ear.gif).



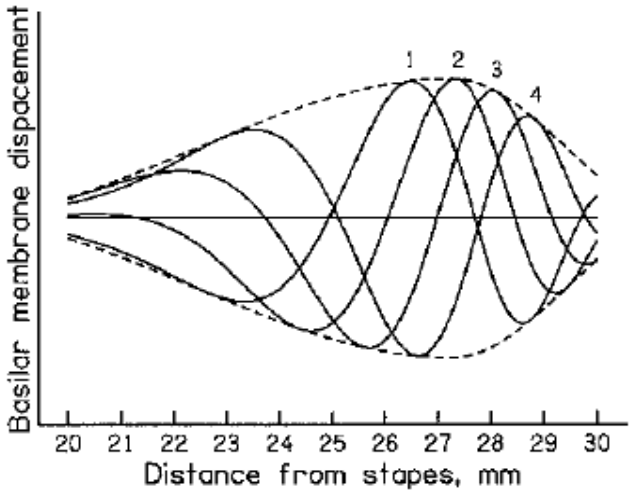
The basilar membrane's respons to sounds is affected by its mechanical properties. At the base, the basilar membrane is stiff and narrow. Towards the apex, the membrane becomes wider and less stiff. The basilar membrane has a tonotopic structure, which means that each frequency has its own place on the membrane. The high frequencies are located at the base and the low frequencies are located towards the apex (see Figure 4).

Figure 4. Representation of the tonotopic organization of the cochlea. The high frequencies are located at the base and the low frequencies near the apex (retrieved from: http://www.sissa.it/multidisc/cochlea/utils/basilar.htm).



When the fluid in the cochlea is set in motion, a traveling wave proceeds along the membrane that attains its maximum amplitude at a distance corresponding to its frequency and then rapidly subside (see Figure 5). The region that vibrates most vigorously stimulates the greatest number of hair cells and these hair cells send the most nerve pulses to the auditory nerve and brain. The brain recognizes the place on the basilar membrane and therefore the pitch of the tone. This is called place coding of pitch. For frequencies up to 3kHz, the rate of stimulation is also an important indicator for pitch. The periodicity of a particular tone is indicated by the firing rate of the neurons. This is called the temporal coding of pitch.

Figure 5. Schematic illustration of the instantaneous displacement of the basilar membrane for four successive instances in time in response to low-frequency sinewave. The four successive peaks in the wave are labeled 1, 2, 3 and 4. Also shown is the line joining the amplitude peaks, which is called the envelope. The response shown here is typical of what would be observed in a non-functioning ear (Moore, 2003, reprinted with permission from Wolters Kluwer Health).



Especially in the case of sound perception consisting of different frequency components, frequencies are carried in the detailed time pattern of nerve spikes. Nerve spikes tend to be *phase locked* or synchronized to a stimulating waveform. Because of the refractory period of the neurons, the neuron cannot respond to every successive cycle of the stimulus. If the neuron responds, it does so around a constant phase of the stimulus. Consequently, the nerve spikes occur around integral multiples of the period of the sine-wave stimulus. For example,

a tone with a frequency of 0.5kHz has a period of 2 milliseconds, the interval between nerve spikes will be close to 2, 4, 6 and 8 milliseconds, and so on. A population of nerves, all phase-locking to the same stimulus, represent in their firing pattern the complete temporal representation of the stimulus. For instance, neurons responding to the speech sound with a formant frequency of 1.4kHz will show phase-locking to that formant frequency. Any change in the spectral composition of the complex sound results in a change in the pattern of phase-locking. Phase-locking occurs for frequencies up to 4 to 5kHz and is referred to as the Temporal Fine Structure.

When listening in noisy backgrounds, normally hearing people perform better in fluctuating than in steady-state noise. Normally hearing people have a capacity called 'dip listening': they are able to glimpse speech in background noise valleys and are able to decide whether a speech signal in the dips of the noise is part of the target speech (Moore, 2008). They are able to do so thanks to the information derived from fluctuations in the temporal fine structure (TFS) of speech sounds (Lorenzi, Gilbert, Carn, Garnier & Moore, 2006). The *Morpheme-in-Noise Perception Deficit Hypothesis* formulated in Chapter 6 crucially builds on this particular listening capacity in noise situations with respect to the perception of morphology.

2.3 Sensorineural hearing loss

Damage to the hair cells disrupts the link between the middle ear and the auditory nerve, causing sensorineural hearing loss. Sensorineural hearing loss leads to a decrease in detecting and discriminating sounds. The reduced discrimination is caused by a loss in frequency resolution. This means that people with sensorineural hearing loss do not have access to the finer details of a sound's spectral profile. Excitation of the basilar membrane by incoming sounds is 'blurred' or 'smeared'. This has dramatic effects on speech recognition, especially in noisy backgrounds.

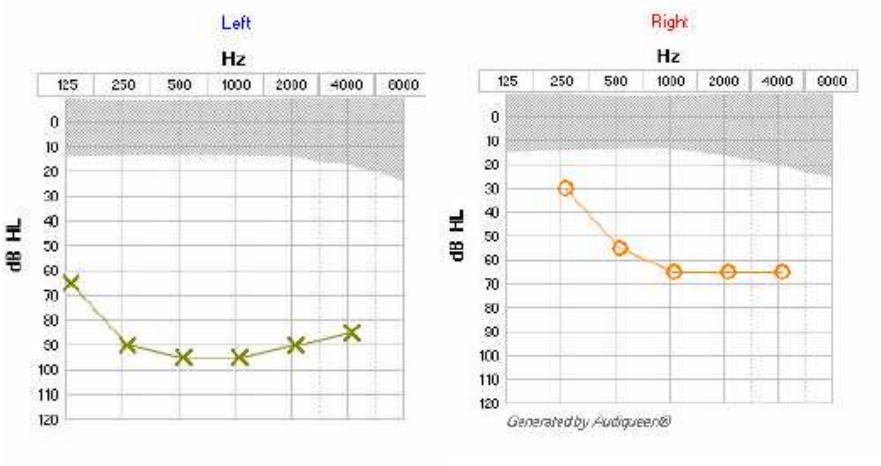
The degree of hearing loss can be ranked from mild to profound. This is measured by the degree of loudness a sound must attain before being detected by an individual. Most individuals with a sensorineural hearing loss have different degrees of hearing loss depending on the frequency of the sound (e.g. in Figure 6, for the right ear a loss of 30dB is measured at 0.25kHz and 65dB at 1kHz). The degree of hearing loss is expressed by the average threshold level, which takes the mean of the hearing loss at 0.5kHz, 1kHz and 2kHz (Pure Tone Average or 'Fletcher Index'). A *mild* hearing loss ranges from 25 to 40dB, a *moderate* hearing loss from 41 to 60dB, *severe* hearing loss from 61 to 80dB and *profound* from 81dB or greater (Katz, Medwtsky & Burkard, 2009).

If sensorineural hearing loss occurs before the acquisition of language (<3 years), this is called prelingual deafness. A congenital hearing loss is thought to be present from birth, or is developed in the first few days of life. Congenital

hearing loss may have a genetic origin (Connexin 26 deafness or syndrome), caused by a disease passed from mother to fetus (e.g. syphilis), or disease of the child (e.g. meningitis). Congenital severe to profound hearing loss occurs in 0.5 to 3 per 1000 live births (Niparko, 2000).

Sensorineural hearing loss occurring after the acquisition of language is called postlingual deafness. Acquired sensorineural hearing loss can be caused by trauma, disease or the side-effects of medicine.

Figure 6. Presentation of an audiogram. Loudness in decibels (dB) is presented on the vertical axis and frequency in Hertz (Hz) and on the horizontal axis. A circle (right ear) or cross (left ear) is drawn at the loudness level were a tone at a particular frequency is heard (reprinted with permission from The Eargroup, Antwerp-Deurne).



2.4 Hearing rehabilitation

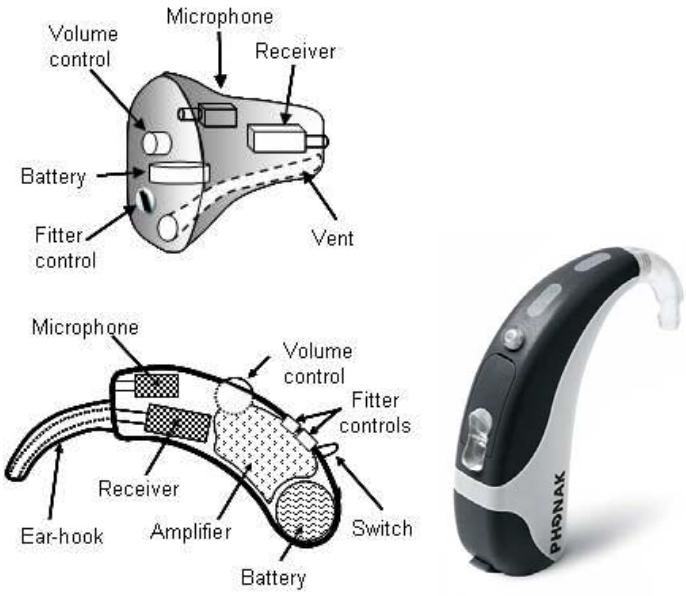
2.4.1 The classical hearing aid

The main function of classical hearing aids is to amplify sound. This means that the detection level of sound decreases, but frequency resolution is not really improved. Classical hearing aids have three basic components, common to all types of models and styles (see Figure 7).

The sound enters through the *microphone*, which converts the sound waves into an electrical signal. The *amplifier* increases the strength of the electrical signal, which is converted back into an acoustic signal in the *receiver*. The amplified sound is channeled into the ear canal via an earmold or a tube. The battery gives the hearing aid the electrical energy. Hearing aids can be equipped with *telecoils*, which are designed to use hearing aids with the telephone or

induction loop systems. The telecoil picks up the electromagnetic signals, amplifies them and converts them to acoustic energy.

Figure 7. A schematized picture of two common hearing aid styles: In-the-ear style and the Behind-the-ear style (retrieved from: *http://www.hearing.com.au/product-type*) and a presentation of Behind-the-ear-hearing aid (retrieved from: www.oorzaken.nl/Phonak_Naida_Ultrapower.htm).



Most hearing aids are equipped with Digital Noise Reduction (DNR) schemes. The goal of DNR is to distinguish between speech and noise in the listener's immediate environment and reduce the 'noise' component. The first generation of DNR is based on the observation of Dudley in 1930 that the speech signal is formed by modulations in the spectral shape of the sound, which is produced by the vocal mechanism. These modulations are periodic, produced by vocal cord vibration, and aperiodic produced by turbulent airflow at a constriction. These periodic and aperiodic modulations result in amplitude modulations and are called the temporal envelope of speech.

In the past 50 years, it has been shown that these amplitude modulations in the waveform are important in speech perception (Rosen, 1992). As such, the first generation of DNR analyzed the signal at the microphone to determine whether the modulation in amplitude is similar to those observed in speech. However, most of the background noise is made up of multiple talkers,

reducing the delineation between speech and noise. Today, a multifaceted approach is taken to noise reduction. Algorithms are used with rules of spectral make-up, fluctuations of level and frequency and even the spatial separation of the incoming sounds (Katz et al., 2009).

2.4.2 The cochlear implant

For some individuals with sensorineural hearing loss, conventional hearing aids provide little or no benefit. Their hearing loss is too severe and amplification does not reach the area of the speech spectrum. To date, the criteria for cochlear implant candidates include those individuals who have a severe loss (average threshold >70dB) when speech-sound discrimination and open-set speech recognition with conventional hearing aids are not sufficient (Schauwers, 2006).

Cochlear implants are electronic devices that function as a sensory aid. They transmit sounds directly to the auditory nerve through electrical stimulation of the cochlea, by-passing the ear canal, ear drum and middle ear. They consist of an implanted component that is inserted during an operation and external components that are worn on the head or body like a conventional hearing aid (see Figure 8).

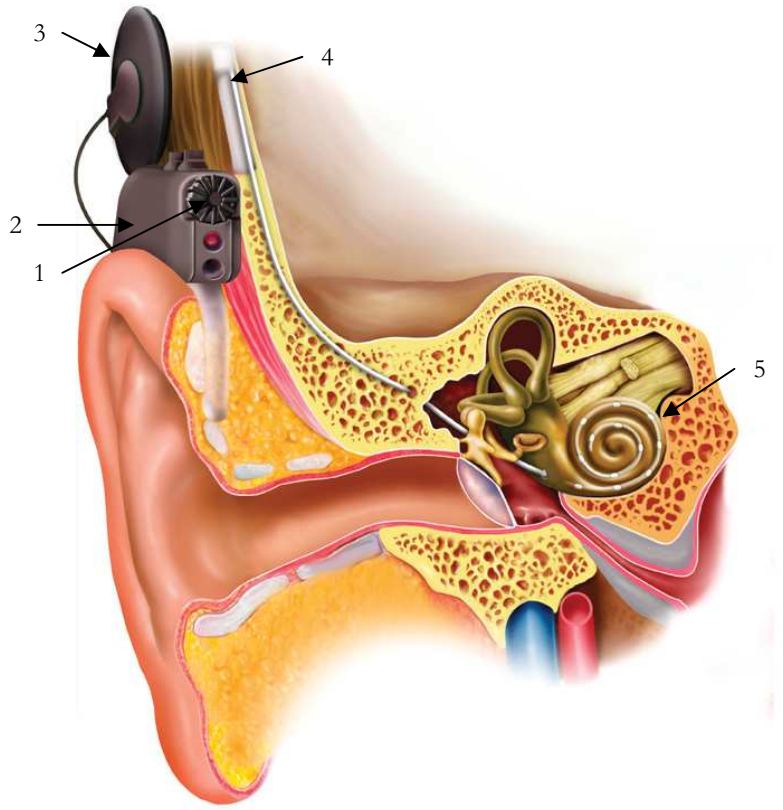
The *microphone* (see 1 in Figure 8) receives the acoustic signals, which are converted into an electrical signal in the *speech processor* (2). The output of the processor represents the informational aspects of speech in such a way that the implant recipient can perceive them. Several strategies are used to achieve this objective, but this is not within the scope of the dissertation. The processor transmits the digitally coded sound through the *external transmitter coil* (3) to the *implant* (4) just under the skin. The implant converts the digitally coded sound to electrical signals, which are sent to an array of *electrodes* (5) that extend from the implant to the cochlea.

The electrodes in the cochlea are able to stimulate the cochlear neurons of the auditory nerve. The implant processor that filters the signal into several frequency bands, maps these filtered signals onto appropriate electrodes to code the spectral shape of sounds. The tonotopic organization of the cochlea allows for place coding of pitch (see subsection 2.2), thereby partially restoring the frequency resolution of the cochlea. Thus, the location of the electrode within the cochlea helps to define the frequency information. The amount of current defines the amplitude of the sound.

However, the coding of sounds is still poorer than in the normally functioning ear. First of all, the number of frequency bands is limited by the number of electrodes, which is less than in the normal ear. Secondly, there is mismapping in the allocation of frequency bands to electrodes. For instance, a filter at 1kHz is used to drive an electrode at 2kHz within the cochlea. Thirdly, temporal information relating to frequencies is not conveyed appropriately.

Therefore, temporal cues (rate of neuron firing, see subsection 2.2) cannot be used optimally to derive pitch information.

Figure 8. Presentation of the cochlear implant with its external components, 1) microphone, 2) speech processor and 3) external transmitter coil, and internal components 4) internal implant and 5) electrode array in the cochlea. (retrieved from: http://www.speechpathology.com/articles/article_detail.asp?article_id=44)



The cochlear damage degrades the ability to code TFS (Lorenzi et al., 2006) and the cochlear implant is not able to restore this. This implies that listeners with sensorineural hearing loss do not benefit from the dips in fluctuating noise to achieve better speech understanding. CIs are not able to restore the information obtained from TFS. Therefore, CI users are limited in perceiving speech when background sounds are present.

3. Language development in CI children

3.1 Effectiveness of CI in language development

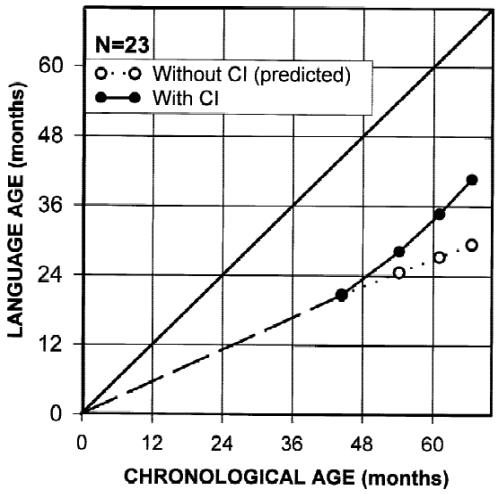
Most children who are born with a severe to profound hearing loss fall significantly behind their TD peers on language development. Delays on all of the major language domains exist, such as syntax and morphology (Cooper, 1967; Norbury et al., 2001; Hansson et al., 2007), pragmatics, semantics and phonology (Gilbertson & Kamhi, 1995; Briscoe, Bishop & Norbury, 2001). One of the major goals of cochlear implantation for prelingually profoundly deaf children is to provide sufficient auditory speech experience to enable them to use audition to develop speech and language.

It has been demonstrated that the cochlear implant has a beneficial effect on the acquisition of language. In the study by Svirsky et al. (2000), the actual language growth of profoundly deaf children who received a cochlear implant has been compared to the predicted language growth for these children if they had not received implants. Language growth is the function between language age and chronological age. For TD children, there is a strong correlation between chronological age and language age. This means that at the age of 2 these children have a linguistic age of 2 (as illustrated by the diagonal in Figure 9). The language growth for the CI children in the study of Svirsky et al. is predicted according to chronological age, residual hearing and the communication mode (oral-only or oral-and-sign) employed by the children.

The results of this study indicated that the CI children showed greater gains in language development than would be predicted for children who have not been implanted (see Figure 9). Moreover, the implant prevented the initial language delay from increasing further.

The study of Tomblin, Spencer, Flock, Tyler & Gantz (1999) included a group of CI children and HA children, who were considered implant candidates. From all children spontaneous language samples were obtained and transcriptions were analyzed on the Index of Productive Syntax (IPsyn). The CI children had higher scores than the HA children on all subscales of the IPsyn (i.e. noun phrase, verb phrase, questions/negations and sentence structure). A linear regression function was performed on the total IPsyn scores of the HA children and their chronological age. This regression function indicated the growth in productive syntax as a function of chronological age. When comparing the scores of the CI children to this regression function, it was observed that more than half the CI children scored significantly above the growth in productive syntax found for the HA children (see also Spencer, Tye-Murray & Tomblin, 1998). This study, as well as the study of Svirsky et al. (2000), points out that profoundly deaf children are better able to acquire oral language if they receive an implant than if they receive a hearing aid.

Figure 9. Average language age as a function of chronological age for the 23 CI children in the study of Svirsky et al. (2000) before implantation and at three intervals after implantation (black circles). The white circles represent the expressive language growth predicted for these same children, had they not received CI's. The diagonal present the language growth expected for a TD child (Svirsky et al., 2000, reprinted with permission from John Wiley and Sons, Chicester).



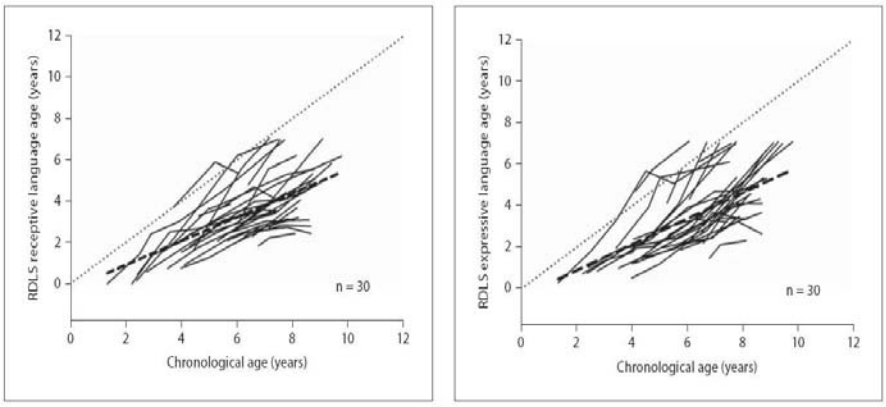
It has been suggested that the hearing of profoundly deaf children can now be improved by the implant to the point where it is equivalent to that of severely hearing-impaired children (Snik, Vermeulen, Brokx, Beijk & Van den Broek, 1997; Blamey et al., 2001). Accordingly, it was expected that CI children and HA children with severe hearing loss performed similarly on language measures. In the study of Blamey et al. (2001), CI children with a mean unaided hearing loss of 106dB and HA children with a mean unaided hearing loss of 78dB, aged 4 to 12 years, were tested on receptive vocabulary, receptive and expressive language and MLU. The results showed that there was little difference between the CI and HA children on any of the language measures. Therefore, the authors concluded that on language measures CI children perform like HA children with a mean hearing loss of about 78dB.

3.2 Variability in language outcomes

It is well known that CI children are characterized by their variability in language outcomes. Hay-McCutcheon et al. (2008) followed the language acquisition of 30 CI children longitudinally up to the age of 18. The language measures were derived from tests that were suitable for the child's age and

language abilities. The graphs in Figure 10 express the receptive (left-side) and expressive (right-side) language outcomes of the 30 CI children individually, as measured on the Reynell Developmental Language Scales (appropriate for children aged between 1 to 7 years). From both figures it can be observed that the language outcomes vary widely. Some CI children perform at or near the average of the TD children (dotted diagonal), whereas others perform far below the average performance of TD children.

Figure 10. The Reynell receptive (left) and expressive (right) language age is presented on the vertical axis. The chronological age is presented on the horizontal axis. Each solid line represents the data for 1 child. The dotted line represents the normative data. The dashed line represents the best-fit linear regression line. (Hay-McCutcheon et al., 2008, p.374, reprinted with permission from S. Karger AG, Basel).



The study of Duchesne et al. (2009) included 27 French-speaking CI children aged between 3 and 8 years, who received their implant between 8 and 28 months of age. The language measures included receptive and expressive language, receptive and expressive vocabulary and receptive grammar. As a group, the CI children performed within normal limits on all language components. However, individual analysis added a nuance to this general finding.

Four language profiles emerged from the individual analysis. The first profile included 4 CI children who performed within normal limits on all language measures. The second profile included 3 CI children who performed below the norm on all language measures. The CI children in the third profile had normal lexical abilities but performed poorly on receptive grammar, and the fourth profile included CI children who showed discrepancies across language domains (e.g. low scores on receptive vocabulary and grammar and scores within the normal range on expressive vocabulary).

There has been great interest in identifying factors that explain the observed variability in language outcomes of CI children. In a recent study by Geers et al. (2009), higher language outcomes were associated with higher PIQ scores, higher education of the parents, gender (girls scored higher than boys) and younger ages at implantation. Other essential factors are communication mode (oral-only or sign-and-oral) and educational setting (special or mainstream education).

To date, the majority of the literature has been directed towards the effect of age at implantation; the earlier a child receives the CI, the greater the child's potential to benefit from the optimal time periods for neural development.

3.3 Sensitive period and age at implantation

It is generally acknowledged that early intervention in the case of a hearing impairment is of vital importance for language acquisition. The organization of neural connections for language systems depends on auditory experience within a certain time-window (Lenneberg, 1967; Locke, 1997; Kuhl et al., 2005). Two different views exist with respect to this time-window for neural connectivity. They are referred to as respectively the sensitive or the critical period. The sensitive period is defined as a time in development in which the child is particularly responsive to auditory experience. Alternatively, the critical period is viewed as a time in which auditory experience must occur to organize the neural connections in the brain. Under such a view, the absence of auditory experience is likely to result in irreversible language delays. In contrast, sensitive periods do not necessarily result in irreversible language delays (Tomblin et al., 2007).

The implementation of the universal auditory screening for newborn children has made early detection and intervention of hearing loss possible. It has been shown that the children whose hearing loss was identified by 6 months of age had significantly higher expressive and receptive language scores as compared to children identified after the age of 6 months. The effect of early intervention was evident across age, gender, socioeconomic status, ethnicity, cognitive status, degree of hearing loss, mode of communication and presence/absence of other disabilities (Yoshinaga-Itano, Sedey, Coulter & Mehl, 1998).

An overwhelming body of literature reports better language outcomes for children who received their implant early in life (e.g. Kirk et al., 2000; Kirk et al. 2002; Svirsky et al., 2004; Tomblin et al. 2005; Dettman et al. 2007; Hay-McCutcheon et al., 2008; Geers et al., 2009). Nicholas & Geers (2007) analyzed spontaneous language samples of 76 children who received their CI between their 1st and 3rd birthdays. Spontaneous language samples were collected twice, at the age of 3.5 and 4.5. The spontaneous language samples were analyzed on MLU, number of bound morphemes and number of different bound

morphemes. Results revealed that CI children with younger ages at implantation produced longer utterances, more bound morphemes and a greater number of different bound morphemes. Below an implant age of 24 months, consistent advantages in language outcomes were present at any given duration of auditory speech experience. This means that children who received their implant at 12 months had better language outcomes as compared to children implanted at 18 months.

The earlier-the-better approach to cochlear implantation nowadays includes children who received their implant before their first year of life. Dettman et al. (2007) reported language outcomes for 19 CI children with a mean age at implantation of approximately 10 months and 87 CI children with a mean age at implantation of approximately 20 months. Language measures included the language comprehension and expression subscales of the Rossetti Infant-Toddler Language Scale (RI-TLS). The results of this study indicated a significant difference in the average growth rate for language comprehension and expression between the early (<12 months) and late (12-24 months) implanted children. Moreover, some of the early implanted children demonstrated language comprehension and expressive development comparable to that of their TD peers.

Partially overlapping results were found in the study of Holt & Svirsky (2008). This study included four groups of CI children divided according to their age at implantation. The first group of CI children received their implant < 12 months of age, the second group between 13 and 24 months of age, the third group between 25 and 36 months and the fourth group between 37 and 48 months of age. Holt & Svirsky report that the majority of the CI children had delayed language skills. However, there was a trend for the younger implanted children to perform within 2 SD of the mean of the TD children as compared to the older implanted children. On receptive language development was an advantage found for implanting children <12 months of age versus waiting until the child is between 1 and 2 years. No such effect for implantation <12 months was observed for expressive language development.

For infants implanted younger than 12 months, language benefits should be considered against the potential risks for misidentifying hearing loss and anesthetic risks in infancy. In an overview of the literature on both topics, Holt & Svirsky (2008) conclude that the anesthetic risks and the risk of misidentification are relatively low. Therefore, they argue that the earlier a child receives his/her implant the faster the child will approach age-appropriate language levels.

Accordingly, a more promising hypothesis has been put forward, that CI children who receive their implant early in life exhibit language skills that are on a par with their TD peers before they enter nursery school (Nicholas & Geers, 2007). In the same vein, a longitudinal investigation of 9 CI children of Coene et al. (to appear/a) indicates that CI children who received their implant before

the age of 16 months had accelerated language growth rates. This allows them to catch up with their TD peers at later language developmental stages.

3.4 Variability across language domains: grammatical morphology

The suggestion that young implanted CI children may catch up with their TD peers is based on very broad language measures of general language achievement, such as the Reynell or CELF test. However, it is well known that language consists of a range of sub-skills, such as phonology, syntax and morphology. Young & Killen (2002) reported the outcomes on language subtests for 7 CI children with a mean age of 8;7 years. They found that the scores on semantics and expressive vocabulary were well within the normal limits, whereas expressive syntax and morphological development were areas of weakness for the CI children (see also Geers et al., 2009). With respect to receptive grammar, Hawker et al. (2009) report that CI children who scored typically on a range of clinical language tests fell significantly behind their TD peers.

Szagun (2000) followed 10 CI children longitudinally after they received their implant between 1;2 and 3;10 years. Spontaneous language samples were collected for these children and analyzed on MLU and grammatical morphology (noun plural, inflectional morphology and determiners). Results revealed that by and large all CI children had moved into productive grammar one and a half years after implantation. Compared to TD children matched on MLU, the overall grammatical progress of CI children was generally slower.

Individual longitudinal grammatical developmental data of 22 CI children is reported in Szagun (2002). This study showed considerable individual differences in the development of grammatical morphology. Ten CI children compared well with MLU-matched TD children on grammatical competence, whereas 12 CI children did not. The latter group did not seem to catch up within the time period of 3 years after implantation.

This corresponds with the results of Nikolopoulos, Dyar, Archbold & O'Donoghue (2004), who found that 3 to 5 years after implantation only 40% to 67% of the CI children were able to reach the 25th percentile of their TD-peers on receptive grammar. Fewer than 50% of the 8 to 9-year-old CI-children in the study of Geers (2004) produced morphemes within the range of TD children. These results seem to suggest that difficulties in receptive and expressive grammatical morphology are persistent for some of the CI children.

Persistent difficulties in the use of grammatical morphology have also been reported for children with HAs. It has been shown that 8 to 10-year-old HA children show better performance on tasks eliciting verbal morphemes (e.g. third person *–s* and past tense *-ed*) than 6-year-olds (Norbury et al., 2001; Hansson et al., 2007). Nevertheless, despite these improvements, the observed delay in the development of verbal morphology does not seem to be reversible,

at least not for all HA children: by the age of 11-15 years, more than 30% of the HA adolescents have lower-than-normal scores on expressive grammar and grammatical judgment tasks (Delage & Tuller, 2007).

4. Specific Language Impairment

4.1 Definition

Children with SLI exhibit deficits in language development that cannot be explained by other problems, such as hearing impairments, neurological damage or mental retardation (Leonard et al., 1997). It is said that the diagnosis of SLI is based on exclusionary conditions instead of conditions for inclusion (Aram, Morris & Hall, 1993; De Jong, 1999). The lack of an appropriate definition of SLI in children poses problems for the reliable identification of SLI. In an attempt to estimate the prevalence of SLI in the population of TD children, Tomblin et al. (1997) found that between 7.4% of the monolingual English-speaking nursery school children presented delayed language development.

4.2 Delayed verbal morphological development

SLI children show deficits in a range of language areas, but they have a more serious deficit in the acquisition of grammatical morphology. For instance, Leonard et al. (1992) found that English and Italian-speaking SLI children omitted grammatical morphemes more often in obligatory contexts than the MLU-matched TD children. For the English children, grammatical morphemes included articles, plurals, 3rd person singular inflections, regular past inflections, irregular past and copulas. For the Italian children, grammatical morphemes included articles, plurals, 3rd person singular inflections, gender agreement in adjectives and clitics.

It has been shown that the production of verbal morphology in particular is difficult for SLI children (e.g. Conti-Ramsden & Jones, 1997; Bedore & Leonard, 1998, Conti-Ramsden, 2003, Marchman et al., 1999). Bedore & Leonard (1998) performed discriminant analysis on a group of 38 children of whom 19 had SLI and 19 had typical language development. The aim of discriminant analysis is to find language measures that reliably distinguish SLI children from TD children. The discriminant analysis in the study of Bedore & Leonard included three variables, MLU and two grammatical morpheme composites. The first composite included verbal morphemes, which are regular past tense inflections, regular 3rd person singular present inflection, copula and auxiliary *be* forms. The second composite included possessive *'s*, plural *–s* and articles. Results revealed that especially the verbal morphemes composite was successful in discriminating between SLI and TD children, with a small improvement in classification of SLI when MLU was added.

The verbal morphemes included in the composite score of Bedore & Leonard have been found to be difficult for SLI children across studies. Oetting & Horohov (1997) found limited productivity of the English regular past tense for the 6-year-old SLI children as compared to the MLU-matched TD children. Rice, Wexler & Hershberger (1998) found in their study that the 8-year-old SLI children still performed below the 100% correct use of the regular past tense, 3rd person singular and the auxiliary *be* in obligatory contexts. In contrast, the TD children in this study already increased to 100% correct use of verbal morphemes in obligatory contexts between the ages 3 and 4. The Swedish SLI children, aged between 4;3 and 5;7, in the study of Hansson, Nettelbladt & Nilholm (2000) produced less present copulas, present tense inflections and regular past tense morphemes as compared to their TD-peers. Also for Dutch SLI children it has been observed that they produce less regular past tenses in obligatory contexts as compared to chronological matched TD children and language matched TD children (De Jong, 1999).

4.3 SLI accounts

A number of hypotheses have been put forward to explain the observed deficit in the production of morphology in SLI children. These hypotheses range from language-specific accounts to general cognitive accounts. The latter accounts are based on the finding that SLI children also perform more poorly than their TD peers on non-linguistic tasks, rather than on linguistic tasks only. The hypotheses that are presented in this chapter do not provide an exhaustive list of SLI hypotheses. It is a general overview of the hypotheses that received a great deal of attention in the literature.

4.3.1 A genetic language-specific disorder

In TD children, early verbal morphological development is characterized by the presence of two types of declarative sentences: one with a finite verb (i.e. the target-like adult form) and one with a non-finite verb (i.e. deviating from the target grammar). In the literature, this stage of development has been labeled the Optional Infinitive stage (OI) (Wexler, 1994), as early child grammar seems to optionally allow the finite verb to be replaced by a non-finite form (see chapter 3, section 2).

Between the ages of 2 and 3, TD hearing children steadily abandon the use of infinitives in favor of target-like finite verb forms (Phillips, 1995, 1996). According to Rice, Wexler & Cleave (1995) and Wexler (1998), SLI children have an Extended Optional Infinitive (EOI) stage, i.e. they remain in the OI stage for a longer period of time as compared to their TD peers. The underlying cause of this EOI stage is assumed to be genetic, as the switch from

the OI stage to the target-like finite stage is a maturational process under the guidance of a genetic program (Wexler, 1998).

Other researchers subscribe to the language-specific genetic hypothesis. Bishop et al. (1999) and Bishop (2006) have shown that monozygotic twins - obviously genetically identical - compared to each other in SLI diagnoses more closely than dizygotic twins. Bishop and colleagues suggest that SLI resembles a complex genetic disorder that runs in families without a clear dominant or recessive pattern of inheritance.

4.3.2 A general cognitive disorder

Besides the genetic-innate hypothesis, which attributes the language impairment to language itself, more general cognitive accounts have been proposed. Many authors suggest that SLI children have limited processing capacities (Joanisse & Seidenberg, 1998; Miller, Kail & Leonard, 2001; Hayiou-Thomas, Bishop & Plunkett, 2004; Montgomery & Leonard, 2006) Such limited processing capacities can refer to either the speed of processing or to limitations in working memory.

Auditory processing disorder

Tallal & Piercy (1974, 1975), Tallal & Stark (1981), Benasich & Tallal (2002a) attribute the language difficulties of the SLI children to a central auditory perceptual deficit in temporal analysis. Using the results of several series of studies as support, Tallal and colleagues conclude that SLI children are impaired in their perception of verbal stimuli that are characterized by brief or rapidly changing temporal cues. For instance, they showed that SLI children needed more trials to correctly discriminate between the two syllable pairs [ba-da] and [da-ta] as compared to their TD peers. The first syllable pair, [ba-da], is characterized by an initial brief transitional period in which the formants move towards the steady-state portion of the vowel. The second syllable pair, [da-ta], differs in voice-onset-time, that is the interval between the release of the burst and the onset of voicing. Importantly, the discrimination difficulties disappeared when duration of the verbal stimuli was decreased or protracted.

Limited working memory capacity

Limitations in working memory capacity refer to reduced processing and storing of information in the working memory. This means that successfully comprehending and producing language relies on the ability to actively maintain and integrate linguistic information in working memory (Ellis-Weismer, 1996). Limitations in working memory are demonstrated with non-word repetition tasks. In these tasks children are asked to recall nonsense words. These words

range in syllable length so as to increase memory load. It has been shown that SLI children have significantly lower scores on these non-word repetition tasks as compared to their TD peers. These tasks, in addition to language measures, can therefore assist in identifying SLI children (Ellis-Weismer et al., 2000). According to Baddeley (2003) poor scores on the non-word repetition task are due to a deficit in the phonological storage of the working memory. In the working memory model of Baddeley, Gathercole & Papagno (1998), retention of the information is supported by a sub-vocal rehearsal loop. This loop crucially depends on acoustic and phonological representations of the input material.

Surface account

It has been pointed out in Chapter 1 that the joint operation of perceiving a grammatical morpheme with low phonetic substance and determining its grammatical function seems challenging for SLI children (Leonard et al., 1997). Phonetic substance has been defined primarily in the physical term of relative duration and acoustical terms of unstressed syllables, lower fundamental frequency and amplitude (Leonard et al., 1997; Montgomery & Leonard, 2006).

Under the so-called Surface Account as proposed by Leonard and colleagues, the acquisition of (English) morphemes is dependent on their physical and acoustic properties (Leonard et al., 1997). Crucially, this account assumes that SLI children can perceive low phonetic substance morphemes in isolation (Leonard et al., 2003) but that *'The difficulty seems to rest in the combined effects of perceiving the form and treating it as a morpheme'* (Leonard et al., 1992 p:1077). Regarding the acquisition of grammatical morphemes, not only must a child perceive a grammatical morpheme, he or she must also place it in the proper cell of the paradigm (Pinker, 1984). This additional operation, together with the low perceptual salience of the grammatical morpheme, can result in incomplete processing of the morpheme.