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

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

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The research reported here was conducted in the context of the Dutch Organization for Scientific Research (NWO) funded VIDI-project: *morphosyntactic development of children with cochlear implants. A comparison with children using hearing aids, normally hearing children and children with SLI* awarded to prof. dr. Martine Coene, principal investigator.

Acknowledgements

Writing a dissertation is a solo project; doing research is not. As the topic of this dissertation involves the acquisition of language, doing research was only possible thanks to the many children willing to talk about themselves and their families in front of the camera. I gratefully acknowledge all children, parents, teachers, language pathologists and school boards of *KIDS* in Hasselt, *Jonghelinckshof* in Antwerp, *Bertha Mullerschool* in Utrecht, *Triangel* in Hengelo, *Sint Jozefschool* in Antwerp and *Sint Laurensinstituut* in Wachtebeke.

I had the privilege to spend the first three months of my research at the CNTS (University of Antwerp) and The Eargroup in Antwerp-Deurne. I would like to thank my fellow (and former fellow) researchers at the CNTS. Also thanks to the staff of The Eargroup for teaching me about audiology and cochlear implants and for their hospitality. Special thanks to Paul Govaerts, head of The Eargroup, for giving me valuable comments on my data analysis. My stay in Antwerp gave me the opportunity to join a group of colleagues who were all doing research on language acquisition and were working with cochlear-implanted children. Working in a team inspires and makes hard work easier.

For this dissertation almost 100 spontaneous speech samples have been recorded. Anyone who has worked with this kind of data knows that it is a time consuming business to get these recordings ready for analysis. I had the luck of working together with Agnita, Annemie, Coby, Eva, Ineke, Karen, Martine & Øydis. Thanks to all! I also want to thank Eva and Charlotte for helping me preparing the experiment and testing the children.

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I would also like to thank my friends for being interested in my research and above all in me. During the past three years, I sometimes lost myself in this research and dissertation. I am very grateful to have friends who showed me that, and I quote Maarten, '*there is more to life than a dissertation*'. That is true and I hope that within a couple of years we will go on holiday without books and articles!

I warmly thank those individuals whose names I am not supposed to mention according to the Leiden tradition. They have encouraged me to do more than I thought I could - which is more than I had ever expected.

Geloven in wat je doet is mij ingegeven door mijn ouders.

Leiden, March 2010

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CHAPTER 1

General introduction

Already in 1800, Alessandro Volta experienced that hearing could be stimulated with electrical current. He connected batteries to two metal rods, which he inserted in his ear. Volta described the sensation as 'une recousse dans la tête', followed by a sound similar to that of boiling thick soup. This rather uncomfortable experiment was not repeated too often.

Some 157 years later, the battery-supplied electrical current was first used to stimulate the auditory nerve in deafness. In the 1960s and 70s, great advances were made in the clinical applications of the electrical stimulation of the auditory nerve. This resulted in a device with multiple electrodes driven by an implantable receiver and speech processor, the Cochlear Implant (henceforth CI). In 2009, 188,000 severely to profoundly deaf individuals worldwide received auditory input by means of a CI.

The technological advances of the CI and the effectiveness of this prosthetic device in speech perception has placed the emphasis on lowering the age criteria for implantation from adults to infants. In the Netherlands, severely to profoundly deaf children receive their implant generally between 18 and 24 months of age with a trend towards implanting between 12 and 18 months (Ministerie van Volksgezondheid, Welzijn en Sport, 2004). This trend has continued; in August 2009, for instance, breaking news reported the bilateral implantation of a 4-month-old boy in the Netherlands (VU medisch centrum, 2009).

In Belgium, cochlear implantation within the first year of life has been implemented since the year 2000 (Schauwers, 2006). Already in 2000, the University of Antwerp, in close collaboration with The Eargroup (Antwerp-Deurne), started to collect longitudinal speech samples of very early implanted CI children (between 0;6 to 1;9 years). The purpose of this data collection was to investigate the effect of a CI on the development of oral language. The present dissertation pursues this investigation. For the present study, the existing corpus has been enlarged with speech samples from CI children as well as from hearing impaired children wearing classical hearing aids, and children with specific language impairments. The present research is the result of a collaborative project carried out at Leiden University, the University of Antwerp and the Eargroup, and is funded by the Dutch Organisation for Scientific Research (NWO) VIDI project: *The morphosyntactic development of children with cochlear implants. A comparison with children using hearing aids, normally hearing children and children with SLI.*

Aim of this dissertation

Before the advent of the CI, language delays were particularly prevalent in the severely to profoundly deaf children who did not have sufficient gain from conventional Hearing Aids (henceforth HA) (Cooper, 1967; Gilbertson & Kamhi, 1995; Svirsky, Robbins, Kirk, Pisoni & Miyamoto, 2000; Norbury, Bishop & Briscoe, 2001; Hansson, Sahlén & Mäki-Torkko, 2007). For these children, the efficacy of the CI in the development of oral language has been shown systematically. Nowadays, for some of the CI children the expectation is that they will achieve language skills comparable to their Typically Developing (henceforth TD) peers (Nicholas & Geers, 2007; Coene, Schauwers, Gillis, Rooryck & Govaerts, to appear).

However, further analysis of the language data reveals that the development is not uniform across language domains. This means that some language domains are more difficult to master than others: CI children tend to reach age-appropriate lexical skills more easily compared to syntactic and grammatical skills (Geers, Moog, Biedenstein, Brenner & Hayes, 2009; Duchesne, Sutton & Bergeron, 2009).

Therefore, the aim of the present study is to enhance our knowledge of whether a CI provides sufficient access to auditory speech input to acquire grammatical morphemes. In this dissertation we concentrate on the acquisition of verbal morphology in CI children aged between 4 and 7 years.

Stages in Language Development

Language development starts from birth and continues to the tenth year of life (Gillis & Schaerlaekens, 2000). Language development occurs in four phases. The **first phase** (0 – 12 months) is the prelingual phase, in which the infant produces vocal sounds that lead to babbling. The first words occur in the **second stage** (>12 months). In this stage, words are put together to form 'telegraphic-like' utterances. Children also use *formulaic* utterances. Formulaic utterances are holistic phrases, that are not analyzed on grammar. In this stage, children are not aware that words consist of different elements such as morphemes. In phase 2 they collect utterances which are subjected to analysis in the **third stage** (>20 months). The stored utterances are decomposed and analyzed on structure. The analysis locates recurring elements within and across utterances, which enables a child to learn the rules of the language. The integration of systemic rules in the acquisitive systems allows for a rapid increase in lexical capacity and syntactic processing. This elaboration and integration of rules appears in **stage four** (>3 years) (Locke, 1997).

Figure 1. The four developmental stages as outlined by Locke (1997 p:268) (reprinted with permission from Elsevier, Oxford).

Phases and Processing Systems, and Neural and Cognitive Mechanisms, Associated with the Development of Linguistic Capacity, along with the Corresponding Areas of Language

Age of onset	Developmental phases and systems	Neurocognitive mechanisms	Linguistic domains
Prenatal	Vocal learning	Specialization in social cognition	Prosody and sound segments
5–7 months	Utterance acquisition	Specialization in social cognition	Stereotyped utterances
20–37 months	Analysis and computation	Grammatical analysis mechanism	Morphology Syntax Phonology
3+ years	Integration and elaboration	Social cognition and grammatical analysis	Expanded lexicon, automatized operations

Sensitive phases in language development

In 1967, Lenneberg related the acquisition of language to the plasticity of the brain. He proposed that between the age of 3 and early teens, children are especially sensitive to acquiring language. He labeled this the critical period. After the age of 10, primary language acquisition comes to be inhibited as the brain has reached its mature state. Lenneberg argued that *'the language skills not acquired by that time, except for articulation, remain deficient for life'* (1967 p:158). The developmental constraints on language learning are somewhat smoothened in the view of the sensitive period. The period for optimal language acquisition may never close completely; it is rather a case of sensitivity being diminished (Tomblin, Barker & Hubbs, 2007).

Locke (1997) argues that each phase in language development has its own critical/sensitive period, and that these periods occur in a fixed and overlapping sequence. The four phases in language development each have their own commitment of neural resources. An essential element in the neural organization of the brain and subsequent language development is early perceptual experience (Locke, 1997). Early exposure to auditory input changes future learning abilities, resulting in long-term language learning effects (Ruben, 1997; Kuhl, 2004; Kuhl, Conboy, Padden, Nelson & Pruitt, 2005; Zhang, Kuhl, Imada, Kotani & Tohkura, 2005).

The notion of the critical/sensitive period has motivated the decrease in age at implantation. Early auditory exposure allows the child to optimally use the critical/sensitive period for language learning. The beneficial effect of early implantation on language acquisition has been reported frequently in the literature (e.g. Kirk, Miyamoto, Ying, Perdew & Zuganelis, 2000; Kirk, Miyamoto, Lento, O'Neill & Fears, 2002; Svirsky, Teoh & Neuburger, 2004; Tomblin, Barker, Spencer, Zhang & Gantz, 2005; Dettman, Pinder, Briggs, Dowell & Leigh, 2007; Hay-McCutcheon, Kirk, Henning & Gao Rong Qi, 2008; Geers et al., 2009). On that account, our aim is to analyze the verbal morphology production of CI children as a function of their age at implantation.

Delayed language development

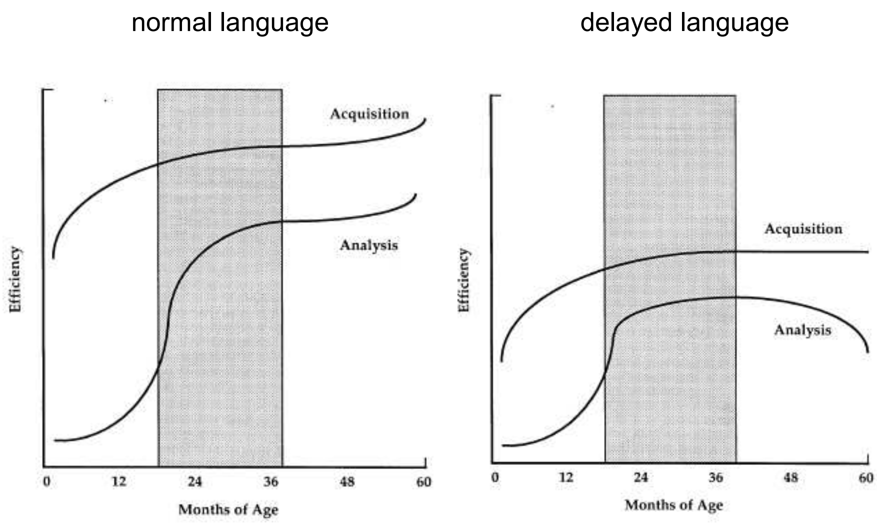
An important aspect of the language developmental theory of Locke (1997) is that the developmental phases are interdependent. This means that the storage of utterances (phase 2) triggers or reinforces the activation of the analytical stage (phase 3). This is presented in Figure 2. Delayed language occurs when the shortage of lexical items prevents the use of analytical mechanisms to acquire grammar. The shortage of lexical items can be due to reduced input. Reduced input may relate to a reduced *effective* exposure to linguistic behavior, as in the case of Specific Language Impairment (henceforth SLI), or to the reduced *auditory* exposure to speech input, as in the case of a hearing impairment (p:282). On that account, the language difficulties of children with SLI and hearing impairments should be comparable, regardless of any different underlying problem (cognitive versus auditory).

Therefore, the present dissertation includes children with SLI and children who wear classical HAs. The purpose of including these clinical groups is to compare the language scores of the CI children with those obtained by the HA and SLI children. These comparisons have the potential to contribute to our knowledge of the prerequisite for language development.

Delayed acquisition of morphology

It has been argued in the literature that the perceptual salience of morphemes partially predicts the order of morpheme acquisition (Goldschneider & Dekeyser, 2001). Perceptual salience refers to the phonetic substance, syllabicity and sonority of the morpheme. The rationale is that morphemes that are more perceptually salient are acquired before morphemes that are less perceptually salient. Besides the physical properties of morphemes, perceptual salience is defined in the acoustical terms of stress, fundamental frequency and amplitude (Leonard, Eyer, Bedore & Grela, 1997; Montgomery & Leonard, 2006).

Figure 2. Phases and systems in which linguistic capacity develops. The stippled area is a critical period in which utterance acquisition must reach a certain level of demonstrated efficiency in order to fully activate and stabilize an utterance-analytic mechanism that, for its part, is intrinsically 'ready' to respond to experience (reprinted with permission from Elsevier, Oxford).



Morphemes are usually unstressed syllables, are lower in fundamental frequency and amplitude and are therefore more difficult to acquire than lexical items.

For SLI children, it has been shown that the production of grammatical morphology in particular is difficult (e.g. Conti-Ramsden & Jones, 1997; Bedore & Leonard, 1998; Conti-Ramsden, 2003, Marchman, Wulfeck & Ellis-Weismer 1999). Leonard and colleagues (1992, 1997, 2003) attribute the deficit in grammatical morphology of SLI children to the combined effect of perceiving the grammatical morpheme and hypothesizing its function. This is called the Surface Account.

For CI children it has been demonstrated that they produce the uncontractable copula more often in an elicitation task as compared to the plural morpheme and past tense morpheme (Svirsky, Stallings, Lento, Ying & Leonard, 2002; Ruder, 2004). This developmental pattern is different from the pattern observed for TD and SLI children, who acquire the plural morpheme before the copula. As such, Svirsky et al. (2002) proposed the Perceptual Prominence Hypothesis, which states that the developmental pattern of morphemes for CI children is predicted by the perceptual salience of these morphemes.

As both accounts stress the importance of perceptual salience, our purpose is to analyze the production of verbal grammatical morphemes in the light of the perceptual salience of these morphemes. This type of analysis aims at enhancing our knowledge of the role of perceptual salience in the acquisition of grammatical morphemes.

Research questions

Based on the aforementioned observations, this dissertation concentrates on the following research questions:

- How do CI children aged between 4 and 7 years compare to their *a)* TD peers, *b)* HA peers and *c)* SLI peers in their verbal morphological development?
- Is there an effect of early implantation in the development of verbal morphology?
- Is there an effect of perceptual salience of grammatical morphemes in the acquisition of these morphemes?

Outline of this dissertation

Chapter 2 gives an overview of the three clinical groups included in this dissertation, which are the CI, HA and SLI children. The hearing-impaired children included in this dissertation have a sensorineural hearing loss. As such, this chapter starts with a short overview of speech perception in the normally functioning cochlea and dysfunctioning cochlea, after which both prosthetic devices (i.e. the cochlear implant and hearing aid) are discussed. This chapter ends with an overview of the literature on language acquisition of the CI, HA, and SLI children.

Chapter 3 presents an overview of the literature on the acquisition of tense and agreement in TD children. A puzzling phenomenon in the acquisition of agreement is that children aged between 2 and 3;6 use infinitive verbs in contexts where a finite verbs is appropriate in the adult speech. However, at the same time, they also produce finite verbs. The co-occurrence of infinite and finite verbs is fairly well documented and several accounts are available to explain this phenomenon. These accounts are summarized in this chapter. In this chapter, we also outline the temporal reference system and how children acquire this system. Special attention is given to the models related to the acquisition of regular and irregular past tense as this underlies the experimental task in chapter 6. We point out that the acquisition of the temporal reference system is related to cognitive maturation.

In **chapter 4**, we examine the STAP test on psychometric criteria. In this dissertation, we analyze spontaneous speech samples using a standardized language test, the STAP test. Prior to the implementation of this test, we conducted a small-scale study to investigate the validity and reliability of the language measures included in this test.

Chapter 5 consists of two sections. In ***section 5.1***, we compare the CI children with their HA peers on their production of verbal morphology in spontaneous speech. The scores of the CI children are analyzed as a function of their age at implantation. The scores of the CI and HA children are analyzed in the light of the Perceptual Prominence Hypothesis. In ***section 5.2***, we compare the CI children with their SLI peers on their production of verbal morphology in spontaneous speech. In this section, the scores of the CI and SLI children are analyzed in the light of the Surface Account.

In **chapter 6**, we examine the production of past tense morphology by CI and SLI children in spontaneous speech and on an experimental task. The experimental task included TD children, which allows for a comparison between both clinical groups with their TD peers. For CI children, further analysis investigates the effect of age at implantation in the production of past tense. This chapter starts with an overview of the acquisition of productive past tense morphology by TD and SLI children.

In **chapter 7,** general conclusions, directions for future research and clinical implications are reported.

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.

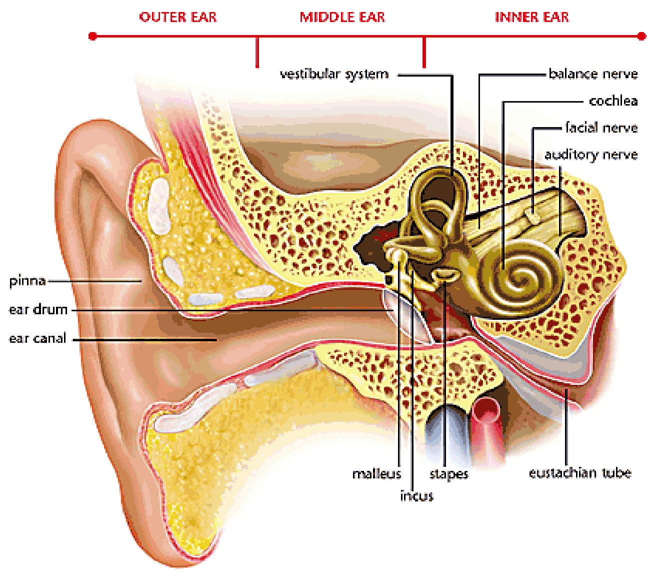
This chapter will end with the description of the SLI children and the accounts that have been given to explain their language difficulties (section 4).

2. Hearing impairment and intervention

2.1 Anatomy of the ear

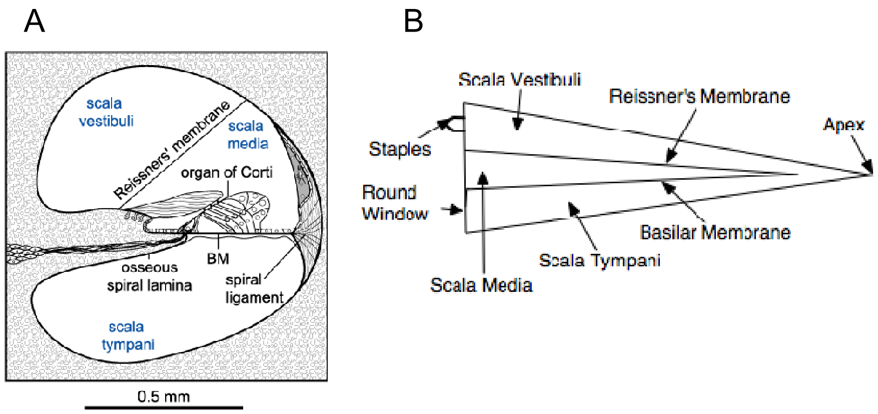
The ear can be divided into three sections, which include the outer, middle and inner ear (see Figure 1). The outer ear is made up of the ear flap (pinna) and the ear canal which is approximately 3 cm in length. The middle ear consists of the tympanic cavity, which starts with the ear drum (tympanic 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.

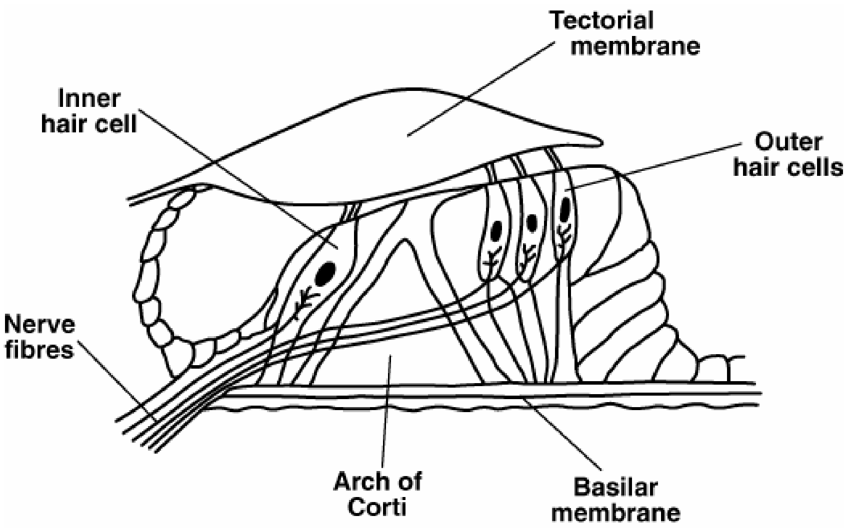
Figure 2. Cross section of the cochlea. Panel A shows the three compartments, which are divided by the basilar membrane (BM) and Reissner's membrane (retrieved from: *www.bai.ei.tum.de/research*). Panel B shows a schematized unrolled cochlea (retrieved from: *www.postaudio.co.uk/education/acoustics/ear.html*).



2.2 Auditory perception

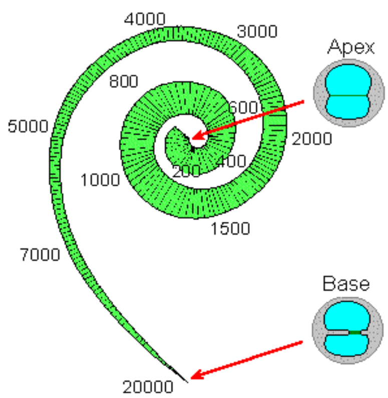
The waves in the scala tympani are transmitted to the endolymph in the scala media. As a result, the basilar membrane starts to vibrate. Subsequently, this causes the organ of Corti to move. The organ of Corti has one row of Inner Hair Cells (IHC) and three rows Outer Hair Cells (OHC) (see Figure 3). 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).



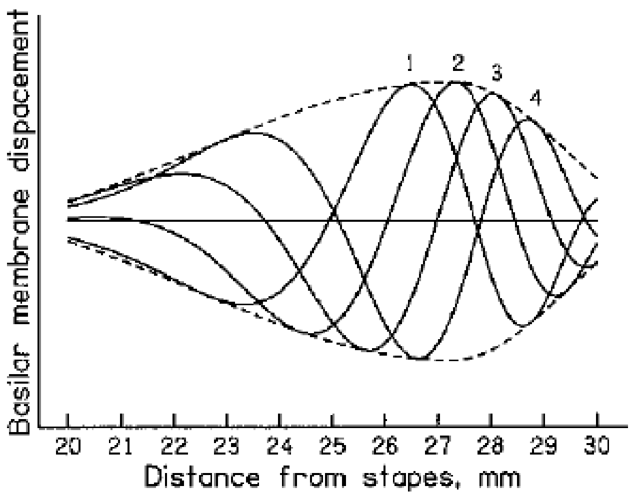
The basilar membrane's respons to sounds is affected by its mechanical properties. At the base, the basilar membrane is stiff and narrow. Towards the apex, the membrane becomes wider and less stiff. The basilar membrane has a tonotopic structure, which means that each frequency has its own place on the 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

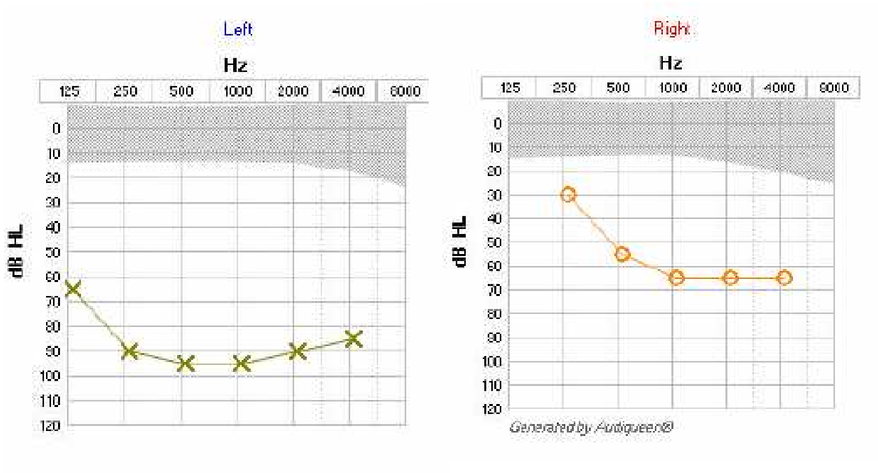
Damage to the hair cells disrupts the link between the middle ear and the auditory nerve, causing sensorineural hearing loss. Sensorineural hearing loss leads to a decrease in detecting and discriminating sounds. The reduced discrimination is caused by a loss in frequency resolution. This means that 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).



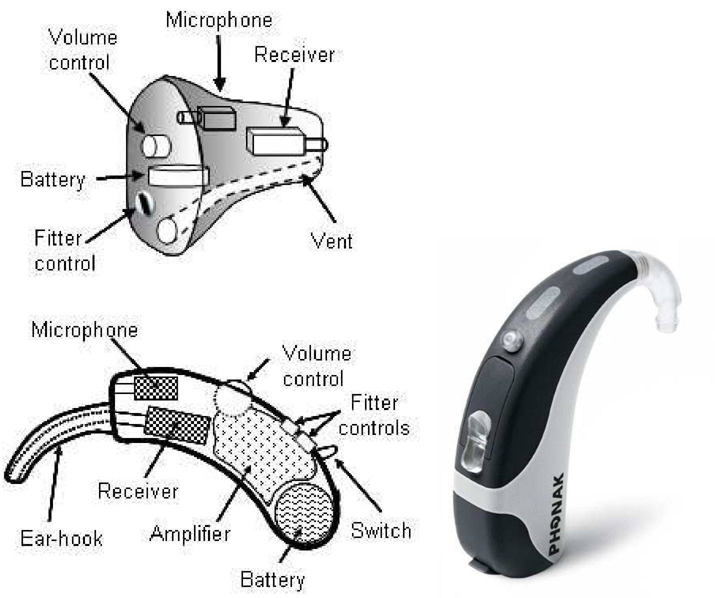
2.4 Hearing rehabilitation

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).

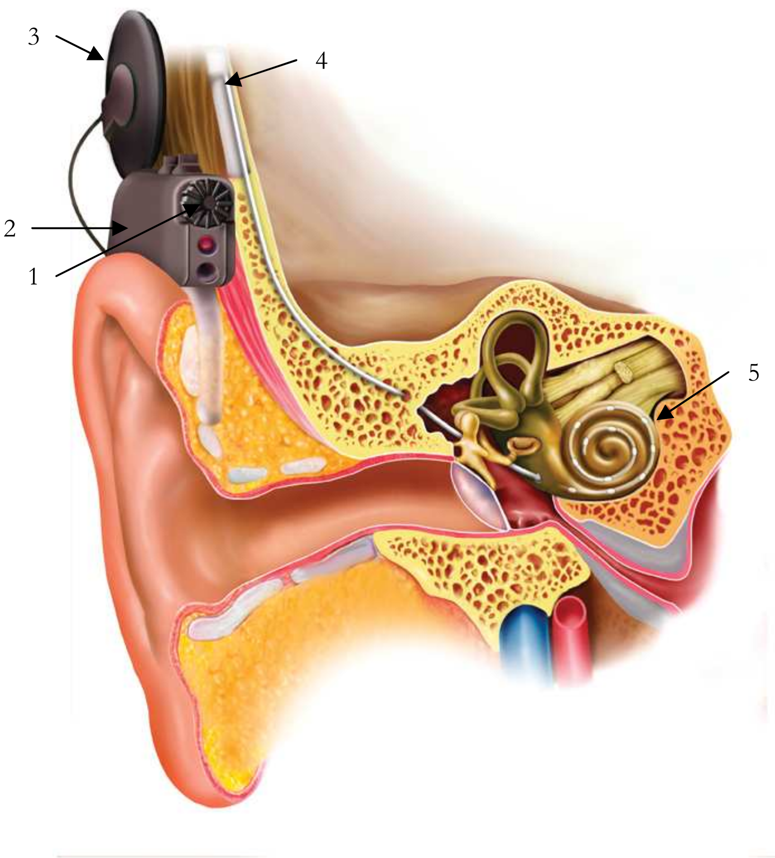
The *microphone* (see 1 in Figure 8) receives the acoustic signals, which are converted into an electrical signal in the *speech processor* (2). The output of the processor represents the informational aspects of speech in such a way that the implant recipient can perceive them. Several strategies are 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

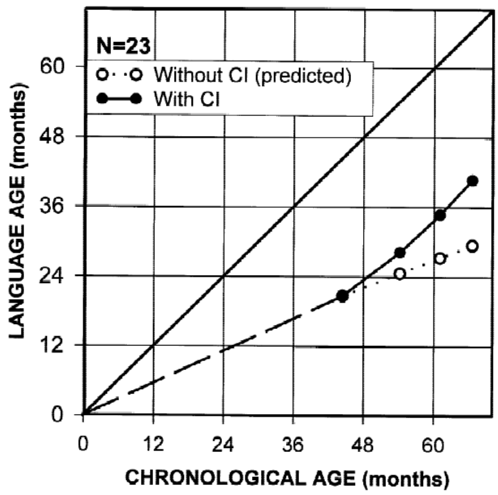
Most children who are born with a severe to profound hearing loss fall significantly behind their TD peers on language development. Delays on all of the major language domains exist, such as syntax and morphology (Cooper, 1967; Norbury et al., 2001; Hansson et al., 2007), pragmatics, semantics and phonology (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).

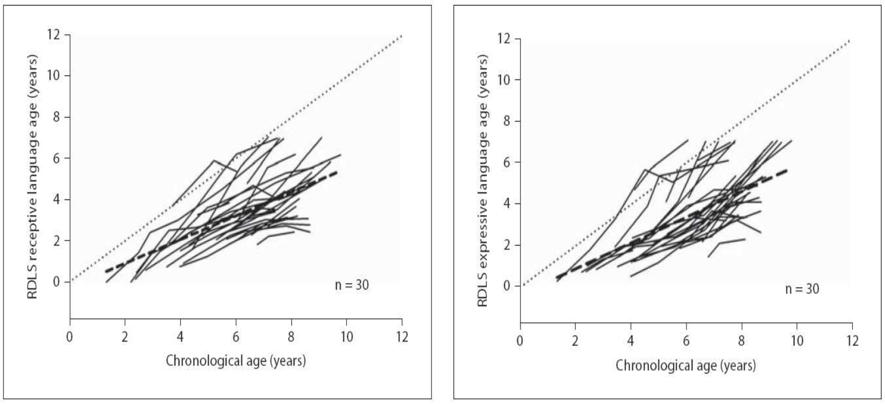


It has been suggested that the hearing of profoundly deaf children can now be improved by the implant to the point where it is equivalent to that of severely hearing-impaired children (Snik, Vermeulen, Brokx, Beijk & Van den Broek, 1997; Blamey et al., 2001). Accordingly, it was expected that CI children 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.

CHAPTER 3

Background: The acquisition of agreement and tense

1. Introduction

In some languages, including Dutch, children go through a stage in which finite and infinite verbs co-occur in their speech. This has been called the Optional Infinitive stage. This stage is fairly well documented and several accounts have been put forward to explain this phenomenon. We elaborate on the acquisition of finiteness in section 2 of this chapter.

In section 3, we summarize the literature on the acquisition of tense. The early productions of infinitives seem to imply that these are temporally free, because these verbs lack overt tense morphemes. In subsection 3.1, we will outline how, although overt tense is missing, the infinitives are not completely temporally free, but interact with aspect. The influence of aspect is also visible in children's early production of the finite past tense. We will elaborate on this in subsection 3.2. The last paragraph is dedicated to the acquisition of the regular and irregular past tense. This is an important topic in this dissertation as it underlies the elicitation task presented in chapter 6.

Finally, in the last section of this chapter, we will elaborate on research demonstrating the relation between the development of Theory of Mind (ToM) and language in general and more specifically between ToM and the acquisition of tense. Under a modular view of the human mind (Fodor, 1983), there is a close relation between language and cognition. Language is one of the 'modules' of perception, i.e. a fast, informationally encapsulated domain-specific system that interacts with the central cognitive system to which ToM belongs. As such, there is reason to expect a relation between the development of tense and ToM.

2. From infinite to finite

2.1 The Optional Infinitive stage

For a number of languages, in early verbal morphological development, children allow two forms 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 [1]). The use of non-finite declaratives in child speech has been documented for several languages:

(1) a. Die papegaai zo vliegen
That parrot so fly-INF
'That parrot flies like this'
b. Hij doet 't niet
He does it not
'He doesn't do it'
(Dutch, Haegeman 1995)

(2) a. Zahne pussen
Teeth brush-INF
b. Mein Hubsaube had Tiere din
My helicopter has animals in it
(German, Wexler 1994)

(3) a. Pas tomber bébé
Not fall-INF baby
b. Marche pas
Walks not
(French, Wexler 1994)

Depending on the theoretical point of view, this stage of development has been labeled either the Optional Infinitive stage (OI) (Wexler, 1994) or the Root Infinitive stage (Rizzi, 1993). Numerous accounts have been put forward to explain the so-called optional use of finiteness. These accounts are either based on a generative perspective on language development or usage-based perspective on language development. In this chapter we will only present the core-ideas of these accounts. It is beyond the scope of this dissertation to report the evidence of these accounts.

[1] Non-finite declarative sentences occur in adult grammar; however their use is more restricted than in child grammar (see Haegeman, 1995).

It has been claimed that Root Infinitives (henceforth RI) are not explained by a child's complete lack of inflection morphology. Poeppel & Wexler (1993) argue that inflection morphology is not randomly distributed among different types of subjects. In the longitudinal analysis of the German-speaking boy Andreas, they found that first and third person singular subjects always occurred with the correct inflection morpheme. In a detailed analysis of the Dutch-speaking girl Jasmijn, Jordens (1990) reports that at the age of 2 Jasmijn produced some errors in the use of first and second person singular inflection morphemes. However, a half year later these types of errors had disappeared.

Based on the analysis of longitudinal Italian child data (ages between 1;8 – 2;7), Guasti (1993) showed that children did not produce systematic agreement errors. The percentage of errors ranged between 1 and 3%. Moreover, Guasti shows that the target-like inflected verbs were not rote-learned; the same verbs occur with different inflection morphemes.

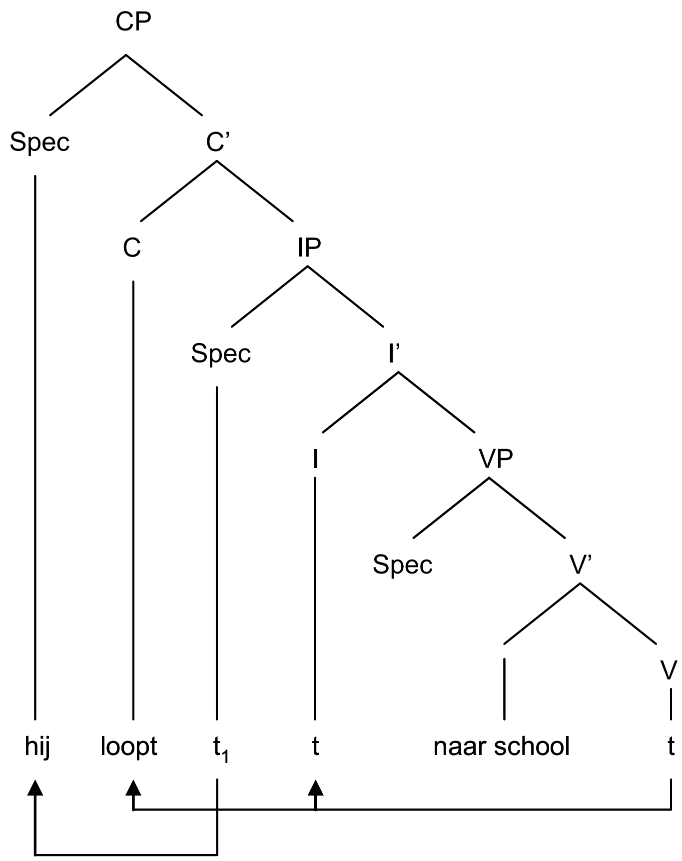
It is important to note that it is not claimed that children know *all* inflection morphemes by the age of 2 (see Poeppel & Wexler, 1993 p:9). For instance, Gillis & Schaerlaekens (2000) point out that number inflection (singular versus plural) is acquired after the age of 3. They report that, at this age, 30% of the utterances with a plural subject occur with singular inflection. This percentage has dropped to 14% at the age of 3;6. This indicates that the learning of agreement is a gradual process rather than a sudden burst of adult target-like inflection morphemes. With respect to the acquisition of the regular past tense, Brown (1984) has found that this morpheme is acquired well after the age of 3;6. An more detailed description of the acquisition of past tense is given in chapter 6.

2.2 Full *vs* Reduced Competence Hypothesis

The generative OI-accounts consider the use of RIs in declaratives as representative of a 'deficit' in children's syntax. From a generative perspective on language development, languages share an underlying syntactic representation of phrase structure, which is innate to humans. This is called Universal Grammar (UG). This syntactic representation is presented in Figure 2.

Language variation arises because elements in this representation can move or legally be omitted (e.g. subject-drop languages). These shifts in syntactic representation are language specific. An example of movement is the verb second (V2) phenomenon in Germanic languages. The (non-finite) verb is generated under VP and moves to C, picking up the inflection in I on the way. Therefore, the finite verb moves to the second position in the syntactic representation, whereas the non-finite verb remains in situ. This movement is illustrated in Figure 2.

Figure 2. The syntactic representation underlying sentences. The verb is generated under VP and inflection under IP. The verb moves from VP to IP to be inflected. In Germanic languages the verb moves to CP.



Poeppel & Wexler (1993) analyzed transcripts from a German-speaking boy Andreas at the age of 2;1. From the total of his 282 utterances, the finite verb occurred in second position (under CP) in 216 utterances and only 7 were produced sentence-final. In contrast, from the 51 RI utterances, 44 occurred sentence-final and 15 in second position. This shows that syntactic operations, such as movement, are known to the child already early in life [2].

[2] Children's knowledge of verb movement is also demonstrated by the use of negation in French. Children always place the negator *pas* correctly, i.e. post-verbally in finite contexts and pre-verbally in non-finite contexts (see Wexler's report (1994) of Pierce's data).

The OI accounts that have been proposed within a generative perspective on language development vary quite considerably as to the nature of this deficit in syntactic representation. Some accounts state that a child's syntactic representation is a reduced version of the adult's representation, i.e. some functional projections are lacking in a child's representation (see subsection 2.2.1). Other OI accounts depart from a full syntactic representation available in a child's grammar. This means that children in the OI stage have full knowledge of the universal principles and processes that underlie clause structure (Poeppel & Wexler, 1993) (see subsection 2.2.2).

2.2.1 The Reduced Competence Hypothesis

According to Radford (1990), child grammars are comprised of a set of lexical categories and projections, and lack functional categories and projections. The functional projection of IP is absent in child grammar. Therefore, the status of the verbal clause in child grammar is VP, whereas in adult grammar this status is IP. Evidence for this is found in the absence of modals in child speech. Radford argues that modals are base-generated in I. Consequently, if I is absent, modals are also lacking.

However, finite verbs do occur in early child speech (see examples 4a-c taken from Radford, 1990). Radford suggests that the past tense form in (4a) does not correspond with the adult past form. Rather, the context in which the form occurs indicates that the form in (4a) corresponds to the adult perfective/passive participles ('*I've lost it*'). The utterance in (4b) could be analyzed as carrying 3rd person singular inflection. However, Radford analyses this type of utterance as a formulaic expression, which is not representative of the range of productive structures that fall within a child's competence at the OI stage. Likewise, the production of the copula in (4c) is also not representative of the child's knowledge of the 3rd person singular morpheme (-*s*). According to Radford, these utterances are semiformulaic expressions.

(4) a. Lost it
b. Here it is!
c. Where's bee?

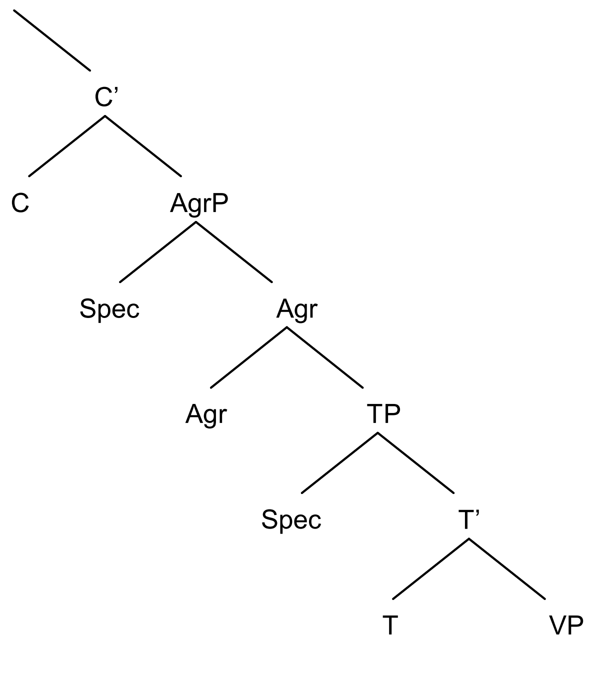
2.2.2 The Full Competence Hypotheses

Underspecification account

The IP in Figure 2 can be split into an Agreement node (AgrP) and a Tense node (TP), as in Figure 3. Wexler (1994) suggests that the TP is 'optional' for the child.

In adult grammar, the AgrP selects a tensed clausal complement (TP). If TP is projected, the verb will rise, hence tense and agreement are present. If TP is not projected, then the sentence will be treated as an infinitival sentence, hence tense and agreement are lacking. The underspecification of tense means that it has no semantic role. Therefore, the value of TP (past-present) in the clausal structure does not have an effect on the interpretation of the sentence. Wexler (1994) points out that this does not mean that children have no understanding of time, *'the child may not know tense, but that says nothing about the understanding of time. Tense is a formal syntactic notion; time is not'* (Wexler, 1994 p:338).

Figure 3. The IP can be split into an Agreement node (AgrP) and Tense node (TP).



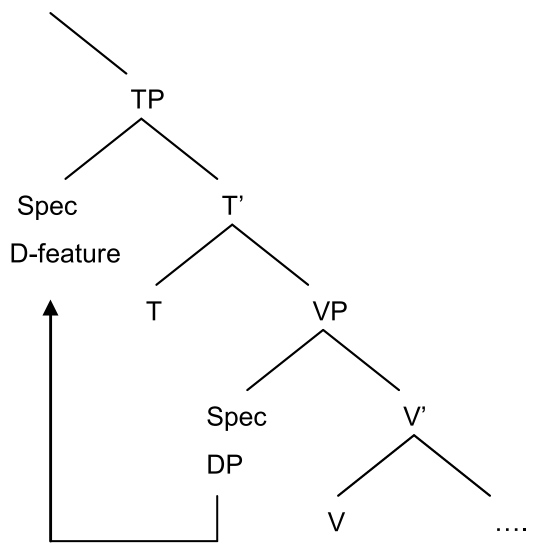
The OI account proposed by Rizzi (1993) converges with Wexler's account (1993) in that children allow tenseless clausal representations. In adult grammar, the clausal structure is always generated from the CP, as in Figure 2. According to Rizzi (1993), children can select any point of departure to generate a clausal structure. If the selected starting point is lower than the TP (see Figure 3) then an RI will occur. RIs are the result of truncated structures (see also Haegeman, 1995).

Schütze & Wexler (1996) argue that tense *and* agreement can be independently underspecified in a child's RIs, an argument which is called the

Agreement and Tense Omission Model (ATOM). Data of English children shows that between 4 and 30% of the past tense forms co-occur with default case marking (accusative in English) (e.g. her said no), which indicates that this is a grammatical option for children. Under the assumption that AgrP assigns/checks nominative case, these constructions are only possible when AgrP is underspecified. This explains the occurrence of RIs with nominative or accusative case assigned to the subject, such as *he cry* [-tense, +agreement] and *him cry/him cried* [+tense, -agreement].

The underspecification of either tense or agreement results from the Unique Checking Constraint (UCC), which operates at the OI stage (Wexler, 1998). The rationale behind this constraint is that both TP and AgrP have a D-feature, which must be eliminated by checking against the D-feature of a DP (i.e. subject) that rises up for checking. The UCC states that '*the D-feature of DP can only check against one functional category'* (Wexler, 1998 p:59). If the D-feature on TP attracts the subject DP, then the D-feature on tense will be checked off. The D-feature of AgrP can no longer be checked, as the UCC restricts the checking of D-features twice. This is illustrated in Figure 4.

Figure 4. The illustration of the Unique Checking Constraint as proposed by Wexler (1998). The subject is attracted by the TP to check off the D-feature. The constraint prohibits the checking off of the D-feature at AgrP, hence agreement is lacking.



According to Hoekstra & Hyams (1998), RIs result from the underspecification of number. In their view, finite clauses are grammatically anchored by a tense chain. This chain contains a Tense Operator (in C), a TP and the temporal location of the eventuality provided by the lexical verb (in VP). How the tense chain becomes visible depends on the morphological extensions a language uses. Finiteness can be expressed by a tense morpheme (e.g. Japanese), person morphology (e.g. Italian) or number morphology (e.g. Dutch). In languages where finiteness is only marked by number morphology, the underspecification of number leads to RIs. In an invisible tense chain, tense receives the status of a free pronoun that can be interpreted discursively.

The OI account put forward by Hoekstra & Hyams (1998) implies that not all languages allow for RIs and this seems to correspond with the child data. For instance, data on Italian children shows that between 0 and 16% of the analyzed utterances are RIs, whereas data on Dutch children shows that between 26 and 36% of the utterances are RIs (respectively Guasti 1994 and Weverink 1989 as reported by Hoekstra & Hyams, 1998). The difference can be explained by the expression of finiteness through person morphology in Italian and not number morphology.

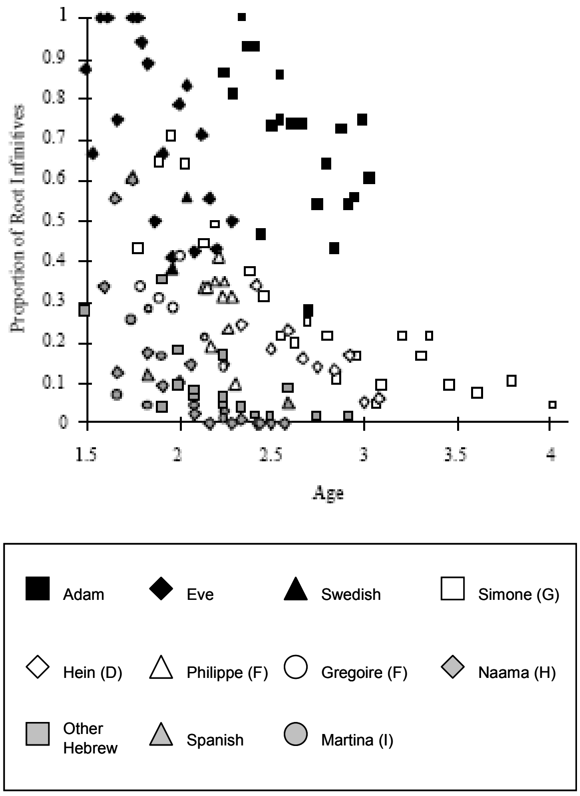
The mixed competence- performance model

Phillips (1995) shows that there is a correlation between the richness of the inflectional paradigm and the occurrence and time period in which children use RIs. His correlation graph is presented in Figure 5. This graph shows that children acquiring a highly inflected language produce small proportions of RIs (at the bottom of the graph) and children acquiring a poorly inflected language produce higher proportions of RIs.

Phillips (1995, 1996) argues that RIs arise as children have difficulties in connecting the verb with inflection syntactically. The assessment of the inflectional paradigms is an overlearned process for adults. In contrast, this is not an automatic process for children. RIs occur when the costs of accessing a morphological form are greater than failing to realize it. A rich inflectional paradigm facilitates the rapid automatization of inflectional access.

As the child's process of accessing morphological knowledge moves from controlled to automatized, the number of RIs will decrease gradually. This is in accordance with child production data. The RIs are not given up once finiteness is acquired, rather a gradual transition takes place from the OI stage towards finiteness only (Behrens, 1993).

Figure 5. The proportion of RIs across languages (Phillips, 1995, reprinted with permission from the author).



The null auxiliary/modal hypothesis

Boser, Lust, Santelmann & Whitman (1992) observe that RIs are not the only non-finite forms that occur in the OI stage, but also participial forms occur. This is also observed by Behrens (1993). Moreover, Behrens found that the transition from infinite to finite only holds for main verbs, the other categories (modals, auxiliaries, copulas) appear as finite right away. Boser et al. (1992) argue that the RIs and participles are selected by a non-overt tensed auxiliary. The CP is occupied by a phonetically null auxiliary moved from its position in IP. This is called the Null Auxiliary Hypothesis.

In the same vein as Boser et al. (1992), Ferdinand argues that RIs have a modal or aspectual meaning as they are preceded by a null-element (auxiliary or modal). In a study of four French-speaking children, Ferdinand (1996) shows that RIs were exclusively eventive and finite verbs were stative. The modal only selects eventive verbs.

The distinction between eventive and stative verbs follows the classification of Vendler, as outlined by Shirai & Anderson (1995). Four classes of verbs are distinguished according to their inherent temporal features. The temporal features are telicity (having an inherent endpoint), punctuality (having no duration), and dynamicity (energy is required). The verb classes are achievements [+telic], [+punctual] and [+dynamic], accomplishments [+telic], [+dynamic], activities [+dynamic] and states, which has none of the temporal features. Eventive verbs denote eventualities with the temporal properties of [+dynamic]. Static verbs are atelic and without duration, i.e. static verbs do not relate to a specific point in time.

The distinction between eventive RIs and stative finite verbs has also been found for Germanic languages, however less stringent as compared to the data of the French-speaking children (Jordens, 1990; Ingram & Thompson 1996; Blom, 2003). For Germanic languages it has been observed that the eventive RIs receive a modal interpretation, which needs to be inferred from the discourse (see examples, taken from Hoekstra & Hyams 1998).

(5) a. Eerst kaartje kopen!
First ticket buy-INF
'*We must first buy a ticket*"

b. Niekje buiten spelen
Niekje outside play-INF
'Niek (=speaker) wants to play outside'

The modal interpretation of RIs has also been interpreted in terms of the presence of deontic modality and the absence of epistemic modality in young children. I will return to this in subsection 4.1 of this chapter.

2.3 An input bias?

A usage-based view on language development argues that the predominance of early infinitival forms is related to children's patterns of language input and speech processing mechanisms. It has been argued that children's language learning is strongly biased to lexical elements that occur in sentence-final position (Slobin, 1973). As such, the RIs of young children mirror the infinitival part of the frequently used composed verbal predicates (i.e. finite auxiliary or modal + lexical infinitive) in child-directed speech. Due to the sentence-final processing constraint, lexical infinitives in sentence-final position are picked up, but finite verbs are not. For example, the English utterance *Can he go* results in the RI *he go*, or for Dutch, *wil hij spelen* (Wants he play-INF) results in the RI *hij spelen* (Freudenthal, Pine, Aguado-Orea & Gobet, 2007).

Wijnen, Kempen & Gillis (2001) have shown that the sentence-final infinitives are more informative than finite verbs in child-directed speech. They observed that the type-token ratio (a measure for lexical diversity) was considerably higher for infinitives than for the finite verbs. This means that to determine if there is a difference in meaning between two arbitrarily selected sentences, sentence-final infinitives are most informative. Therefore, Wijnen et al. (2001) argue that RIs reflect the combined effect of the sentence-final processing bias of young children and the high information load of the lexical infinitives in composed verbal predicates.

In Freudenthal et al. (2007) and Freudenthal, Pine & Gobet (2009), RIs are simulated with the MOSAIC computer model, which is based on the sentence-final processing bias in learning. This processing bias leads to the production of partial sentences that were present as sentence-final phrases in the input. With respect to RIs, this means that the sentence-final part of composed verbal predicates is reproduced. Gradually the model produces longer sentence-final phrases as a function of the input. Modals and auxiliaries appear, which replace the RIs with composed verbal predicates.

Interestingly, MOSAIC is able to mimic the cross-linguistic differences in the use of RIs because of the different distributional characteristics of the input. For instance, RIs occur frequently in the speech of Dutch children but not in the speech of Spanish children. The input of both languages contain equal percentages of utterances with composed verbal predicates. However, as Spanish is an SVO language, the complement occurs in sentence-final position rather than the infinitive. This contrasts with Dutch, which is an SOV language. In Dutch, the complement precedes the infinitive and thus the infinitive always appears in sentence-final position. The low rate of RIs when the model is exposed to Spanish language input is a direct consequence of the model that processes the input from the right edge of the utterance (Freudenthal et al., 2007).

3. The acquisition of tense

3.1 Temporal reference of RIs

Cross-linguistic data shows that for some languages the temporal reference of RIs correlates with telicity (lexical aspect) and perfectivity (grammatical aspect). English bare verbs (English analogue for RI) denote present or past events. Past reference appears most often with telic verbs and present reference with atelic verbs. See examples, taken from Hyams (2007).

(6) a. Child: He fall-INF down.
Mother: He did?

past reference

b. Mother: What's she doing with the tiger now?
Child: Play # play-INF ball with him

present reference

In (6a), the mother interprets the telic RI as denoting a past event. In (6b), the child responds with atelic RI denoting an ongoing event.

In Russian and Polish, past reference is predominantly perfective (completed) and present reference is imperfective (ongoing). Consider the following examples from Russian as mentioned by Hyams (2007), from Brun (1999).

(7) a. Mama maslo kupit'
Mommy butter-buy-INF
'Mommy has bought the butter'

past reference

b. Kupat'sya
bath-INF
(He) is bathing.'

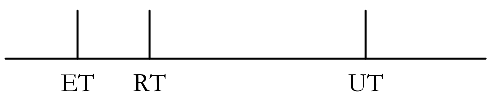
present reference

Tense relates the event denoted in the utterance (ET) to the time at which the utterance was uttered (UT), or to the reference time (RT). The RT is the time point or time interval which is mentioned in the preceding context (Klein, 1994). Consider the following sentences.

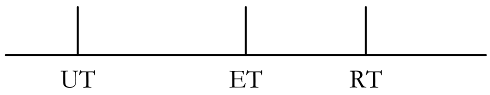
(8) a. [When Mary came to the party $_{RT}$], [John had left $_{ET}$]
b. [Tomorrow at four o'clock $_{RT}$], [John will have left $_{ET}$]
c. [Last year $_{RT}$], [John left Surbiton $_{ET}$]

In (8a), the ET 'John's leaving', occurred before the RT, which are both before UT. This is schematized in (9a). In (8b), the ET occurs before RT, which both occur after UT (9b). In the last example, (8c), ET and RT overlap and are prior to UT.

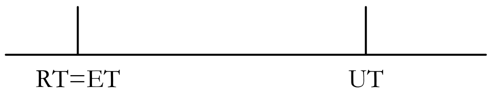
(9) a.



b.



c.



The relation between ET and RT becomes different when we compare (8b) with (10).

(10) [Tomorrow at four o'clock $_{RT}$], [John will be leaving $_{ET}$]

In (10), the ET coincides with RT because of the use of the progressive form (*–ing)*. In (8b), the event is seen as completed (=perfective), and in (10) as ongoing (=imperfective). The perspective a speaker takes with regard to the temporal course of some event is called grammatical aspect (Klein, 1994).

With respect to RIs, Hyams (2007) argues that the temporal reference of RIs is assigned according to the topological property of the event closure. This is called the Closed Event Hypothesis. The event can either be closed by telicity, where the end state or result (telos) is linked to the UT. Another event closure mechanism is perfectivity. Perfective verbs are linked to UT by the insertion of a null modal. How these options are manifested in child language depends on the aspectual system of the language.

For Germanic languages, no temporal reference exists for RIs, i.e. lexical or grammatical aspect does not determine past, present or future reference for RIs (Dutch, Wijnen, 1998; German, Behrens, 1993). According to Hyams, (2007) this is due to the lack of perfectivity of Dutch verbs. Therefore, the past reference for Germanic RIs is excluded, and the insertion of a null modal becomes a free option.

3.2 The aspect – tense interface

It is hypothesized that verbal morphology initially marks aspect rather than tense. This is called the Aspect First Hypothesis (Wagner, 2001). According to the strong version of this hypothesis, a child's early production of past tense/perfective is *restricted* to closed events [+telic] (*achievement* and *accomplishment*) and the imperfective (e.g. progressive in English) to open events [-telic] (*activity*).

The cross-linguistic data seems to be in accordance with a relative rather than an absolute version of the Aspect First Hypothesis, i.e. past tense is *predominantly* used with closed events[3]. The production data of three English children, aged between 1;6 and 2;4, showed that the production of past tense morphology was initially restricted to achievement verbs [+telic] and extended later to other verb types. The progressive /*-ing*/ was predominantly used for activity verbs and achievement verbs denoting action in progress (Shirai & Anderson, 1995; see also Johnson & Fey, 2006).

The correlation between telicity and past tense marking was also found for Polish children. Telic verbs emerge in the past perfective at the age of 2;2, whereas atelic verbs in past perfective emerge at 3. The correlation between progressive (imperfective) and atelic predicates was much less prominent for English speaking children. Progressive aspect with atelic verbs emerged at the age of 3 and with telic predicates at 3;1 (Weist, Pawlak & Carapalla, 2004).

German children also start to use past participles and/or perfect predominantly with telic verbs. Past tense marking on atelic verbs becomes more frequent in the course of development (Behrens, 1993).

A prototype theory is also proposed to account for the interaction between telicity and grammatical aspect/past tense (Shirai & Anderson 1995, Anderson & Shirai 1996). In prototype theory, categories are formed with good members (or prototypes) and marginal members. Some lexical aspects correspond better with the prototypical meaning of verb morphemes than others. For instance, they argue that the lexical aspects of [+telic], [+punctual] and [+result] correspond with the prototypical meaning of the past tense morpheme. The expansion of the past tense morpheme to other lexical aspects follows a hierarchy. This is also demonstrated for progressive aspect.

> deictic past (achievement → accomplishment → activity → state → habitual or iteratative past) → counterfactual or pragmatic softener
>
> (Anderson & Shirai, 1996 p:557)
>
> process (activity → accomplishment) → iterative → habitual or futurate→ stative progressive
>
> (Anderson & Shirai, 1996 p:558)

According to Shirai & Anderson (1995), the hierarchy in past tense and progressive can be attributed to maternal input. Distributional analysis of maternal speech showed that between 55 and 66% of the past tense inflections occurred on achievement verbs and between 61 and 65% of progressive inflection on activity verbs.

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[3] For an overview of the crosslinguistic evidence see Anderson & Shirai, 1996.

3.3 Regular and irregular past tense

The literature on past tense acquisition has been dominated by the debate on how children learn the productive process of regular past tense. The debate is centered around two models of past tense acquisition, which diverge on the role they attribute to the frequency of past tense forms occurring in the speech input to acquire the regular and irregular past tense and the contribution of memory in this process. In the following subsections we will give an overview of the essential characteristics of the dual-route and single-route models. It is our aim to highlight the most relevant aspects of the acquisition of regular and irregular past tense.

3.3.1 The dual-route model

The dual-route model is embedded in a theory that postulates an innate capacity for language learning. The child is assumed to be equipped with the overall structure of the grammar and its universal rules. The universal rules contain parameters whose values differ from one language to another. Parameter setting is influenced by the input, although in limited ways: to avoid large amounts of computation, the child does not use all sentences heard to build up grammar, but rather sets up hypotheses based on a limited set of utterances (Pinker, 1984).

According to Pinker (1998), the basic design of human language is comprised of a memory mechanism (e.g. the lexicon) and a symbolic computational mechanism (e.g. syntax). These two psychological mechanisms treat past tense formation differently, resulting in irregular and regular past tense. The irregular past tense forms are stored in memory. This memory mechanism is partly associative, thereby explaining the family resemblance categories within the class of irregular verbs (e.g. keep-kept, sleep-slept and feel-felt) and the occasional generalization of irregular patterns to new verbs by adults. The regular past tense form is generated by a standard symbol-concatenation rule, such as → add *–ed* to the verb. This suffixation rule can apply to any instance of the symbol 'verb' without access to the contents of memory. Therefore, the symbolic computational mechanisms afford unlimited productivity (Prasada & Pinker, 1993). The interplay between both psychological mechanisms in past tense inflection is formulated in the blocking principle, which states that if a verb can provide its own past tense form from memory, the regular rule is blocked (Pinker, 1998 p:6). The mechanisms encompassing memory (or the lexicon) and the rule for past tense inflection has been called the dual-route model.

3.3.2 The single-route model

The connectionist view challenges the need for symbolic rules underlying language. Rumelhart & McClelland (1986) argue that the psychological mechanism underlying language is *characterizable by rules, but that the rules themselves are not written in explicit form anywhere in the mechanism* (p:2). The basic tenet of their alternative past tense model is that regular and irregular past tense arises from one single mechanism, hence is referred to as the single-route model.

This model is based on a usage-based view of language learning. This view assumes that syntax and grammar are created out of concrete utterances, rejecting the hypothesis of language being innate. The learning of grammar involves processes of functional reanalysis of the language input and analogy by using general cognitive abilities. Straightforwardly, frequency of occurrence in the input plays an important role in language acquisition (Tomasello, 2003).

The single-route model of Rumelhart & McClelland (1986) is based on computer simulations of language development. Their simulation consists of a simple pattern-associater network, which learns the relationship between the base form (i.e. phonological form of the stem) and the past tense form, and a decoding network that converts featural representation of the past tense form into a phonological representation. The pattern associater connects each input unit to each output unit by a simple neuron-like activation process. The connections are strengthened through the process of learning. The input units represent each phoneme, together with its predecessor and its successor, from the word form (e.g. _he, hel, elp and lp_). If the stem ends in an unvoiced sound (like the /p/ in help), the past tense will be formed by adding the unvoiced /t/. Because the pattern-associater will be exposed to regular past tenses, positive connections will be built up between the input unit of unvoiced stem phonemes and the output units by adding the unvoiced suffix. The irregular past tense is formed in exactly the same way as the regular past tense. The input units of these irregulars are connected to units that code for exceptional aspects of inflection. These connections are strengthened by exposure to these irregular forms (Rumelhart & McClelland, 1986; McClelland & Patterson, 2002).

4. Tense and cognitive maturation

4.1 Deontic and epistemic modality in RIs

In subsection 2.2.1, it was mentioned that Germanic RIs receive a modal interpretation. Modal verbs are ambiguous between epistemic and deontic readings. Epistemic modality refers to the knowledge of possibility or necessity and deontic modality to the necessity, desire and permission of the speaker. The choice between the modalities is triggered by the complements with which the modal verb combines. According to Hoekstra & Hyams (1998), a stative verb + modal triggers an epistemic reading (see 11a) and an eventive verb + modal a deontic reading (see 11b). Consider the following examples in (11) of the modal *must* combined with two different complements:

(11) a. John must know the answer → *must* + stative 'know'
b. John must read this book → *must* + eventive 'read'

Hoekstra & Hyams (1998) argue that the restricted use of eventive verbs in RIs is the consequence of the fact that children in the OI stage only have deontic modality at their disposal. In a longitudinal analysis of a French child, Bassano (1996) observed that deontic modality was already expressed before the age of 2. The first epistemic utterances, however, occurred in the second half of the third year. Papafragou (1998) reports that after the age of 4, epistemic utterances become more frequent and appear in a larger number of modal items. Around the age of 5, children begin to grasp the distinctions between epistemic modality and unmodalized declaratives.

Blom (2003) attributes the absence of epistemic modality in children in the OI stage to cognitive immaturity, more specifically, lack of ToM. ToM refers to the ability to attribute mental states, such as beliefs, whishes and intentions to both oneself and others. Blom argues that as epistemic modality is concerned with knowledge of belief, children will not use this modality before they have a ToM. Papafragou (1998) and Blom (2003) show in their overview of the literature on both topics that there is a strong correlation between the use of epistemic modality and the emergence of a representational model of the mind.

4.2 Theory of Mind and complementation

It is demonstrated that ToM and language are closely related. Propositional attitudes such as beliefs, whishes and intentions are often expressed by means of verbs related to mental state that take complements. Complementation is unique in that it allows us to express truth and falsity in someone else's mind as being different from our own. For example, we know that the embedded statement in (12) is false (the world being flat). However, as the false statement is embedded in a true matrix clause, the whole statement is true, i.e. the belief that the world is flat is attributed to John's mind.

(12) John thinks that the world is flat

The production of mental states and their complements emerge at the age of 3 and 4, which roughly coincides with children's successful performance of False Belief (henceforth FB) tasks which test the ability to attribute FB to another individual (De Villiers & Pyers, 2002). An example of such an FB task is to show a child a familiar candy container, which unexpectedly contains pencils instead of the familiar candy. Another puppet is brought into the room and the child is asked what the puppet will think is in the box. Three-year-olds are prone to say that pencils are in the box, therefore failing to attribute FB to the other person.

De Villiers and Pyers (2002) hypothesize that the emergence of FB understanding rests on a child's mastery of the grammar of complementation. They tested 28 children aged between 3 and 5 years for four consecutive years on several FB tasks and language mastery. Language mastery was tested with the IPsyn, the index for the range and complexity of the grammatical forms used by the child, which includes a measure for complements. Memory for complements was tested with a picture task accompanied by a story which included a falsely embedded proposition, e.g. *he thought he found his ring (first picture), but it was really a bottle cap. (second picture). What did he think?* It has been shown that such questions are difficult for young children to answer.

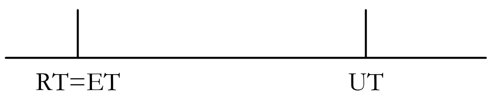
Results showed that the language measures pertaining to complementation predicted the FB performance of children in the next round. The prediction was not reciprocal, i.e. the FB performance did not predict complementation measures in the next round. De Villiers and Pyers (2002) conclude that a child who fails to retain the appropriate syntactic representation for a complement construction will not have it available as a form of mediating representation for FB understanding.

4.3 Sequence of Tense and Theory of Mind

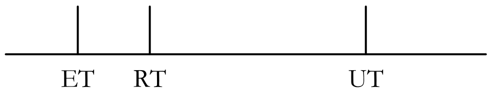
Hollebrandse (1998) has shown that the acquisition of complementation is also a prerequisite for the understanding of sequence of tense, just as it is for ToM. Sequence of tense means that the tense form in the complement must equal the tense form in the matrix clause, i.e. when the verb in the matrix clause is in the past or past perfect, the verb in the complement *must* be in the past or past perfect. This restricts the temporal interpretation of complements. Consider the following sentence:

(13) [Koekiemonster zei $_{RT}$] [dat hij een rood bordje had $_{ET}$]
Cookie Monster said that he a red plate had
'*Cookie Monster said that he had a red plate*'

The sentence in (13) has two temporal readings, both RT and ET are simultaneous, (14a) or the ET occurs before RT, (14b).

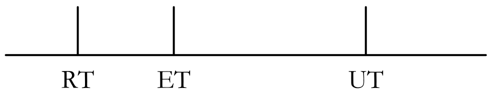
(14) a.


b.



The dependency between the tenses in complements prohibits the occurrence of the ET just before the UT (see 15), i.e. Cookie Monster has a red plate just before uttering the sentence (such a reading is possible in a relative clause cf. *Cookie Monster saw a men who had a red plate*).

(15)



The hypothesis of Hollebrandse is that children who fail to understand complementation allow the interpretation of (14a), (14b) *and* (15), whereas children who understand complementation only allow (14a) and (14b). Hollebrandse assumes that a child's understanding of complementation reflects the pass on FB tasks.

In his experiment, he tested 62 Dutch children in the age range 2;7 to 7;2. The FB task resembled the task described in subsection 4.2. To test the Sequence of Tense, a truth value judgment task was given. See the example:

(16) B: Zal ik eens kijken of ik een banaan voor je kan vinden, Koekiemonster?
(*Let me have a look whether I can find a banana for you, CM?)*
CM: Ja Bert, ik wil een banaan op mijn bordje hebben.
(*Yes Bert, I will have a banana on my plate*)
Action: B puts the banana on CM's plate

Exp: Zei Koekiemonster dat hij een banaan op zijn bordje had?
(*Did Cookie Monster say that he had a banana on his plate?)*

If a child fails to understand Sequence of Tense, he/she will answer yes.

Results showed that an adult-like interpretation of Sequence of Tense correlates with the point at which they start to understand ToM. Hollebrandse argues that children who lack complementation also lack RT, i.e. they take their temporal point of reference at UT. The acquisition of RT rests on a child's awareness that different references can be made to the same element depending on the point of view. Therefore the child needs to know the difference between direct speech (17a) and indirect speech (17b), which both refer to the same thing.

(17) a. Cookie Monster: 'I am at the store'
(view of Cookie Monster)

b. Cookie Monster said that he went to the store
(speaker's view)

This is in the same vein as Weist, Wysocka and Lyytinen (1991), who argue that the transition from an absolute tense system (ET linked to UT) to a relative tense system (ET is linked to RT) is explained by a conceptual development based on the general process of decentration, which occurs at the age of 4;6. They showed that children aged between 2;6 and 3;6 fail to comprehend sentences including a RT, which are solved by children aged 5;6 and 6;6.

5. Summary

In early language development, children go through a stage in which they use infinite (Root Infinitives) and finite verbs. This is called the Optional Infinitive (OI) stage. The OI stage cannot be attributed to a lack of knowledge of the verbal paradigm, as subject-verb agreement errors in this stage are rare. Rather, this stage has been attributed to a 'deficit' in the child's syntax. According to some, this deficit implies that children lack functional projections. Others argue that the full syntactic structure is in place, but functional projections are optionally presented, truncated or not overtly expressed. It has also been argued that RIs occur because young children's language learning is strongly biased to lexical elements that occur in sentence-final position.

In some languages, RIs receive temporal reference from the discourse. Events can be closed via telicity (e.g. English) or perfectivity (e.g. Russian), depending on the aspectual system of the language. Between the ages of 2 and 4, a child's use of past tense morphology is predominantly applied with telic verbs, leading to the hypothesis that children use past tense morphology to mark aspect rather than tense. Much of the literature on past tense acquisition has been directed to the acquisition of regular versus irregular past tense forms. Two models have emerged. In the dual-route model, irregular past tense forms are stored in an associative memory-- the regular past tense forms are generated by a standard symbol-concatenation rule. In the single-route model, irregular and regular past tense forms are stored in an associative memory.

The ability to mark tense is bound to the transition from an absolute tense system to a relative system. The development towards a full understanding of the verbal system interacts with the development of mental representations, such as ToM.

CHAPTER 4

Language assessment and research method

1. Introduction

The aim of this dissertation is to assess the development of verbal morphology in hearing- and language-impaired children. In this chapter we will focus on the methodological issues in language assessment in general and the methodology used in this dissertation in particular.

This chapter will start with a short outline of the language assessment procedures. As already pointed out by Masterson and Kamhi (1991): *'one extrinsic factor affecting the language knowledge attributed to a child is the way that information about language abilities is obtained'* (p:549). Language assessment procedures can be divided into two main categories: psychometric testing and spontaneous language sampling. The choice in favour of one assessment tool rather than the other is determined purely by the objectives of the researcher. We will elaborate on both assessment procedures and discuss the methodological issues of reliability and validity.

In this dissertation, we want to compare the scores of the hearing- and language-impaired children with a group of hearing peers with typical language development. We therefore use a norm-referenced standardized test. For Dutch, the only norm-referenced test that assesses morphosyntactic complexity and correctness is the STAP test. This test provides norms for children aged between 4 and 7 years (Verbeek, Van den Dungen & Baker, 1999). The STAP test will be discussed in more detail in section 3.

Prior to the implementation of the STAP test in our research, a small study was set up to explore whether this test satisfied psychometric criteria. This study is presented in section 4.

2. Language assessment

2.1 Objectives in language assessment

A psychometric test is defined as a behavioral measure in which a sample of behavior is obtained in a highly structured setting and under conditions in which the child is assumed to perform at his or her best (McCauley, 2001). As a language evaluation tool, psychometric testing is an efficient method to assess maximum language behavior, especially when the clinician or researcher is interested in a specific linguistic area. Comparing an individual score to a group score easily assesses language proficiency (Bacchini, Kuiken & Schoonen, 1995; Braam-Voeten, 1997). However, the language measures are obtained in a structured setting that deviate from daily speech. Therefore generalizability of the results is limited.

The goal of spontaneous language sampling is to obtain a language sample that maximally corresponds with the daily speech of the child and to offer insight into the full repertoire of syntactic structures that a child has at his or her disposal. This language evaluation tool does not follow a clear-cut format; samples vary in format from an unstructured setting in which a child plays with toys and the clinician/researcher only marginally stimulates the child to talk, to a more structured setting where the child is asked to tell a story using picture books. The effects of sampling method on language use have been addressed in several studies.

For instance, Southwood and Russell (2004) investigated the effects of three different sampling methods in 5-year-old typically developing African boys. The first method was a conversation between researcher and child structured by a questionnaire. The second method involved a play session with toys, called freeplay. The last sampling method was a story generation task in which a child was asked to tell the researcher something that happened to him/her. All samples were time-framed in 15 minutes. The last method elicited significantly less utterances as compared to the conversation and freeplay methods. However, the utterances produced were significantly longer. Both conversation and story generation tasks stimulated children to use complex syntactic structures, whereas freeplay did not. With respect to the variety of syntactic structures and errors, no differences between sampling methods were found.

Longer utterances in story generation tasks as compared to conversations were also found by Wagner, Nettelbladt, Sahlén and Nilholm (2000), who studied 28 SLI children aged between 4;11 and 5;9. They attributed the difference in utterance length to the occurrence of more elliptical answers in conversations as compared to story generation tasks. When questionnaires are used, children easily respond with a one or two-word answer. The inclusion of elliptical answers could also account for the results found by Southwood & Russell (2004), as they used questionnaires in their conversations.

In addition to the longer utterances in story generation tasks, Wagner et al. (2000) report a higher number of grammatical morphemes per utterance in this task as compared to conversations. Grammatical morphemes included the free-standing grammatical morphemes (articles, prepositions, auxiliaries) and the bound morphemes (verb inflections and plural).

With respect to the analysis of grammatical morphemes, a more sophisticated approach is to calculate the proportional use of a particular morpheme in an obligatory context. The method of spontaneous language sampling, irrespective of the format used, has a serious drawback in this respect. An adequate number of obligatory contexts need to be present in a child's sample in order to evidence the production (or non-production) of a particular morpheme (Lahey, Lievergott, Chesnick, Menyuk & Adams, 1992; Sealey & Gilmore, 2008).

The production of obligatory contexts for finite verbs and the accuracy of these finite verbs across four different sampling formats was taken up in the study of Sealey & Gilmore (2008). The first format was a freeplay session with minimal interference by the researcher, the second format was called 'storyboard' and involved a story-telling task using props. The child was given a model story, after which the he or she could tell his or her own story using the props. During the third sampling session the child was asked to retell a story that was first told by the researcher. In the fourth sampling format the child had to tell a story using a wordless picture book. No model story was given beforehand. All sampling sessions were time-framed in 15 minutes. Five SLI children and 5 TD children, aged between 3;11 and 5;6 participated in this study. Results showed that the number of obligatory contexts for finite verbs was the highest in freeplay sessions as compared to the other sampling formats.

However, interestingly, when samples are controlled for language production, rather than time, effects between sampling formats disappeared. No significant difference between sampling formats was found in the overall proportion of finite verbs to the total number of morphemes (lexical and grammatical). Moreover, when adult target-like use of finite verb forms was expressed as a proportion of the number of obligatory contexts, no significant sampling effects occurred. This suggests that not only should the method of sampling be carefully considered, but also how the samples are approached in language assessment.

2.2 Methodological concepts: reliability and validity

2.2.1 Defining reliability

The language evaluation tools of spontaneous language sampling and psychometric testing can be placed on a continuum from an unstructured setting to a relatively highly structured setting. The language samples lacking any form of structure, such as freeplay, are located at the right-hand end of the continuum. The use of questionnaires and picture books in eliciting speech gives more structure to the language samples, causing a move to the left. The left-hand end of the continuum is taken up by the more experimental approach to language assessment, called psychometric testing.

The benefit of obtaining language measures in a structured setting is the likelihood of replicating findings when the same individual is tested on another occasion. Replication in test theory is an important methodological concept and is referred to as reliability. The term reliability is defined as the consistency between measures, i.e. the agreement in scores when a test is applied multiple times. In order to measure a linguistic aspect consistently, one needs to measure that aspect systematically. To clarify this it is helpful to express reliability mathematically as has been done in the Classical Test Theory.

The underlying idea of the Classical Test Theory is that the *observed score (X)* of an individual is composed of the individual's *true score (T)* and an *error score (E)*. The component of interest is the true score, which is a constant. A random variation, or error, is added to this constant. This variation occurs through factors related to the individual (e.g. fatigue, loss of attention, low motivation) and to the test situation (e.g. noisy environment, room is to warm). An individual's observed score can be expressed in the following way:

$$X=T+E$$

The Classical Test Theory makes two assumptions when the same individual repeats a test multiple times. The first assumption is that the mean of the errors is 0, i.e. positive and negative values level each other out. This means that the average of the observed score estimates the true score. The second assumption is that the random error is normally distributed around the true score. This is called the standard error of measurement. The fact that the error scores do not correlate with each other and the true score, means that the error term does not allow any systematic variance. In the case of one individual repeating the test multiple times, the standard deviation of the errors equals the standard deviation of the observed scores. From here it follows that the smaller the standard deviation of the errors, the more compactly the random errors are grouped around the true score.

Instead of giving one individual the same test over a hundred times, a sample of 100 different people can be given the test. The same assumptions apply for this sample as for the individual case. It is interesting to note here that the variance in the observed scores is the sum of the variance in true scores (i.e. not everybody has the same true score) and the variance in the random error.

$$VAR\ (X) = VAR\ (T) + VAR\ (E)$$

To calculate reliability, the variance in true scores has to be divided by the variance in the observed scores.

$$R = VAR(T) / VAR(X)$$

A test has perfect reliability when the variance in the true scores equals the variance in the observed scores (R=1). Poor reliability is obtained when the variance of the observed scores equals the variance in the error scores (R=0). This becomes clearer when the above formula is rewritten.

$$R = 1 - (VAR(E) / VAR(X))$$

The Standard Error of Measurement and the reliability are both important to estimate the accuracy of a measure. When the variance of the observed scores is kept constant, the formula below shows that with increasing reliability the variance in random error decreases.

$$VAR(E) = VAR(X)\sqrt{(1-R)}$$

Using the standard error of measurement a 95% confidence interval can be calculated. This is the range that reflects a 95% probability that it includes the true score of an individual and 5% that it does not. A small range indicates a higher accuracy of estimating a child's true score as compared to a large range.

The most straightforward way to calculate the reliability coefficient is to collect two spontaneous language samples from the same individual or to give an individual a psychometric test at two consecutive moments. The correlation coefficient between the two test moments can be taken as the reliability coefficient. This procedure is termed the test-retest method. This term is interchangeably used with stability, because it measures the stability of a test over a period of time (Van den Brink & Mellenberg, 1998; McCauley, 2001; Drenth & Sijtsma, 2006). The measurement of test stability also hints at a practical problem with the test-retest method, namely the determination of the time-interval between the two test moments. This interval should be large enough to optimize the independency of the two test scores and small enough to ensure stability of the matter to be measured within the subject.

In terms of the reliability of language assessment tools, the primary interest is not the stability of a test in assessing a child's language proficiency at consecutive intervals. On the contrary, it is believed that a language assessment tool should identify the language development experienced over consecutive intervals. This does not mean that reliability is of no importance in language assessment.

With regard to spontaneous language sampling, we want to prevent the language measures derived from one set of utterances differing from the measures obtained from another set of utterances, when both sets are taken from the same sample. This type of reliability is also called internal consistency reliability. An effective procedure for calculating this reliability coefficient is to split a test in half, the split-half method. The correlation coefficient between both halves can be considered as the reliability coefficient for half the test. We can correct the reliability coefficient for the complete test using the Spearman-Brown formula. In the formula below R_k stands for the reliability coefficient calculated for half the test, K refers to the number of parts in which a test is divided and R is the reliability coefficient for the complete test.

$$R= (KR_k)/ 1 + (K-1) R_k$$

The conclusions drawn from test reliability are related to the purpose of a study. For individual comparisons, a reliability of >.90 can be considered as acceptable. As the main purpose of this dissertation is to compare groups of atypical developing children with TD children, a reliability of >.70 can be regarded as a rule of thumb. It has to be kept in mind that the accuracy of measurements in group comparisons is also determined by group size (Drenth & Sijtsma, 2006).

2.2.2 Defining validity

The methodological concept of reliability is closely related to the concept of validity. Validity refers to the degree to which a test measures the intended objective for which the test was designed. The metaphor of archery can easily demonstrate the relation between both methodological concepts. If an archer hits the mark consistently, his aims are reliable and valid. A second possible situation is that the archer neither hits the mark nor shoots consistently, resulting in invalid and unreliable aiming. When an archer hits a target consistently but near the mark, his aim is reliable, though invalid (McCauley, 2001). From here it follows that a valid measure needs to be reliable, whereas the opposite, a reliable measure is valid, is not true.

Despite the clear definition of validity, many subtle changes have been made to this definition depending on the purpose of the test for which validity measures were taken. All subtypes can be placed under the umbrella term of construct validity. This umbrella distinguishes two broad categories. The first category is content validity, which *'involves the demonstration that a measure's content is consistent with the construct or constructs it is being used to measure'* (McCauley, 2001 p:56). With respect to language assessment, this entails that the language measures need to be independent of non-verbal skills, such as memory and auditory processing.

The second category is criterion-referenced validation, that *'refers to the accumulation of evidence that the measure being validated is related to another measure – a criterion – where the criterion is assumed to have been shown to be a valid indicator of the targeted construct'* (McCauley, 2001 p:61). One type of criterion-referenced validation is concurrent validity that measures how well test scores correspond with a criterion, which are both taken at the same moment. The criterion should be a 'gold standard', reflecting the 'true' measurement of the behavior under validation (McCauley, 2001 p: 218). For language assessment tools such a gold standard is not available and the alternative method of contrasting groups is used (Aram et al., 1993; McCauley, 2001). The contrasting groups method determines how well a test discriminates between subjects with and without the disorder, in which the groups are chosen with prior knowledge that they differ on the construct to which the test applies.

The discriminating abilities of a test are expressed in terms of sensitivity and specificity. Sensitivity indicates the percentage of SLI children who are correctly identified as such by a particular test (in Table 1: A/A+B). Specificity indicates the percentage of children with normal language who are also identified as such by the specific test (in Table 1: D/C+D) (Dunn, Flax, Sliwinski & Aram, 1996). The accepted level for sensitivity is 90% or above. For specificity, 70% is considered 'fair', and 80% is 'good' (Plante & Vance, 1995 as cited by McCauley, 2001).

Table 1. Outline of the sensitivity and specificity of a test to identify SLI children using the contrasting groups method.

Test outcomes → *Group ↓*	*SLI*	*Non-SLI*	
SLI	A	B	A+B
non-SLI	C	D	C+D

2.3 Methodological concepts in language assessment tools

The validation of language assessment tools is driven by the clinical need for consistent criteria in identifying children with SLI. In clinical practice we want to assess a child's language proficiency to draw conclusions about the age appropriateness of the child's language level. The language measures as well as the normative data provided by the test should therefore distinguish children with SLI from the children with age-appropriate language levels. However, when it comes to language assessment tools there is a false believe that below a predefined cut-off point in a norm-referenced test a second population exists, which can be labeled language delayed (Gavin, Klee & Membrino, 1993). This second population is generally not statistically underpinned in test manuals. The best indicator of validity is therefore the demonstration that a language test accurately discriminates between language delayed and non-delayed children.

In diagnostic evaluation, psychometric language tests seem to under-identify children with language impairments. Plante and Vance (1994) validated four psychometric language tests that met a high number of psychometric criteria (e.g. description of the normative samples in test manuals, sample sizes, means and standard deviations). Forty 4 to 5-year-old children, equally divided in a group of SLI and TD children, were given the tests. Results revealed that a sensitivity percentage of 90% was reached for only one test measuring morphosyntactic production. The other tests all had sensitivity percentages lower than 80%, indicating that in less than 80% of the cases a congruence was found between the clinical diagnosis of SLI and the psychometric diagnoses of SLI. These results are compatible with the results of Aram et al. (1993) from their earlier large-scale study. From the 252 SLI children, only 20% to 70% were correctly identified as SLI using psychometric language tests. This implies that if the diagnosis of SLI is solely based on psychometric test outcomes, between 30% and 80% of the clinically diagnosed language delayed children will be misidentified.

Dunn et al. (1996) analyzed spontaneous language samples of SLI children, with the objective to extract language measures that adequately classify children with SLI. When base rate information was taken into account (i.e. correcting for unequal sample sizes of SLI and TD children included in the study) SLI was correctly predicted in 90.2% of the cases. This optimal classification was reached with a combination of the MLU, percent structural errors and age measures. Qualitative analysis revealed that the majority of structural errors involved morphological errors.

As pointed out by Bedore & Leonard (1998), one way of increasing accuracy in identifying SLI is to include a clinical marker, which is variable in the SLI population and stable in the children with typical language development. A large number of studies have indicated weaknesses in the area of morphology in SLI children, especially in their use of verbal morphology (e.g. Leonard et al., 1992; Conti-Ramsden & Jones, 1997; De Jong, 1999; Blake, Myszczyszyn & Jokel, 2004; Rice et al., 1995). In the study by Bedore & Leonard (1998) good sensitivity (>90%) was reached when SLI diagnosis was based on the production of regular past tense, 3rd person singular present inflections, copulas and the auxiliary *be* and MLU.

It thus seems that spontaneous language samples robustly discriminate between children with and without SLI, on condition that valid measures are included in the formula. However, in-depth qualitative analysis of the sample is essential in pinpointing the language difficulties of a particular child.

3. The STAP test

3.1 The STAP method

The STAP test requires conversational languages samples, in which topics of interest to the child are discussed. The test procedure consists of recording conversations between a child and an adult. The child is followed in his or her spontaneous speech as to limit the interference of the adult. The manual indicates that approximately 10 to 20 minutes of recording is needed to elicit sufficient speech to conduct analysis. Sufficient speech means that the transcribed recordings include minimally 50 utterances. The definition of an utterance is adopted from Hunt's T-unit: *one main clause plus any subordinate clause or non-clausal structure that is attached to or embedded in it* (Hunt, 1970 p:4 as cited by Verbeek, Van den Dungen, Baker, 1999). Conjunctions are analyzed separately.

The morphosyntactic analysis is based on the 50 utterances selected from the transcript. The following types of utterances were discarded: repeated and unintelligible utterances and idioms (e.g. 'weet ik niet' *I don't know*) as well as elliptical answers i.e. answers to preceding questions without a finite verb and/or other utterance parts that can be inferred from the preceding question (e.g. adult: 'does it hurt' child: 'a little bit').

The analysis of the STAP test can be divided into two parts: the first part includes the quantifying morphosyntactic measures and the second part includes the qualifying morphosyntactic measures. The first part consists of language measures, which indicate the number of grammatical elements produced in a 50-utterance sample (e.g. number of finite verbs). All utterances are judged on morphological and syntactic correctness. Morphological errors include the incorrect use of inflectional suffixes for nouns, verbs and adverbs. On a syntactic level, errors include deletion, insertion, substitution and inversions of utterance parts. These utterance parts refer to nouns, verbs and determiners.

The main purpose of this dissertation is to compare the production of verbal morphology of hearing- and language-impaired children with the production of TD children. The measures belonging to the verbal domain are therefore of interest here. These measures are summarized and specified in Table 2.

Table 2. Overview and specification of the quantifying and qualifying morphosyntactic measures pertaining to the verbal domain.

quantifying measures	*specification*
finite verb	Total number of finite verbs. Fifty finite verbs are to be expected, -1 is scored when a finite verb is lacking, +1, 2 …k is scored with each extra finite verb that is produced (in the case of subordinations).
composed verbal predicates	Total number of composed verbal predicates, which include COP/AUX + past participle, COP/AUX + infinitive, COP/AUX + *aan het* infinitive, COP/AUX + *om te* infinitive. Both verbs need to be produced.
past participle	Total number of past participles, correct and incorrect (e.g. prefix is omitted).
past tense	Total number of past tenses, correct and incorrect.
qualifying measures	
main verb absent	Total number of omissions of the main verb (lexical or modal).
agreement errors	Total number of agreement errors, including incorrect subject-verb agreement (NB. Subject needs to be realized) and the deletion of the copula or AUX when main verb is present.
past participle error	Total number of past participle errors, including the deletion of the prefix.
past tense error	Total number of past tense errors, excluding the cases in which the context requires a past tense and the present tense is produced.

3.2 Psychometric review

To enhance our knowledge of the psychometric characteristics of the STAP test, an evaluation was carried out using the 10 psychometric criteria listed by McCauley & Swisher (1984). This is not an exhaustive list of criteria, but highlights a number of important psychometric criteria. The list can serve as a guideline to explore the potential use of the STAP test for the purpose of this dissertation. The STAP manual and its supplement (Van den Dungen & Verbeek, 1994; Verbeek et al., 1999) were consulted to complete the criteria list. The criteria and their content are presented in Table 3. A positive judgment is given whenever the information is included in the manual and/or its supplement. The absence of information resulted in a negative judgment.

Table 3. Psychometric review of the STAP-test (psychometric criteria taken from McCauley & Swisher, 1984). A positive judgment is indicated by ✓ and a negative judgment by ✗.

no.	*criteria*	*definition*	*judgment*
1.	Description of the normative sample	Clarification of normative sample, including geographic information, 'normalcy' of subjects and socioeconomic status.	✓
2.	Sample size	Adequacy of (sub) sample size, subgroups with a minimum of 100 participants.	✗
3.	Item analysis	Systematic item analysis evidenced by quantitative methods.	✓
4.	Means and SD	Measures of central tendency and variability should be available.	✓
5.	Concurrent validity	Empirical evidence should be provided that the test categorizes children as normal or impaired.	✗
6.	Predictive validity	Empirical evidence should be provided that the test predicts performance on another, valid measuring the same aspect of language behavior.	✗
7.	Test-retest reliability	Empirical evidence should be provided that the test has a stability coefficient of .90.	✗
8.	Inter-examiner reliability	Empirical evidence should be provided for congruence between examiners, with a correlation coefficient of .90.	✓
9.	Description of test procedures	The test procedure should be described in such a detail that the test user can duplicate test administration.	✓
10.	Description of tester	The test manual should provide information about the qualifications a tester needs to adequately perform the test.	✓

The STAP manual and its supplement provide information to meet 6 out of the 10 psychometric criteria. The sample sizes on which the norms are based are too small. A total of 240 children, divided over 60 children per age group is to small to receive a positive judgment. Moreover, all children were drawn from the same geographical area of the Netherlands, namely the Amsterdam region. Careful consideration should be taken of the STAP norms.

According the STAP supplement, language measures have concurrent validity when a score below ≤ -2 SD can be obtained. This is closely related to the frequency of occurrence of a particular morphosyntactic element. For example, within the TD population, children are found who produce no past tenses within a spontaneous language sample. The consequence of this is that SLI children cannot be discriminated on the production of past tenses. However, this reasoning does not provide sufficient (empirical) evidence for concurrent validity.

No information has been found on predictive validity in the STAP manual and its supplement. Predictive validity requires a follow-up of the children included in the norms. This is time-consuming and is usually lacking in test manuals (McCauley & Swisher 1984; Plante & Vance 1994; Drenth & Sijtsma 2006).

The manual briefly reports on the test-retest reliability. Two language samples were obtained from 8 children. The time interval between these samples is not mentioned. The reliability of a measure was compromised if: 1) one score of the child was within 1 SD from the mean (i.e. reflecting a normal score) whereas the other score is 2 SD from the mean (i.e. reflecting a deviant score) or 2) one score was positively deviant and the other negatively deviant. Results of their analysis revealed instability on 14 language measures on at least one sample pair (i.e. one child). However, the authors do not elaborate on these language measures.

3.3 Implications and considerations

As mentioned in subsection 3.2, the reference population is rather small. Therefore, the accuracy of the norms is substantiated if the same scores are obtained with another group of TD children. Another motivation for including this second group is that the hearing-impaired children participating in this study were all monolingual speakers of Flemish. As the norms are based on Dutch-speaking children, the norms need to be tested for regional robustness.

The lack of empirical support for the concurrent validity of the STAP test motivated a validity study. The discriminating abilities of the language measures can be observed when a group of SLI children is contrasted with the group of TD children. Good validity implies that the language measures can be used to pinpoint children with a language performance beyond age expectancy and can readily be used for diagnostic evaluation.

Due to time limitations, a full study of the reliability is not possible. Some insight into the reliability can be obtained when applying the split-half test for internal consistency reliability, as mentioned in subsection 2.2.1. The underlying idea of this test is that utterances selected from a speech sample do not (or to a limited extent) differentiate from another set of utterances taken from the same sample in its grammatical and syntactic structure. Stability within one sample increases the likelihood that the true score of the child can be estimated.

4. Reliability and validity testing

4.1 Participants

Fourteen TD children aged between 72 and 82 months (M=77) were selected to participate in this study. They were all monolingual speakers of Dutch, attended mainstream education and had no cognitive, perceptual or attentional disorders. The children were drawn from the East and North West of Flanders (Limburg). Another group of 15 6-year-old children clinically diagnosed with SLI participated in the present study. The group of SLI children had a mean age of 76 months (ranging from 72 to 83 months). All children in this group attended special education and did not have additional problems, besides their language impairment. Seven children lived in the Netherlands (Amsterdam) and 8 children lived in the East and North West of Flanders. For an overview of the participants see Appendix.

4.2 Data collection

Spontaneous language samples were recorded for the children in an individual setting, following the STAP protocol. For the TD children, the setting involved the researcher and the child. In the case of the SLI children conversations were held by a speech/language therapist, who knew the child well. These conversations were recorded by the researcher. According to the STAP guidelines, a familiar interviewer could ameliorate speech production in SLI children and therefore providing a language sample, which is comparable with the daily speech production of the SLI child. The topics of conversations varied from one sample to another, as the adults encouraged the child to discuss his/her own interests to reduce as much as possible any silent periods during the registration session. If the conversation was strained, picture books were used to elicit speech. Transcriptions were made according to the CHAT conventions, available through the Child Data Exchange System (MacWhinney, 2000)

4.3 Results

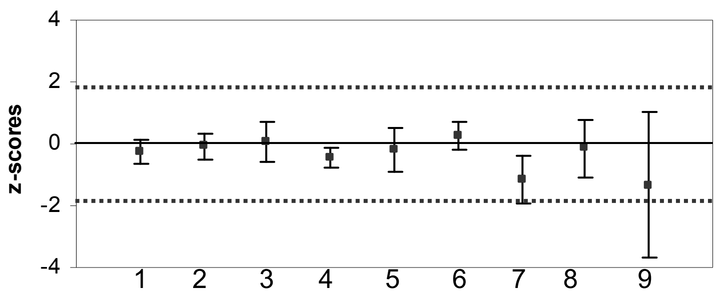
Norms

The means and standard deviations of the 14 TD children on MLU, quantifying and qualifying language measures are presented in Table 4. These results are compared to the scores of the reference group by transforming the raw scores of the 14 TD children into z-scores. This places each individual score within the normal distribution of the reference group. The mean z-score and standard error of the mean per language measure is visualized in Figure 1. Z-scores are given for the reference group on the vertical axis; a z-score of 0 corresponds with the mean of the reference group, the dotted lines indicate the 95% confidence interval (i.e. between z ± 1.96).

Table 4. Mean scores and standard deviations per language measure for the 14 typically developing children.

language measures	*mean*	*SD*
MLU	6.58	0.61
quantifying verb measures		
finite verb	52.29	2.92
composed verbal predicates	14.86	6.69
past participle	3.86	2.38
past tense	11.21	10.28
qualifying verb measures		
main verb absent	0.79	1.05
agreement errors	1.43	1.22
past participle error	0.14	0.54
past tense error	0.50	1.34

Figure 1. Mean z-scores and standard deviations for the 14 TD children compared to the reference group. A z-score of 0 corresponds with the norm mean and the dotted lines indicate the 95% confidence interval. 1. MLU, 2. finite verb production, 3. composed verbal predicate, 4. past participle, 5. past tense, 6. main verb absent, 7. agreement error, 8. past participle error, 9. past tense error.



The mean z-score for the 14 TD children is for the measure of agreement errors and past tense errors over a standard deviation discrepant from the group on which the test norms are based. For all other language measures, mean scores are comparable between the two groups of TD children.

Reliability testing

The raw scores of the TD and SLI children are used to calculate the internal consistency reliability coefficient. The set of 50 utterances per child is divided in two. For both halves raw scores are calculated for MLU, the quantifying and qualifying verb measures of the STAP.

The split results in two raw scores per language measure and per child. The raw scores are entered in a correlation analysis. The Pearson correlation coefficient is taken as the reliability coefficient for half the test, i.e. R_k. This coefficient is used to calculate the reliability coefficient for the complete test (R) with the Spearman-Brown formula (see subsection 2.2.1).

The reliability coefficient can be used to calculate the Standard Error of Measurement (Var (E)). With this error term it is possible to calculate a 95% confidence interval. This is the range that includes the true score of the child with a 95% probability.

The results are summarized in Table 5.

Table 5. Reliability results for the STAP measures. R_k indicates the reliability coefficient for half the test (with p indicating if R_k is statically significant), R indicates the reliability coefficient for the complete test, var (E) refers to the standard error of measurement.

language measures	R_k	*p*	R	*var (E)*	*95% interval*
MLU	.88	<.01	.93	.21	.82
quantifying measures					
finite verb	.91	<.01	.95	1.14	5.53
composed verbal predicates	.54	<.01	.70	2.90	11.83
past tense	.38	ns	.55	5.23	20.05
past participle	.17	ns	.29	.84	6.24
qualifying measures					
main verb absent	.78	<.01	.88	.41	1.62
agreement error	.77	<.01	.87	.29	1.13
past tense error	-.09	ns	-.19	.32	1.28
past participle error	.74	<.01	.85	.12	.47

The MLU and finite verb production are reliably measured within one speech sample. Coefficients for both measures are above .90. The omission of the main verb (Main verb absent) and agreement errors are also fairly consistent across the speech sample, as indicated by consistency coefficient >.80. The occurrence of composed verbal predicates has a coefficient of .70, which is fair. However, the high variance in observed scores results in a high loss of accuracy. This means that a child's true production score lies almost 6 predicates above or below his/her observed score.

The occurrence of past tenses and participles is variable within a speech sample, resulting in a low reliability coefficient (<.70). The low reliability for the production of past tenses within one sample may not be surprising, as the use of the past tense is strongly dependent on context. When a child talks about something that happened to him/her in the past, then past tenses will occur. Including these utterances in the analysis will give a result for this variable. Choosing an utterance set excluding the 'past-tense' utterances then no score can be given for the past tense variable. Yet, the latter zero score does not mean that the child has no mastery over past tense morphology, it was just not present in the sample. The same accounts for the low reliability of errors in past tense production.

Validity testing

The contrasting-groups method is used to test the discriminating abilities of the language measures included in the STAP analysis. This method of validity testing is chosen because a criterion, or gold standard, for morphosyntactic development to which the STAP can be compared is not available for Dutch. Moreover, the evaluation of the diagnostic value of a test by means of the contrasting-groups method is frequently reported in the literature (see subsection 2.3).

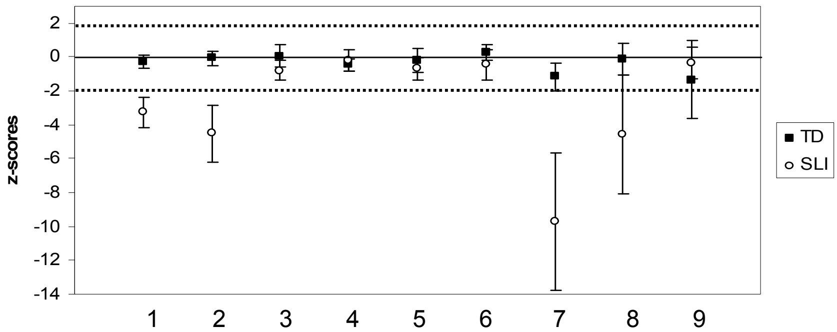
STAP analyses were conducted for 15 SLI children, all 6 years of age. The means and standard deviations of the measures of interest to this dissertation are presented in Table 6. The raw scores are transformed into z-scores according the data given in the STAP manual. The mean z-scores as well as the standard deviations of this SLI group are plotted with the scores of the 14 typically developing children in Figure 2.

The graph in Figure 2 shows that the SLI children's score deviates from the reference group and the Flemish TD children on the MLU measures, finite verb production, agreement errors and past participle errors. The SLI children produce significantly shorter utterances when compared to their chronological peers with normal language ($U=22.0$, $p<.01$). Also, the SLI children produce significantly less inflected verbs as compared to their TD peers ($U=26.0$, $p<.01$). This could be explained by a high production of elliptical utterances and/or the omission of copula and auxiliaries to a greater extent (no. 7 in Figure 2).

Table 6. Means and standard deviations of the language measures for the SLI children.

language measures	*mean*	*SD*
MLU	4.19	1.41
quantifying measures		
finite verb	35.47	12.71
composed verbal predicates	10.20	6.14
past participle	4.87	4.49
past tense	7.33	10.70
qualifying measures		
main verb absent	1.47	1.96
agreement errors	8.47	6.78
past participle error	1.47	2.07
past tense error	0.33	0.72

Figure 2. Mean z-scores and standard deviations for the SLI group compared to the 14 TD children and the reference group. A z-score of 0 corresponds with the norm mean and the dotted lines indicate the 95% confidence interval. 1. MLU, 2. finite verb production, 3. composed verbal predicate, 4. past participle, 5. past tense, 6. main verb absent, 7. agreement error, 8. past participle error, 9. past tense error.



The frequently reported weaknesses in the use of inflection morphemes for the SLI children is supported by the results in Figure 2. At the age of 6, the speech of TD children hardly contains any subject-verb agreement errors or errors in the production of past participles. By contrast, the SLI children produce significantly more agreement errors and past participles errors when compared to their typically developing peers (respectively U=13.0, p<.01 and U=11.0, p<.01).

4.4 Conclusion

With respect to the norms of the STAP test, this small scale study indicates that these are robust for MLU, all qualifying verbal measures and for the variable measuring the omission of the main verb and past participles. High to very high internal consistency reliability was attained for MLU, finite verb production, composed verbal predicates, omission of the main verb and agreement errors. Only four measures discriminated between SLI and non-SLI children. These were MLU, finite verb production, agreement errors and past participle errors. Therefore, the outcomes on MLU, finite verb production and agreement errors are reported in chapter 5, because these language measures are valid and reliable.

CHAPTER 5

The acquisition of agreement

SECTION 5.1
CI children in comparison to HA children[4]

1. Abstract

In this study, we compared the development of Dutch verb morphology in 48 4 to 7 year-old cochlear-implanted (CI) children to that of 31 hearing aided (HA) children by analyzing spontaneous speech samples. Both groups had similar aided hearing thresholds. Standardized language testing was used to compare both populations with their TD peers. Measures involved Mean Length of Utterance (MLU), finite verb production and verbal agreement errors.

The results revealed that CI and HA children did not significantly differ on language outcomes and were both able to catch up with their TD peers on MLU and finite verb production. We found that CI and HA children have persistent problems in verbal agreement marking. Additionally, we found that both hearing-impaired groups did not have a greater error rate on the low salient verb morphemes as compared to the omission of the high salient inflected verb in obligatory contexts. No significant correlations were found between age at implantation and hearing age on MLU and verbal agreement errors. As for finite verb production, hearing age was a predicting factor, whereas age at implantation was not.

This study provides evidence that CI children are able to acquire verb morphology and that hearing age is a crucial variable in their acquisition process.

[4] This section has been submitted for publication in the Journal of Speech, Language and Hearing Research (On the relation between early implantation and verbal morphology production, A. Hammer, M. Coene, S. Gillis, J. Rooryck & P. Govaerts).

2. Introduction

Spoken language perception and verbal morphology

It is well known that predominant acoustic elements in speech production are more easily perceived as compared to those that are acoustically less salient. Maintained by literature on the subject, it has been shown that in developing children, perceptual salience plays an important role in the acquisition process: highly salient elements typically emerge earlier in the child's grammar than non-salient ones (Zobl & Liceras 1994; Goldschneider & De Keyser, 2001). In this view, with respect to verb morphology, free verb morphemes will be more noticeable than bound morphemes and verb stems will be more salient than verbal inflection. It is therefore expected that short, unstressed and bound verb morphemes will be easily missed in incoming speech and will therefore be particularly challenging for the acquisition process.

The reduced perceptual salience of bound morphemes is expected to have an even higher impact on the acquisition of verbal morphology in children with auditory deficits. Different degrees of perceptual salience of free/bound verbal morphology may explain their different order of acquisition. This is commonly known as the Perceptual Prominence Hypothesis (Svirsky et al., 2002). Under this hypothesis, monosyllabic unbound morphemes such as the copula '*is*' (e.g. John *is* nice) will emerge before bound ones, such as *–s* (e.g. John sing*s* a song) or *–ed* (e.g. John work*ed* hard yesterday).

Important delays in the acquisition of morphology have indeed been reported for profoundly deaf children wearing classical hearing aids (henceforth HA) (Cooper, 1967; Quigley, 1976; Brown, 1984; Norbury et al., 2001). At an average age of 9 years, HA children have been shown to perform as accurately as 4-year-olds with typically developing hearing (henceforth TD) (Brown, 1984). Improvements in the production of verbal morphology are found alongside an increase in the children's age with 8 to 10-year-olds showing 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). Despite these improvements, not all HA children have been found to catch up with their hearing peers: by the age of 11 to 15 years, more than 30% of the HA adolescents will have lower than normal scores on expressive grammar and grammatical judgment tasks (Delage & Tuller, 2007). As the order of verbal morpheme acquisition does not differ from that found in younger TD children, HA children may be seen to demonstrate a delayed rather than deviant acquisition pattern.

Verbal morphology production in CI children

Conventional HAs are hearing devices worn outside the body and are best suited for mild to moderate hearing impairments. Today, many profoundly deaf children are given access to spoken language by means of a cochlear implant (henceforth CI), an implantable electronic device that bypasses the cochlea by means of direct stimulation of the auditory nerve, providing the sensation of hearing. CIs are known to both amplify and fine-tune sounds, providing a highly qualitative acoustic signal. Thanks to this device, many deaf-born children, provided they are implanted early in life, are able to develop oral language in a similar fashion and at the same rate as their hearing peers (Robbins, Svirsky & Kirk, 1997; Hammes et al., 2002; Geers, Nicholas & Sedey, 2003; Svirsky et al., 2004; Geers, 2004; Nicholas & Geers, 2007).

If CIs indeed provide profoundly deaf children with qualitatively better speech input than classical HAs, it is expected that improved language outcomes will be found in the first group as compared to the second. With respect to the acquisition of verbal morphology, the expectation is borne out that CI children who have similar amounts of hearing loss have been shown to use more verbal morphemes in their conversational speech than HA children (Spencer, Tye-Murray & Tomblin, 1998).

Additionally, it has been claimed that the use of a CI positively influences language growth rates. Profoundly deaf children wearing a CI develop oral language faster than their profoundly deaf peers wearing a classical HA (Robbins et al., 1997; Tomblin, Spencer, Flock, Tyler, Gantz., 1999; Svirksy, Robbins, Kirk, Pisoni, Miyamoto, 2000). However, it should be noted that with duration of use of the device held as a constant, a significant amount of variability with respect to language growth rates in CI children is apparent. About half the CI children have growth rates in morphology that are comparable with their TD peers, whereas the other half develop morphology at a slower rate (Szagun, 2002).

Effects of age at implantation and of hearing age

As most CI children are not implanted before the second half of their first year of life, their access to spoken language input will inevitably be delayed, thus triggering. a negative influence on the onset of language development.

At least two factors may influence the language outcomes in CI children: (i) the duration of aural language experience with the device, i.e. the children's hearing age; and (ii) the age at which the children are given first access to spoken language input by means of a CI, i.e. the age at implantation. In terms of the impact of the duration of hearing on verbal morphology production, it has been shown that CI children with longer aural language experience produce more verbal morphemes as compared to children with shorter spans of experience (Spencer et al., 1998; Tomblin et al., 1999). With respect to the time at which deaf children are given first access to oral language by means of a CI, studies show that early implantation is positively related to language learning rates (Kirk et al., 2000; Tomblin et al., 2005; McDonald Connor, Craig, Raudenbush, Heavner & Zwolan, 2006; Holt & Svirsky, 2008). Svirsky et al. (2004) report that CI children receiving their implant at the age of 2 are respectively 6 and 10 months ahead in their language development as compared to CI children implanted at 3 and 4 years.

Significantly, as seen in the relevant literature, the positive effect of timely access to linguistic input on language outcomes has been advanced as an argument in favor of the existence of a so-called sensitive period for language development. A few studies report oral language deficits within hearing individuals deprived of linguistic input during childhood (Itard, 1962; Curtiss, 1977). Studies based on populations of oral deaf children with a CI show that language learning declines after the second year of life (Svirsky in Nature News, 2005), and that children receiving CIs in the third and fourth years of life demonstrate important general language delays as compared to children implanted before that age (Waltzman & Cohen, 1998; Geers et al., 2003). More recent work indicates that the language levels of CI children who are implanted between at 12 and 16 months are likely to fall within the normal range when they are 4.5 years of age. By this point, owing to steep language-learning rates experienced early in life, these children are able to match their TD peers in their variety of morphology production (Nicholas & Geers, 2007). Previous research by our team confirms the perceived advantage of early implantation. Children implanted before 15 months have faster than normal language-learning rates (Coene et al., to appear/a). This raises the possibility that early implanted CI children close the gap with their TD peers in later childhood.

3. Research purposes

CI children have a perceptual deficit, which could make it difficult to perceive verbal morphemes, as these morphemes are short, non-salient items. Although studies have shown that CI children are able to acquire verbal morphology with their implant (Szagun, 2000, 2002; Nicholas & Geers, 2007), it can be expected that they will experience a significant delay in the production of verbal morphology, especially with respect to the least salient type of morphology.

In this study, we intend to compare the acquisition of verbal morphology in profoundly deaf CI children (110dBHL SD 11) to that of HA children with a moderately severe hearing loss (67dBHL SD15), but with a similarly aided hearing loss (CI=33dBHL 7SD, HA=28dBHL 5SD). The motivation behind such a comparison is to be found in previous studies that have reported equivalent outcomes with respect to speech perception between profoundly deaf CI children and severely hearing-impaired HA children (Snik et al., 1997; Blamey et al., 2001). By comparing these two populations of hearing-impaired children with similar aided-hearing levels, we will be able to determine the possible effect of the specific devices on language outcomes. If the outcomes are different for both populations, they may be considered to be an effect of qualitative differences in speech input resulting from a difference in the processing of the acoustic signal. If, on the other hand, no such differences are found, comparable aided-hearing levels may be understood to yield similar language outcomes irrespective of the type of device used by the hearing-impaired individual.

The second aim of this study is to compare the verbal morphological development of CI children with that of their TD age-matched peers. Standardized data from TD children indicate that hearing children produce a large variety of verbal morphemes between the ages of 4 and 7. Moreover, the accuracy of verbal morpheme production is increasingly rapid over the years. Therefore, if CI children have difficulties with verbal morphology, these difficulties should be evidenced within the accuracy of verbal morpheme production.

The third aim is to analyze the verbal morphology production of CI children as a function of the age at implantation and hearing age. Several studies report better language outcomes for young implanted children as compared to older implanted children (Geers et al., 2003; Geers, 2004; Nicholas & Geers, 2007). In addition, based on normative data coming from age-matched TD peers, it is possible to determine which CI children will be able to catch up with their hearing peers by the age of 4 to 7. It has been reported that early implanted children have faster than normal language-learning rates, which result in age-appropriate language outcomes for children aged 4 to 5 (Coene et al., to appear/a). Therefore, we expect early implanted children to close the gap with their TD peers by the age of 4.

In this study, language outcomes will be measured using the Mean Length of Utterance (MLU) in words and by means of the production of bound and unbound verb morphemes. In the light of the Perceptual Prominence Hypothesis discussed in section 1, we expect to find a larger error rate for bound verb morphemes as compared to the omission of inflected verbs, i.e. the complex morpheme consisting of a lexical stem followed by a bound morpheme. The rationale behind this expectation is that language items containing a lexical stem (in combination or not with a bound morpheme (e.g. *walks*) are perceptually more salient than the bound inflection by itself (e.g. *-s*).

Alternatively, one could hypothesize that, due to the underspecification of inflection in young children's grammar (Hyams, 1996), an equal number of both inflected verbs and bound verbal morphemes will be dropped. Under the latter hypothesis, once inflection is acquired, the child should be able to produce all types of verbal agreement markings, regardless of their perceptual prominence status.

In this study, we make use of MLU as a broad, general measure of language development. Studies of the content validity of MLU generally agree that syntactic growth is visualized in sentence lengthening up to a MLU of 4.0

(measured in morphemes), which corresponds to a chronological age of approximately 3 years. Longer MLU's lose their indicative value for syntactic growth, as the development of syntactic complexity does not necessarily result in longer utterances (Miller & Chapman, 1981; Klee & Fitzgerald, 1985; Rondal, Ghiotto, Bredart & Bachelet, 1987). Despite its lack of robustness for content validity, MLU has a broad concurrent validity that persists into middle childhood (5 to 9 years). The longitudinal data of Rice, Redmond & Hoffman (2006) have shown that MLU is a stable discriminator between children with low language production and children with normal language production up to the age of 9. Therefore, we take MLU to be a general indicator of language production, but do not interpret its subsequent outcomes as reflections of syntactic competence.

4. Research method

Participants

Forty-eight CI children and 31 HA children participated in this study. The CI and HA children were drawn from special schools for deaf children and from an audiology centre, all located in Flanders, Belgium. The CI children were aged between 47 and 93 months, the HA children between 48 and 95 months. All of them were monolingual speakers of the Dutch language. A summary regarding age characteristics (i.e. chronological age and age at implantation/hearing age for the CI children) is presented in Table 1 for the CI children and in Table 2 for the HA children. The CI children were evenly distributed across age groups with respect to age at implantation ($F(3.44)=.279$, $p=.841$).

Table 1. Mean, SD and ranges for chronological age, age at implantation and hearing age of CI children.

	chronological age			*age at implantation*			*hearing age*		
	M	SD	Range	M	SD	Range	M	SD	Range
4 yrs (N15)	50.9	4.8	46.8-59.7	14.8	7.3	5.2-34.8	36.1	5.5	23.9-41.6
5 yrs (N14)	63.2	4.1	59.7-70.2	17.7	10.2	5.2-34.5	45.5	8.6	29.5-58.8
6 yrs (N10)	73.5	2.5	72.1-80.6	15.5	10.8	5.2-43.2	58.0	11.4	29.5-70.3
7 yrs (N9)	85.8	2.7	84.0-92.9	15.6	6.7	5.2-25.5	70.2	6.2	59.9-79.2

Table 2. Mean, SD and range for chronological age of HA children.

	chronological age		
	M	SD	Range
4 yrs (N10)	51.9	4.5	47.6 – 59.7
5 yrs (N9)	63.7	5.4	60.2 – 74.5
6 yrs (N6)	76.6	4.1	72.4 – 81.9
7 yrs (N6)	88.7	4.9	83.9 – 95.4

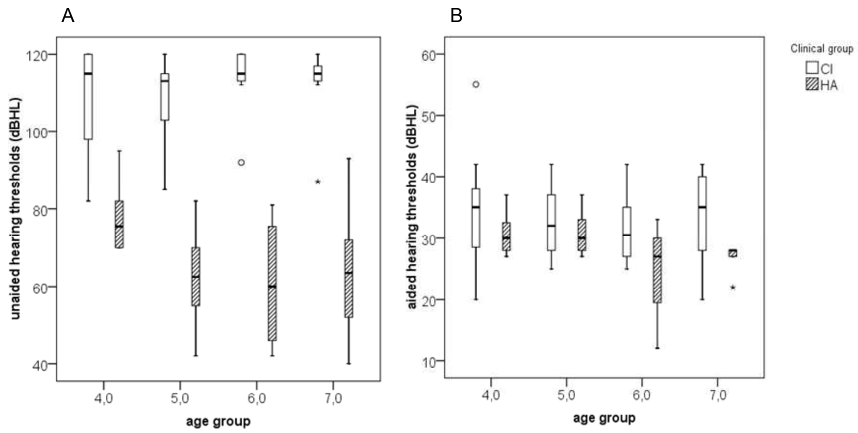
For each age group, the minimum unaided hearing loss (i.e. hearing thresholds averaged over 500, 1000 and 2000Hz for the best ear) of the CI children is between 82-92dB. Such thresholds are expected, given that in Flanders, a hearing loss within this range is one of the prerequisites for cochlear implant candidacy. As a consequence, significantly lower unaided hearing thresholds are found for the CI children as compared to the HA children and partially explain the choice for this particular hearing device. Importantly, both hearing-impaired groups are equivalent in aided hearing thresholds, see Figure 1 and Table 3 for statistical results (unaided and aided hearing threshold means, standard deviations and ranges are placed in Table 1 of the Appendix).

For all CI and SLI children selected for the present study, informed consent was obtained from the parents prior to participation. For an overview of all CI and HA children see Appendix Table 3 and 4 respectively.

Table 3. Statistical results for the comparison between CI and HA children on unaided and aided hearing thresholds. Comparisons are conducted using a one-way ANOVA and, in the case of unequal sample sizes, a Mann-Whitney U-test (Two-sided testing with alpha .01, corrected for multiple testing).

	unaided hearing thresholds (dB)	*aided hearing thresholds (dB)*
4 yrs	$F(1,21)=36.13$, $p<.01$	$F(1,21)=.92$, $p>.01$
5 yrs	$F(1,17)=55.37$, $p<.01$	$F(1,17)=.68$, $p>.01$
6 yrs	$U=.00$, $p<.01$	$F(1,11)=2.51$, $p>.01$
7 yrs	$F(1,13)=44.12$, $p<.01$	$U=11.0$, $p>.01$

Figure 1. Unaided hearing thresholds are presented in panel A for the CI and HA children. Panel B presents the aided hearing thresholds for both hearing-impaired groups.



Language assessment

Thanks to standardized language testing, normative data of 240 Dutch-speaking, hearing children between 4 and 7 years of age were available. The test assesses the children's morphosyntactic skills by analyzing 50-utterance spontaneous speech samples (STAP-test; Verbeek, Van den Dungen & Baker, 1999). It includes such aspects as quantitative and qualitative measurements of verbal morphological production. Regarding the measures under investigation in this study, we have previously shown that the internal consistency reliability for such a 50-utterance sample is high to very high (split-half method with Spearman-Brown formula, (Drenth & Sijtsma, 2006) coefficient .87 – .95, for more details see chapter 4, subsection 4.3).

The test procedure consisted of recording conversations between a child and an adult. The interacting adult was either one of the parents, a speech therapist or the first or second author of this paper. The topics of conversation varied from one sample to another, as the adults encouraged the children to discuss their own interests in an effort to reduce the number of possible silent periods during the registration session. All conversations were videotaped using a Panasonic NV-GS180 camera.

The spontaneous speech samples were transcribed by an experienced speech therapist familiar with listening to the speech of deaf children. Transcriptions were made according to the CHAT conventions, available through the Child Data Exchange System (MacWhinney, 2000). In agreement with the test procedure, the first 50 child utterances were analyzed. The following type of utterances were discarded: repeated and unintelligible utterances and idioms (e.g.

'weet ik niet' *I don't know*) as well as elliptical answers, i.e. answers to preceding questions without a finite verb and/or other utterance parts that can be inferred from the preceding question (e.g. adult: 'does it hurt' child: 'a little bit').

Mean Length of Utterance (MLU) was measured in words. For verbal morphological production, we used a quantitative and a qualitative measure. We counted the number of finite verbs produced in a 50-utterance sample as part of the quantitative measure for verbal morphology. The qualitative measure for verbal morphology builds on (i) the omissions of inflected verbs in an obligatory context such as in (1), defined as a context in which a finite verb needs to be present in order for the utterance to be grammatical; and (ii) the non-target like use of bound verb morphemes, for instance omission of the third person singular (see (2)) or plural morpheme or the mismatch between the bound verb morpheme and the subject (see (3)).

(1) Ikke *(ben) naar de film geweest
I *(am) to the movie been
'I have been to the movie"

Omission finite verb

(2) Die slaap*(t) in een bedje
That sleep*(s) in a little bed
'That one sleeps in a little bed'

Omission 3rd p. sg morpheme

(3) Hier *waren\ was het podium
There were the stage
'There was the stage'

Plural verb form in singular contexts

An overview of the Dutch verbal paradigm is presented in Table 4.

Table 4. Inflection morphology for the present tense subject-verb agreement, exemplified for the verb lopen (*to walk*).

person	*singular*	*plural*
1st	stem + ø loop	stem + en lop*en*
2nd	stem + t# loop*t*	stem + en lop*en*
3rd	stem + t loop*t*	stem + en lop*en*

Reliability

To examine the coding reliability, 10% of the grammatical annotations were reanalyzed by an independent, experienced coder. Correlations were calculated to determine the degree of correspondence between the first and the second coding. These were as high as .99 for MLU and finite verb production and .96 for verb agreement errors/omissions.

According to the standardized test, language development may be identified as being deviant or not, with deviance representing language outcomes that correspond to a 2.5 percentile or less in hearing controls. To determine the degree of correspondence between the two coding sessions in this deviant/non-deviant categorization, we calculated Kappa coefficients (Landis & Koch, 1977). Here, a coefficient of 1 was found for MLU (in words) and .75 and .71 for finite verb production and verb agreement errors/omission respectively.

Data analysis

The raw scores on each measure have been standardized according to the norms of the TD children. This standardization consists of transforming each individual's raw score into a z-score. A z-score denotes the distance to the mean of the population of TD children. The mean of this population is indicated by a z-score of 0 and the 95% confidence interval lies within the z-scores of -1.96 and 1.96. If a child obtains a z-score lower then -1.96, the child has performed significantly below age expectations. Statistical testing between the CI and HA children at each age is done with a one-way ANOVA if the assumption of equal variances is met. If not, the non-parametric Mann-Whitney U-test was utilized. To adjust for multiple testing, we lowered alpha to .01.

In order to determine the effect of Perceptual Prominence in the acquisition of free versus bound morphemes, a comparison was made between the percentage of finite verb use in obligatory contexts and that of target-like use of bound morphemes as a function of the total number of finite verbs. A significantly higher percentage of inflected verbs as compared to target-like agreement morphemes would indicate that perceptual salience plays an important role in the acquisition of verbal morphology.

To examine the effect of age at implantation and of hearing age on language outcomes, we performed linear regression analyses across age groups. In all regression analyses, the two factors, i.e. age at implantation and duration of CI use, (i.e. hearing age) were entered together.

5. Results

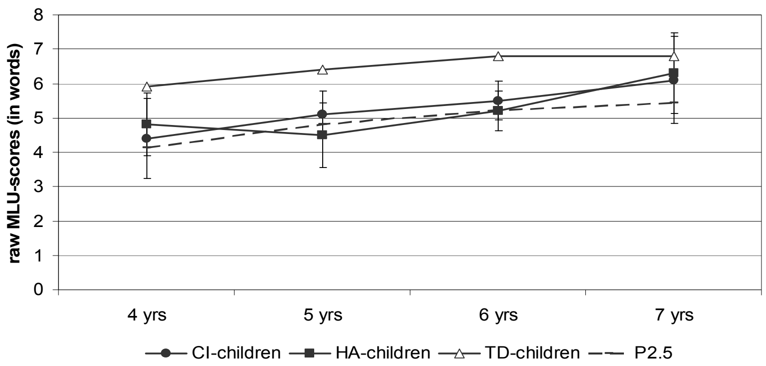
General language and verbal morphology production

MLU

The mean raw scores and standard deviations for MLU are presented in Figure 2. The results of the CI and HA children are plotted against the mean scores of the TD children. The dotted line indicates the lower boundary of the 95% confidence interval of the TD children (P2.5).

The TD children show an increase in MLU up to the age of 6. After this age, their scores level off. Mean age group scores for the CI and HA children are within the lower boundary of the 95% confidence interval at 4 years of age. The CI and HA children increase their MLU over the years and therefore approach the mean MLU of the TD children at the age of 7.

Figure 2. Mean raw MLU scores and SD per age group for the CI children and HA children. Reference scores are plotted in each graph, with the dotted line indicating the lower boundary of the 95% confidence-interval in TD children (P2.5).



The raw scores have been standardized for all age groups by transforming them into z-scores. These are plotted in Figure 3. These data give more information about the variation within each age group for both CI and HA children. Here, the horizontal line indicates the lower and upper boundary of the 95% confidence interval (P2.5 and P97.5) in hearing controls. The dotted horizontal lines indicate the boundaries of the 68% confidence interval (P31 and P68) in hearing controls

With respect to Mean Length of Utterance, no significant differences were observed between the CI and HA children at any age (see Table 5). A closer inspection of the data shows that for the CI children, the median MLU improves with the increasing age of the children. For the HA children, no such improvement is observed before 7 years of age.

Figure 3. Box plots represent the standardized MLU scores for the CI and HA children per age group. Reference values from hearing controls are depicted by dotted lines representing the area within one SD from the mean (z-scores -1 – 1), and by solid lines marking the 95% confidence interval (z-scores -1.96 – 1.96).

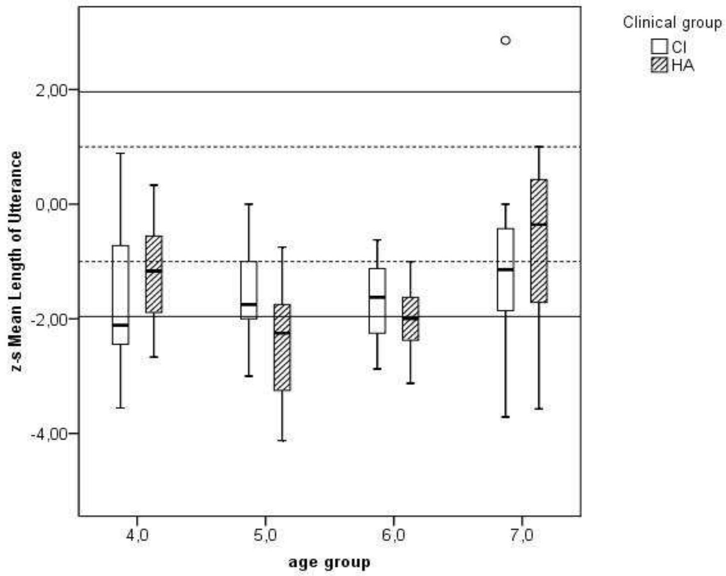


Table 5. Statistical results for the group comparison between CI and HA children on MLU.

	statistical results
4 yrs	F(1,23)=.869, p=.361
5 yrs	F(1,21)=3.313, p=.083
6 yrs	F(1,14)=1.093, p=.314
7 yrs	F(1,13)=.085, p=.775

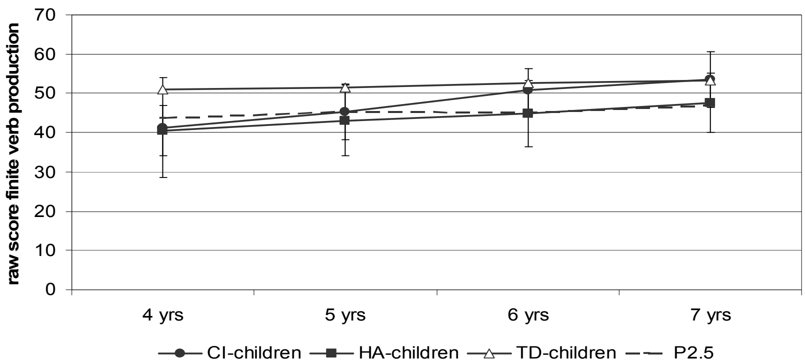
The data also shows that there is a large variation amongst children at all ages for both hearing-impaired populations, and that the proportion of children performing within normal range differs for the four age groups. At the age of 4, 46.7% of the CI children perform well within the 95% confidence interval, whereas 53.3% fall below the P2.5. At ages 5, 6 and 7, an increasing percentage of the children move within the 95% confidence interval. This indicates a steady growth in MLU scores over the years for about 75% of the CI children.

For the HA children, it can be seen that at age 4, 80% fall within the 95% confidence interval. Contrary to CI children, at age 5 and 6, there is no increase in the proportion of children performing within the 95% confidence interval. At 7 years, however, over 75% of the HA children perform within the normal range.

Finite verb production

With respect to finite verb production as detailed in Figure 4, the aged-4 TD children already perform at maximum capacity. At this age, the mean production of finite verbs for the CI and HA children falls below the P2.5. The CI children rapidly catch up with their TD peers, and by the age of 6, their mean finite verb production is comparable to that of TD children. In contrast, by age 6 the HA children barely reach the P2.5 of the TD children in their finite verb production. By age 7, they have yet to move beyond this P2.5.

Figure 4. Mean raw scores on finite verb production per age group and SD for the CI children and HA children. Reference scores of hearing children are plotted in each graph, with the dotted line indicating the lower boundary of the 95% confidence-interval (P2.5).



Here, too, raw scores have been standardized by transforming them into z-scores for each age group. The results are depicted in Figure 5.

Group comparisons between CI and HA children show that there is no significant difference between both hearing-impaired groups in regard to finite verb production (see Table 6).This is probably due to the large variation in outcomes among children for both groups. The standardized results show that at age 4, more than 50% of the CI children perform as well as their TD peers. As for the HA children, a percentage of them reach a performance level that is comparable to that of their TD peers. However, at all ages, most HA children score within the lower boundary of the normal distribution (between the z-scores of -1.96 and -1). This implies that the CI children are slightly better performers than their HA peers (e.g. at age 7 median CI = 0.11, HA: -1.73).

Figure 5. Box plots represent the standardized finite verb production scores for the CI and HA children per age group. The reference data from hearing children are indicated by horizontal lines. The area within one SD from the mean is indicated by a dotted line (z-scores -1 – 1). The 95% confidence interval is indicated by a solid line (z-scores -1.96 – 1.96).

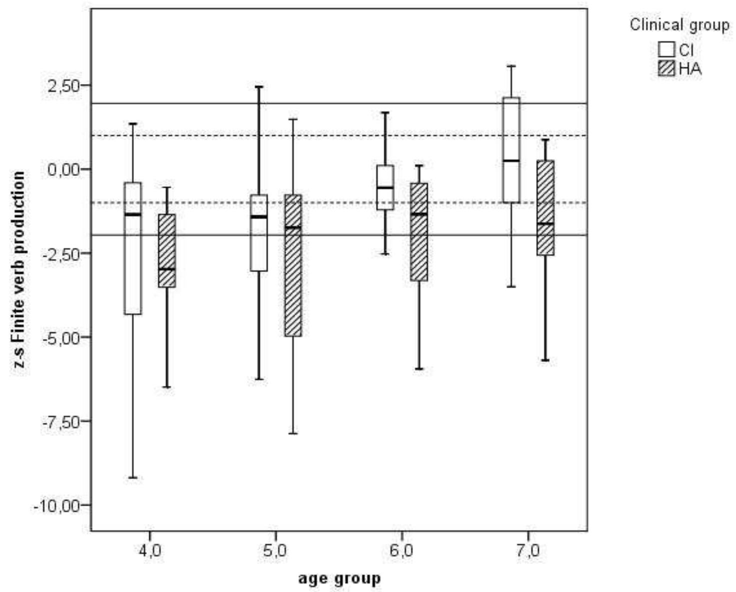


Table 6. Statistical results for the group comparison between CI and HA children on finite verb production.

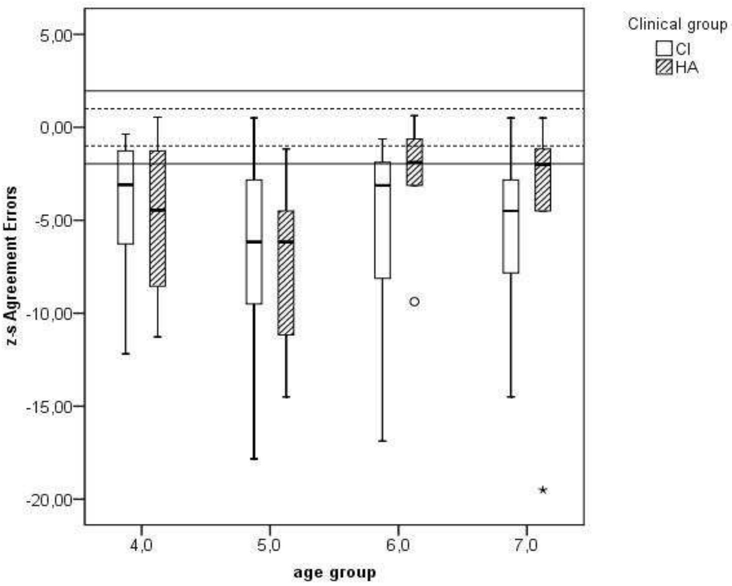
	statistical results
4 yrs	U=59.0, p=.37
5 yrs	F(1,21)=.415, p=.527
6 yrs	F(1,14)=2.984, p=.106
7 yrs	F(1,13)=2.340, p=.150

Errors\omission of verbal agreement

For the TD children, as early as at age 4 the mean occurrence of verbal agreement omission (bound and unbound morphology in obligatory contexts) is less than one. This indicates that in hearing children between 4 and 7 years of age, the accuracy in agreement marking is high.

As regards the hearing-impaired populations, the standardized scores of both CI and HA children as depicted in Figure 6 show that the majority of the children do not perform within the normal range at any age.

Figure 6. Box plots represent the standardized agreement error scores for the CI and HA children per age group. The reference data from hearing children are depicted by horizontal lines. The area within one SD from the mean is indicated by a dotted line (z-scores -1 – 1). The 95% confidence interval is indicated by a solid line (z-scores -1.96 – 1.96).



No significant differences were found between the CI and HA children at any age (see Table 7). Once again, a considerable variation can be observed within each age group for both the CI and HA children. For more than two thirds of the CI children, the number of agreement errors made was not within the normal range. Significantly, the data reveal that there was no clear improvement over the years. The HA children also show difficulties in verbal agreement production. At the ages of 4 and 5, more than 70% of the children fell outside the normal range. At the ages of 6 and 7, this percentage dropped, with more than 20% performing outside the normal range.

Table 7. Statistical results for the group comparison between CI and HA children for errors/omission of verbal agreement.

	Statistical results
4 yrs	F(1,23)=.143, p=.709
5 yrs	F(1,21)=.466, p=.502
6 yrs	F(1,14)=1.278, p=.277
7 yrs	F(1,13)=.075, p=.789

Perceptual prominence

To analyze the influence of perceptual prominence on the acquisition of verbal morphology, we compared the percentages of finite verb production in obligatory contexts with those of target-like bound verb morphemes for the total number of finite verbs in both CI and HA populations. Table 2 of the Appendix provides information about the number of obligatory contexts and the total number of finite verbs used in the analysis.

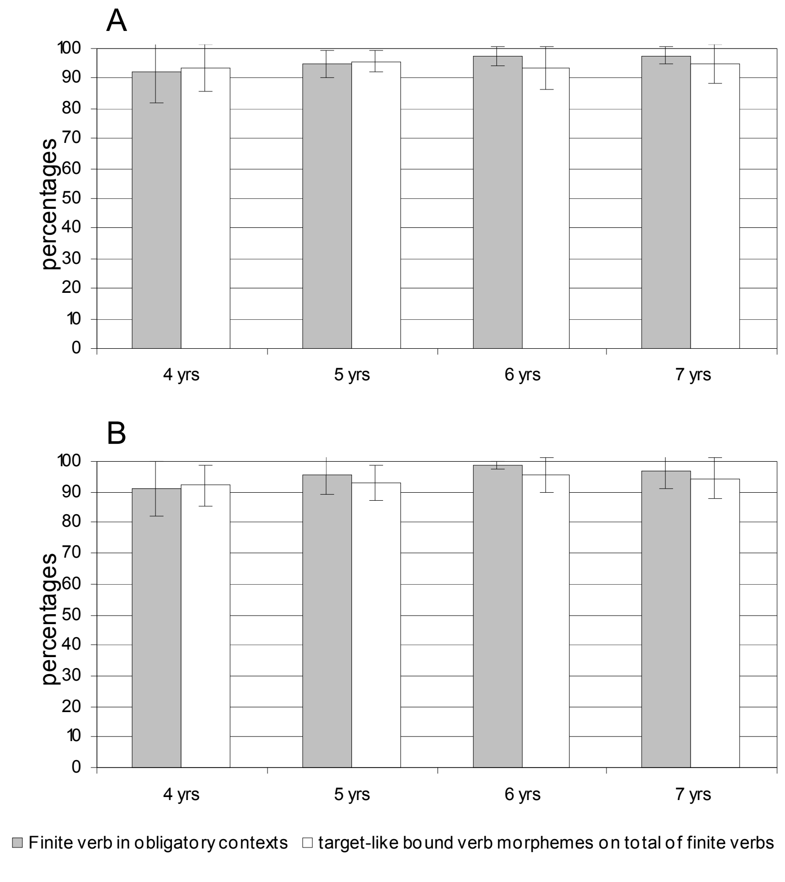
The results in Figure 7 indicate that over the years, CI and HA children produce slightly higher percentages of finite verbs in obligatory contexts. In contrast, both groups of children fail to show the same increase in the target-like production of bound verb morphemes over the years. This means that as children grow older, they tend to produce more verbs, yet at the same time, they do not necessarily mark these verbs correctly with respect to subject-verb agreement.

However, none of the age groups showed significant differences between the two types of verbal morphology measures for either the CI or HA children (see Table 8 for statistical results).

Table 8. Statistical results for the comparison between production of finite verbs in obligatory contexts and target-like production of bound verb morphemes.

	CI-children	*HA-children*
4 yrs	U=106.0, p=.81	U=48.5, p=.91
5 yrs	U=88.5, p=.67	U=28.0, p=.30
6 yrs	U=33.5, p=.22	U=11.5, p=.31
7 yrs	U=28.0, p=.30	U=14.0, p=.59

Figure 7. Mean percentages and standard deviations per age group for the production of finite verbs in obligatory contexts and target-like production of bound verb morphemes on total number of finite verbs produced. (In Panel A for the CI children and in Panel B for the HA children).



Age at implantation and hearing age

The variation between the CI children on MLU and target-like production of bound verb morphemes is not significantly related to the age at which the children received their implants or the duration of their aural language experience (respectively F(2,45)=1.995, p=.148 and F(2,45)=.457, p=.636).

For finite verb production, however, the regression function in which both factors have been entered together is significant (F(2,45)=8.323, p=.001) and accounts for 27% of the variance. In this regression function, only hearing age is a significant predictor whereas age at implantation is not (see Table 9). This indicates that the CI children need a similar length of aural language experience to reach age-appropriate scores on finite verb production, regardless of their age at implantation.

Table 9. Regression analyses for the three verbal measures under investigation with age at implantation and hearing age entered together as factors.

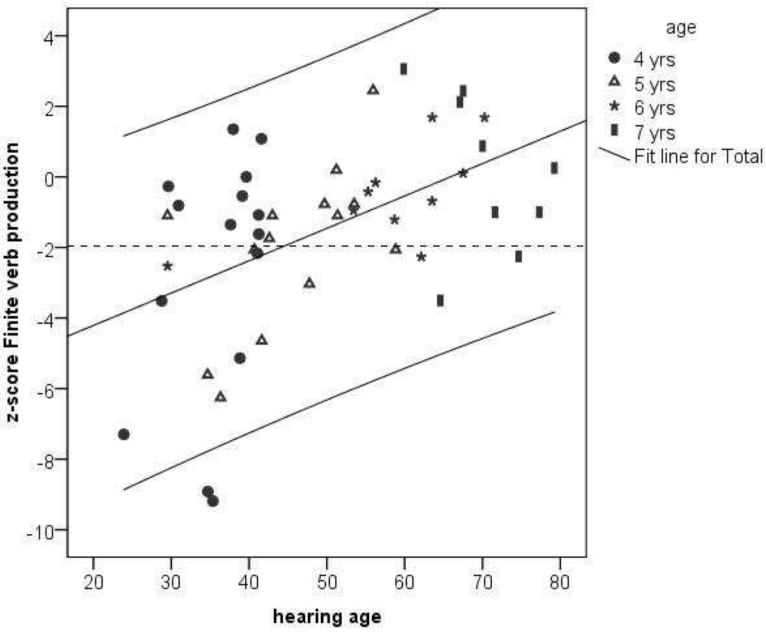
	MLU		*finite verb production*		*% subject-verb agreement errors*	
	β	*p*	*β*	*p*	*β*	*p*
age at implantation	-.123	.444	.165	.265	.123	.464
hearing age	.207	.208	.421	.005*	-.032	.846

In Figure 8, we plotted the finite verb z-scores for each child against the hearing age of the child. This figure shows the regression line as well as the 95% confidence interval. The horizontal dotted line indicates the P2.5 of hearing children. CI children scoring below the P2.5 can be considered deviant from the TD population.

From this Figure, it can be seen that the regression line intersects the P2.5 at approximately 44 months of age. This indicates that 4 to 7-year-old CI children need approximately 44 months of aural language experience to produce a percentage of finite verbs that is within the normal range.

From Figure 8, it can also be observed that the number of finite verbs produced by about 56% of all CI children (across age groups) is within the normal range. Obviously, this percentage is not consistent across age groups, but increases over time: it is as low as 40% for the 4-year-olds, but reaches 78% for the 7-year-olds.

Figure 8. Scores obtained by CI children in finite verb production as a function of hearing age. The regression of age onto finite verb z-scores as well as the 95% confidence interval are indicated by the solid lines. The dotted line presents the P2.5 of the TD children, the reference population.



6. Discussion

Do CI children out-perform their HA peers?

The first aim of our study was to compare the language outcomes of cochlear-implanted children with those of hearing-impaired children wearing classical hearing aids. We hypothesized similar production patterns for CI and HA children with respect to their verbal morphology, as these children compare in perceptual abilities, having similar aided hearing thresholds. This hypothesis is only partially supported by our results. No significant differences were found between CI and HA children at any age on MLU, finite verb production and verbal agreement errors.

However, the increase in finite verb production between the ages of 4 and 7 is steeper for the CI children than for the HA children. At the age of 6, the CI children perform comparably with the mean of their TD peers. The HA children, however, have verbal production scores that are similar to those found in the weaker TD children at age 6 and 7.

Importantly, the lower production of finite verbs for the HA children is not due to a relatively high rate of finite verb omission. Our results show that CI and HA children decrease their finite verb production in obligatory contexts at the same rate (see Table 2 of the Appendix). For the HA children, the low production of finite verbs points towards an overuse of elliptical utterances. Such an overuse of ellipses has been reported frequently in young, normally developing children. The use of ellipses avoids computational overload and is typical for speakers with processing limitations (Kolk, 2001). When adopting the working memory model of Baddeley et al. (1998, see also Baddeley, 2003), processing limitations could explain the low production of finite verbs for the HA children. In this working memory model, phonological material is retained in the phonological loop. This retention enables the permanent storage of the phonological material (e.g. words). The efficiency of the phonological loop, and ultimately of permanent storage, is dependent on the acoustic and phonological representations. Acoustically salient material and strong phonological representations facilitate permanent storage of the phonological material (Baddeley, 2003). It is possible that the HA children build phonological representations more slowly as compared to CI children. Incomplete functioning of the working memory results in protracted language development, because more input is required for adequate processing and incorporation in the child's language system (Leonard, Ellis Weismer, Miller, Francis, Tomblin & Kail, 2007).

It could well be the case that the CI children in this study were able to improve their perception abilities to a level at which the phonological representations allowed more efficient storage of phonological material compared to children wearing a HA. However, the fact that the CI children still produce subject-verb agreement errors to a similar extent as their HA peers implies that within the CI group, perception abilities are not yet optimal. Similar problems with respect to the target-like use of verbal morphology have also been reported by Brown (1984), Norbury et al. (2001) and Hansson et al. (2007).

Do CI children catch up with their TD hearing peers?

As can be observed from the data in Figure 2, the TD children already reach a plateau in finite verb production at the age of 4. CI children also reach such a plateau, but not before the age of 6. This indicates that CI children have a delay in verbal morphology development spanning approximately 2 years, but that they are also able to catch up with their TD hearing peers by the age of 6.

A similar observation is valid for general language development measured by means of MLU in words. From age 6, the MLU of TD children begins to level off. Here, also, CI children show an increase in MLU over the years and approach the mean MLU of the TD children at the age of 7, indicating that by this age, they have caught up with their hearing peers with respect to utterance length.

Can age at implantation or hearing age predict morphology development?

Variation in outcomes is observed between CI children for all the language measures under investigation. The variation in outcomes on MLU and the percentage of subject-verb agreement errors is not explained by age at implantation or hearing age. The outcomes on finite verb production can be partially predicted by hearing age but not by age at implantation.

When comparing outcomes in CI children with the same chronological age, the children's age at implantation is inherently confounded with auditory experience. Children who are implanted earlier in life will also benefit from longer aural language experience. Such a benefit has been reported by Spencer et al. (1998) who show that auditory speech experience correlates with morphology production in a population of 9-year-old CI children when controlled for chronological age. This study confirms that aural language experience may be a crucial variable, instead of chronological age and age at implantation alone. It suggests that CI children are likely to catch up with their hearing peers provided they have had a similar duration of aural language experience.

For the language measures under investigation, TD children show a plateau-effect at some point in their language development. Most CI children will eventually reach this plateau, albeit with a delay. Once the plateau has been reached, language outcomes are steady and age at implantation and/or the hearing age no longer seems to play a role. For MLU, this can be illustrated by the absence of significant correlations between both factors and the children's utterance length. At age 4, most of the CI children perform within the 95% confidence interval, making linear growth minimal (see Figure 2 and 3). In a similar vein, Geers et al. (2003) and Geers (2004) did not find significant correlations between age at implantation and language outcomes for the 8 and 9-year-old CI children participating in their study. Most of these children compared to their TD peers in terms of general language outcomes.

It is important to notice, however, that the congenitally deaf children participating in this study had an initial delay that is proportionally related to the number of months they spent with little to no access to spoken language (i.e. from birth to the moment of activation of the implant). This means that children that reach the plateau level for MLU could only have done so by having faster than normal language learning rates.

Does perceptual prominence play an important role in verb morphology development?

With respect to perceptual prominence, we expected to find a larger error rate for bound verb morphemes alone as compared to omissions of the entire verb form (verb stem + bound morpheme) for CI and HA children. The underlying idea behind this expectation was that complex lexical items such as inflected verbs are perceptually more salient than the bound verb morphemes by themselves. Our findings show that these expectations were not met: CI and HA children did not omit significantly more target-like bound verb morphemes as compared to inflected verb forms in obligatory contexts. In terms of acquisition, this equates to stating that CI and HA children are able to acquire both types of morphology.

We also formulated the alternative hypothesis that the similar use of both types of morphology could reflect the acquisition of grammatical features such as tense and/or agreement. Under this hypothesis, when grammatical tense and agreement remain underspecified, both bound verb morphemes and inflected verbs are expected to be omitted. However, our data indicate that both hearing-impaired populations participating in this study *do* produce inflected verbs within a normal range. As these inflected verbs must be specified for tense and agreement features, the observed findings can therefore not result from mere grammatical underspecification.

However, the agreement markers on the inflected verbs are not always used in a target-like manner. In many cases, person/number features of the subject and the verb do not agree. These problems with subject-verb agreement marking persist up to the age of 7. The number of errors is not related to the children's age at implantation nor to the hearing age. Importantly, subject-verb agreement errors are already uncommon in TD children from age 4.

Both perceptual prominence and tense/agreement underspecification have thus been shown not to be viable. In our view, the observed findings could relate to reduced auditory speech input, causing a delay in hearing-impaired children with respect to the storage of verb morphemes in the paradigm. A substantial amount of research indicates that hearing-impaired people have difficulties perceiving speech in noisy backgrounds (e.g. Lorenzi et al, 2006). As most of the day-to-day speech is typically produced in difficult listening situations, it is not unlikely that in CI and HA children, these morphemes are often missed in continuous speech. Translating this perception deficit in terms of acquisition, one may take the number of stored exemplars of inflected verbs in hearing-impaired children to be too low for adequate morphological analysis. As we know from the literature, the acquisition of verbal morphology starts when the number of stored exemplars (i.e. inflected verbs) exceeds a particular level (the Critical Mass Hypothesis, Marchman & Bates, 1994). Analysis of these exemplars enables a child to discover the verbal morphological paradigm of the native language when a critical mass is reached (see also Locke, 1997). In hearing-impaired children, the absence of such a critical mass therefore results in failure to initiate the morphological acquisition process.

Implications and future research

In the present study, CI and HA children are tested up to the age of 7. Not all children perform within the normal range by this age. Due to this age limit, it is not clear whether the observed delay persists into the older ages, or whether CI and HA children will be able to catch up with their hearing peers with respect to the target-like use of verbal morphology after the age of 7. If so, this would indicate that the use of verbal morphology in these populations is delayed rather than impaired.

It should also be mentioned that although some late-implanted children are able to catch up with their TD peers, it does not imply that age at implantation is of little concern. Earlier age-appropriate language skills could enhance learning on other cognitive domains (i.e. theory of mind) and pragmatic skills. Future research investigating language outcomes should therefore also include cognitive and pragmatic measures.

7. Conclusion

The aim of the present study was to investigate the verbal morphological production of 4 to 7-year-old CI children. The results were compared to those of age-matched, moderately severe hearing-impaired children with classical Hearing Aids (HA). In both populations, production of verbal morphology was investigated quantitatively by counting the number of inflected verbs produced, and qualitatively by analyzing the target-like use of unbound and bound verb morphology in obligatory contexts. The use of standardized language testing allowed us to compare the results of both hearing-impaired populations with the results of age-matched Typically Developing (TD) peers. With respect to the qualitative measure of verbal morphology, we analyzed the results in the light of the Perceptual Prominence Hypothesis (Svirsky et al., 2002). The results of all language measures for the CI children were analyzed as a function of age at implantation and hearing age.

The CI and HA children participating in this study compared to one another in aided hearing thresholds (between 28 – 33dBHL). This allowed us to investigate the influence of aided hearing on language outcomes in terms of the type of device used. No significant differences were found between the CI and the HA group with respect to the number of finite verbs produced, the number of subject-verb agreement errors and the MLU in a representative speech sample. However, over the years, CI children showed a steeper increase in finite verb production than HA children. This has been attributed to speech processing differences between CIs and HAs. As a result, HA children build phonological representations more slowly as compared to their CI peers. This results in incomplete functioning of the working memory and, as a consequence, delayed language development.

At the age of 4, a subgroup of the CI children performs within the normal range on MLU and finite verb production. This subgroup increases with increasing age. The results of these measures are not predicted by age at implantation. For finite verb production, 27% of the variance was predicted by the child's aural language experience only. Thus, it seems that for these CI children, a similar amount of time is needed to reach the performance plateau of the TD children on these measures. However, as aural language experience is proportionally related to the time that CI children have spent with little to no access to spoken language, early-implanted children are likely to reach the plateau earlier as compared to later-implanted children.

CI and HA children show persistent problems in the target-like use of bound verb morphology. This is not explained by the perceptual prominence in the spoken language input or the underspecification of grammatical tense and agreement. Instead, we propose that the delayed acquisition of verb morphology results from the reduced auditory speech input offered by the CI. Hearing-impaired people experience difficulties in speech recognition in noisy surroundings (Lorenzi et al., 2006). As everyday speech is mainly produced in such difficult listening situations, we argue that CI and HA children often miss verb morphemes in continuous speech, and that this may explain their delayed acquisition process.

SECTION 5.2

CI children in comparison to SLI children

1. Introduction

The purpose of this section of chapter 5 is to compare CI and SLI children in their general language development and verbal morphology development by analyzing spontaneous speech samples. The rationale for such a comparison was outlined briefly in chapter 1, where the language developmental theory of Locke (1997) was described. This theory suggests that delays in the acquisition of language occur when there is a shortage of lexical items. This shortage prevents the analytical mechanism from activating. The shortage of lexical items can be due either to the reduced effective exposure to linguistic behavior, as in the case of SLI (see also Conti-Ramsden et al., 1997), or to the reduced exposure to auditory speech input, as in the case of a hearing impairment (Locke, 1997 p:282). In section 2, we elaborate on the influence of auditory speech processing and cognitive processing in the development of oral language.

The second purpose of this section is to determine the role of perceptual salience in the acquisition of verbal morphology. Problems in the use of grammatical morphology are characteristic of SLI children and serve as a clinical marker (Conti-Ramsden & Jones, 1997; Bedore & Leonard, 1998; Marchman et al., 1999; Conti-Ramsden, 2003). These problems have been linked to the perceptual salience of these morphemes and named the Surface Account (Leonard et al., 1997). The Surface Account is explained in section 3 and is subsequently related to hearing impairments.

Hypotheses relating to both research objectives are outlined in section 4. Section 5 contains an outline of the research method, followed by the results in section 6. The research objectives and hypotheses are discussed in section 7, and the chapter closes with section 8, the conclusion.

2. Language processing

2.1 Low-level auditory processing

The ability to discriminate and process auditory stimuli is a critical skill for successful language development. General auditory processing allows infants to identify phonetic units that differ on subtle acoustic cues, such as the spectral and temporal structural cues of speech. Infants learn to perceptually categorize sounds, which they hear as distinct. Strong phonetic perception facilitates the detection of phonotactic patterns, which play an important role in segmentation (e.g. word learning and grammatical morphology). It has been shown that infants with strong skills in native language phonetic perception have better language outcomes at 18 and 24 months of age than infants with less developed perception skills (Kuhl et al., 2004, 2005).

Spoken language requires the processing of rapidly presented, successive auditory stimuli occurring within tens of milliseconds. Acoustic information is carried by formants, which represent the frequency modulation of the speech signal across time. The accurate discrimination of consonants relies on the detection of formant transitions that are relatively short (~40 ms).

These rapidly changing acoustic cues seem to disrupt discrimination abilities of SLI children. Therefore, language difficulties of SLI children have been related to a lower-level processing deficit or auditory processing deficit (Tallal et al., 1974, 1975, 1981; Benasich & Tallal, 2002; Benasich et al., 2002). Using the results of several series of studies as evidence, 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 than their TD peers to correctly discriminate between the two syllable pairs [ba-da] and [da-ta]. 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.

The cochlear implant provides limited spectral information due to the small number of electrodes and the mismapping between the allocation of the frequency bands to electrodes (for example a frequency band centered at 1000Hz is used to drive an electrode at the 2000Hz place within the cochlea) (Moore, 2003). Therefore, the CI users rely also on temporal information to derive pitch and formant cues from the speech input. However, the temporal information offered by the implant is not optimal with respect to formant frequencies (Moore, 2003). This, and the loss of spectral information, makes auditory speech material difficult to process. As such, the degraded speech input interferes with the discrimination and processing of auditory speech material, which could potentially lead to deficits comparable to the auditory processing deficit observed in SLI children (cf. Benasich & Tallal, 2002). It has been shown that CI users differ in their ability to discriminate between phonemes. The variability is only partially explained by the duration of auditory speech experience (Fryauf-Bertschy, 1997; Svirsky et al. 2001; Fu, 2002). Therefore, other factors appear to underlie discrimination abilities, such as lower-level processing abilities (see e.g. Fu 2002 on adult CI users).

2.2 High-level cognitive processing

Adequate processing of speech plays an essential role in higher order cognitive processing (Locke, 1997; Watson et al., 2007). Higher order cognitive processing refers to a temporary storage for information obtained from perception and retrieved from long-term memory. Mental operations are performed on the content of this store, hence this storage is called working memory (Gazzaniga, Ivry & Mangun, 2002). Working memory is limited in capacity and information is subject to fast deterioration. Therefore, to retain information, Baddeley (2003) proposed a subvocal rehearsal loop that crucially depends on acoustic and phonological representations of the input material - the 'phonological loop'. Thus, as the auditory speech stream is processed, phonological representations are fed into the working memory and the rehearsal loop. The data of CI children show positive correlations between the scores on working memory tasks and word recognition, sentence recognition and perception of grammatical morphemes. This points to the importance of auditory processing and working memory in the development of language (Pisoni & Geers, 2002; Pisoni & Cleary 2003; Willstedt-Svensson et al., 2004).

The effects of auditory processing and working memory on the perception of grammatical morphemes have also been reported for TD children. Hayiou-Thomas et al. (2004) have shown that TD children were less accurate in their grammaticality judgments when past tense morphemes, 3rd person singular morphemes and plural morphemes were presented at a faster than normal rate. Accuracy further decreased when these morphemes were embedded in longer utterances in addition to faster presentation rates.

With respect to the close links between perceptual abilities, auditory processing and working memory in the acquisition of morphology, it is reasonable to expect that the language performance of CI and SLI children is not only influenced by what they are able to process on an auditory level, but also by what they are able to do with this information in working memory. Regarding the acquisition of grammatical morphemes, a child not only has to perceive a grammatical morpheme but must also place it in the proper cell of the paradigm (Pinker, 1984).

Leonard et al. (1997) point out that the joint operation of perceiving an acoustically low-salient grammatical morpheme and hypothesizing its grammatical function seems challenging for SLI children. According to Leonard and colleagues, the incomplete processing of the auditory speech input is due to a higher-order cognitive deficit. The morpheme might be lost before morphological analysis is complete or morphological analysis does not occur at all, because processing is focused on previous material in the speech stream or abandoned prior to the inflection in favor of the next word appearing in the utterance. In the following section, we will elaborate on the hypothesis proposed by Leonard and colleagues.

3. Perceptual salience

We have already pointed out in section 5.1 of this chapter, that the perceptual salience of morphemes plays an important role in the acquisition process of TD children: highly salient elements typically emerge earlier in the child's grammar than non-salient ones, because highly salient elements are easier to process (Zobl & Liceras, 1994; Goldschneider & De Keyser, 2001).

With respect to acoustic features, Goldschneider & Dekeyser (2001) argue that perceptual salience of grammatical morphemes is composed of three factors, namely phonetic substance, syllabicity and relative sonority. Phonetic substance refers to the number of phones in a morpheme. The assumption is that the more phones in a morpheme, the more perceptually salient the morpheme is. For example, the Dutch past tense allomorphs /*-de*/ and /*-te*/ contain in total 4 phones. When divided by the number of allomorphs, this yields a mean of 2 for phonetic substance. The Dutch 3rd person singular morpheme (*-t*) contains only 1 phone. When divided by the number of allomorphs, this yields a mean of 1 for phonetic substance. As such, the regular past tense is perceptually more salient compared to the 3rd person singular morpheme. Syllabicity refers to the presence/absence of a vowel in the surface form of the morpheme. The presence of a vowel is perceptually more salient compared to morphemes without a vowel. In the above-mentioned example, the regular past tense is more salient compared to the 3rd person singular morpheme, because the former morpheme contains a vowel. Regarding relative sonority, the assumption is that the more sonorous the phones in the morpheme, the more perceptually salient the morpheme is. The 3rd person singular morpheme (*-t*) is a stop consonant, which is less sonorous compared to the vowel in the regular past tense morpheme.

3.1 The Surface Account

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). The additional operation of hypothesizing the grammatical function of the morpheme together with the low perceptual salience of morpheme can result in incomplete processing of the morpheme.

To take account of this, Montgomery & Leonard (1998) employed a grammaticality judgment task to assess the child's knowledge of the low perceptual salient past tense morpheme (*-ed*) and the high perceptual salient progressive morpheme (*-ing*). Results indicated that SLI children compared in performance to their TD peers in detecting the omission of the progressive morpheme in an obligatory context. However, the SLI children were less accurate in their grammaticality judgment when the past tense morpheme was omitted in an obligatory context.

In the study by Leonard et al. (2003), the reseachers examined the role of perceptual salience from another perspective. In this study they judged the effect of perceptual salience against the grammatical function of the morpheme. In this study, past tense forms [*the girl pushed the boy*] and passive participles [*the boy got pushed by the girl*] were elicited in an experimental task. The past tense morpheme and the passive participle have the same phonological form (i.e. *–ed*), but differ on grammatical function. The SLI children in this study were significantly less accurate in the use of the past tense morpheme as compared to the passive participles. Based on this finding, Leonard et al. concluded that the weak performance on the production of past tense morphemes could not be solely attributed to the acoustic characteristics of this morpheme. Rather, the function of the grammatical morpheme also plays a role.

3.2 Perceptual salience and hearing impairment

Under Leonard's Surface Account, that stresses the role of the perceptual salience of morphemes, the type of processing limitation observed in SLI children is not different from a perceptual deficit, as in the case of hearing impaired children (Locke, 1997; Norbury et al., 2001). Norbury et al. (2001) compared 14 SLI children aged between 7 and 10 years with 19 hearing impaired children, aged between 5 and 10 years. The hearing impaired children in this study wore conventional hearing aids and had a mild to moderate hearing loss (20-70dB). Two elicitation tasks were given which tested the child's knowledge of the 3rd person singular morpheme and the past tense morpheme. To elicit the 3rd person singular morpheme, the children had to describe what they themselves or their family members do every day, such as, '*every day Mark watches telly*'. They had to use at least 15 different verbs. Past tenses were elicited using the Ullman & Gopnik task (1999). In this task, the child was asked to complete sentences like: *'every day I rob a bank. Just like every day, yesterday I …….a bank'* (example from Ullman & Gopnik p:61).

On both tasks, group analysis showed that SLI children performed more poorly than the HA children. However, individual analysis indicated that 6 HA children showed impaired performance on inflectional morphology. This group of HA children was significantly younger compared to the unimpaired HA children (see also Hansson et al., 2007).

The results of Norbury et al. (2001) suggest that the problems in the target-like production of bound verb morphemes are not prevalent among all HA children, whereas they seem to be so for the SLI children. They argue that if perceptual salience plays a role in grammatical morpheme acquisition, the persisting problems in verb morphology for the SLI children are caused by other factors as well, such as cognitive disorders (e.g. Ellis Weismer et al., 2000), an auditory processing disorder (Tallal et al., 1981) or a phonological processing disorder (Briscoe et al. 2001, Baddeley, 2003). The combination of factors leads to a more severe language impairment, as observed for the HA children (Hansson et al., 2007).

4. Hypotheses

Based on the fact that adequate processing skills at an auditory and cognitive level have a pivotal role in language acquisition, we expect that disrupted processing skills can lead to delayed language acquisition. As outlined in section 2, a number of researchers have argued that SLI is the result of processing limitations (see also chapter 2, section 4). Therefore, we hypothesize that CI children compare to their SLI peers in this respect. It is therefore expected that both clinical groups will show similar outcomes on MLU and their production of unbound/bound verb morphology.

Alternatively, CI children may be seen not to compare to their SLI peers with respect to processing. This implies that the effect of reduced auditory input offered by the cochlear implant does not compare to reduced effective exposure in SLI children. This places more weight on external factors such as the role of input, peripheral hearing and education.

With respect to perceptual salience, we formulated the following hypothesis in section 5.1 regarding verb morphemes: items containing a lexical stem (whether or not in combination with a bound morpheme (e.g. *works*) are perceptually more salient than the inflection by itself (e.g. *-s*). Therefore, we expected to find a higher error rate for bound verb morphemes as compared to omissions of inflected verbs, i.e. the complex morpheme consisting of a lexical stem followed by a bound morpheme. However, the results of section 5.1 show that this hypothesis was not borne out for the CI and HA children.

As an alternative, we hypothesized that the children would omit an equal number of inflected verbs and bound verb morphemes due to the underspecification of inflection in their grammar (Hyams, 1996). According to the latter hypothesis, once inflection is acquired, the child should be able to produce any type of verbal agreement marking, regardless of its perceptual prominence status. For SLI children, it has been shown that they have more difficulty in the acquisition of verb morphemes pertaining to agreement as compared to other grammatical morphemes, such as plural *–s,* possessive *–s* or progressive *-ing* (Bedore & Leonard, 1998; Leonard et al., 2003). Therefore, to disentangle the effect of perceptual salience and underspecification from the acquisition of verbal morphology, we need to include an analysis of a [-AGR/+TNS] morpheme.

In Dutch, the circumfix of the past participle is an instantiation of such a morpheme. In this section, we will elaborate on perceptual salience and its role in circumfix omission of past participles. Past participles of weak verbs are formed by means of a prefix *ge-* and a suffix *–D*, in which *–D* stands for the allomorphs /*-t* /and /*-d*/ (Booij & Van Santen, 1998). In this circumfix, the prefix (*ge-*) is perceptually more salient than the suffix (*-D*). The first, but not the latter, contains a vowel (*schwa*) and is thus syllabified (Goldschneider & Dekeyser, 2001). If perceptual salience does not play a role in the acquisition of morphology, it is expected that *–D* will be omitted at an equal rate as compared to the prefix (*ge-)*. With respect to verbal morphology, this would indicate an underspecification rather than a perceptual salience hypothesis. However, this would also imply that SLI children not only omit the bound verb morpheme more often, but that they also produce fewer finite verbs than their TD peers.

5. Research Method

Participants

A total number of 48 CI children and 38 SLI children participated in this study. The CI children were selected from special schools for deaf children in Flanders (Belgium) and from The Eargroup, an audiology centre in Antwerp-Deurne (Belgium). The CI children were aged between 47 and 93 months and had received their implant between 5 and 43 months of age. All CI children had a minimum of 2 years of exposure to speech with a maximum of 6;7 years. Their mean unaided hearing loss was 110 dB (SD 11dB) (i.e. hearing thresholds averaged over 500, 1000 and 2000Hz for the best ear) (For more details regarding the unaided and aided hearing thresholds, see Table 2 of the Appendix and for individual data, see Table 3 of the Appendix).

Data from two groups of SLI children were analyzed. The first group included spontaneous speech data of 15 children with orthographic transcriptions readily available from the Bol & Kuiken corpus (Bol & Kuiken, 1988), through the

Child Data Exchange System (MacWhinney, 2000). The 19 transcripts involve four 4-year-olds, five 5-year-olds, seven 6-year-olds and three 7-year-old SLI children. The children included in the Bol & Kuiken corpus all attended special education schools in the Netherlands (Amsterdam, Haarlem, Amersfoort and Leiden).

The second group consisted of 19 SLI children who were selected for the present study. These children were selected from schools for special education in Flanders, Belgium.

For both SLI groups, all children were previously diagnosed as being language impaired by a certified speech-language pathologist. They received interventions at their schools for special education. None of the children had hearing losses, neurological/cognitive disorders or social/emotional problems. They were all of normal intelligence. An overview of the group characteristics is given in Table 1 (for individual data see Table 5 of the Appendix).

For all CI and SLI children selected for the present study, informed consent was obtained from the parents before participation.

Table 1. Overview of the CI and SLI children participating in this study.

	group	*N*	*age (SD)*
4 yrs	CI	15	50.9 (*4.8*)
	SLI	5	54.3 (*3.2*)
5 yrs	CI	14	63.2 (*4.1*)
	SLI	9	65.2 (*3.8*)
6 yrs	CI	10	73.5 (*2.5*)
	SLI	15	76.5 (*3.8*)
7 yrs	CI	9	85.8 (*2.7*)
	SLI	9	87.6 (*3.0*)

Language assessment

The CI and SLI children selected for the present study were recorded for 15 – 30 minutes using a Panasonic NV-GS180 digital video camera. To elicit speech, the same procedure was employed as in Bol & Kuiken (1988), which resembles the procedure of the STAP protocol, as explained in chapter 4, section 3. During the interactions, CI and SLI children spoke about daily activities. The topics of conversation varied from one sample to another, as the adults encouraged the children to discuss their own interests in an effort to reduce the number of possible silent periods during the registration session. Toys and books were not incorporated into the procedure eliciting speech. The child's personal school books or picture books were occasionally used as a method to familiarize the child with the situation and/or experimenter. Interactions with the CI and SLI children were carried out by either one of the parents, a speech therapist or by a member of the research group. All recordings were made in quiet rooms at the schools the children were attending or at the audiology centre.

The CI samples were transcribed by an experienced speech therapist familiar with listening to the speech of deaf children. The experienced speech therapist trained a second transcriber, who transcribed the speech samples of the SLI children. Transcriptions were made according to the CHAT conventions, available through the Child Data Exchange System (MacWhinney, 2000).

Following the test procedure, the first 50 child utterances were analyzed. Repeated and unintelligible utterances, idioms (e.g. 'weet ik niet' *I don't know*) as well as elliptical answers i.e. answers to preceding questions without a finite verb and/or other utterance parts that can be inferred from the preceding question (e.g. adult: 'does it hurt' child: 'a little bit') were excluded from the analysis.

The use of standardized language testing allows us to compare the scores of the CI and SLI children with normative data of 240 TD children. This study included the same measures as in section 5.1. These are Mean Length of Utterance (MLU) in words, finite verb production (that counted the number of produced finite verbs in the 50-utterance sample) and a qualitative measure for verbal morphology. For the latter measure, we counted the number of finite verbs omitted in obligatory contexts and the number of non-target-like usages of bound verb morphemes (see section 5.1 of chapter 5 section 4, for examples).

Non-target-like production of verbal agreement

The non-target-like productions of verbal agreement were further analyzed and subdivided into five categories (for the Dutch verbal paradigm see section 5.1 of chapter 5, Table 4).

No.	*Description*
1	Omission of the 3rd p/sg morpheme (i.e. *–t*) Die slaap*(t) in een klein bedje That sleep*(s) in a little bed *'That one sleeps in a little bed'*
2	Bare verb stem in plural contexts [Er] *mag/mogen geen leeuwen in hoor [There] *may no lions in (interjection) *'Lions cannot go in there'*
3	No deletion of the 2nd/3rd p/sg morph. in inversion context (see ex.) *or* use of 2nd/3rd p/sg morpheme with first person singular context Dan *weent jij Than *cries you *'Than you cry'*
4	Plural verb morpheme in singular contexts Hier *waren/was het podium There *were/was the stage *'There was the stage'*
5	Other non-target-like production of bound verb morphemes [De] lepel kanne inne [in de] vrachtwagen [The] spoon can in [in the] truck *'The spoon can be put in the truck'*

Circumfix omission of past participles

The past participle production and errors in the use of weak verbs were also analyzed for both clinical populations. In Dutch, all weak verbs have a circumfix (see (1)). For the strong verbs, the past participle is formed by a prefix, a vowel change in the stem or the use of a bare stem combined with a suffix *–t*/*–en* (see (2) and (3)). All past participles for which the target form requires a circumfix (i.e. the weak verbs) were taken into account and analyzed with respect to the omission of both prefix and suffix.

(1) ge-stem-D — De auto is tegen de boom <u>gebotst</u>
'The car has bumped into the tree'

(2) ge-past tense form — Ik heb koekjes <u>gekocht</u>
'I have bought cookies'

(3) ge-stem/past tense form –en — Ik ben naar huis <u>gelopen</u>
'I have walked home''

Reliability

The language assessment of the STAP test is based on paraphrasing ungrammatical utterances. Although a clear protocol is provided, the paraphrasing guidelines leave room for interpretation. This is demonstrated in the following paraphrased utterances (4b-d) of the original utterance in (4a) (examples taken from Schultz, 2008) (inserted elements in brackets).

(4) a. Alleen met papa kunnen wel lezen bij mij
Only with daddy can-INF indeed read at me

b. Alleen met papa kunnen [we] wel lezen bij mij
Only with daddy can-INF [we] indeed read at me

c. Alleen papa kan wel lezen bij mij
Only daddy can indeed read at me

d. Pappa kan wel [voor] mij alleen lezen
Daddy can indeed [to] me only read
'However, daddy can read to me only'

The options in paraphrasing, as exemplified *supra*, are reflected in the counts on various variables. This places emphasis on determining the coding reliability, particularly when more than one coder is involved. In the present study, STAP analyses were performed by three coders.

To examine the between-coder reliability, 10% of the transcripts were reanalyzed by one of the coders. Correlations were calculated to determine the degree of correspondence between the first and second coding. The correlations were as high as .99 for MLU and finite verb production and .89 for verbal agreement errors/omissions.

The application of standardized language testing allows language development to be identified as being deviant or not. Deviance is represented by language outcomes that correspond to P2.5 or less in TD children. In order to determine the degree of correspondence between the two coding sessions in this deviant/non-deviant categorization, the percentage agreement was calculated. In this analysis, we found 100% agreement for MLU and finite verb production and 89% agreement for verbal agreement errors/omission.

Data analysis

In order to compare the results of the CI and SLI children with their TD peers on MLU, finite verb production and errors/omission of verbal agreement, all raw scores were standardized according to the norms of the TD children. According to this standardization, each individual raw score was transformed into a z-score (for an explanation of the z-scores, see section 5.1 of this chapter, section 4 data analysis). Statistical testing between CI and SLI children at each age was done with a one-way ANOVA when the assumption of equal variances was met. When this was not the case, the non-parametric Mann-Whitney U-test was opted for. We lowered alpha to .01 to adjust alpha for multiple testing.

In chapter 2, section 4, we pointed out that problems in the use of grammatical morphology are characteristic of SLI children and serve as a clinical marker. We have shown that finite verb morphology, measured by means of an equation containing outcomes for the production of regular past tense, 3rd person singular present inflections, copulas and the auxiliary *be* together with MLU (Bedore & Leonard, 1998) is able to successfully discriminate between TD and SLI children. In this section of chapter 5, we intend to use the same measure to assess the morphological development of CI children.

To analyze the effect of perceptual salience on the acquisition of verb morphology, we will analyze the type of subject-verb agreement errors according to the 5 categories outlined above. The weak past participles will be analyzed on circumfix omission.

6. Results

6.1 General language and verbal morphological production

MLU

The first analysis compared the CI and SLI children on their MLU. The mean raw scores and standard deviations for MLU are presented in Figure 1 and Table 3. This Table includes the ranges in MLU scores and the statistical results for the group comparisons.

As already pointed out in section 5.1, CI children show a steady increase in MLU over the years. From Figure 1, it can be observed that no such linear growth in MLU is present for the SLI children. The mean MLU scores of the SLI children fall below the P2.5 at the age of 4, 5 and 6. At the age of 7, the mean lies within the lower boundary of the 95% confidence interval.

Statistical results reveal no significant differences between CI and SLI children at any age. However, at the age of 6, group comparisons begin to reach significance. At this age, there is a strong trend for CI children to produce longer utterances as compared to their SLI peers.

Figure 1. Mean raw MLU scores and SD per age group for the CI and SLI children. Reference scores are plotted in each graph, with the dotted line indicating the lower boundary of the 95% confidence-interval in TD children (i.e. P2.5).

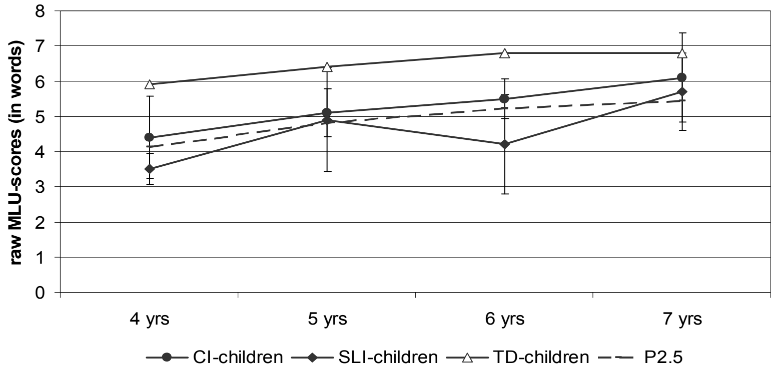


Table 3. Mean MLU scores, standard deviations and range per age group for the CI and SLI children. Statistical results for the group comparisons are also presented.

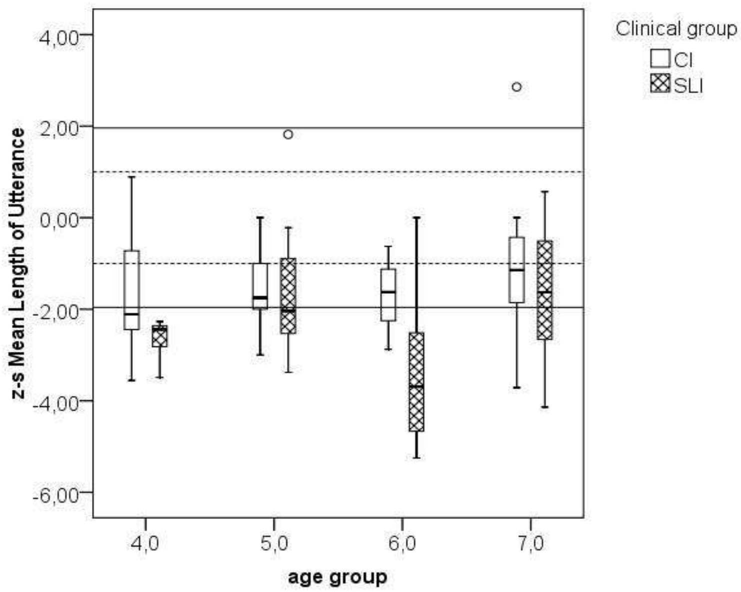
	CI children			*SLI children*			*statistical results*
	M	SD	range	M	SD	range	
4 yrs	4.4	1.2	2.7 – 7.7	3.5	0.5	2.8 – 3.9	U=18, p=.10
5 yrs	5.1	0.7	4.0 – 6.4	4.9	1.5	3.4 – 8.0	F(1,21)=.000, p=.99
6 yrs	5.5	0.6	4.5 – 6.3	4.2	1.4	2.6 – 6.8	U=33, p=.02
7 yrs	6.1	1.3	4.2 – 8.8	5.7	1.1	3.9 – 7.2	F(1,16)=.433, p=.52

The raw scores of the CI and SLI children have been standardized by transforming them into z-scores. These z-scores are plotted in Figure 2. The results are presented in box plots as this presentation type gives information about the intra-group variation. The horizontal lines in the Figure indicate the upper and lower boundary of the 95% confidence interval (P2.5 and P97.5) in TD children. A z-score outside the 95% confidence interval shows significant deviance from the performance of the TD children. The dotted horizontal lines indicate the boundaries of the 68% confidence interval (P31 and P68) in TD children.

At the age of 4, 46.7% of the CI children perform well within the 95% confidence interval. This indicates that approximately 50% of the CI children produce utterances at a comparable length to their TD peers. With increasing age, CI children show a higher level of correlation to their TD peers.

For the SLI children, no consistent increasing pattern correlating with increasing age is observed. All 4-year-old SLI children perform significantly below their TD peers. At the age of 5, 50% of the SLI children perform within the 95% confidence interval. However, at the age of 6, the number of SLI children performing within the 95% confidence interval decreases. At this age, 75% of the SLI children produce significantly shorter utterances as compared to their TD peers. The percentage SLI children performing within the 95% confidence interval increases at the age of 7. At this age, more than 50% of the SLI children perform within the 95% confidence interval.

Figure 2. Box plots represent the standardized MLU scores for the CI and SLI children per age group. Reference values from TD children are depicted by dotted lines representing the area within one SD from the mean (z-scores -1 – 1) and by solid lines marking the 95% confidence-interval (z-scores -1.96 – 1.96).



Finite verb production

The mean number of finite verbs per age group as well as standard deviations are presented in Figure 3 for CI and SLI children. Table 4 presents the mean, standard deviations and range in raw finite verb production scores per age group for both clinical groups. The CI and SLI children were statistically compared on their finite verb production and the results are given in Table 4.

The results in Figure 3 show that whereas CI children show a steep increase in finite verb production between the age 4 and 7, SLI children remain well below the P2.5 of their TD peers. This means that the gap between the SLI children and their CI and TD peers increases over the years. Statistical analysis shows that CI and SLI children compare in their finite verb production at the ages of 4 and 5. However, the SLI children produce significantly fewer finite verbs compared to their CI peers at the ages of 6 and 7 (see Table 4).

Figure 3. Mean raw finite verb production scores and SD per age group for the CI and SLI children. Reference scores are plotted in each graph, with the dotted line indicating the lower boundary of the 95% confidence-interval in TD children (i.e. P2.5).

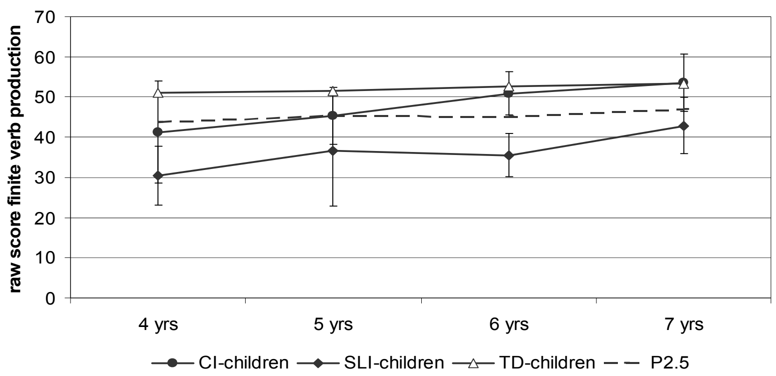
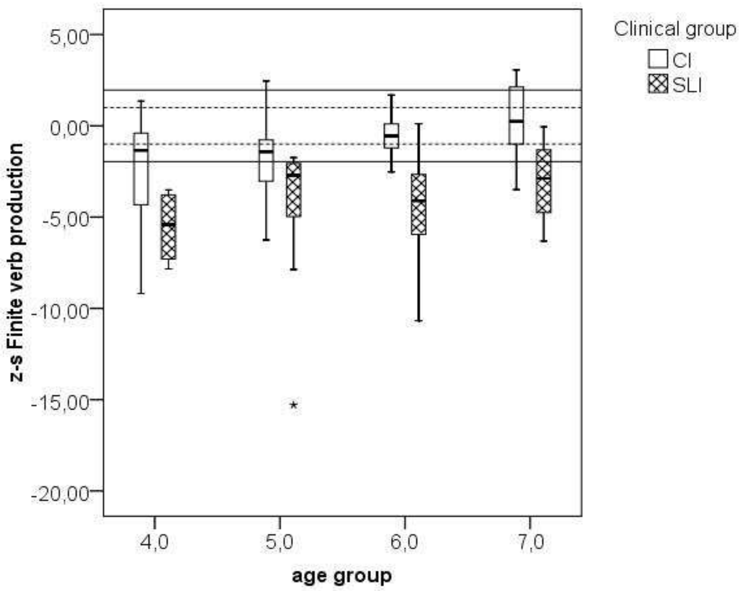


Table 4. Mean raw scores, standard deviations and range for finite verb production per age group for the CI and SLI children. Statistical results for the group comparisons are also presented.

	CI children			*SLI children*			*statistical results*
	M	SD	range	M	SD	range	
4 yrs	41.3	12.8	17 – 56	30.4	7.3	22 – 38	F(1,18)=3.198, p=.09
5 yrs	45.3	7.2	32 – 59	36.7	13.8	4 – 46	F(1,21)=3.910, p=.06
6 yrs	50.8	5.4	43 – 59	35.5	12.7	12 – 53	U=22, p=.002*
7 yrs	53.6	7.1	42 – 63	42.9	6.9	33 – 53	F(1,16)=10.376, p=.005*

For the CI and SLI children, raw scores on finite verb production are adapted to the age norms by transforming them into z-scores. The z-scores of the CI and SLI peers are plotted in Figure 4. The z-scores are presented in box plots as these types of plots give information about the intra-group variation. The horizontal lines in the box plot indicate the upper and lower boundary of the 95% confidence interval (i.e. P97.5 and P2.5).

Figure 4. Box plots represent the standardized finite verb production scores for the CI and SLI children per age group. Reference values from TD children are depicted by dotted lines representing the area within one SD from the mean (z-scores -1 – 1) and by solid lines marking the 95% confidence interval (z-scores -1.96 – 1.96).



The increasing gap between the CI and SLI children on finite verb production becomes evident from Figure 4. Between the ages of 4 and 7, the CI children move towards the mean of the TD children. In contrast, no such improvement is observed for the SLI children. At all ages, more than 50% of the SLI children remain below the P2.5.

The intra-group variation decreases for the CI children from age 4 to 7. At the age of 4 and 5, some weak-scoring CI children are observed. These CI children perform more poorly as compared to their CI peers on finite verb production. The group of weak-scoring CI children decreases at the ages 6 and 7. In contrast, the SLI children do not show such a decrease in intra-group variation.

Errors/omission of verbal agreement

The mean and standard deviations for the CI and SLI children are depicted in Figure 5 and represented in Table 5 for the errors/omissions in the production of verb morphology (i.e. bound and unbound verb morphology in obligatory contexts). The mean scores for the production of errors/omissions in verb morphology are considerably higher for the CI and SLI children as compared to the mean of the TD children. In addition, the means of both clinical populations are well beyond the P97.5 (i.e. the upper limit of the 95% confidence interval, indicating the maximum number of errors/omissions a child can make to be within normal range).

Figure 5. Mean raw scores and SD for omissions/errors of verb morphology for the CI and SLI children. Reference scores are plotted in each graph, with the dotted line indicating the upper boundary of the 95% confidence interval in TD children (i.e. P97.5).

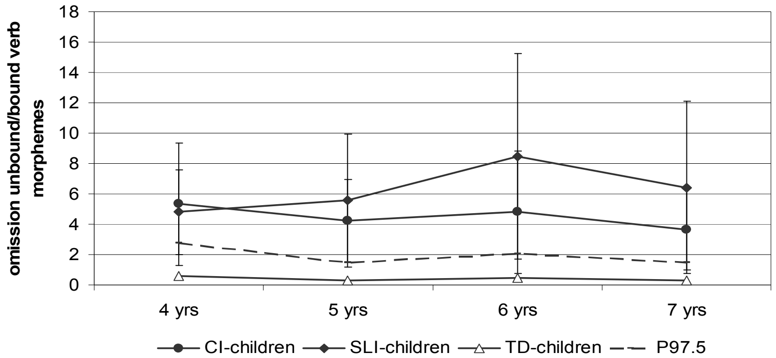


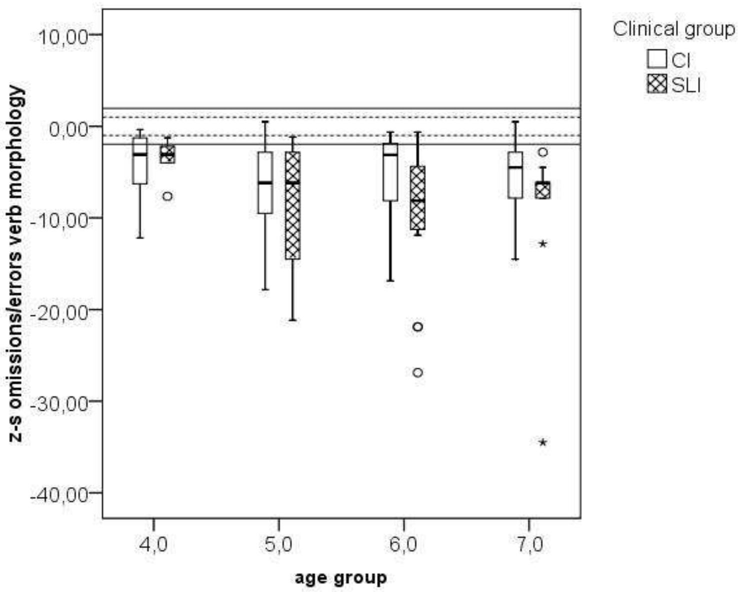
Table 5. Mean raw scores, SD and range for omissions/errors of verb morphology per age group for the CI and SLI children. Statistical results for the group comparisons are also presented as well.

	CI children			*SLI children*			*statistical results*
	M	SD	range	M	SD	range	
4 yrs	5.3	4.0	1 – 14	4.8	2.8	2 – 9	F(1,18)=.142, p=.71
5 yrs	4.2	2.7	0 – 11	5.6	4.4	1 – 13	F(1,21)=.832, p=.37
6 yrs	4.8	2.8	2 – 9	8.5	6.8	1 – 25	F(1,23)=2.294, p=.14
7 yrs	5.6	4.4	1 – 13	6.4	5.7	2 – 21	F(1,16)=1.444, p=.25

Figure 5 shows that a gap starts to emerge between CI and SLI children. The latter groups tend to produce more errors/omissions in verb morphology as compared to their CI peers. However, at no age does the difference between CI and SLI children become significant (see Table 5). This could be due to the large intra-group variation.

All raw scores are transformed into z-scores. These scores are depicted in Figure 6. This figure shows that more than 75% of the CI children produce significantly more agreement errors than their TD peers and this percentage does not decrease over the years. For the SLI children, it is observed that the median z-score decreases with increasing age. This indicates that the gap between the SLI children and their TD peers increases with increasing age.

Figure 6. Box plots represent the standardized agreement error scores for the CI and SLI children per age group. The reference data from hearing children are depicted by horizontal lines. The area within one SD from the mean is indicated by a dotted line (z-scores -1 – 1). The 95% confidence interval is indicated by a solid line (z-scores -1.96 – 1.96).



With respect to the intra-group variation, Figure 6 shows that the variation within the group of CI children is consistent with age. This contrasts with the SLI children, for whom it is observed that the intra-group variation increases with increasing age. At the age of 7, some SLI children produce more agreement errors compared to their SLI peers.

6.2 Combining scores on MLU and verbal morphology

Correlation between language measures

According to Wexler's Optional Infinitive account (Wexler et al., 1994), the transition from non-finite to finite utterances involves an increase in syntactic and grammatical complexity. It is generally assumed that this increase in syntactic complexity cannot be measured in MLU (Miller & Chapman 1981; Klee & Fitzgerald, 1985; Rondal et al. 1987). For example, the production of a finite verb as in (6) is not different in MLU as compared to the utterance in (5). Moreover, an increase in MLU can be observed in purely nominal contexts, i.e. in utterances where there is no finite verb, compare (7) and (8). This leads to the expectation that there is no one-to-one relation between MLU and the production of finite verb morphology.

(5) Die papegaai zo vliegen (MLU in words: 4)
That parrot so fly-INF

(6) Die papegaai vliegt zo (MLU in words: 4)
That parrot flies so
'That parrot flies like this'

(7) Jan in de tuin (MLU in words: 4)
Jan in the garden

Jan werkt in de tuin (MLU in words: 5)
Jan works in the garden

(8) Marie mee naar school (MLU in words: 4)
Marie with to school
'Marie with us to school'

Marie niet mee naar school (MLU in words: 5)
Marie not with to school
'Marie not with us to school'

When controlled for age, strong significant correlations are found between MLU and finite verb production for the CI children (r=.664, p=.000) and the SLI children (r=.802, p=.000). This indicates that the increase in sentence length as measured by the MLU in words is mainly due to an increase in finite verb production.

When controlled for age, no significant correlations are found between the production of finite verbs and the errors in bound verb morphology for the CI children and the SLI children (respectively, r=-.089, p=.551 and r=.078, p=.646). This suggests that a higher finite verb production is not necessarily associated with more errors in the production of bound verb morphology, indicating that there is a qualitative improvement over time.

MLU and verb morphology

The fact that MLU measures to some extent complexity, the scores on MLU and finite verb production were combined to compare the CI and SLI children individually. When multiple variables are combined, the alpha will decrease and, as a consequence, the risk of a type II error increases (considering a child non-deviant, when in fact the child is deviant). To prevent this, an alpha of .05 should be applied to the composite of variables (MLU, finite verb production and errors in bound verb morphology), rather than to one variable only. When applying an alpha of .05 to the composite of MLU, finite verb production and subject-verb agreement errors, the estimated cut-off lies between the P5 and P37[5]. A cut-off of P20 has been substantiated and used by several researchers who also use multiple variables in their diagnosis (Tomblin et al., 1997; Dunn et al., 1996). Therefore, the P20 that corresponds with a z-value of -1.28 will be used to discriminate between impaired and non-impaired language proficiency.

The MLU z-scores are plotted as a function of the z-scores on finite verb production. (See Figure 7, panel A for the CI children and Figure 7, panel B, for the SLI children). The vertical line in Figure 7 A and B indicate the P20 of the finite verb production. The horizontal line in Figure panel A and B indicates the P20 of the MLU. This means that the upper right quartile represents the CI and SLI children who compare to their TD peers in MLU and finite verb production.

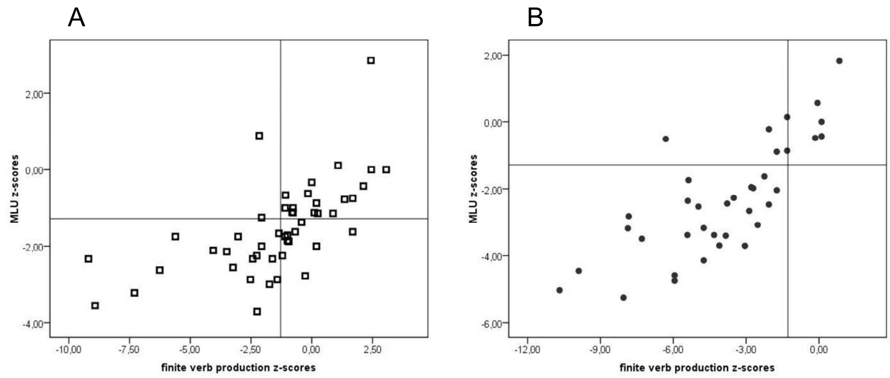
From Figure 7, panel B, it is observed that the majority of the SLI children perform below the age expectations on finite verb production and MLU (72.9%) (lower-left quadrant). 8.1% of the SLI children compare to their TD peers in MLU, but produce fewer finite verbs than their TD peers (upper-left quadrant). Another small group of SLI children (18.9%) compare to their TD peers on MLU and finite verb production (upper-right quadrant). None of the SLI children produce significantly shorter utterances than their TD peers, and produce an equal number of finite verbs as their TD-peers.

For the CI children, it is observed that 35.4% perform below age expectations on MLU and finite verb production (lower-left quadrant). 6.3% of the CI children compare to their TD peers in MLU, but produce fewer finite

[5]When combining MLU, finite verb production and bound verb morphology errors, the cut-off point lies at P37 (two-sided) ((37/100)x(37/100)x(37/100)=5/100[3]). However, this would be true if all language measures were independent of each other. As this is not the case with the language measures used here, the estimated cut-off point lies between the P5 and P37.

verbs (upper-left quadrant). Of the CI children, 29.2% compare to their TD peers on MLU and finite verb production (upper-right quadrant). 29.2% of the CI children compare to their TD peers in finite verb production, and fall behind their TD peers on MLU. This contrasts with the SLI children.

Figure 7. Individual MLU z-scores plotted as a function of the z-scores on finite verb production, in panel A for the CI children and in panel B for the SLI children. The vertical line in the graphs indicates the P20 of the finite verb production. Scores that fall on the left side of the line are deviant from the TD children. The scores on the right are non-deviant. The horizontal line in the graphs indicates the P20 of MLU. Scores below the horizontal line are deviant from the TD children; scores above the horizontal line are non-deviant. Clockwise: the upper-right quartile represents the children who compare to their TD peers in finite verb production and MLU. The lower-right quartile represents the children who are deviant on MLU, but not on finite verb production. The lower-left quartile represents the children that score deviant on finite verb production and MLU, and the upper-right quartile represents the children that score non-deviant on MLU and deviant on finite verb production.

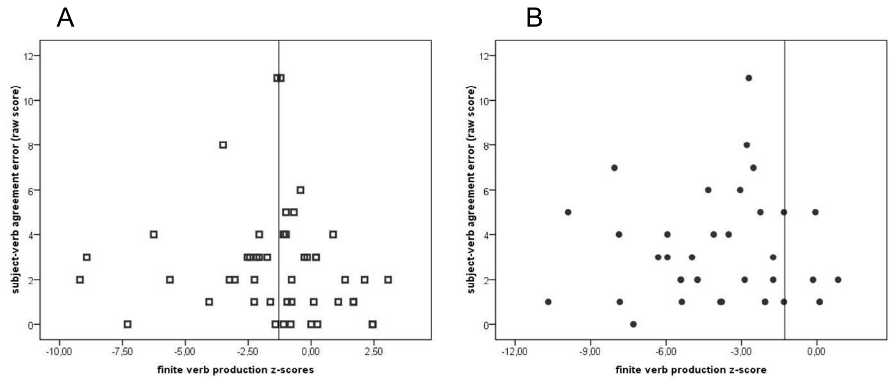


Analysis on age group level indicates that the majority of the CI children who perform deviantly on MLU and finite verb production belong to the age groups 4 and 5, rather than the age groups 6 and 7. Twenty-seven per cent of the 4 and 5-year-old CI children perform poorly on MLU and finite verb production as opposed to 8.3% in the group of 6 and 7-year-olds. No such pattern is observed for the SLI children. Of the 4 and 5-year-old SLI children, 29.7% perform deviantly on MLU and finite verb production as compared to 43.2% of the 6 and 7-year-old SLI children.

In Figure 8, subject-verb agreement errors (e.g. *she *sleep/sleeps*, excluding finite verb omissions in obligatory contexts) for each child are plotted against the finite verb production z-scores. This can be seen in panel A for the CI children and in panel B for the SLI children. The vertical line indicates the P20 for the finite verb production. All finite verb scores below the P20 (falling on the left side of the vertical line) are considered deviant from the TD population. No norms are available for the subject-verb agreement errors, therefore no cut-off line is depicted for this measure.

The plots in panel A and B confirm the lack of correlation between the production of finite verbs and the subject-verb agreement errors for the CI and SLI children. This indicates that the increase in finite verbs is not related to the production of more agreement errors. These findings indicate an improvement.

Figure 8. Individual subject-verb agreement errors (raw scores) are plotted against the finite verb production z-scores, in panel A for the CI children and in panel B for the SLI children. The vertical line in the graphs indicates the P20 of the finite verb production. Scores on the left side of the line are deviant from the TD children.



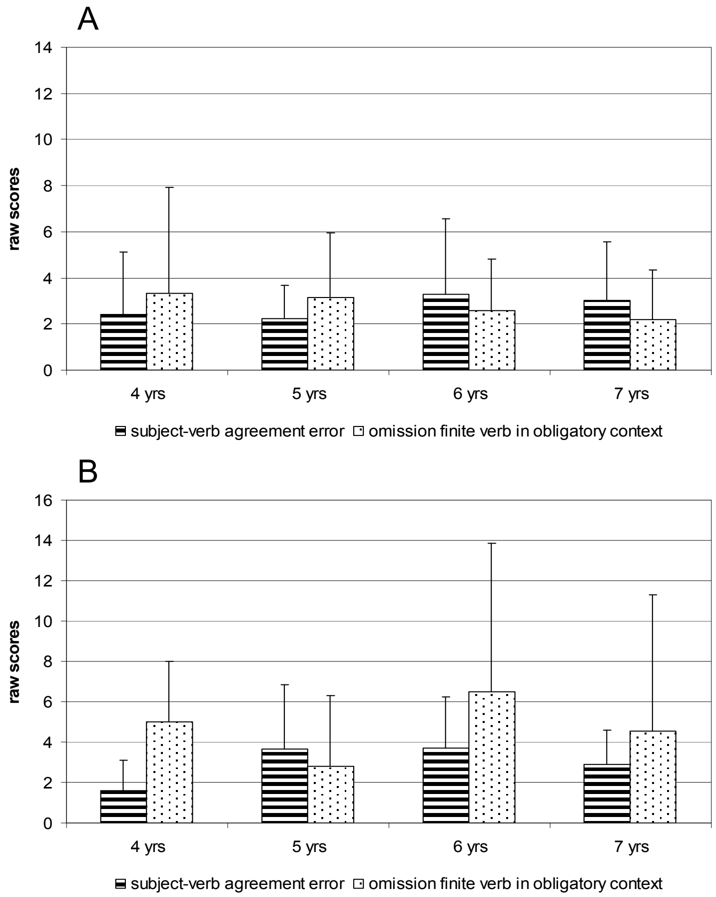
6.3 Analysis of agreement errors

Finite verb omission and subject-verb agreement errors

The finite verb omissions in obligatory contexts and subject-verb agreement errors are presented separately in Figure 9 for the CI and SLI children. The total number of finite verb omissions and subject-verb agreement errors is divided by the number of children in the age group to obtain the mean and standard deviations of both measures.

At the ages of 4 and 5, CI children tend to omit the finite verb more often compared to the production of subject-verb agreement errors. This pattern changes at the ages of 6 and 7, when CI children tend to produce more subject-verb agreement errors as compared to the omission of finite verbs. The difference between finite verb omissions and subject-verb agreement errors is not significant at any age (see Table 6 p:116).

Figure 9. The raw number of finite verb omissions in obligatory contexts and subject-verb agreement errors is presented separately for each age group and clinical group. The results for the CI children are presented in panel A, and for the SLI children in panel B.



No such shift is observed for the SLI children. These children omit the finite verb more often than they produce subject-verb agreement errors at the ages of 4, 6 and 7. At the age of 5, this pattern is reversed. At this age, the SLI children produce more subject-verb agreement errors as compared to the omission of finite verbs in obligatory contexts. The difference between finite verb omission and subject-verb agreement errors begins to reach significance at the age of 4 (see Table 6). No significant difference is observed in subsequent years.

Table 6. Statistical results for the comparison between finite verb omission in obligatory contexts and subject-verb agreement errors.

	CI children	*SLI children*
4 yrs	U=107.0, p=.838	U=3.0, p=.056
5 yrs	U=90.0, p=.734	U=29.5, p=.340
6 yrs	U=47.0, p=.853	U=87.5, p=.635
7 yrs	U=33.5, p=.546	U=39.0, p=.931

No significant difference is found between the CI and SLI children in terms of their omission of finite verbs and their production of subject-verb agreement errors at any age. However, for the SLI children, it is observed from Figure 6 that the variation between these children is higher when compared to their CI peers on the omission of finite verbs (cf. CI and SLI children at age 6). These results point towards a more severe problem in the acquisition of finiteness among SLI children as compared to their CI peers.

Table 7. Statistical results for the comparison between CI and SLI children on finite verb omission in obligatory context and number of subject-verb agreement errors.

	finite verb omissions	*subject-verb agreement*
4 yrs	U=21.5, p=.168	U=31.5, p=.612
5 yrs	U=54.5, p=.600	U=49.5, p=.403
6 yrs	U=49.5, p=.235	U=57.5, p=472
7 yrs	U=33.0, p=.546	U=39.0, p=.931

Subject-verb agreement errors

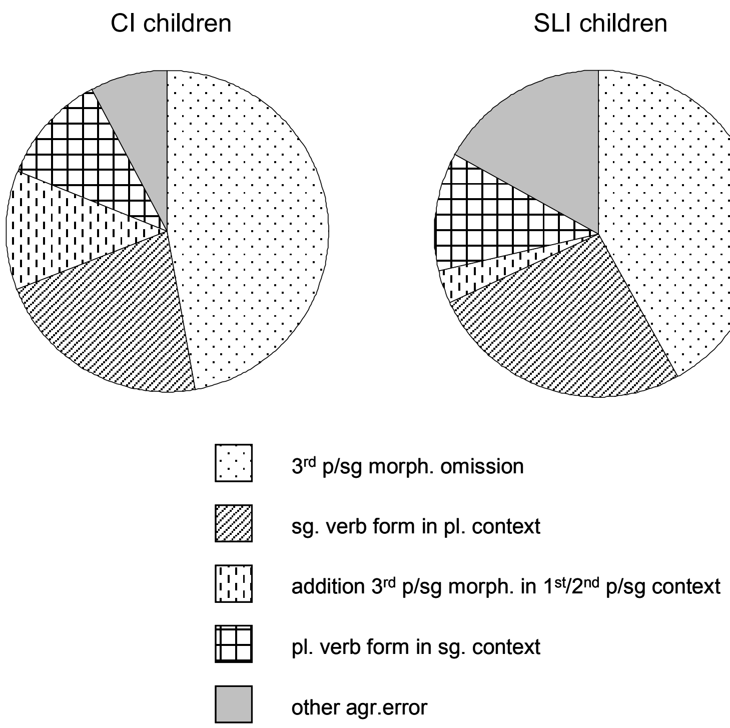
The CI children produced 2250 finite verbs between the ages of 4 and 7. A total of 127 subject-verb agreement errors were counted. This indicates that 5.6% of the finite verbs produced were incorrect. For the SLI children, a total of 1418 finite verbs were counted, of which 119 were produced incorrectly. This indicates that 8.4% of the finite verbs were incorrectly marked for finiteness.

The pie charts in Figure 10 depict the distribution of subject-verb agreement errors across the five categories (outlined in section 5 of this chapter) for the CI and SLI children. From the pie charts, it is observed that the distribution is comparable between the CI and SLI children. The majority of the subject-verb agreement errors involve the omission of the 3rd person singular morpheme. The production of bare verb stems is also a common subject-verb agreement error for the CI and SLI children. This type of error may include the omission of the plural morpheme (*-en*), or the use of a 1st person singular morpheme instead of a plural one, as illustrated in (9):

(9) De wespen is [zijn] in de appel
The wasps is [are] in the apple
'The wasps are in the apple'

Although the majority of subject-verb agreement errors involve the omission of the agreement morpheme, some substitutions may occur. This implies that some CI and SLI children use a third person singular form when the subject is first or second person or they may insert a plural verb form in a singular context (see examples under category 3 and 4, section 5, language assessment).

Figure 10. Percentage of subject-verb agreement types from total number of subject-verb agreement errors for the CI and SLI children.



Past participle errors

The CI children produced a total of 216 past participles between the ages of 4 and 7. Fifty-eight of these past participles were formed with circumfix. From these 58 past participles, 41% were produced incorrectly. The difference between the omission of the prefix and the suffix is 7%, with more omissions of the prefix occurring than the suffix (see Table 8).

The SLI children produced 177 past participles between the ages of 4 and 7. Fifty-five of these past participles were formed with circumfix. Of these 55 past participles, 27% were produced incorrectly. The difference between the omission of the prefix and suffix is 9% (see Table 8). The SLI children omitted the suffix more often than the prefix.

Table 8. Number of past participles with circumfix that were analyzed; raw number of omissions of the prefix and omissions of the suffix. Percentages in parentheses were calculated by dividing the raw number of omissions by the total number of past participles that were analyzed.

	number of past participles analyzed	*omission of the prefix*	*omission of the suffix*
CI children	58	14 (24%)	10 (17%)
SLI children	55	5 (9%)	10 (18%)

7. Discussion

Do CI children out-perform their SLI peers?

In this section of chapter 5, we compared CI and SLI children aged between 4 and 7 years on their MLU, finite verb production and errors/omission of verbal agreement. Based on the literature indicating difficulties in the acquisition of grammatical morphology for both populations, we concentrated on the question: To what extent does the vulnerability of morphology in language acquisition by CI children resemble the behavioral language pattern observed in SLI children?

The results indicate that for the CI children, a steady growth in MLU is found between the ages of 4 and 7, although shorter utterances were found for the SLI children that almost reached significance at the age of 6. The CI children demonstrated a sharp increase in the production of finite verbs, whereas the SLI children remained below the lower boundary of the 95% confidence interval. At the ages of 6 and 7, the SLI children produced significantly fewer finite verbs as compared to their TD peers. From the age of 6, the gap between the CI and SLI children continued to increase. Nevertheless, no significant differences were found between both clinical groups in their production of subject-verb agreement errors at any age.

Also, positive correlations were found between MLU and finite verb production for the CI and SLI children. Between 44 and 64% of the increase in MLU was due to the increased production of finite verbs. This is a remarkable result, as it has been argued that longer MLUs lose their indicative value for syntactic growth as the development of syntactic complexity does not necessarily result in longer utterances after the age of 3 (Miller & Chapman 1981; Klee & Fitzgerald, 1985; Rondal et al. 1987). The positive correlation found in this study suggests that the growth in verbal syntactic complexity can be measured to some extent with MLU for the CI and SLI children up to the age of 7.

Taken together, MLU and finite verb production have been used to identify children who show a deviance in language development. Of the SLI children, 73% performed below age-expectations on this combined measure of language production. By contrast, only 38% of the CI children had outcomes that are below age-expectations. Therefore, only a subgroup of the CI children compare to their SLI peers. Roughly speaking, only 1 out of 3 early implanted CI children demonstrated a deviant developmental pattern. Importantly, this proportion falls within the SLI prevalence estimate of hearing impaired children presented in other studies, which is between 22% and 50% (Gilbertson & Kamhi, 1995; Norbury et al. 2001; Hansson et al. 2007).

A close inspection of this subgroup of CI children with deviant language development indicates that the majority belong to the youngest age groups (4 and 5-year-olds). This suggests that the atypical language development identified does not persist into the older age groups (6 and 7-year-olds). Similar observations have been made for children with classical hearing aids. Younger HA children have been said to have more language difficulties than older HA children (Norbury et al. 2001; Hansson et al., 2007), indicating that they somehow outgrow their language development problems.

Interestingly, 21% of the CI children compare in their finite verb production to their TD peers, but fall significantly behind on MLU. This indicates that both populations are comparable in verbal complexity. This profile is not observed for the SLI children, indicating more severe problems in the acquisition of finiteness in comparison with their CI peers. The findings observed thus question the fact that processing limitations and sensory deprivation may yield similar language outcomes (Locke, 1997). The effect of the reduced auditory input of CI children and of the processing limitations found in SLI children are therefore not directly comparable.

What is the role of perceptual salience in verb morphology development?

The second objective consisted of comparing CI and SLI children on subject-verb agreement errors in relation to perceptual salience. According to the Surface Account proposed by Leonard and colleagues (1997), the joint operation of perceiving an acoustically low-salient grammatical morpheme and identifying its grammatical function is challenging for SLI children.

CI and SLI children have been found to be comparable in the distribution of subject-verb agreement error types. In most cases, both populations omit the 3rd person singular morpheme. Less frequently, they use a singular form in a plural context. The latter type of agreement error includes the omission of the plural verb morpheme. As the plural morpheme in Dutch contains a vowel, it may be taken to be perceptually more salient as compared to the 3rd person singular morpheme (*-t*). The results show that both CI and SLI children are more likely to omit the 3rd person singular morpheme as compared to the plural verb morpheme. This is in accordance with the Surface Account.

Since SLI children are especially impaired in their acquisition of finiteness, we also included an analysis of past participles. Weak past participles in Dutch require a circumfix, in which the prefix is relatively more salient than the suffix. The result of this analysis indicates that SLI children omit the suffix slightly more frequently compared to the omission of the prefix. This is also expected under the Surface Account. This underlines the effect of perceptual salience in the acquisition of morphology for SLI children.

No effect of perceptual salience was found for the CI children in the omission of the circumfix of past participles. Remarkably, these children tend to omit the prefix slightly more often than the suffix. In contrast to SLI children, their results are therefore not predicted by the Surface Account.

This finding contrasts with that of subject-verb agreement omissions, where results were explained by the Surface Account. However, taken together with the results obtained in section 5.1 (where no effect of perceptual salience was found for the acquisition of unbound versus bound verb morphology), we argue that the delay in target-like subject-verb agreement marking is not primarily related to perceptual salience. Rather, the delay results from speech perception difficulties in noisy day-to-day environments. This is proposed in the newly formulated *Morpheme-in-Noise Perception Deficit Hypothesis* in chapter 6, subsection 8.2.

Implications and future research

In this study, 85 CI and SLI subjects were tested in 4 different age groups. Consequently, the number of tested subjects per age group for each population is relatively small. The question that rises therefore concerns the generalizability of the results to the population of CI and SLI children. For both populations, heterogeneity and variability between subjects was reported (De Jong, 1999; Geers et al., 2004; Tomblin et al., 2005; Hay-McCutcheon et al., 2008; Duchesne et al., 2009). For the CI children, a large body of research was dedicated to accounting for the variability between CI children. Research was directed to factors such as age at implantation, hearing age, oral or total communication mode and perception abilities (Nicholas & Geers, 2007, Bo Wie, Falkenberg, Tvete & Tomblin., 2007). Research was conducted for the SLI children to reveal the mechanisms behind the slow intake of language, such as processing speed and working memory capacities. Much of the research was focused on one of the clinical groups, rather than both clinical groups together. The present study has taken a new perspective on CI and SLI children by comparing them directly. This type of study suggests avenues for future research as it enhances our understanding of determinants of successful language development.

The present study is also limited with respect to the time span in which the CI and HA children were tested. The upper limit for testing was 7 years of age, mainly due to the availability of standardized testing material up to this age. Nevertheless, it would be interesting to see whether the CI and SLI children are able to catch up with their TD hearing peers with respect to verbal morphology production after the age of 7. If so, this would indicate that in both populations, verbal morphology production is delayed rather than impaired.

Finally, the influence of perceptual salience on the acquisition of morphology can be investigated only to a limited extent in Dutch. Given that Dutch is a language which lacks rich verbal morphology, there is rather limited variation with respect to perceptual salience in verbal morphemes. A cross-linguistic comparison of the results with those from CI and SLI children in morphologically rich languages would yield interesting insights with respect to the presumed role of perceptual salience in the acquisition of verbal morphology in both populations.

8. Conclusion

The objectives of the present study were to compare 4 to 7-year-old CI and SLI children on their general language production, finite verb production and agreement errors. This study provided an in-depth analysis of the type of subject-agreement errors produced by these CI and SLI children. The errors identified were related to the perceptual salience of the verbal morphemes.

The results show that 73% of the SLI children performed below age-expectations on general language production and finite verb production. Only a subgroup of the CI children (38%) showed a similar pattern. The majority of this subgroup of CI children were younger CI children (4 and 5 years of age). This indicates that the delay in MLU and finite verb production does not persist into the older ages (6 and 7 years) for all CI children.

The CI children were compared to the SLI children on the number and type of subject-verb agreement errors. Most errors involved the omission of the 3rd person singular morpheme and the plural morpheme. The delay observed in the acquisition of low salient grammatical morphemes is predicted by the so-called Surface Account.

In terms of the acquisition of past participle morphology, SLI children tended to omit the low salient suffix (*-t* e.g. *gewerkt*) more often than the relatively more salient prefix (*ge-* e.g. *gewerkt*). This is, once again, in line with the Surface Account and underlines the effect of perceptual salience in the acquisition of morphology for these children. By contrast, in CI children, the acoustically less salient suffix was not omitted more frequently than the more salient prefix. The results of the acquisition of past participle morphology indicates that perceptual salience of morphemes alone cannot account for the high error rate in verb morphology, and that the results of the prefix and suffix omission is therefore difficult to explain under a Surface Account.

Based on data from the errors/omission of verbal agreement as discussed in section 5.1, we propose that the findings observed are best explained under the newly formulated *Morpheme-in-Noise Perception Deficit Hypothesis*. According to this hypothesis, the deficits in verbal morphology production in CI children are the result of perceptual deficits in noisy day-to-day environments regardless of the morphemes' acoustic salience.

CHAPTER 6

The acquisition of past tense

1. Introduction

It is well known that SLI children are severely delayed in their acquisition of the regular past tense as compared to their TD peers. This delay has been attributed to incomplete processing of the low salient regular past tense morpheme, which protracts the time needed for analysis before the grammatical morpheme can be placed in the verbal paradigm. This has been named the Surface Account (Leonard et al., 1997, see chapter 5, section 5.2). Under such a view, which stresses the role of perceptual input on language learning, the type of processing limitation observed in SLI children is similar to a perceptual deficit, as in the case of CI children (Locke, 1997; Norbury et al., 2001).

Therefore, the first purpose of this chapter is to compare 5 to 7-year-old CI and SLI children in their production of regular and irregular past tense in spontaneous speech and on a past tense elicitation task. The elicitation task allows us to compare the results of both clinical populations with their TD peers. A norm-referenced approach to past tense production using spontaneous speech is not viable, because the variable past tense cannot be reliably assessed (see chapter 4, section 4). This chapter will start with an overview of the regular and irregular past tense acquisition in TD children (section 2) and in SLI children (section 3).

The second purpose of this chapter is to relate the production of regular and irregular past tense to the frequency with which past tense forms occur in the adult target speech. The rationale behind the inclusion of frequency lies in the two models of past tense acquisition, which have been outlined in chapter 3 (subsection 3.3). In short, according to the dual-route model, regular past tense inflection involves the symbol-manipulating rule of *add –ed* (e.g. *work-worked*) which operates as a default, whereas irregular forms are memorized pairs of words (e.g. *ring-rang*). Alternatively, according to the single-route model, regular and irregular verb forms arise from an associative memory system. As such, a rule for regular past tense does not exist in the language system. The two models make different predictions regarding the role of frequency in regular past tense acquisition. This will be explained in more detail in section 4.

The hypotheses will be outlined in section 5. The past tense analysis in spontaneous speech and the results are given in section 6. The results of the past tense elicitation task are presented in section 7. The results of both analyses are discussed in section 8, followed by a conclusion in section 9.

2. The acquisition of past tense in TD children

2.1 First past tense forms

The analyses of (English) longitudinal child language data have provided valuable insights into the development of past tense. Brown (1973) conducted an extensive analysis of spontaneous language data of Adam, Eve and Sarah to determine the order of grammatical morpheme acquisition. In his analysis he adopts a criterion for acquisition in which the morpheme of interest appears in its obligatory context 90% of the time in three successive samples (i.e. correct productions of irregulars in 90% of the situations in which irregulars are required is considered to evidence a child's acquisition of the irregular past tense form). Brown observes that Adam and Sarah acquire irregular past tense prior to the regular past tense. The irregular past tenses are numerous and varied, such as came, went, did, made, saw, ate.

However, it has been argued that the children's early productions of past tenses are restricted to high-frequency forms occurring in the linguistic input of the child. Most high-frequency verbs belong to the class of the irregulars, rather than the regulars (Rumelhart & McClelland, 1986). Kuczaj (1977) argues that these early past tense forms are semantically appropriate but syntactically unanalyzed. As such, these irregular forms have not been acquired yet. The children learn when these high-frequency past tense forms may be used and thus occasionally use them appropriately.

Based on the longitudinal study of the boy Abe, Kuczaj concludes that, in the course of past tense development, the irregular past tense is more difficult to acquire than the regular past tense. In his longitudinal analysis of Abe, compared with data from 14 children cross-sectionally, he observes that all children reached the 90% criterion for regular past tense from MLU 3.00 onwards. In contrast, a stable 90% success rate for the irregular past tense was only achieved for three children with an MLU above 4.50, who were included in the cross-sectional sample. Abe reached the 90% criterion for irregulars 20 months later as compared to the regulars.

It is important to note, however, that the study by Kuczaj (1977) is biased regarding regular past tense as it also includes overgeneralizations. Overgeneralizations refer to the application of the regular suffix (*-ed*) to irregular verbs, e.g. eat – eated. Kuczaj scored overgeneralizations as instances of regular past tense usage, as these overgeneralizations are correct instances of the regular past tense suffix in the appropriate context. This increased the number of regular past tense inflections and consequently influenced the attainment of the 90% criterion.

2.2 Overgeneralizations

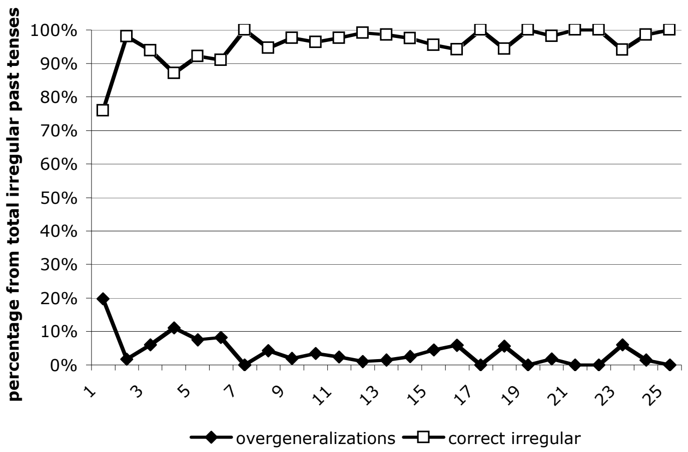
The phenomenon of overgeneralizations provides valuable cues as to the processes that underlie past tense acquisition. On this account, the analysis of overgeneralizations has received a great deal of attention in the literature. In the analysis of the Adam, Eve and Sarah transcripts, both Cazden (1968) and Brown (1973) report the occurrence of overgeneralizations. Adam, Eve and Sarah all use forms like 'comed', 'goed', 'falled' and 'maked'. The analysis of overgeneralizations is elaborated by Marcus et al. (1992). Marcus et al. distinguished two types of overgeneralizations, in which the first type attaches the regular suffix *–ed* to the verb stem (e.g. eat – eated) and the second type to the past tense form of the irregular (e.g. ate – ated). The latter occurs in approximately 1-2% of all past tense forms produced.

In the present analysis, a more stringent definition of overgeneralization is adopted by referring only to the first type of overgeneralization, i.e. verb stem + suffix *–ed* or the 'eat –eated' type. This decision is motivated by the fact that overgeneralizations of the 'ate – ated' type are not target-like past tense forms according to regular past tense process (i.e. verb stem +- *ed*), whereas the 'eat – eated' type is. The 'ate – ated' type involves the feeding of the irregular past into the regular past tense process. These forms compare to errors like 'wenting' and 'ating', which are occasionally produced by children. The progressive is fully regular, so these forms could only be produced by inserting the irregular past into the morphological process (Hoeffner, 1992). Fortunately, Marcus et al. (1992) presented individual overgeneralization data of the 25 children included in their study. This allows recalculation of overgeneralization rates of the 'eat – eated' type solely.

Figure 1 presents the percentages of target-like irregular forms and overgeneralization of the 'eat - eated' type from the total number of past tense forms belonging to the irregular verb class. Percentages are given per child (N=25). These percentages are recalculated versions from Marcus et al. (1992 p: 36) which exclude the 'ate-ated' type of overgeneralization. This means that the percentages of correct irregular forms and overgeneralizations in Figure 1 do not add up to 100% for all children. For example in the case of child 1, 20% of the irregular verbs received regular past tense marking and 75% target-like irregular marking. This means that 5% of the irregular verbs received regular past tense marking on the irregular verb ('ate- ated' type).

The average rate of overgeneralization (only 'eat-eated'-type) across the 25 children is 3.88%, which indicates that overgeneralizations are extremely rare in spontaneous speech. Across the board, children produce more correct irregulars as compared to overgeneralizations.

Figure 1. Recalculated percentages of target-like irregular past tense productions and overgeneralizations from the total number of past tense forms produced. Overgeneralizations include present tense irregular+suffix and exclude past tense form irregular+suffix. Percentages are given per child. Data from Marcus et al. (1992 p:36).



2.3 U-shaped development of irregular past tense

In the development of irregular past tense, Cazden (1968) observed that 11 out of the 32 overgeneralized past tense forms appeared earlier in the transcripts with the correct irregular form. She reports that Eve said 'comed' three times between 25 and 27 months when she previously used came 11 times between 20 to 22 months. This has led to the claim that children follow a U-shaped developmental pattern in acquiring irregular past tense inflection. The U-shaped development, as proposed by Cazden (1968), Rumelhart & McClelland (1986), Marcus et al. (1992) and refers to a transition from a period in which irregular past tense forms are marked correctly to a period in which overgeneralizations coexist with target-like irregular past tenses. This definition is based on the fact that the regular past tense inflection does not completely replace all irregular past tenses. Rather, overgeneralizations and irregular past tenses temporarily coexist (Cazden, 1968; Kuczaj, 1977).

In their extended longitudinal analysis of 9 children, Marcus et al. (1992) have shown that 7 of these 9 children used target-like irregulars before the appearance of their overgeneralized forms. This indicates that there is evidence for an U-shaped development. The coexistence of overgeneralizations and target-like irregulars in spontaneous speech is fairly steady from the age of three to at least into the sixth year. It has even been reported that overgeneralizations persist into the tenth and eleventh year of life (Kuczaj, 1977). The overgeneralization rate decreases extremely gradually. As irregulars need to be learned from the input, the decrease depends on the frequency with which a irregular occurs in the input. It has been shown that irregular verbs that are used less often in the past tense are more likely to be overgeneralized (Marcus et al., 1992). We will return to the frequency effect in section 4.

2.4 Past tense marking of nonce verbs

To test a child's knowledge of morphological generalizations, Berko (1958) elicited past tense forms of nonce verbs. The underlying idea is quite straightforward. The nonce verbs are not available in the input; therefore past tense forms of these verbs could not be learned and stored. The nonce verbs can only receive past tense inflection if the child has (implicit) knowledge of morphological generalizations.

The elicitation task included 6 nonce verbs, which were made up following the rules for phonological sequences in English, and 2 existing verbs. All verbs were accompanied by drawings on a card, for example, a man standing on the ceiling (see Figure 2, next page). Then the experimenter would say *'This is a man who knows how to bing. He is binging. He did the same thing yesterday. Yesterday he….'*. The child was requested to provide the past tense form. 47 girls and 33 boys, aged between 4 to 7 years, participated in the study.

In the experiment by Berko, the adult responses on the nonce verbs were considered as target-like responses. This made it possible to rate each child's answer as target-like or not. The first analysis revealed that younger children, aged between 4 and 5 years, scored slightly less target-like past tense forms as compared to the older children, 5;6 to 7 years. The percentages of target-like responses per verb for both groups of children are presented in Figure 3, adapted from Berko (1958 p:160).

Berko's results provide evidence that children as young as 4 years have knowledge of the process of regular past tense formation. All children have a high percentage of target-like use of both regular past morphemes /*-t*/ and /*-d*/ (e.g. *ricked, spowed*). The regular pattern is extended even in nonce verbs ending in –ing, such as *bing* and *gling*, for which the irregular would yield *bang* and glang (cf. *ring-rang*). 50 to 75% of the adults opted for these irregular responses. However, the children did not have control over the irregular form yet, as indicated by the low scores on the past tense form rang. Consequently, children did not form new past tenses according to this form. The regular productions of *bing* and *gling* can be considered as overgeneralizations. Children did not seem to be able to extend the use of the past tense allomorph /*-id*/ as in *melt-melted* to nonce verbs of the type *mot-motted*. Instead, for the forms ending in -t or -d, the children added nothing to form the past tense.

Figure 2. Picture to elicit the past tense form of 'bing', as presented in the experiment by Berko (1958). Picture retrieved from http://childes.psy.cmu.edu/topics/.

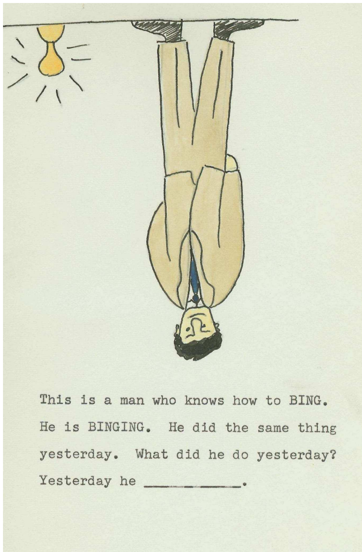
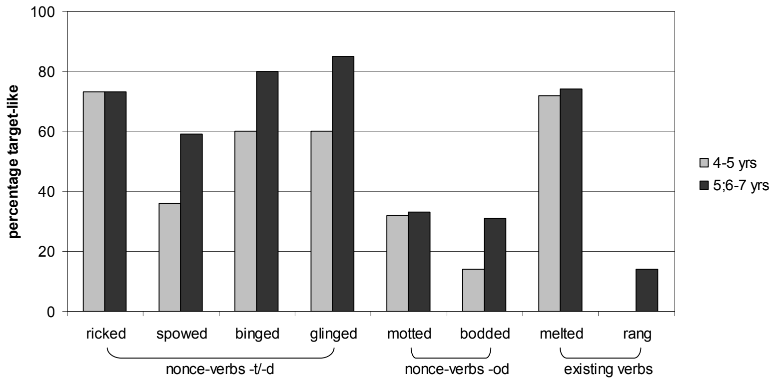


Figure 3. Percentage of target-like productions on nonce verbs for young children (4-5 years) and older children (5;6-7 years). Percentages are taken from Berko (1958 p:160).



3. The acquisition of past tense in SLI children

3.1 Regular past tense

With respect to the development of regular past tense in SLI children, longitudinal analysis has been carried out by Rice, Wexler & Hershberger (1998). In their study they compared SLI and TD children in their target-like use of past tense morphemes in obligatory contexts, both in spontaneous speech samples and elicitation data. The SLI children in their study were aged between 4;5 to 8;9 years and the TD children between 2;6 to 8;9 years. All children were tested at 6-month intervals. The results from the spontaneous speech and elicitation data indicated that the 6-year-old SLI children compare to their 3;6-year-old TD peers in the production of target-like regular past tense. This indicates a delay of approximately 2.5 years in the development of regular past tense for the SLI children.

The production scores of the 6-year-old SLI children of Rice et al. (1998) compare to the results of Oetting & Horohov (1997). On their elicitation task, they found that 6-year-old SLI children marked 15 out of 30 regular verbs target-like for past tense. This score was significantly lower when compared to their language-matched (LM) peers, who were approximately 2 years younger. The LM children marked 22 verbs target-like out of 30. Oetting & Horohov also analyzed spontaneous speech samples on target-like use of regular past tense in obligatory contexts. The SLI children produced 87% target-like regulars in obligatory contexts as compared to 92% by the LM children.

For the TD and SLI children a similar development pattern in past tense production has been observed. For the spontaneous data, a sudden increase is observed in percentage target-like regular past tense use. Between the ages of 5 and 6, the SLI children increase from 0% target-like regulars to 90%. For the TD children, this sharp development of target-like regulars starts before data collection (i.e. <3 years) and moves between the ages 3 to 3;6 from 50 to 90%. In the elicitation task, the development of target-like regulars is more gradual. At the age of 3, when data collection starts, the TD children perform at chance level. They reach ceiling performance one and a half year later. This means that at 4;6 years, they produce all regulars target-like. In contrast, the SLI children have not yet reached ceiling performance at the age of 8. Between the ages of 5 to 8 their production of target-like regulars increases from 30 to 88% (Rice et al., 1998).

It is questionable whether SLI children are able to catch up with their TD peers after the age of 8. Van der Lely & Ullman (2001) show that their 11-year-old SLI children are still significantly worse on target-like regular past tense production than the 6-year-old TD children, as indicated by an elicitation task. Interestingly, Van der Lely & Ullman found frequency effects in the production of regulars for the SLI children, but not for the TD children. Their 11-year-old

SLI children produced significantly more target-like past tenses for the high frequency regular verbs as compared to the low frequency verbs. However, conclusions must be drawn cautiously, as the SLI children in this study were selected on having extreme difficulties with morphology. This poses problems for generalization of the findings across the population of SLI children.

3.2 Overgeneralizations

The delay in the acquisition of the regular inflectional process is reflected in the lower numbers of overgeneralizations for the SLI children as compared to TD children, as observed in the elicitation tasks. Oetting & Horohov (1997) calculated percentages of overgeneralizations by dividing the number of overgeneralizations by the number of irregulars included in the elicitation task minus the target-like irregulars. The results indicated that the percentage of irregular forms receiving regular marking was significantly lower for the 6-year-old SLI children as compared to their chronological age-matched (CA) peers and LM peers (4 years of age), respectively 34%, 81% and 61%. For the CA peers, higher percentages of overgeneralizations can be attributed to a higher number of correct irregulars (6 out of 10), thereby decreasing the denominator. For the LM children, the difference from the SLI children is striking. As the number of target-like irregulars is almost comparable with the SLI children (2/3 out of 10), results indicate that the LM children produce twice as many overgeneralizations as compared to the SLI children.

These results are in accordance with the results of Rice, Wexler, Marquis & Hershberger (2000). They analyzed the percentage of overgeneralizations from the total number of inflected irregulars minus the correct irregulars. Their 6-year-old SLI children produced almost 35% of the irregulars with regular inflection. Up to the age of 8, the percentage of overgeneralizations for the SLI children remained between 35 and 40%, whereas their CA peers showed a clear decrease in the overgeneralization rate within the same period.

Marchman, Wulfeck & Ellis Weismer (1999) indicate that if SLI children produce overgeneralizations it is more likely that they overregularized low frequency irregulars than high frequency irregulars. The influence of frequency on overgeneralization rates is also observed for the TD children (cf. Marcus et al., 1992, see subsection 2.3 from this chapter).

3.3 Irregular past tense

When only target-like irregular past tenses are considered, Rice et al. (2000) observed a steady growth in percentage target-like for the SLI children on their elicitation task. At the age of 4;6, the SLI children scored 13% target-like irregulars and slowly increased to 48% at the age of 8. This developmental pattern was similar to that observed for the younger LM children. They started with 24% target-like irregulars at the age of 3 and reached 48% target-like at the age of 6. Significant differences were found between the SLI children and their TD peers at every test instance on a 6-month interval base. The latter group reached a score of 86% target-like irregulars at the age of 8, whereas the 8-year-old SLI children produced target-like irregulars at chance level (i.e. 50%).

Similar to the development of regulars, it is questionable whether SLI children catch up with their TD peers. In the study by Van der Lely & Ullman (2001), the 11-year-old SLI children produce significantly less correct irregulars when compared to the 7 and 8-year-old TD children. Again, Van der Lely & Ullman found frequency effects for the SLI children. The SLI children are more likely to produce a target-like irregular for high frequency verbs than for verbs that occur less often in the input. The same pattern was observed for all TD children included in their study.

3.4 Cross-linguistic differences

By and large, the literature on past tense acquisition has focused on TD and SLI children acquiring English. For the SLI children, cross-linguistic studies with respect to past tense acquisition are increasing. As the language of interest in this dissertation is Dutch, I will present some data on past tense development in SLI children for Germanic languages.

Hansson et al. (2000, 2003) investigated the past tense production of Swedish SLI children aged between 4;3 and 5;7. Production scores of the SLI children were compared with CA peers and LM peers, aged between 2;1 and 3;7. The Swedish past tense system compares to the Dutch system (which is outlined in section 3 of this chapter). In short, the regular past tense morphemes in Swedish are */–de/* and */–te/*, their distribution being phonologically conditioned. The former morpheme attaches to a stem ending in a voiced consonant, the latter to an unvoiced consonant. The irregulars involve a vowel change, sometimes a consonant is added to the stem in addition to a vowel change.

The analysis of spontaneous samples by Hansson et al. (2000) indicate that the SLI children produce significantly less target-like regulars in obligatory contexts as compared to the CA, and LM children. Although, percentages of regular production in the samples were high for the SLI children (i.e. 86%), The difference between SLI children and LM and CA children becomes more pronounced when regulars are elicited. Hansson et al. (2003) found that SLI children produced 37% of the regulars target-like, whereas the LM and CA children score between 87% and 99% target-like. This leads to a significant difference between the SLI children and their TD peers. These results indicate that the Swedish SLI children are more than 2 to 3 years delayed on their acquisition of the regular inflectional process.

On irregular past tense use, differences are found in production scores when spontaneous speech samples and elicitation data are compared. In Hansson et al. (2000), the speech samples of SLI children show a production of 94% target-like irregulars in obligatory contexts. For the LM and CA children this percentage is around 99%. No statistical difference between groups is observed. In contrast, the elicitation data show a percentage of 45% for the SLI children and 66% for the LM children in their target-like production of irregulars. The production score of the SLI children is significantly lower when compared to their CA peers and is comparable to TD children who are 2 to 3 years younger.

De Jong (1999) analyzed past tense productions in a narrative task of 28 Dutch SLI children, with a mean age of 7;8 years. Results are compared to those of LM children (mean age 5 years) and CA peers. Results showed that the SLI and LM children produced 10% regular past tense inflections out of the total number of produced past tenses. This percentage was significantly lower when compared to the production of regular past for the CA peers (22%). For the production of irregular past, no significant differences were observed between the SLI, LM and CA children. Between 49 and 55% of all past tenses produced were target-like irregulars. An interesting observation is that the SLI and LM children produced significantly more constructions with the verb 'to go' + infinitive (ging(en) + infinitive) as compared to the CA children. The SLI and LM children used this construction between 33 and 38% out of all past tenses produced as opposed to 21% for the CA children. De Jong (1999) argues that the use of 'to go' can be seen as an alternative strategy for expressing tense; the auxiliary carries the tense marker, but has no semantic load that adds to the main predicate.

4. Frequency effects in past tense acquisition

According to the dual-route model, the trigger for overgeneralization is the acquisition of the process responsible for regular past tense marking. This means that the onset of overgeneralizations is predicted by the mastery of the regular 'rule'. Marcus et al. (1992) have shown that overgeneralizations are not predicted by an increase in regulars from the input. About one-quarter of the parental verb tokens from Adam, Eve and Sarah were regular, and this proportion did not change before and after overgeneralizations began. The correlations between the rate of monthly change in proportion adult regular verb tokens and the child's overgeneralizations were negative or close to zero. This implies that the input does not interfere with the onset of overgeneralizations (Marcus et al., 1992). Therefore, the dual-route model does not expect to find frequency effects for regular past tenses. Marcus et al. (1992)

observed that the onset of overgeneralizations is followed by a rapid increase in regular past tense forms.

The dual-route model expects to find frequency effects in the acquisition of irregular past tense. If children fail to retrieve the irregular form to mark the verb for past tense, they inflect the stem productively. Retrieval of irregular forms fails because the memory trace is still weak. Hearing the irregular more often strengthens the memory trace. This is supported by frequency effects observed in irregular past tense: the more often a child hears an irregular form, the less likely it is that the child will overgeneralize it (Marcus et al., 1992; Pinker, 1998; Marchman et al., 1999).

The expectations drawn from the dual-route model partially contrasts with those from the single-route model. The single-route model expects frequency effects for irregular and regular past tenses. Rumelhart & McClelland (1986) hypothesize that as the child learns more and more verbs, the proportion of regular verbs increases more strongly relative to the irregulars (see also Ragnarsdottir et al., 1999). This new experience alters the connections within the network. The network learns the regular pattern, because of the predominance of regulars in the input. This leads to temporary overgeneralization of the newly learned pattern to the irregulars, which were already stored in the network. In their computer simulation of past tense acquisition, Rumelhart & McClelland (1986) show that their model overgeneralizes irregulars when it is exposed to high numbers of regulars.

Nevertheless, the influence of a verb's frequency of past tense occurrences in the input remains open to question. As demonstrated by Marcus et al. (1992), the production of regular verbs remains fairly stable in child-directed speech and regular verbs never dominate. Therefore, the training of the computer-based past tense acquisition model of Rumelhart & McClelland (1986) does not seem to correspond with the child's linguistic environment.

Despite this, subtle frequency effects have been reported for regular and irregular verbs. In the study by Ragnardottir et al. (1999), it is shown that Norwegian and Icelandic children produced more correct regular and irregular past tenses for verbs that occurred frequently in the input as compared to verbs that are lower in input frequency. In Norwegian and Icelandic, three classes of verbs occur, two regular classes and one irregular class. In their elicitation task, they included, for each verb class, verbs that occur often in the input (i.e. high frequency) and verbs that occur less often in the input (i.e. low frequency). For the Norwegian children, the percentage of target-like past tense marking on high frequency verbs was 10% higher as compared to the low frequency verbs. The same result was found for one regular verb class. On all verb classes, the Icelandic children showed better performance on high frequency verbs as compared to low frequency verbs. Moreover, the frequency effect was stronger for the regular verb classes as compared to the irregular verb class, respectively 11-14% and 5%.

5. Hypotheses

The aim of the current study is to compare 5 to 7-year-old CI and SLI children in their production of regular and irregular past tense forms. Spontaneous language samples of CI and SLI children are analyzed on number of past tense productions and types of past tense used. The production of past tense is also assessed using an elicitation task with regular, irregular and nonce verbs. In this task, TD children are included as controls.

We hypothesize that CI children compare to their SLI peers in the production of past tense. In chapter 5, section 5.2, we have already pointed out that adequate processing skills on an auditory and cognitive level have a pivotal role in language acquisition. For SLI children it has been hypothesized that their language delay is due to processing limitations (see also chapter 2, section 4). Hearing impairment disrupts processing skills on an auditory level, which could lead to similar language outcomes.

The regular past tense morphemes in Dutch are /*–de*/ and /*–te*/. The distribution of the morphemes is phonologically conditioned. The former morpheme attaches to a stem ending in a voiced consonant, the latter to an unvoiced consonant. The irregulars involve a vowel change (Booij & Van Santen, 1998). Examples for all forms are given in (1).

(1) spelen '*to play*'	– speel<u>de</u> '*played*'	regular /*-de*/
werken '*to work*'	– werk<u>te</u> '*worked*'	regular /*-te*/
komen '*to come*'	– kwam '*came*'	irregular

The regular past tense morphemes are weak syllables and therefore low in perceptual salience. In contrast, the irregular past tense is monosyllabic, carrying stress, and hence is perceptually salient in the speech input. The hypothesis is that the low salient regular past tense morpheme is more difficult to process than the irregular past tense for CI and SLI children (following the Surface Account outlined in chapter 5, section 5.2). Therefore we expect that CI and SLI children have more difficulties in the production of the regular past tense as compared to the irregular past tense.

Alternatively, one may assume that CI children do not compare to their SLI peers with respect to past tense production. This implies that the effect of reduced auditory input offered by the cochlear implant does not compare to reduced effective exposure in SLI children. This places more weight on external factors such as the role of input, peripheral hearing or education.

The acquisition of the regular past tense involves the generalization of regularities observed in the speech input. Most of the literature on past tense acquisition is concerned with the question of how children develop these generalizations. According to the dual-route model, past tense acquisition involves mainly top-down processes driven by innate language mechanisms. In contrast, the single-route model states that the frequency with which a past tense occurs is of vital importance as regularities are only discovered when enough speech material is present.

Therefore, the elicitation task used in this study include past tense verbs that occur relatively frequently in the adult target speech and past tense forms that occur less often in the adult target speech. If frequency effects are found on regular and irregular verbs for the CI and SLI children, as hypothesized by the single-route model, this would underline the importance of speech input in the acquisition of grammatical morphology.

6. Past tense production in spontaneous speech

6.1 Research method

Participants

This study includes spontaneous language samples of 30 CI children and 31 SLI children. The CI children were drawn from schools for special education (Antwerp and Hasselt) and an audiology centre (Antwerp), all located in Flanders. At the time of the study, the CI children were aged between 60 to 93 months and received their implant at between 5 and 34 months of age. They had a mean hearing loss of 111dB (i.e. hearing thresholds averaged over 500, 1000 and 2000 Hz for the *best* ear). None of the CI children had additional disorders, besides their hearing impairment. (For individual data of the CI children see Table 3 of the Appendix to chapter 5)

The SLI children consisted of 2 subgroups. The first SLI subgroup included 15 transcripts from the Bol & Kuiken corpus (Bol & Kuiken, 1981), available through the Child Data Exchange System (MacWhinney, 2000). The 15 transcripts included 5 for the 5-year-old SLI children, 7 for the 6-year-olds and 3 for the 7-year-old SLI children. The SLI children of the Bol & Kuiken corpus attended special education in the Netherlands (Amsterdam, Haarlem, Amersfoort and Leiden).

The second SLI subgroup (N=18) was selected for the present study. These SLI children were drawn from schools for special education in Flanders, Belgium.

The SLI children in both subgroups were diagnosed as language- impaired by a certified speech-language pathologist. The children received intervention at the schools for special education they were attending. None of the SLI children presented hearing losses, neurological and cognitive disorders or social-emotional problems. For individual data see Table 5 of the Appendix to chapter 5).

For the CI and SLI children, who were selected for the present study, informed consent was obtained from the parents to participate in the study. An overview of the group characteristics is presented in Table 1.

Table 1. Overview of the number of participants per group and corpus (Bol & Kuiken corpus = B&K corpus). For the SLI and CI group age (in months) means and standard deviation in parentheses are given. For the CI children, additionally, means and standard deviations for Hearing Loss without devices (HL) and Age At Implantation (AAI, in months) are given.

		5 yrs	B & K corpus	*6 yrs*	B & K corpus	*7 yrs*	B& K corpus
SLI	N	4	5	8	7	6	3
	Age	66	64	79	74	89	86
		(*3.0*)	(*2.8*)	(*2.8*)	(*2.6*)	(*3.2*)	(*2.1*)
CI	N	13		8		9	
	Age	64		74		86	
		(*4.2*)		(*2.8*)		(*2.7*)	
	HL	108.3		113.8		112.7	
	(dB)	(*10.2*)		(*8.7*)		(*6.7*)	
	AAI	17.7		15.5		15.6	
		(*10.2*)		(*10.8*)		(*6.7*)	

Data collection and procedure

The CI and SLI children (selected for the present study) were recorded for 15 to 30 minutes using a Panasonic NV-GS180 digital video camera. To elicit speech, the same procedure was followed as in Bol & Kuiken (1988). During interactions, the CI and SLI children talked about daily activities and events outside the here and now. Toys and books were not incorporated in the procedure to elicit speech. The child's personal school book or picture books were sometimes used to familiarize the child with the situation and/or experimenter. Interactions with the CI and SLI children were carried out by either a caregiver, a speech therapist or by a member of the research group. All video recordings were made in a quiet room at the audiology centre or at the schools the children attended.

All video recordings from the CI children were transcribed by an experienced speech therapist. The experienced speech therapist trained a second transcriber, who transcribed the video recordings of the SLI children.

All transcriptions were made according to the CHAT conventions, available through the Child Data Exchange System (MacWhinney, 2000).

Data analysis

In previous studies, spontaneous language samples have been analyzed according to past tense use in obligatory contexts (see Brown, 1973; Kuczaj, 1977; Oetting & Horohov, 1997; De Jong, 1999; Hansson et al., 2003). However, it is difficult to define an obligatory context for the simple past. First of all, the use of past participles is preferred to refer to past events in Dutch as compared to the use of the simple past (De Houwer, 1997). Secondly, children go through a developmental stage in which they refer to past events with present tense forms (Kuczaj, 1977). Therefore, in this study past tense productions were studied when children grammatically encode past tense.

From each transcript, 50 utterances were selected for analysis. Elliptical answers, repeated and unintelligible utterances are not included in this 50-utterance sample. For the selection of utterances, the STAP protocol (Verbeek et al., 1999) was followed. On each 50-utterance sample, the number of past tense productions were counted and categorized as regular or irregular. The aim of this analysis was to obtain an inventory of past tense productions per verb class (i.e. regular or irregular) and variation in verb type and tokens for the CI and SLI children. Differences between the CI and SLI children on past tense productions were tested with a Mann Whitney U-test (alpha .05). This non-parametric was used because of the group outliers.

For every past tense type, frequency of occurrence (i.e. tokens) in adult conversational speech was calculated to obtain an indication for adult target speech. The analysis is based on the Corpus Gesproken Nederlands (CGN) database, 'spontaneous conversation' component. The 'spontaneous conversation' component involves conversational face-to-face speech only. This component of the corpus consists of 3 million words, subdivided into a Flemish corpus of 1 million words and a Dutch corpus of 2 million words. The number of occurrences per verb type was combined for the Dutch and Flemish corpus.

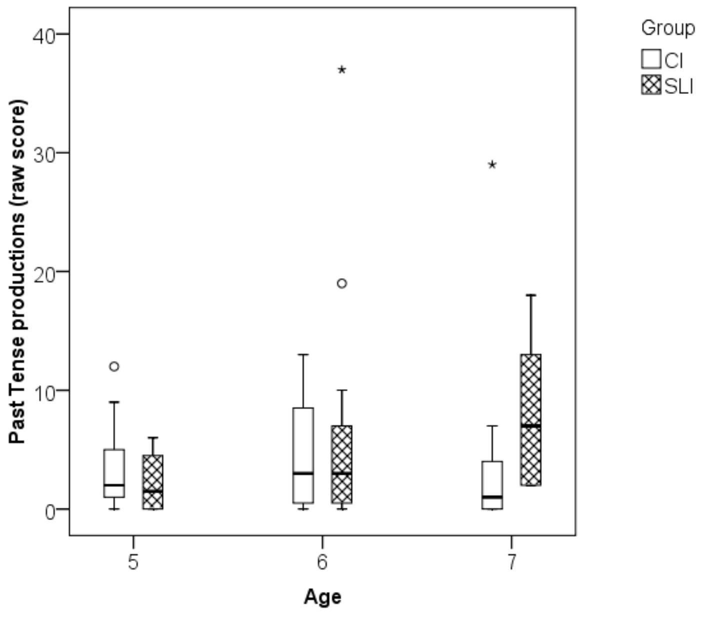
Spearman correlations were carried out between the past tense tokens (i.e. the number of past tense occurrences of a verb type) of the CI and SLI children and the adults (alpha .05). A non-parametric test was used because the distribution of past tense tokens across verb types was not normally distributed. This type of analysis reflects the relation between past tense forms used in adult target speech and past tense production of the CI and SLI children.

6.2 Results

Past tense productions

The number of past tense productions was counted per age group for the CI and SLI children. This number of past tense productions was based on a 50-utterance sample. The median raw past tense production scores and the variation within each age group is presented in Figure 4. The median past tense productions for the 5-, 6- and 7-year-old CI children is respectively 2.00, 3.00 and 1.00. The SLI children produced 1.50 past tense forms at the age of 5, 3.00 at 6 years and 7.00 at 7 years. For the CI and SLI children, large within-group variation was observed in past tense productions. No significant differences were observed between the CI and SLI children at any age (5 years: U=44.00, p=.595, 6 years: U=59.00, p=.975, 7 years: U=19.00, p=.063).

Figure 4. Box plots present the variation in raw past tense productions as measured in spontaneous speech samples for CI and SLI children. Results are presented per age group.

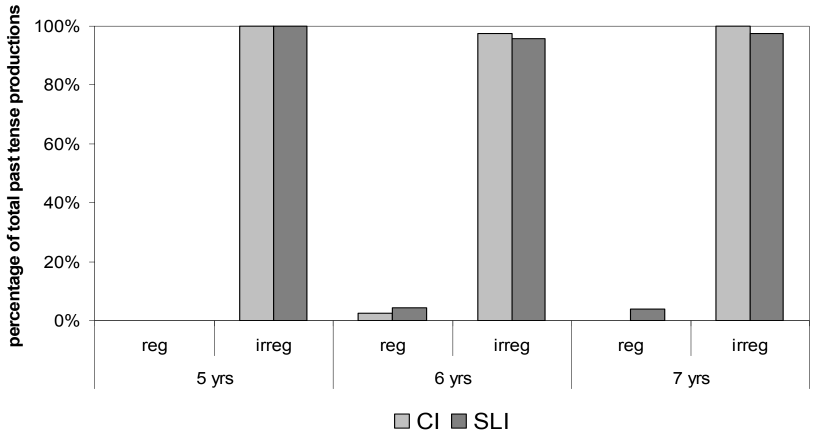


Regular versus irregular

All past tense productions were categorized in regular and irregular past tense productions. Accordingly, the total number of regulars and irregulars was divided by the total number of past tense productions to obtain a percentage of regular and irregular past tense productions. Calculations were carried out per age group. The percentages are presented in Figure 5.

The percentages in Figure 5 indicate that most past tense productions were irregular past tense productions rather than regular past tense productions. This pattern is equal between the CI and SLI children and persists across ages.

Figure 5. The bars present the percentage of regular and irregular past tense verbs from the total number of past tenses produced per age group.



Types and adult target speech

All past tense productions are classified by type for the CI and SLI children. The number of occurrences of each type is also counted (i.e. tokens). The results of this analysis are presented in Table 2. For each past tense type, frequency of occurrence in adult target speech is presented as well.

The past tense types that occurred most often in the spontaneous speech of CI and SLI children are forms of the auxiliaries 'zijn' *(to be)* and 'hebben' *(to have)*. These past tense types are also highly frequent in the adult target speech. The CI and SLI children produced ≥10 tokens of the past tense types 'gaan' *(to go)* and 'moeten' *(moesten)*. The past tense 'gaan' *(to go)* occurred most often in a construction of 'gingen' *(went)* + infinitive (see examples in (2)). For the CI children this construction occurred 16 times out of 16 past tense tokens of the verb 'gaan', and for the SLI children 10 times out of 14. The past tense of 'gaan' *(to go)* and 'moeten' *(must)* do not occur relatively more often in spontaneous speech of adults when compared to other past tense types (cf. 'zullen' *(shall)* and 'vinden' *(to find)*).

(2) a. En toen ging de kapitein zijn hoed aan Berend geven
and then went the captain his hat to Berend give
'And then the captain gave his hat to Berend'

b. En dan ging de uil verder vliegen
And then went the owl afar fly
'And the owl flew afar'

Across the board, the number of past tense tokens for the irregular verbs is higher when compared to the regulars in the adult target speech (see Table 2). This pattern is reflected in the spontaneous speech of CI and SLI children; the CI and SLI children produce more past tenses for the irregular verbs as compared to the regular verbs. Significant positive correlations are found in past tense tokens between the spontaneous speech of CI and SLI children and adults, respectively rs= .534, p=.018 and rs=.517, p=.028.

Table 2. Overview of the number of past tense occurrences of each verb type. The number of occurrences per verb type was measured for the CI children, SLI children and adults (CGN).

		CI children	*SLI children*	*CGN*
verb type	regular/ irregular	Occurrence child spontaneous speech	Occurrence child spontaneous speech	Occurrence adult spontaneous speech
zijn *(to be)*	irregular	**62**	**85**	**21549**
gaan *(to go)*	irregular	**16**	**14**	**2987**
hebben *(to have)*	irregular	**13**	**34**	**11263**
moeten *(must)*	irregular	**10**	**12**	**2720**
komen *(to come)*	irregular	3	4	1916
willen *(to want)*	irreg(reg)	3	3	1691
mogen *(to may)*	irregular	2	5	540
denken *(to think)*	irregular	2	0	2171
vliegen *(to fly)*	irregular	2	0	38
vinden *(to find)*	irregular	1	1	2211
slapen *(to sleep)*	irregular	1	2	44
staan *(to stand)*	irregular	1	0	1405
weten *(to know)*	irregular	1	1	1029
doen *(to do)*	irregular	1	1	906
kunnen *(can)*	irregular	1	2	1753
worden *(to become)*	irregular	1	5	1010
krijgen *(to get)*	irregular	1	1	680
zullen *(shall)*	irregular	1	0	5446
vallen *(to fall)*	irregular	1	0	234
hangen *(to hang)*	irregular	1	0	111

zitten *(to sit)*	irregular	0	5	2018
zien *(to see)*	irregular	0	5	827
jeuken *(to itch)*	regular	1	0	0
maken *(to make)*	regular	0	1	153
botsen *(to bump)*	regular	0	1	0
spugen *(to spit)*	regular	0	1	0
bedoelen*(to mean)*	regular	0	1	55

6.3 Summary

In this study, spontaneous speech samples have been analyzed on past tense production for 5 to 7-year-old CI and SLI children. Results show that CI and SLI children produce equal numbers of past tenses in their spontaneous speech. Moreover, the CI and SLI children produce more irregular past tenses in their spontaneous speech as compared to regulars. This pattern persists up to the age of 7. The most frequently occurring irregulars are forms of the auxiliaries 'zijn' *(to be)* and 'hebben' *(to have)*. The type of past tense occurrence in CI and SLI child speech is partially explained by the number of occurrences of the past tense type in target adults speech, as positive correlations have been found between past tense tokens (per verb type) for children and adults

7. Past tense elicitation task

7.1 Research method

Participants

For this task, three groups of children are included, aged between 5 to 7 years. The first group included 74 TD children who were drawn from mainstream schools in Flanders (Westmalle) and the east of The Netherlands (Hengelo). Numbers of TD children from Flanders and the Netherlands are specified in Table 3 as well as mean ages and standard deviations (individual data of the TD children is presented in Table 2 of the Appendix). All TD children were monolingual speakers of Dutch and did not present any disorders, such as hearing losses, language impairments, social-emotional problems or cognitive delays. The group of TD children served as controls for the CI and SLI children.

The second group included 14 CI children between the ages 5 to 7. The CI children were drawn from schools for special education in Flanders (Antwerp and Hasselt) and an audiology centre (Antwerp). Five of these CI children also participated in the study of past tense analysis based on spontaneous speech samples. These samples were been recorded 1 or 2 years prior to the present elicitation task. The CI children had a mean unaided hearing loss of 104dB (SD 13.8dB) (i.e. hearing thresholds averaged over 500, 1000 and 2000 Hz for the *best* ear). They received their implant at between 7 and 59 months, with a mean of approximately 26 months for age at implantation. All CI children were monolingual speakers of Dutch. None of the CI children had additional disorders, such as cognitive disorders or social-emotional disorders. Mean age, hearing loss and age at implantation per age group are presented in Table 3 (for individual data see Table 3 of the Appendix).

Table 3. Overview of the number of participants per group and age is presented. The TD children were subdivided in a group tested in the Netherlands and Flanders. Mean age and standard deviations are given for the TD, SLI and CI children. For the SLI children mean Hearing Loss (HL) for the worst ear is given. For the CI children mean Hearing Loss for the best ear is given as well as the mean age of receiving an implant (AAI).

		5 yrs		*6 yrs*		*7 yrs*	
		NL	VL	NL	VL	NL	VL
TD	N	10	14	6	18	12	11
	Age	66.8	66.6	80.0	79.2	88.4	87.3
		(*4.5*)	(*2.6*)	(*2.9*)	(*3.4*)	(*3.7*)	(*2.8*)
SLI	N		8		9		8
	Age		65.7		77.1		88.4
			(*4.3*)		(*3.7*)		(*3.6*)
	HL (dB)		14.2		15.0		12.7
			(*4.0*)		(*11.2*)		(*3.3*)
CI	N		6		5		3
	Age		67.0		77.0		91.6
			(*2.4*)		(*3.9*)		(*4.2*)
	HL (dB)		105.8 (		102.8		103.4
			(*16.6*)		(*13.0*)		(*16.5*)
	AAI		28.6		26.6		17.9
			(*19.9*)		(*13.0*)		(*9.9*)

The third group included 25 SLI children, who were selected from schools for special education in Flanders (Antwerp and Hasselt). The SLI children were all diagnosed as language-impaired by a certified speech-language pathologist and received therapy at the schools they were attending. None of the SLI children presented hearing losses, as indicated by the most recent audiograms (mean hearing loss 14dB (7.2dB) (i.e. hearing thresholds averaged over 500, 1000 and 2000Hz for the *worst* ear). No additional disorders, besides their language impairment, were reported for the SLI children. The SLI children were all monolingual speakers of Dutch (for individual data see Table 4 of the Appendix).

The parents of the TD, CI and SLI children were informed about the present research and permission was asked for their child to participate. For all participating children, the relevant permission was obtained.

Tasks

Pretest: Discrimination task

To evaluate the discrimination abilities of the CI and SLI children we used the Auditory Speech Sounds Evaluation test (A§E®, ©PJ Govaerts, Antwerp, Belgium). This test is language-independent and gives information about the auditory function with as little cognitive bias as possible (Govaerts, 2006). The test uses an oddity procedure in which two speech stimuli are presented and the child is conditioned to react to the odd speech sound. The stimuli selected for this test were pairs of verbs. The pairs consisted of the present tense form and the past tense form of the same verb. The pairs are the regular werk-werkte (*to work - worked*) and the irregulars breek-brak,(*to break - broke*) and kijk-keek (*to look- looked*). The children listened to the repetition of the present tense form of the verb and were asked to raise their hand if they heard another word, which was the past tense form of the verb pair. Children passed the discrimination task if they discriminated three past tense forms (of the same verb) in succession.

The discrimination task served as a pretest, if a child failed to discriminate between the stimuli, no past tense elicitation task was given. This assures that children who were participating in the elicitation task were able to discriminate between present and past tense on phonological form when presented in isolation.

The auditory stimuli were played on a laptop with loudspeakers. The children were placed at a distance of one meter from the loudspeakers. Stimuli were presented at 60-65dB as measured by an audiometer on one meter distance from the speakers. The discrimination task was video recorded for all children.

Elicitation task

Berko's experiment from 1958 was used to guide the current analysis. The elicitation task consisted of a short movie in which two characters, Bob and Boris, are building a sandcastle. The movie is composed of an oral story supported by pictures in which the two characters acted out the story (for the full script see Appendix). The pictures served as a visual reminder of the actions of Bob and Boris. The target verbs are interwoven in the story together with the filler verbs. The target verbs are introduced in their present tense form, see example (3a/4a), followed by the test sentence in (3b/4b). All test sentences were recorded in full form, i.e. containing the past tense form of the target verb, to obtain the correct intonation pattern of the sentence. Accordingly, the target verb was replaced by a beep. By leaving only one gap in the test sentence, children were forced to use the simple past (for more information about the task construction see Schultz, 2009). This way of constructing the test sentence avoids the use of past participles or the past tense of the verb 'gaan' *(to go)* combined with an infinitive, which are constructions frequently used by children in Dutch to mark past tense (De Jong, 1999).

Part of the script:

Dit is Bob
'This is Bob'

En dit is Boris
'And this is Boris'

(3) a. 'Hallo' zegt Bob
'Hello' says Bob'
b. Gisteren, toen _______ Bob hallo (zei)
'Yesterday, Bob ______ hello' *(said)*

Boris zegt hallo terug
'Boris says also hello'

Bob en Boris zijn elkaars beste vrienden
'Bob and Boris are each other best friends'

(4) a. Vandaag spelen zij in de speeltuin
'Today they play on the play ground'
b. Gisteren, toen _______ zij in de speeltuin (speelden)
'Yesterday, they ______ on the playground' *(played)*

Stimuli

The elicitation task included 6 regular and 6 irregular verbs. To make sure that the children in our study were familiar with the regular and irregular verbs, we performed frequency counts on the verbs listed in the Dutch version of the MacArthur Communicative Development Inventory (Zink & Lejaegere, 2002), a standardized parent-reporting system used to assess monolingual children's lexical growth. The frequency counts present the number of occurrences of the present and past tense form (singular and plural) of each CDI verb in two child corpora. These counts indicate the degree of familiarity with the verb type in child speech.

The child corpora that were analyzed consist of spontaneous speech samples of CI children and TD children. The procedure for the collection of spontaneous speech samples is outlined in 6.1 of this chapter. For the frequency counts, corpora were analyzed including 48 CI children and 52 TD children aged between 4 and 7 years. All children were monolingual speakers of Dutch and lived in Flanders, Belgium. The frequency counts for each CDI verb are summarized in Table 1 of the Appendix.

The frequency counts of the CDI verbs, based on the child corpora, were compared to the number of past tense tokens per verb type in the adult corpus. The latter frequency measure was used to approach the frequency of occurrence in the adult target speech of the past tense form of each CDI verb. The number of past tense tokens per verb type were calculated using the database from the Corpus Gesproken Nederlands. Frequency counts are based on the 'spontaneous conversation' component of the CGN database, that only involves conversational face-to-face speech. This component of the corpus consists of 3 million words, subdivided into a Flemish corpus of 1 million words and a Dutch corpus of 2 million words. For the present analysis, frequency counts of the Dutch and Flemish corpora were added together.

Results of the frequency counts per CDI verb are presented in Table 1 of the Appendix. From the list of regular and irregular verbs, three high frequency verbs and three low frequency verbs were selected (see Table 4 in this chapter). High frequency indicates that adults produce the past tense form relatively often in their spontaneous speech, hence the past tense form is highly frequent in the adult target speech. Low frequency indicates that adults produce the past tense form less often in their spontaneous speech as compared to the high frequency verbs. To put it in other words, the low frequency verbs occur less often in the adult target speech.

Across the board, the high frequency regular verbs occurred less often as compared to the high frequency irregular verbs (cf. spelen *(to play)* with zeggen (*to say)* in the Table 4). Frequency counts in the adult spontaneous speech coincide with the frequency counts in the child corpora (see Table 4). This indicates that the children were relatively more familiar with the high frequency verbs than the low frequency verbs. However, this does not imply that the children were familiar with the past tense form of the verb, as the frequency counts are mainly based on present tense forms.

Table 4. Overview of the stimuli included in the elicitation task, categorized in high frequency and low frequency. Frequency counts for the children indicate familiarity with the verb. Frequency counts are based on number of past and present tense occurrences of the verb in child corpora. Frequency counts for the adult corpora (CGN) are based on past tense occurrences in adult spontaneous speech. This measure indicates input frequency.

	regular	*child corpora*	*adult corpora*
High frequency	spelen *(to play)*	110	103
	stoppen *(to stop)*	26	23
	leggen *(to lay down)*	34	18
Low frequency	botsen *(to bump)*	4	0
	schoppen *(to kick)*	1	1
	schommelen *(to swing)*	5	2
	irregular		
High frequency	zeggen *(to say)*	91	3676
	vallen *(to fall)*	87	234
	kijken *(to look)*	362	160
Low frequency	schrijven *(to write)*	4	41
	brengen *(to bring)*	5	29
	breken *(to break)*	2	5

Four nonce verbs (see data analysis) were created for each verb selected by replacing the onset for the first syllable and maintaining the rhyme (e.g. [b]otsen – [w]otsen). According to Prasada & Pinker (1993), the maintenance of the rhyme is the most salient factor for a nonce verb to be considered a prototypical verb. Prototypical verbs are phonologically acceptable. For adults it has been shown that they are more likely to produce a past tense form for a phonologically acceptable nonce verb as compared to less phonological acceptable nonce verbs (Albright & Hayes 2003).

Procedure

The elicitation task was played on a laptop (Dell latitude D600) with external loudspeakers (Trust, portable sound station SP2986Bi). The elicitation task was presented at 65 – 70dB as measured by an audiometer at one meter distance from the speakers. Children were seated approximately one meter in front of the laptop and loudspeakers. They were given the following instruction: *'You are going to watch a movie of Bob and Boris. They are each other's best friends. Today they are playing in the playground. They do a lot of things. Some things are familiar; probably you have done them, too. But they also do a lot of crazy things. Then we have to pay attention of what they are doing. But, the movie has some beeps. Can you tell me what Bob and Boris did?*

The elicitation task is preceded by two practice items (lopen '*to walk*' and gooien '*to throw*'). If the children did not respond to the first practice item the procedure of the task was explained to them again and, if necessary, the past tense of the first practice item was given by the experimenter. Movie fragments were repeated if children were unable to remember a particular verb, or if they produced the wrong stem for a target verb. Two versions of the elicitation task were made, one with a Dutch female narrator and one with a Flemish female narrator. The Dutch children were given the Dutch version of the movie, the Flemish children were given the Flemish version of the movie.

Data analysis

The past tense responses on the verbs in the elicitation task were judged target-like or non-target-like. Target-like responses conform to the past tense responses of adults. The first step to obtain target-like responses for the nonce verbs was to embed all nonce verbs (48 in total) in intransitive sentences. The sentences were given to 22 adults who placed all nonce verbs in its past tense form. A cut-off level of 75% agreement between adults on the past tense form of the nonce verb was a prerequisite for eligibility in the elicitation task. This prerequisite was met for 6 nonce verbs, which are listed in Table 5. Of those, only 'glijven' was deemed irregular ('gleven').

Table 5. Overview of the nonce verbs included in the elicitation task. Percentages of agreement among adults on the past tense form of the nonce verb are included.

nonce verb	*past tense form*	*percentage agreement*
joppen	jopten	95.8%
prommelen	prommelden	100%
wotsen	wotsten	100%
grallen	gralden	91.7%
teggen	tegden	79.2%
glijven	gleven	75%

After this reduction in nonce verbs, 28 adults performed the elicitation task (20 adults from The Netherlands, 8 adults from Flanders). These adults followed the same procedure as the children. The results of the adults are presented in Table 6. The nonce verbs 'glijven' and 'teggen' fell below the cut-off level of 75% agreement. Therefore, these two nonce verbs are discarded for further analysis.

Table 6. The target-like past tense forms of the verbs taken up in the elicitation task. Target-like responses are based on the responses given by 28 adults. The percentage of agreement for each past tense form is given.

regular	*agreement*	*irregular*	*agreement*	*nonce verbs*	*agreement*
speelden	100%	keek	100%	jopten	86%
legden	96%	viel	100%	prommelden	100%
stopten	100%	zei	96%	wotsten	100%
schopten	100%	brak	100%	gralden	89%
botsten	100%	schreef	100%	*tegden*	*68%*
schommelden	100%	bracht	100%	*gleef*	*50%*

The TD, CI and SLI children were compared in their production target-like past tense responses with a Mann-Whitney U-test (for a detailed analysis of target-like responses per verb for the TD, SLI and CI children see Willemsen (2008-2009). A non-parametric test was used because the assumption of equal variances was not met. The non-target-like responses were further categorized. Statistical analysis is performed on the largest non-target-like categories. These are present tense responses instead of past tense responses and null responses (i.e. no answer is given for the stimulus). Differences between TD, CI and SLI children are tested with a Mann-Whitney U-test. Again, a non-parametric test is used because of unequal variances between groups.

For the irregular verbs, a separate analysis involves overgeneralizations. As outlined in the introduction (see subsection 2.2), overgeneralizations in this study refer only to the feeding of the stem of the verb into the regular process. For example, the past tense form of the irregular verb 'kijken' *(to look)* becomes 'kijkte'. The feeding of the past tense form of the irregular verb into the regular process is excluded from the analysis of overgeneralizations (e.g. 'keken' *(looked)* → 'keekte'). The proportion of overgeneralizations and target-like irregulars was calculated for the TD, SLI and CI children per age group.

All target-like regular and irregular responses are divided into low and high frequency categories. The parametric ANOVA test was applied for statistical analysis in the case of equal variances in production of high versus low frequent verbs. If the assumption of equal variances was not met, Mann-Whitney U-tests were performed.

Pearson correlations were performed to test the relation between target-like production scores on regular, irregular and pseudoverbs. Correlations were performed across ages, with age included as a covariate in the correlation analysis. For the CI children we also correlated past tense production scores with age at implantation. The effects of frequency (i.e. high versus low frequent) on past tense production scores were also tested within each group. If the parametric assumptions were met, ANOVA analysis was performed, otherwise a Mann-Whitney U-test was used. For all statistical testing we adopted an alpha of .01.

7.2 Results elicitation task

7.2.1 Regular past tense

Figure 6 presents the percentage target-like responses for the TD, SLI and CI children from age 5 to 7 as compared to the non-target-like responses. The grey-shaded area indicates the category of target-like regular responses. The non-target-like responses are categorized as follows:

1. no answer or null responses
   (i.e. no answer is given to the stimulus)
2. past tense forms with a different allomorph
   (e.g. 'legte' instead of 'legde')
3. present tense forms
4. attempts to form an irregular past tense form
   (e.g. 'leggen' – 'lag')
5. past participles
   (e.g. heeft gelegd)
6. the past tense form of 'gaan' *(to go)* combined with an infinitive
   (e.g. ging leggen)
7. a residual category
   (e.g. when another verb was used 'gooide' instead of 'legde')

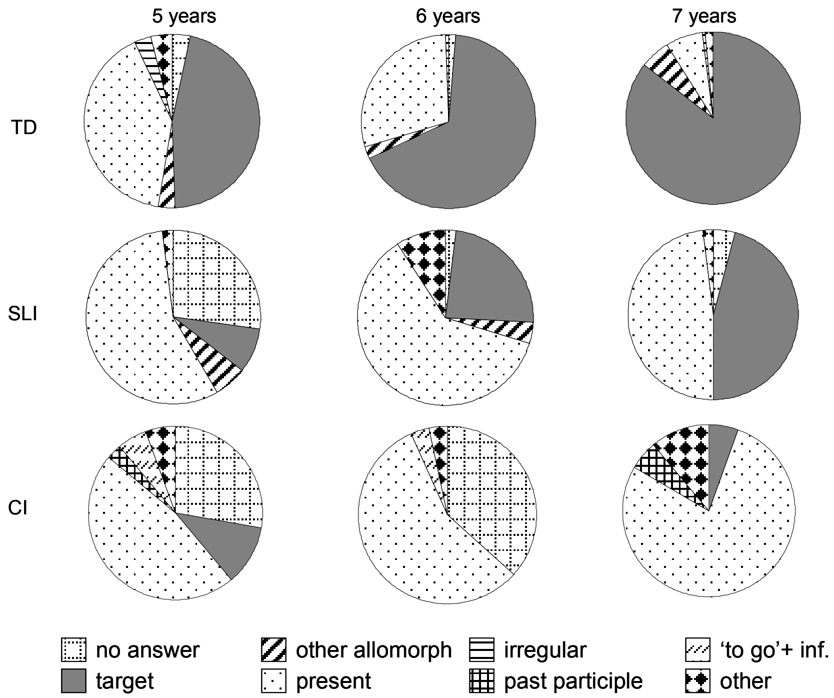
Percentages were calculated by dividing the number of responses within a category (i.e. target-like responses and the 7 non-target-like responses) by the number of regular verbs included in the elicitation task (i.e. 6). The first analysis compared TD, CI and SLI children on non-target-like responses.

Non-target-like responses for regular verbs

Present tense forms

The pie charts in Figure 6 indicate that the TD, CI and SLI children often gave the present tense form of the verb instead of the past tense form. For the TD children, there is a strong decrease in the non-target present tense production across years. The percentage decreases from 40% at the age of 5 to 7% at the age of 7. Such a decrease is not observed for the SLI and CI children. For the SLI children, the production of the non-target present tense form remains fairly constant over the years. At the age of 6 and 7, an overall significant difference in present tense production is found between the SLI and TD children (respectively U=33.5, p=.002 and U=24.5, p=.001). CI children show an increase in the production of non-target present tense responses from 47% at 5 years to 78% at the age of 7. Only at the age of 7 is a significant difference found between the CI and TD children (U=0.0, p=.001). No significant difference on the production of non-target present tense forms is found between SLI and CI children at any age.

Figure 6. Proportion of target-like responses and non-target-like responses from the total number of regular verbs (i.e. 6). Results are presented for the TD, SLI and CI children separately and per age group.



Null responses

For the 5 to 7-year-old TD children, the percentage of non-target null responses is close to zero. This is in contrast with the younger SLI and CI children. At the age of 5, the percentage of non-target null responses is higher for the SLI and CI children as compared to their TD peers. This difference reaches significance (U=20.0, p=.003) only between the 5-year-old CI and TD children. At 6 years, the proportion of null responses has decreased for the SLI children, but remains high for the CI children. The higher proportion of null responses for the 6-year-old CI children as compared to the TD and SLI children is not significant. The percentage of non-target null responses is zero or close to zero for the 7-year-old TD, SLI and CI children.

Other non-target-like responses

The CI children produce two other categories of non-target-like responses, which do not occur for the TD and SLI children. The CI children use other constructions to mark past tense, such as the past participle and the past tense form of 'gaan' *(to go)* combined with the infinitive. Despite the constraint in the elicitation task (i.e. children were forced to use the simple past) some CI children produced other sentences to allow for alternative constructions to place the event in the past tense.

Regular target-like past tense responses

The variability between children in the production of target-like regular past tense is presented in Figure 7. This graph presents the mean percentages of target-like regular responses and standard deviations for the TD, SLI and CI children.

The results for the TD children show an increase in the production of target-like regular past tense over the years. At the age of 5, the TD children produce target-like regular past tense at chance level (50%). However, some TD children are able to produce 80% of all regular verbs target-like even at this early age. The mean performance of the TD children is near ceiling at the age of 7.

Similarly to the TD children, the SLI children show an increase in the production of target-like regular past tense between the ages of 5 to 7. However, at all ages their production of target-like regular past tense remains significantly below the production scores of their TD peers (see Table 7 for the statistical results). All 5 and 6-year-old SLI children perform below chance level in their production of target-like regular past tense. They reach chance level at the age of 7, with some SLI children reaching a score of 80% target-like regular past tense. This indicates that their production of target-like regular past tense compares to the 5-year-old TD children.

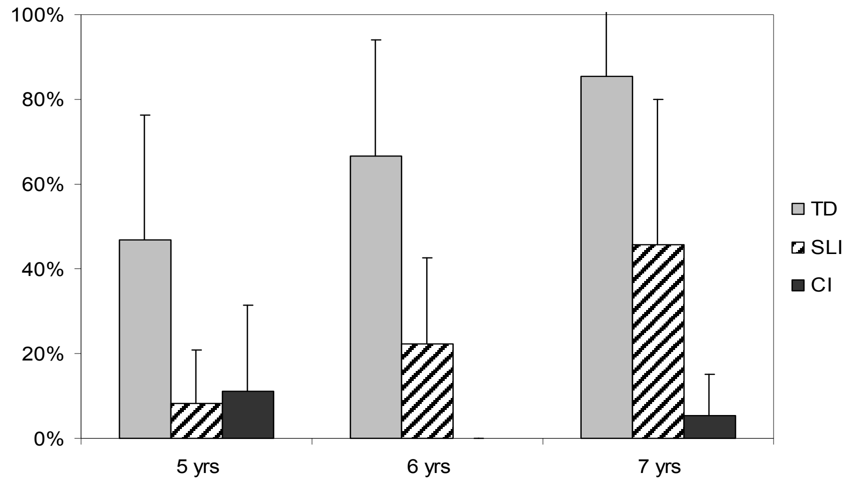
The production of target-like regular past tense for the CI children is below 20% at all ages. They do not show an increase in target-like regular past tense production, which is in contrast with their TD and SLI peers. When compared to their TD peers, CI children produce significantly lower percentages target-like responses at all ages (see Table 7). No significant differences in regular target-like responses are found between the CI and SLI children at any age (see Table 7). The lack of any significant identifiable difference between the CI and SLI children at the age of 7 could be attributed to the low number of CI children in this group (N=3).

Table 7. Results of the Mann Whitney U-test, comparing the TD, SLI and CI children on regular target-like past tense production.

	TD – SLI	*TD – CI*	*SLI – CI*
Age 5 yrs	U=23.5, p=.000**	U=23.5, p=.006*	U=24.0, p=1.0
6 yrs	U=22.5, p=.000**	U=2.5, p=.000**	U=7.5, p=.042
7 yrs	U=29.0, p=.002*	U=0.0, p=.001*	U=3.0, p=.085

* significant at alpha .01 ** significant at alpha .001

Figure 7. Mean percentage target-like regular past tenses and standard deviations for the TD, SLI and CI children. Results are presented per age group.



7.2.2 Irregular past tense

Figure 8 presents the percentages of target-like and non-target-like responses to stimuli that require an irregular past tense form for the TD, SLI and CI children. The grey-shaded area indicates the category of target-like irregular responses. The non-target-like responses are categorized as follows.

1. no answer or null responses
   (i.e. no answer is given to the stimulus)
2. target-like irregular responses with double marked past by concatenation of an irregular past verb stem with a regular past morpheme
   (e.g. 'viel' *(fell)* – 'viel-te' (*fell-ed)*)
3. target-like irregular response with a regular present tense agreement marker

(e.g. 'viel' *(fell)* – 'viel-t' (fell-s*)*)
4. overgeneralization in which the stem of the irregular verb is concatenated with the regular past tense allomorph
(e.g. 'vallen' *(to fall)* – 'valte' *(fall-ed)*
5. non-target-like irregular past tense, possibly based on the past participle stem
(e.g. 'brook' instead of 'brak' *(to break)*).
6. present tense forms
7. past participle is used to place the event in the past tense
(e.g. zijn gevallen)
8. construction with the past tense form of the verb 'gaan' *(to go)* and infinitive
(e.g. ging vallen)
9. residual category
(e.g. 'bruin' for the irregular 'bracht' (*brought*))

Percentages were calculated by dividing the number of responses within a category (i.e. target-like responses and the 9 non-target-like responses) by the number of irregular verbs included in the elicitation task (i.e. 6). The first analysis compared TD, CI and SLI children on non-target-like responses.

Non-target-like responses for irregular verbs

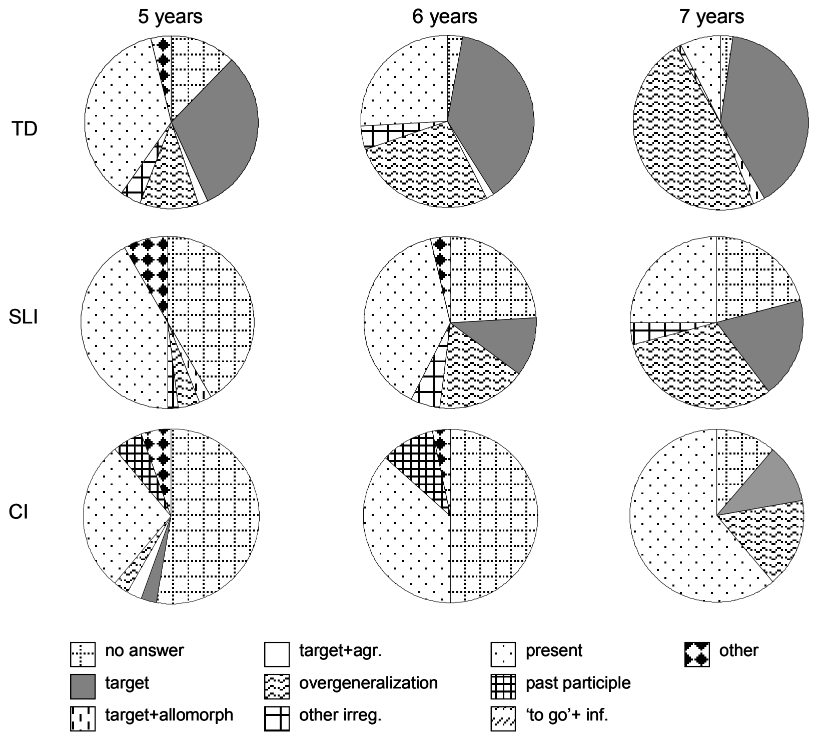
Present tense responses

The pie charts in Figure 8 show that for the 5-year-old TD, SLI and CI children the production of the non-target present tense form is the most frequent non-target-like response. For the TD and SLI children, the production of non-target present tense forms decreases between the ages of 5 to 7. No significant differences are found between the TD and SLI children in the production of non-target present tense at any age. In contrast, the CI children increase in their production of non-target present tense forms across the years. A significant difference is found between the CI and TD children at the age of 7 (U=1.5, p=.001). No significant difference is found between the CI and SLI children at any age on the production of non-target present tense.

Null responses

The TD children have low percentages null responses at the age of 5 and this percentage decreases in subsequent years. The 5-year-old SLI children have significantly more null responses when compared to their TD peers (U=36.0, p=.004). The percentage of null responses remains high for the 6 and 7-year-old SLI children when compared to their TD peers, but the difference is not significant. For the CI children, it is observed that at the age of 5 and 6 approximately half the irregular stimuli do not elicit any answer. The 5 and 6-year-old CI children have significantly more null responses when compared to their TD peers (respectively U=21.5, p=.004 and U=4.0, p=.000). At the age of 7, the number of null responses is comparable between the TD and CI children. No significant differences are observed between the CI and SLI children at any age.

Figure 8. Proportion of target-like responses and non-target-like responses from the total number of irregular verbs (i.e. 6). Results are presented for the TD, SLI and CI children separately and per age group.



Overgeneralizations

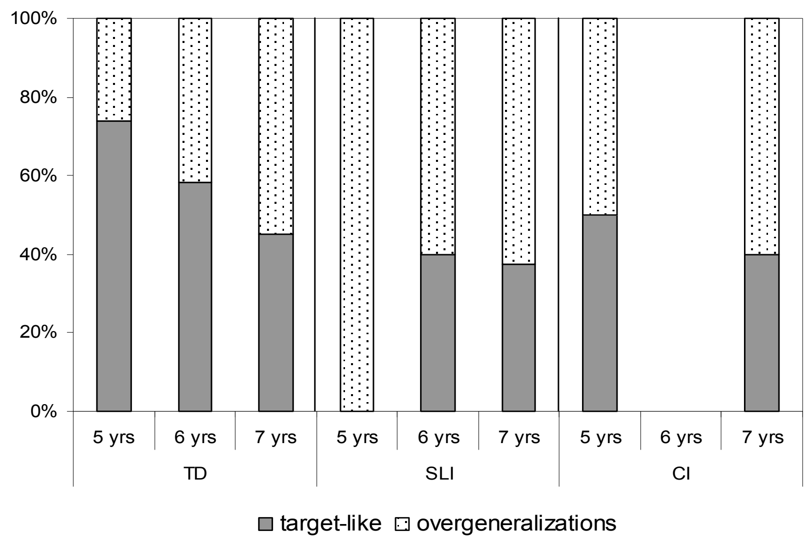
For the TD, SLI and CI children it is observed that the percentage of overgeneralizations increases between the ages of 5 to 7 (see Figure 8). The TD children produce more overgeneralizations across the board as compared to the SLI and CI children. A significant difference in the production of overgeneralizations is found only between the 6-year-old CI and TD children

(U=15.0, p=.007). No further significant differences between the TD, SLI and CI children were found at any age.

The production of overgeneralizations indicates that the TD, SLI and CI children are able to use the regular process to mark irregular verbs for past tense. From the pie charts in Figure 8, it becomes clear that the production of non-target-like overgeneralizations and target-like irregular past tense forms co-occur. The proportion of regularized past tense forms and target-like irregular past tense forms is presented in Figure 9.

For the TD children, the proportion of overgeneralizations increases between the ages 5 and 7. Consequently, the number of target-like irregular past tense responses decreases. At the age of 7, approximately 50% of the irregular verbs received either regular past tense marking or are target-like irregular past tenses.

Figure 9. Proportion of target-like irregular past tenses and overgeneralizations from the total number of past tenses formed via suffixation or via target-like (i.e. irregular) responses.



Interestingly, the 5-year-old SLI children used only regular past tense marking for the irregular verbs. The target-like irregulars appear in subsequent years, However, at the ages of 6 and 7, the SLI children predominantly mark irregular verbs via the regular past tense process. At the ages of 5 and 7, the CI children produce approximately 50% of the irregulars either target-like or with a regular suffix. None of the 6-year-old CI children produced either target-like irregulars or overgeneralizations. This probably explains the significant difference in the percentage of overgeneralization between the 6-year-old CI and TD children, which was reported earlier.

Other non-target-like responses

Other constructions to express past tense, such as past participles and the past tense of the verb '*to go*' combined with an infinitive, are used by the CI children at the ages of 5 and 6. None of the TD and SLI children make use of these constructions to mark past tense at any age.

Target-like irregular past tense responses

The variability between children in the production of target-like irregular past tense is presented in Figure 10. This graph presents the mean percentages of target-like irregular responses and standard deviations for the TD, SLI and CI children.

The TD children show a small increase in target-like irregular past tense production between the ages 5 to 7. Their mean performance remains below chance level at all ages. Only some 6 and 7-year-old TD children produce between 60 to 70% target-like irregulars.

The first target-like irregulars are observed when the SLI children are 6 years of age. At this age they produce significantly fewer target-like irregulars when compared to their TD peers (see Table 8 for statistical results). The SLI children increase in their production of target-like irregulars from age 6 to 7. At the age of 7, their production of target-like irregulars compares to the production observed for their TD peers.

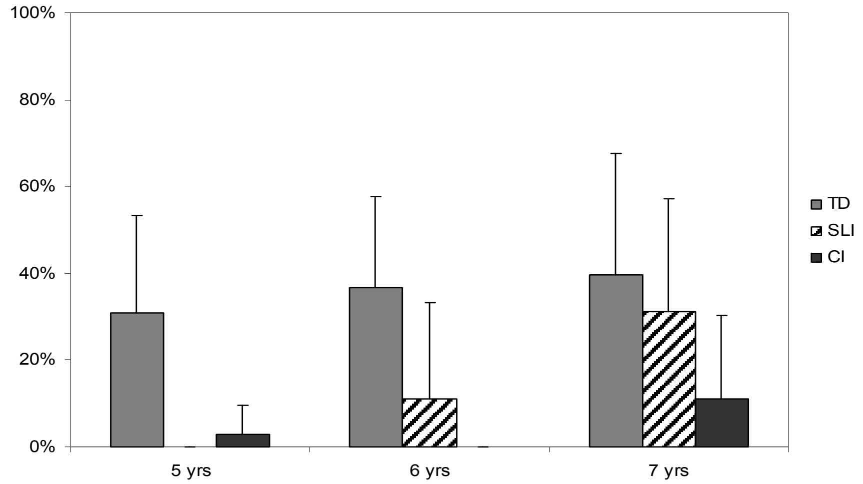
The CI children show poor performance on the production of target-like irregulars across all ages. At the age of 5, they produce significantly fewer target-like irregulars as compared to their TD peers. At 6 years, no target-like irregulars are produced at all. The 7-year-old CI children show lower percentages of target-like irregulars as compared to their TD peers. This difference is not significant, probably due to the low number of CI children in the group of 7-year-olds (N=3). Between the CI and SLI children, no significant differences were observed at any age. Although, at the age of 7, the CI children show lower percentages of target-like responses than the SLI children.

Table 8. Results of the Mann Whitney U-test, comparing the TD, SLI and CI children on irregular target-like past tense production.

	TD - SLI	*TD - CI*	*SLI – CI*
Age 5 yrs	U=16.0, p=.000**	U=18.0, p=.002*	U=20.0, p=.662
6 yrs	U=18.0, p=.003*	U=5.0, p=.000*	U=15.0, p=.364
7 yrs	U=79.5, p=.480	U=14.5, p=.101	U=6.0, p=.279

* significant at alpha .01 ** significant at alpha .001

Figure 10. Mean percentage of target-like irregular past tenses and standard deviations for the TD, SLI and CI children. Results are presented per age group.



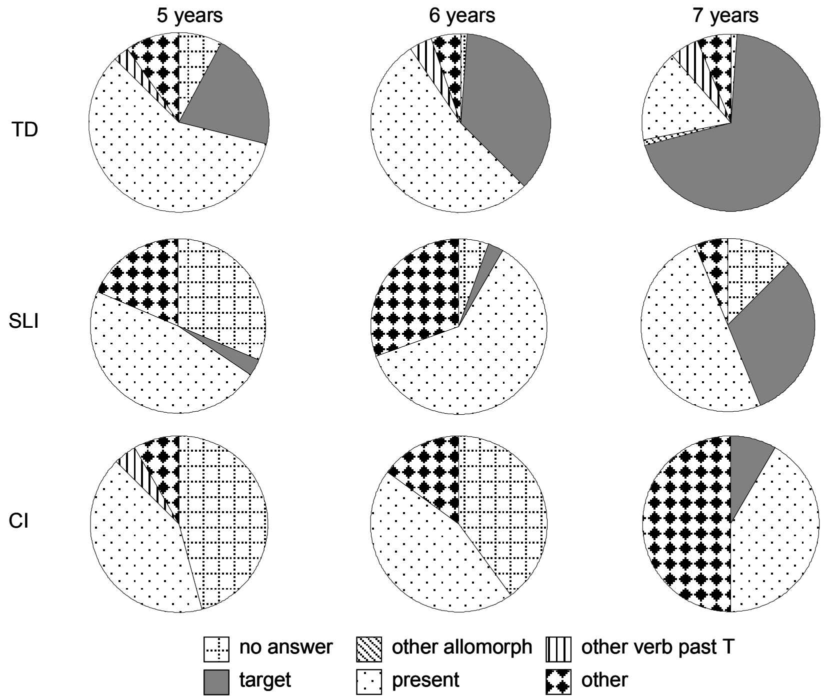
7.2.3 Past tense on nonce verbs

Figure 11 presents the percentages of target-like and non-target-like responses for the nonce verbs. Results are presented for the TD, SLI and CI children separately. The grey-shaded area indicates the category of target-like responses for the nonce verbs. All nonce verbs received regular past tense marking by the adults (see Table 6). The non-target-like responses for the nonce verbs are categorized as follows:

1. no answer or null response
2. another allomorph is attached to the stem (e.g. jopde instead of jopte),
3. present tense marking
4. a residual category (e.g. 'grammen' as a past tense of the nonce verb 'grallen')

Percentages were calculated by dividing the number of responses within a category (i.e. target-like responses and the 4 non-target-like responses) by the number of nonce verbs included in the elicitation task (i.e. 4). The first analysis compared TD, CI and SLI children on non-target-like responses.

Figure 11. Proportion of target-like responses and non-target-like responses from the total number of nonce verbs (i.e. 4). Results are presented for the TD, SLI and CI children separately and per age group.



Non-target-like responses of nonce verbs

Present tense responses

For the TD children, the number of non-target present tense forms decreases from age 6 to 7. The SLI and CI children produce approximately 50% of the nonce verbs in their non-target present tense form. The production of non-target present tense forms does not decrease over the years for the SLI and CI children. No significant differences between the TD, SLI and CI children are found at any age.

Null responses

The TD children show low percentages of null responses at all ages. The 5-year-old SLI children have more null responses as compared to their TD peers. In subsequent years, the percentage of null responses decreases for the SLI children. No significant differences between the SLI and TD children are found at any age. The CI children have more null responses as compared to their TD peers at the ages of 5 and 6. At the age of 7, no null responses are observed for the CI children. No significant differences between the TD, SLI and CI children were found at any age on the number of null responses.

Other non-target-like responses

The production of other responses is high for the 5 and 6-year-old SLI children and 6 and 7-year-old CI children as compared to their TD peers. Further analysis shows that, in the majority of cases, the nonce verbs are repeated with a different stem without past tense suffix.

Target-like past tense for nonce verbs

The variability between children in the production of target-like past tense for nonce verbs is presented in Figure 12 (see p:160). This graph presents the mean percentages of target-like past tense responses and standard deviations for the TD, SLI and CI children on nonce verbs.

The TD children show an increase in target-like past tense production on nonce verbs between the ages 5 to 7. However, the mean production of target-like past tenses for the 5 and 6-year-old TD children remains below chance level. Only some 6-year-old TD children perform above chance level. At the age of 7, mean target-like past tense production on nonce- verbs is well above chance level (at 70%), and some TD children perform at ceiling.

The SLI children increase in their production of target-like past tense on nonce verbs between the ages 6 to 7. However, their production of target-like past tenses remains significantly below their TD peers at the ages of 6 and 7 (see Table 9 for statistical results). The 7-year-old SLI children compare to the 6-year-old TD children in their production of target-like past tense of nonce verbs. This means that the mean performance of the 7-year-old SLI children is approximately at chance level, with some SLI children performing above chance level.

The CI children do not produce target-like past tenses for any of the nonce verbs at the ages of 5 and 6. At the age of 7, approximately 10% of the nonce verbs received target-like past tense marking. The CI children produce significantly fewer target-like past tenses for nonce verbs as compared to their TD peers at the ages 6 and 7. No significant differences are observed between the CI and SLI children at any age, although the 7-year-old CI children produce fewer target-like past tenses for nonce verbs as compared to the 7-year-old SLI children.

Figure 12. Mean percentage of target-like past tenses for pseudo-verbs and standard deviations for the TD, SLI and CI children. Results are presented per age group.

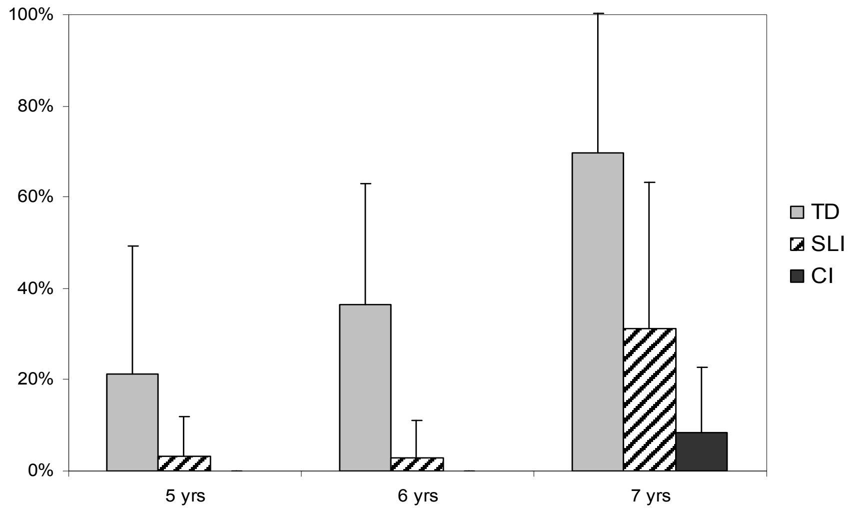


Table 9. Results of the Mann Whitney U-test, comparing the TD, SLI and CI children on target-like past tense production for pseudo-verbs.

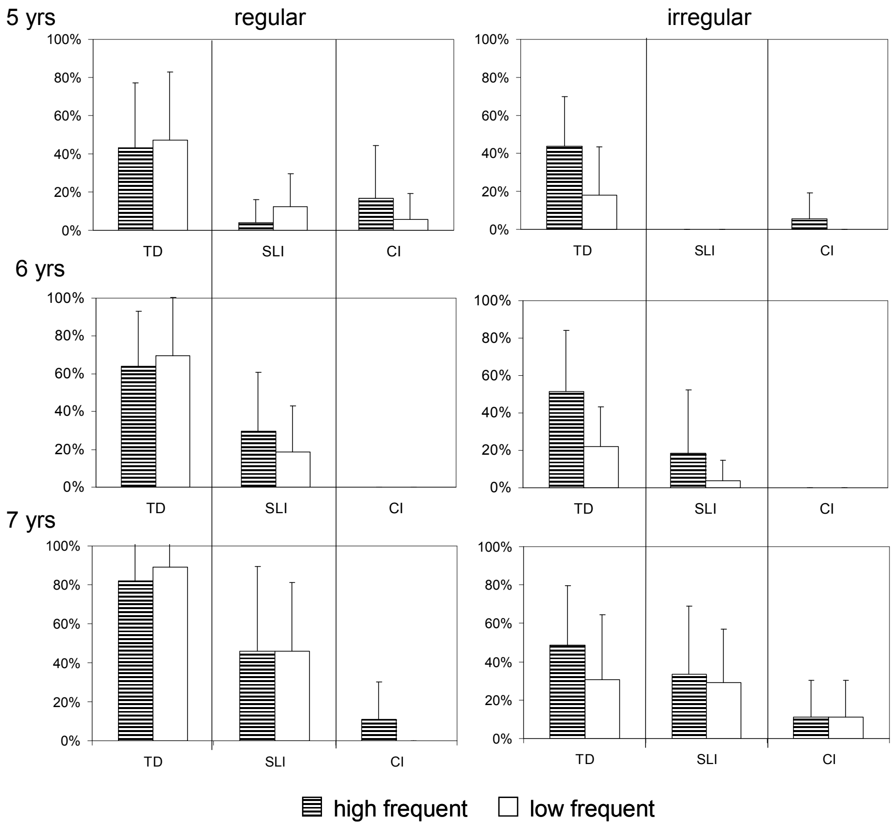
	TD - SLI	*TD - CI*	*SLI – CI*
Age 5 yrs	U=62.5, p=.092	U=39.0, p=.062	U=21.0, p=.755
6 yrs	U=32.5, p=.001*	U=15.0, p=.007*	U=20.0, p=.797
7 yrs	U=37.5, p=.009*	U=4.5, p=.008*	U=7.0, p=.376

* significant at alpha .01 ** significant at alpha .001

7.2.4 Frequency effects

The regular and irregular verbs are divided in high frequency (i.e. the past tense form occurs relatively frequently in the target adult speech) and low frequency (i.e. the past tense form occurs relatively infrequently in the target adult speech). The production of target-like past tenses for the regulars and irregulars is presented in Figure 13 for the TD, SLI and CI children separately. The percentages were calculated by dividing the number of target-like past tenses by the total number of past tenses within the category (i.e. 3 verbs). Categories are high-frequency regular and irregular and low-frequency regular and irregular. The statistical results for the comparison between high and low-frequency verbs are presented in Table 10.

Figure 13. Target-like production scores for the regular and irregular verbs divided by frequency of occurrence. Results are presented per age group for the TD, SLI and CI children separately.



For the TD children, no significant effects are observed for frequency in adult target speech in the production of target-like regular past tense at any age. In contrast, significant effects of frequency are observed in adult target speech for the irregulars. The 5 and 6-year-old TD children produce significantly more past tense productions for high-frequency irregulars as compared to low-frequency verbs. The difference between high and low frequency irregulars is lost at the age of 7.

For the SLI and CI children, no significant effects for input frequency are observed for either regular or irregular verbs.

Table 10. ANOVA and Mann Whitney U-results comparing target-like past tense production scores between high and low-frequency regular and irregular verbs. Statistical analysis was performed per age group for the TD, SLI and CI children separately.

		TD *HF - LF*	*SLI* *HF - LF*	*CI* *HF - LF*
Regular	5 yrs	F(1,51)=.071, p=.791	U=24.0, p=.442	U=14.5, p=.589
	6 yrs	F(1,47)=.407, p=.527	F(1,17)=.720, p=.409	
	7 yrs	F(1,47)=1.242, p=.271	F(1,15).000, p=1.000	U=3.0, p=0.700
Irregular	5 yrs	F(1,51)=12.821, p=.001*		U=15.0, p=.699
	6 yrs	U=143.0, p=.001*	U=31.0, p=.436	
	7 yrs	F(1,47)=3.698, p=.061	F(1,15)=.068, p=.798	U=4.5, p=1.000

* significant at alpha .01 ** significant at alpha .001

7.2.5 Correlation analysis of target-like past tense production

Development of target-like past tense production

For the TD, SLI and CI children, correlations are performed between age and target-like production of regular and irregular past tense, overgeneralizations and target-like past tense production of nonce verbs. It has been argued that the onset of overgeneralizations is followed by a rapid increase in regular past tense forms (Marcus et al., 1992). Moreover, the onset of past tense marking on nonce verbs indicates that the child has knowledge of morhphological regularizations (Berko, 1958). As such, it is expected that correlations exist between the regular past tense marking, overgeneralizations and past tense marking of nonce verbs. Pearson correlations are performed between age, measured in months, and the four past tense variables (see Table 11).

For the TD children, significant positive correlations are found between age and target-like regular past tense, overgeneralizations and target-like past tense production of nonce verbs. Firstly, this indicates that TD children produce more target-like past tenses for regular verbs and nonce verbs as they mature. Secondly, the significant increase in overgeneralizations across years prohibits a positive correlation between age and target-like irregulars, as the variables are interrelated (i.e. overgeneralization decreases the chance for a target-like irregular).

The SLI children show significant positive correlations between age and target-like regular and irregular production. This indicates that the SLI children produce more target-like regular and irregular past tenses with increasing age. The correlation between age and target-like past tense production of nonce verbs failed to reach significance. No significant correlation is found between age and overgeneralization for the SLI children.

In contrast to the TD and SLI children, the CI children do not show any positive correlation between age and target-like past tense production and overgeneralization. This means that the CI children do not produce more target-like past tenses between the ages of 5 to 7.

Table 11. Pearson correlation coefficients and p-values for age correlated with the production of target-like regulars, irregulars and nonce verbs, as well as overgeneralizations. Results are presented for the TD, SLI and CI children.

age	*target-like regular*	*target-like irregular*	*overgeneralization*	*target-like nonce verbs*
TD	.477 p=.000**	.111 p=.537	.517 p=.000**	.465 p=.000**
SLI	.525 p=.007*	.536 p=.006*	.411 p=.041	.494 p=.012
CI	-.190 p=.515	.411 p=.144	.421 p=.134	.462 p=.096

* significant at alpha .01 ** significant at alpha .001

Correlation among target-like past tense productions

Partial correlations were performed between target-like regular and irregular past tense, overgeneralizations and target-like past tense of nonce verbs. Age was included as a covariate in all correlations. This analysis investigates whether a particular target-like past tense production (e.g. regular past tense) is affected by performance on another target-like past tense production (e.g. performance on nonce verbs). The results are presented separately for the TD, SLI and CI children (see Table 12).

For the TD children, the production of target-like regular past tense is positively correlated with target-like irregular and target-like past tense on nonce verbs. This indicates that TD children who score highly on target-like regular past tense production also tend to perform highly on target-like irregulars and past tense of nonce verbs. The correlation between target-like regular past tense and overgeneralizations failed to reach significance. A significant negative correlation is found between the production of target-like irregulars and overgeneralizations. This is expected as both variables are related.

The production of target-like past tense of nonce verbs is not correlated with the production of target-like irregulars or overgeneralizations.

Table 12. Results from the partial correlation, with age inserted as covariate, between the past tense variables.

TD children	*target-like regular*	*target-like irregular*	*overgeneralization*	*target-like nonce verbs*
Regular	-	.327 p=.006*	.302 p=.011	.537 p=.000**
Irregular		-	-.351 p=.003*	.197 p=.103
Overgeneralizations			-	.246 p=.040
SLI children	*target-like regular*	*target-like irregular*	*overgeneralization*	*target-like nonce verbs*
Regular	-	.118 p=.582	.749 p=.000**	.600 p=.002*
Irregular		-	-.258 p=.224	.130 p=.545
Overgeneralizations			-	.575 p=.003*
CI children	*target-like regular*	*target-like irregular*	*overgeneralization*	*target-like nonce verbs*
Regular	-	.075 p=.808	.690 p=.009*	-.039 p=.899
Irregular		-	.091 p=.767	-.367 p=.218
Overgeneralizations			-	-.409 p=.165

* significant at alpha .01 ** significant at alpha .001

The SLI children show a significant positive correlation between target-like regular past tense production and overgeneralizations. This indicates that SLI children who produce more target-like regular past tenses tend to produce more overgeneralizations as compared to SLI children with lower production of target-like regulars. The same relation is found between target-like regular past tense and the production of target-like past tense on nonce verbs. Moreover, a significant positive correlation is found between the production of target-like past tenses on nonce verbs and overgeneralizations. The production of target-like irregulars does not correlate significantly with any of the other past tense production variables.

For the CI children a positive correlation is found between the production of target-like regular past tense and overgeneralizations. This indicates that CI children with high scores on target-like regular past tense tend to produce more overgeneralizations as compared to the CI children with lower production of regular past tense. No further correlations are found between past tense production variables.

Effect of age at implantation, hearing age and hearing loss

Additional correlations were carried out for the CI children. Pearson correlations were carried out between the past tense production variables and age at implantation, hearing age (i.e. the time (in months) the CI children had access to auditory speech input) and unaided hearing loss. This analysis investigates whether external variables influence scores on past tense production. Pearson correlation coefficients and p-values are presented in Table 13.

Table 13. Results of the correlation analysis between target-like past tense productions of regulars, irregulars and nonce verbs, as well as overgeneralizations and age at implantation, hearing age (chronological age – age at implantation) and unaided hearing loss.

	age at implantation	*hearing age*	*unaided hearing loss*
Regular	-.282 p=.329	.119 p=.684	.370 p=.263
Irregular	-.115 p=.695	.297 p=.302	-.411 p=.210
Overgeneralizations	-.149 p=.611	.328 p=.252	-.028 p=.934
Nonce verbs	-.354 p=.215	.506 p=.065	.384 p=.244

* significant at alpha .01 ** significant at alpha .001

No significant correlations are found between past tense production and the external variables. This is partially due to the low past tense production scores within the group of CI children.

7.3 Summary

The elicitation task in this study compared 5 to 7-year-old CI and SLI children in their past tense production, with TD children included as controls. The SLI children improve significantly in their production of regular past tense between the ages of 5 to 7. However, when compared to their TD peers, SLI children show a delay in regular past tense production of approximately 2 years.

The CI children do not show any significant improvement in regular past tense production between the ages of 5 to 7. When compared to their TD peers, significant lower production scores are found for the regular past tense at all ages. With respect to regular past tense production scores, the CI children cannot keep up with their SLI peers. Therefore, the CI children have lower production scores when compared to their SLI peers, but this does not lead to significant differences.

With respect to the production of irregular past tense, SLI children show a significant improvement in irregular past tense production across years. Also in irregular past tense marking a delay is observed for the SLI children, when their production scores are compared to their TD peers. However, this delay is less severe than in the case of regular past tense production. The SLI children catch up with their TD peers in irregular past tense production at the age of 7.

The CI children do not show a significant improvement in irregular past tense production across years. Their production of irregulars falls significantly below their TD peers at the age of 5 and 6. Nevertheless, the delay in irregular past tense production is less severe as in the case of regular past tense marking. The CI children compare to their TD peers at the age of 7 in terms of the production of irregulars. CI children compare to SLI children in their production of irregular past tense at all ages.

The CI and SLI children show lower production scores on target-like past tense of nonce verbs as compared to their TD peers. Only for the TD and SLI children is a positive correlation found between the production of regular verbs and nonce verbs. No such correlation is found for the CI children. The production of overgeneralizations is positively correlated with regular past tense production for the CI and SLI children. This shows that the CI and SLI children extend the regular suffix to irregular verbs.

The elicitation task found frequency effects only for the TD children in their production of irregular past tense. TD children produced more target-like irregulars for those irregulars that occur frequently in the input. No further frequency effects are found in the elicitation task.

8. Discussion

In section 6, the 50-utterance spontaneous speech samples of the CI and SLI children have been analyzed on past tense production. The results yielded extremely low numbers of past tense verb forms. Moreover, almost all of them were irregular verb forms. As such, no conclusions can be drawn with respect to the acquisition of past tense morphology. These findings were expected as in Dutch speakers replace the simple past tense by the present perfect. This implies that the input to Dutch children will contain more instances of the type 'Gisteren heb ik wat rondgefietst' lit. '*Yesterday I have a bit biked around*', than of the type 'Gisteren fietste ik wat rond' lit. '*Yesterday I biked around a bit*'. This is not the case for languages such as English where the simple past is also frequently used in spontaneous speech.

The difference between these two languages with respect to the use of the simple past in spontaneous speech is reflected in the acquisition process. De Houwer (1997) has shown that the spontaneous speech of a bilingual 3-year-old Dutch-English child contains simple past forms in English but present perfect forms in Dutch.

Our analyses of spontaneous speech samples were therefore complemented by an elicitation task. The rationale behind this additional study design is that it allows us to investigate the acquisition of infrequently used morphology in the input.

The aim of the elicitation task was to compare the past tense production of 5 to 7-year-old CI children with their SLI and TD peers. The task included CI , SLI and TD children; the TD children were included as controls. The CI and SLI children were compared on their production of target-like past tenses of regular, irregular and nonce verbs.

It was hypothesized that the CI and SLI children perform similarly on past tense production. This hypothesis is based on literature regarding the joint operation of auditory perception, processing and working memory in the acquisition of grammatical morphology. For instance, the delay in the acquisition of the regular past tense morpheme reported for the SLI children has been attributed to the incomplete processing of the perceptually low salient morphemes (Leonard et al. 1992, 1997, 2003). Under such a view, which stresses the role of perceptual input on language learning, the type of processing limitation observed in SLI children is no different from a perceptual deficit, as in the case of CI children (Locke, 1997). Given this, we expected that the CI and SLI children show a delay in their acquisition of the regular past tense morpheme, due to the low perceptual salience of this morpheme.

The present study shows that CI children, at all ages, produce significantly fewer regular and nonce verb past tenses as compared to the TD children. No significant difference was identified between CI and SLI children when compared to their SLI peers, in the production of regular and nonce verb past tenses. However, the regular past tense production of the SLI children significantly improves between the ages of 5 to 7. In contrast, no such improvement in regular past tense production is observed for the CI children. This indicates that the gap between CI and SLI children is increasing over the years. As will be discussed in subsection 8.1, these results are difficult to place under the perceptual salience hypothesis. Therefore, we will propose an alternative hypothesis in subsection 8.2 in which the delay in grammatical morpheme acquisition is related to possible speech perception deficits in 'incidental' learning contexts.

In addition to the analysis on the effects of perceptual salience in grammatical morpheme acquisition, the present analysis sought to determine the effect of past tense usage in adult speech on the acquisition of past tense by CI children. According to the dual-route-model of past tense acquisition such an effect is expected to be found for irregular verbs, but not for the regular ones. The rationale behind this is that, according to the dual-route model, regulars are generated by a standard symbol-concatenation rule, whereas irregulars need to be stored in an associative memory. In contrast, the single-route-model suggests that regulars and irregulars need to be stored in an associative memory, hence effects of adult target speech are expected to be present in both regular and irregular verbs.

8.1 The effect of perceptual salience on past tense marking

It has been shown that SLI children are severely delayed in their acquisition of the regular past tense morpheme (Oetting & Horohov, 1997; Rice et al., 1998; Marchman et al., 1999; Hansson et al., 2000; Conti-Ramsden, 2003). The results of the elicitation task given in section 7 are in accordance with these findings. SLI children show a significant lower production of regular past tense as compared to their TD peers. This delay is approximately 2 years. Instead of producing the target-like past tense form, SLI children were more likely to use the non-target present tense form of the verb. The production of the non-target present tense in obligatory contexts for past tense has also been reported for the 6-year-old SLI children in the study of Marchman, Wulfeck & Ellis Weismer (1999).

The morphological difficulties of the SLI children have been attributed to the limited processing of perceptually low salient morphemes, i.e. the Surface Account (Leonard et al., 1997, 2003, 2007; Benasich & Tallal, 2002). In order to test the influence of perceptual salience on the acquisition of past tense morphology, one first needs to define the notion of perceptual salience. According to Goldschneider & Dekeyser (2001), perceptual salience is composed of three factors, namely phonetic substance, syllabicity and relative sonority. Phonetic substance refers to the number of phones in a morpheme. The assumption is that the more phones in a morpheme, the more perceptually salient the morpheme is. Syllabicity refers to the presence/absence of a vowel in the surface form of the morpheme. The presence of a vowel renders the morpheme perceptually more salient as compared to morphemes without a vowel. Regarding relative sonority, the assumption is that the more sonorous the phones in the morpheme, the more perceptually salient the morpheme is. Past tense morphemes have low scores on all three factors. As such, these morphemes are difficult to perceive and to process, and they can therefore easily be missed in incoming speech.

The results of this study challenge the role of perceptual salience in the acquisition of past tense morphology as all CI children in the present study were able to discriminate regular verbs inflected for past tense morphemes (e.g. werkte '*worked*') from present tense verb forms (e.g. werkt '*works*') tested in an oddity paradigm with the present tense form as background stimulus and the past tense verb form as the odd form to be discriminated. Clearly, the minimal pair (werkt - werkte) needs to be discriminated on a low salient phoneme (*schwa).* This suggests that CI children are able to perceive stimuli that differ on perceptually low salient features. Previous research has shown that for CI children a close link exists between the perception and production of speech, which implies that improved perception skills contribute to better production skills (Blamey et al., 2001; Duchesne et al., 2009). Interestingly, the perception of the regular past tense morpheme by CI children is not reflected in their production of this morpheme on the elicitation task. In general, CI children show poorer performance on regular past tense production when compared to their SLI peers.

The low regular past tense production of the CI children in this study could not be attributed to other characteristics particular to the CI group, such as later access to auditory input or shorter durations of speech input. In the present study, neither age at implantation nor hearing age (i.e. the duration in months that a CI child has access to speech input) correlated significantly with the production of regulars. This is in accordance with the results from previous studies in which age at implantation did not predict scores on grammar (Willstedt-Svensson et al.; 2004; Duchesne et al.; 2009).

The overall low performance on regular past tense production of CI children cannot be attributed to the low perceptual salience of the morphemes per se. As these children by definition have a perceptive deficit, it seems reasonable to hypothesize that it is rather the qualitatively degraded speech input offered by the implant that makes auditory speech material difficult to perceive. As processing, and consequently acquisition, are dependent on perception, the qualitatively degraded speech input has an important impact on the development of grammar, in particular on those morphemes that are perceptually low salient. In the following paragraph we intend to outline why we consider the speech input to CI children to be qualitatively degraded and how this interferes with the acquisition of grammatical morphology.

8.2 Morpheme-in-Noise Perception Deficit Hypothesis (MIND)

It is common practice to assess the perception abilities of CI children in quiet environments, which is the optimal listening situation. This is precisely how the speech discrimination task in this study was administered. Based on these results, we assumed that the poor outcomes on past tense morpheme production in CI children could not be related to a mere perceptual deficit. In everyday life, CI users are hardly ever confronted with speech in such ideal listening situations. Young CI children will encounter noisy backgrounds in all aspects of their lives, including classrooms, where there is a constant level of noise ranging from 34 to 73 dB (Knecht, Nelson, Whitelaw & Feth, 2002). This implies that the perception abilities demonstrated in clinical practice are not always representative of perception abilities in everyday life. To date, no research has been conducted on how noisy backgrounds affect the perception of grammatical morphemes, although, there is a considerable body of research indicating that particularly noisy backgrounds make the perceiving of speech difficult for CI users (Eisenberg, Kirk, Martinez, Ying & Miyamoto., 2004; Lorenzi et al., 2006).

When listening in noisy backgrounds, normal-hearing people perform better in fluctuating than in steady-state noise. Normal-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 this due to the information derived from fluctuations in the temporal fine structure (TFS) of speech sounds (Lorenzi et al., 2006).

Cochlear damage degrades the ability to code TFS (Lorenzi et al., 2006). This implies that the 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. CI users are, therefore, limited in perceiving speech when background sounds are present.

Given this, it can be hypothesized that the CI children do not adequately perceive grammatical morphemes in everyday speech, as this speech is embedded in a noisy background.

It has been shown that TD children are able to learn language when the linguistic input is in the background and the child is not directed to listen to the speech stream (Saffran, Aslin & Newport, 1997). As perception precedes auditory and cognitive processing, it seems reasonable to hypothesize that CI children will have a *Morpheme in Noise Perception Deficit* (MIND), i.e. a suboptimal perception of low salient grammatical morphemes that delays the acquisition of these morphemes.

If residual low-frequency hearing is present in profoundly deaf people, this can be acoustically stimulated. The benefit of acoustic stimulation is to provide low-frequency TFS that is not conveyed by a CI (Lorenzi et al., 2006). The TFS increases the spectral resolution, which is particularly helpful in perceiving speech in noise (Turner, Gantz, Vidal, Behrens & Henry, 2004; Gantz, Turner, Gfeller, Lowder, 2005). Research to date has indicated that acoustic stimulations of the residual low-frequency hearing of CI users improves speech recognition in noise. Better speech-in-noise recognition has been shown for CI users who received electrical/acoustical stimulation (EAS) (Gantz et al., 2005) as well as for CI users who wear a Hearing Aid (HA) in the opposite ear (Dunn, Tyler & Witt, 2005; Ching et al., 2005; Coene. Daemers, Govaerts & Rooryck, to appear). Direct comparisons between CI and HA children have shown that the difference in speech recognition scores in a quiet and noisy environment is greater for CI children as compared to their HA peers, who have a moderate-to-severe hearing impairment (Eisenberg et al., 2004). This implies that the HA children had less difficulty perceiving speech-in-noise than the CI children.

It is therefore likely that HA children show better skills in perceiving morphemes-in-noise. This is confirmed indirectly, as it has been shown with respect to the acquisition of the regular past tense, that HA children tend to produce more target-like past tenses than their SLI peers, as measured on an elicitation task (Norbury et al., 2001; Hansson et al., 2007). This finding is interesting as it differs from our findings from comparisons of SLI children with CI children, who also have a perceptual deficit. The *Morpheme-in-Noise Perception Deficit* hypothesis therefore suggests avenues for future research.

To test this hypothesis, a perception task should be developed in which different types of perceptually low salient morphemes are to be discriminated. For Dutch, morphemes of interest would include e.g. regular past tense /*-te*/ /*-de*/, possessive *-s* (e.g. Jans boek – *John's book*), plural *-s* (e.g. tafel *table* – tafels *tables*) and 3th person singular agreement morpheme *-t* (e.g. werkt *works*). An inter-group comparison between CI and HA children could then reveal whether the perception of these grammatical morphemes in noisy and quiet conditions is different for both populations of hearing-impaired children. Obviously, the development of such a new discrimination task is beyond the scope of this dissertation but it is an interesting topic for future research.

8.3 Frequency effects

For the TD children in the present study, frequency effects are found for the irregular verbs, but not for the regular verbs. At the ages of 5 and 6, TD children produced significantly more target-like irregulars that occurred frequently in the adult target speech as compared to irregulars that occur less frequently in the adult target speech. No such effect is found for the production of regulars. This seems to correspond with the prediction made by the dual-route-model. This model predicts that regular past tense forms are generated by the symbol concatenation rule, whereas the irregular past tense forms need to be stored in memory. Hearing the irregular past more often strengthens the memory trace and is therefore dependent on frequency of occurrence in the target speech. As the aim of this study is to explore how frequency of past tense forms in the adult target speech affects the production of past tense in CI and SLI children, we are less interested in distinguishing between the dual and single-route model.

The results of the present study indicate that frequency affects the production of past tense in CI and SLI children to an equal extent. In spontaneous speech, CI and SLI children produce more irregular past tenses as compared to regular past tenses. This corresponds with the adult target speech, as in this study it is found that token frequencies of irregular verb types are higher than token frequencies of regular verb types. These results are in accordance with the early past tense productions of young TD children, who produce more irregulars than regulars (Brown, 1973; Rumelhart & McClelland, 1986). Moreover, the frequencies of the past tense verb types in the speech of CI and SLI children correlated significantly with the frequencies of the past tense verb types in adult speech. This suggests that the frequency distribution of the production of past tense verb types is similar between CI and SLI children and the adults.

In the elicitation task, no significant effects are found for frequency on the production of target-like regulars and irregulars for either CI or SLI children. For the SLI children, this finding contrasts with other studies that have reported effects of input frequency for regular and irregular past tense (Ragnarsdottir et al., 1999; Norbury et al., 2001; Van der Lely & Ullman, 2001). It is likely that any frequency effects in the present study have gone unnoticed, because the number of occurrences of the high frequency verbs is actually not high enough. This implies that the difference between high and low frequency verbs is too small to detect an effect of input frequency. A point to remember is that the irregulars that occurred most often in the spontaneous speech of CI and SLI children occurred in the input between 2720 and 21549 times, whereas the high frequency irregulars included in the elicitation task occurred between 160 and 3676 times in the input.

8.4 L2 past tense acquisition

With respect to the effect of frequency in adult target speech on the target-like production of past tense, bilingual children (henceforth L2) have been studied as well. The general assumption is that L2- children perceive less of their L2 as compared to the monolinguals, hence learn their L2 with reduced adult target speech input (Pearson, Fernández, Lewedeg & Oller, 1997). This assumption particularly holds for children who acquire their L2 after the establishment of their L1 (sequential bilinguals). However, even for L2 children, who acquire both languages simultaneous, effects of exposure to the adult target speech input have been reported. Nicoladis, Palmer & Marentette (2007) have shown that their simultaneous L2 children are less accurate in their production of past tense morphology when compared to monolingual children. The authors attribute the lower performance of the simultaneous L2 children to the less frequent L2 exposure of these children.

Leonard et al. (1997) have argued that the '*incomplete processing [of perceptually low salient morphemes] is the functional equivalent of reduced input frequency*' (p:744). Accordingly, SLI children need a greater number of exposures to a particular morpheme in order to adequately process and acquire that morpheme. As L2 children learn their language with a reduced exposure to their L2, it is expected that the L2 and SLI children have similarities in their past tense production.
Regarding this hypothesis, the results presented in the literature are not unequivocal. Paradis & Crago (2000) compared sequential L2 children with SLI children on their correct choice of tense in obligatory contexts, measured on spontaneous speech. The L2 children were exposed to their L2 from nursery school onwards. Results showed that L2 children were significantly less accurate in their choice of past tense as compared to SLI children. L2 children tended to produce present tense forms where the context required a past tense, although, when past tense measures were derived from elicitation tasks, no significant differences between sequential L2 and SLI children occurred in the production of past tense forms (Håkansson, 2001). The sequential L2-children in the study of Håkansson were mainly refugee children, with approximately four months of L1 exposure.

As such, a group of 10 12-year-old sequential L2 children were given the elicitation task used in this study (see Poche, 2009). The L1 of these children is French and their L2 is Dutch. All L2 children attended so-called 'immersion schools' in Brussels. At these schools, some courses are taught by native Dutch speaking teachers and some are taught in their L1. The exposure to the L2 is therefore quite limited.

The percentage of target-like responses of the L2 children is presented in Figure 14 (see p:175), together with the results of the 5 to 7-year-old TD, SLI and CI children. The L2 children produce fewer target-like regulars and irregulars as compared to their 5-year-old TD peers. However, only for the irregulars does this difference reach significance (U=32.0, p=.000). On nonce verbs, L2 children compare to the 5-year-old TD children.

With respect to the SLI children, statistical testing did not reveal any significant differences between the 12-year-old L2 children and the 5-year-old SLI children. However, from Figure 14, it is observed that the production of target-like regular and nonce verb past tenses by L2 children falls between the mean production scores of the 6 and 7-year-old SLI children. For the irregulars, the mean production of the L2 children is lower when compared to the 6-year-old SLI children. This indicates that the L2 children produce more target-like past tenses as compared to the 5-year-old SLI children.

Statistical testing did not reveal any significant differences between the L2 children and the 5-year-old CI children on the production of regular, irregular and nonce verb past tenses. However, the mean target-like responses for the L2 children are higher when compared to the 5 to 7-year-old CI children for the regular and nonce verbs (see Figure 14). This implies that in past tense formation involving regularization, L2 children outperform CI children.

The results of this study indicate that the 12-year-old L2 children compare to the SLI children who are 5 to 6 years younger in their regular and irregular past tense production. This finding suggests that reduced input frequency can have stronger effects on past tense acquisition compared to incomplete processing of perceptually low salient morphemes. The indication is, therefore, that incomplete processing cannot be regarded as the functional equivalent of reduced input, as argued by Leonard et al. (1997). Moreover, the better performance of the L2 children on past tenses requiring regularization as compared to the CI children underlines the importance of sufficient perception of low salient material. This supports our hypothesis that CI children are delayed in their grammatical morpheme acquisition due to their reduced perception of these morphemes.

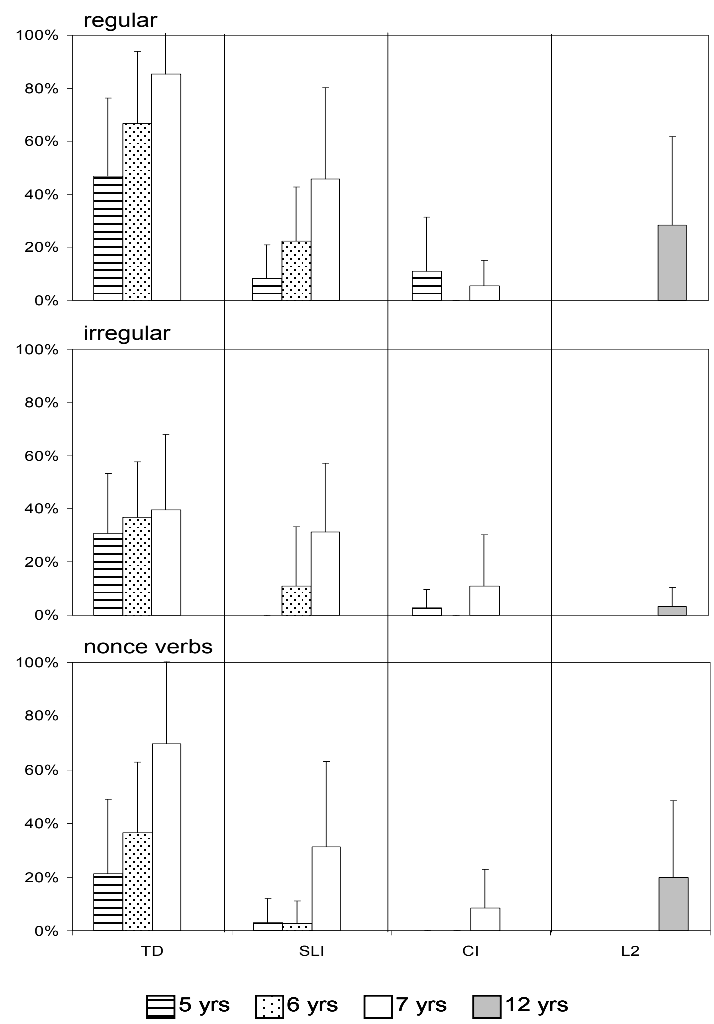
8.5 Morphological generalizations

Nonce verbs were included in the elicitation task in order to discover to what extent CI and SLI children are able to generalize past tense regularities to new verbs. This study has shown that the CI and SLI children had more difficulty than their TD peers in inflecting the nonce verbs for past tense, thus indicating that the CI and SLI children are delayed in their ability to use the regular process for marking past tense. This substantiates the delay observed in regular past tense marking.

The CI and SLI children in this study are more likely to apply the regular past tense suffix to known verbs. Despite the low past tense production of nonce verbs, the CI and SLI children did produce overgeneralization errors. Obviously, these past tense forms could not be rote-learned. In the traditional view it has been claimed that overgeneralizations are an indicator of the development of the regular past tense rule (Marcus et al., 1992; Pinker, 1998). For both groups, children with higher regular past tense production scores had higher overgeneralization scores. As such, these children may be taken to have developed a regular past tense rule.

In contrast to this traditional view, new forms are extrapolated from the lexicon either by similarity-based general analogical processes or by artificial neural networks in which rules and representations are merged (Ernestus & Baayen, 2004). In that case, overgeneralizations produced by the children can also be explained as resulting from analogy effects between existing lexical representations and the newly presented nonce verbs.

Figure 14. Target-like production scores for the regular, irregular and nonce verbs. Results are plotted for the TD, SLI and CI children aged between 5 and 7 and for the L2 children, aged 12.



8.6 Study limitations

The present study is limited in terms of the number of participants included in the group of CI children. It is therefore difficult to generalize the present findings across the population of CI children. To our knowledge, no past tense elicitation task has previously been conducted in this population. Future research should therefore continue to examine the past tense development of CI children.

With respect to the production of past tenses in the elicitation task, it has to be commented that the results of our TD and SLI children are generally lower when compared to the results of the English TD and SLI children in the studies of Rice et al. (1998, 2000). The difference in past tense production could be due to task demands. The elicitation task in the study of Rice et al. used picture pairs, in which the first picture showed a child engaged in an activity and in the second picture the child had completed the activity. It is possible that the task used by Rice et al. provides a greater encouragement to use a past tense form, as children prefer to use past tense for closed events (Wagner, 2001; Shirai & Anderson, 1995; Weist et al., 2004, see also chapter 3 subsection 3.2). Another possibility is that the simple past occurs more often in the input of English children as compared to the speech input of Dutch children (see De Houwer, 1997). For French, it has been shown that the input of the English simple past corresponds to the input of the passé composé, in which an auxiliary verb is combined with a past participle (Nicoladis et al., 2007). The same could hold for Dutch, therewith decreasing input frequency and consequently delaying the past tense acquisition of Dutch children as compared to their peers acquiring English.

9. Conclusion

The first aim of this chapter was to compare 5 to 7-year-old CI children with their SLI and TD peers on past tense production. The results of the past tense elicitation task show that CI children, aged between 5 and 7 years, are delayed in their acquisition of the regular and irregular past tense. With respect to the production of the regular past tense, the gap between CI and their SLI peers tends to widen over the years, with SLI children producing more target-like regular past tenses. This indicates that the effect of the qualitatively degraded speech input offered by the implant has stronger implications for the acquisition of grammatical morphology than the perceptual salience of these morphemes per se. We argued that the qualitatively degraded speech input of the CI children interferes with the perception of speech in noisy backgrounds. The present study therefore hypothesizes that the low production of the regular past tense morpheme is due to the *Morpheme-in-Noise Perception Deficit* of the CI children. Future research should be directed towards the perception of morphemes in noise.

The second aim of this chapter was to relate the past tense production to the frequency with which past tense forms occur in the adult target speech. The CI children produce more irregular than regular verb forms in their spontaneous speech, which corresponds with adult target speech. However, the results of the elicitation task did not show an effect of frequency for the CI and

SLI children; high-frequency verbs are not inflected more often as compared to low-frequency verbs. Further investigation included sequential L2 children, as these children acquire their L2 with reduced input frequency. It is concluded that acquiring a language with reduced input has stronger negative effects on the acquisition of grammatical morphology than the perceptual low saliency of these morphemes. This points to the pivotal role of input in the acquisition of grammatical morphology. In addition, when regularization is involved, L2 children perform better than CI children. This underlines the importance of sufficient perception of grammatical morphemes in the speech input in order for these morphemes to be acquired.

CHAPTER 7

General conclusion

1. Introduction

The present study analyzed the development of verbal morphology of 4 to 7-year-old severely to profoundly deaf children with Cochlear Implants (henceforth CI). Our aim was to enhance our knowledge of whether a CI provides sufficient access to auditory speech input to acquire grammatical morphemes. The motivation for this study was derived from previous research, which indicates that the acquisition of grammatical morphemes is an area of weakness for CI children (Young & Killen, 2002; Hawker et al., 2009; Geers et al., 2009; Duchesne et al., 2009). However, the majority of these investigations have used formal language tests, which are limited in the description of the grammatical behavior of CI children. In such formal language tests, morphosyntax is assessed using sentence completion tasks or sentence repetition tasks. This type of language assessment does not provide information about the morphosyntax a child actually uses in spontaneous speech. Therefore, in this dissertation, the analysis of the verbal morphological development has been mainly based on spontaneous speech samples.

The data of the CI children have been compared with the data of mild-to-moderately hearing-impaired children wearing conventional Hearing Aids (henceforth HA) and with children who were previously diagnosed as having Specific Language Impairments (henceforth SLI). The rationale for these comparisons is based on the language developmental theory of Locke (1997). According to this theory, language delays are caused by a higher-order cognitive deprivation, in which the shortage of lexical items prevents the use of analytical mechanisms to acquire grammar. From this theory it follows that language deficits resulting from such a higher-order cognitive deprivation in the case of children with SLI are not different from those found in children with a sensory deficit as in the case of a hearing impairment (Locke, 1997 p:282).

It is generally acknowledged that auditory experience within a certain window of time is essential for typical language (henceforth TD) development. Such a window of time has been defined as the so-called critical/sensitive period for language development, a particular period in life during which the brain has optimal plasticity. Early auditory experience is necessary to organize the neural connections in the brain for language systems. Therefore, in this dissertation, the language outcomes of CI children have been analyzed as a function of the age at which these severe to profoundly deaf children were given access to auditory input.

Finally, the language outcomes have also been analyzed in light of the perceptual salience of verbal morphemes. It is known that sufficient auditory experience is especially important in the development of grammatical morphemes, because of their low perceptual saliency (Goldschneider & Dekeyser, 2001). Most grammatical morphemes are unstressed syllables which are shorter in duration than adjacent lexical morphemes and often lower in fundamental frequency and amplitude. Delays in the acquisition of grammatical morphemes have been attributed to the low perceptual saliency for SLI children (Surface Account, Leonard and colleagues, 1992, 1997, 2003) and CI children (Perceptual Prominence Hypothesis, Svirsky et al., 2002). This study aimed at contributing to our knowledge of the role of perceptual salience in the acquisition of grammatical morphemes.

Based on the observations mentioned above, in this dissertation we have tried to answer the following research questions:

- How do CI children aged between 4 and 7 years compare to their *a)* TD peers, *b)* mild-to-moderate HA peers and *c)* SLI peers in their verbal morphological development?
- Is there an effect of early implantation in the development of verbal morphology?
- Is there an effect of perceptual salience of grammatical morphemes in the acquisition of these morphemes?

Measures for verbal morphological development

Two methods were used to assess the verbal morphological development: spontaneous speech sample analysis and an elicitation task.

Firstly, spontaneous speech samples were analyzed by means of a standardized language test for morphosyntactical development (chapter 5). In this analysis, we particularly investigated finite verb production and agreement errors (i.e. omissions of verbal agreement e.g. 'Ikke *(ben) naar de film geweest' lit. *'I have been to the movie'* and subject-verb agreement errors e.g. 'Die slaap*(t) in een bedje' lit. *'That one sleeps in a little bed'*). A validation check (see chapter 4) showed that these test variables were valid and could be reliably assessed. The data of the CI children were compared with those of their TD and HA peers (section 5.1, chapter 5) and SLI peers (section 5.2, chapter 5). We have included MLU (in words) as a general indicator for language production.

The second method analyzed the production of past tense using an experimental task (chapter 6). As indicated in chapter 4, the production of past tense could not be reliably assessed in spontaneous speech samples. Therefore we used an elicitation task in which children were asked to inflect regular, irregular and nonce verbs for past tense. The data of the CI children on the elicitation task were compared with their TD and SLI peers.

2. The acquisition of agreement

In the acquisition of finiteness, 2 to 3-year-old TD children move from a stage in which they use finite verbs together with non-finite verbs to a stage in which they exclusively use finite verbs, which is the adult target-like option. The duration of this stage varies according to the language to be learned. For Germanic languages, TD children have acquired finiteness by the age of 4. As soon as TD children use subject-verb agreement morphemes, they produce these morphemes with high accuracy (see chapter 3 for an overview of the literature on the acquisition of finiteness). The production of finite verbs and subject-verb agreement morphemes can therefore be said to be stable in the TD population from age 4 onwards.

Grammatical variables that are stable in the TD population can be used to identify grammatical difficulties in the group of CI children. As such, we expected that if CI children have difficulties in the acquisition of grammatical morphemes, they would produce fewer finite verbs and more subject-verb agreement errors than their TD peers. The results on both grammatical variables are summarized below.

CI children in comparison to TD children

The analyses in section 5.1 revealed that some (<50%) of the 4 and 5-year-old CI children are delayed in their acquisition of finiteness relative to their TD peers. In a restricted set of utterances, these CI children produced fewer finite verbs as compared to their TD peers. However, between the ages of 4 to 7, the number of delayed CI children decreases. This indicates that the CI children are able to reach the plateau of their TD peers in the production of finite verbs before the age of 8.

CI children produced more verbal agreement errors/omissions than their TD peers. No decrease in the number of verbal agreements errors/omissions was observed between the ages of 4 to 7. This suggests that CI children have persistent difficulties in the acquisition of verbal agreement morphemes and do not catch up with their TD peers before the age of 8.

CI children in comparison to HA children

In section 5.1, it has been shown that the increase in finite verb production over the years was less steep for the HA children relative to the CI children. This indicates that HA children have more difficulties with the acquisition of finiteness than their CI peers. However, this conclusion is tentative as no significant differences are found between the CI and HA children.

CI children compared to mild-to-moderate HA children in the production of subject-verb agreement errors. Further analysis of the verbal agreement errors/omissions revealed that the CI and HA children do not omit significantly more subject-verb agreement morphemes than inflected verbs in obligatory contexts.

CI children in comparison to SLI children

The results of section 5.2 have shown that in SLI children the production of finite verbs between the ages of 4 to 7 does not increase. This contrasts with the sharp increase of the CI children on this variable. The CI children produced significantly more finite verbs as compared to their SLI peers at the age of 6 and 7. From this age, a gap starts to exist between the CI and SLI children in the acquisition of finiteness.

The observed outcomes for finite verb production are positively correlated with MLU for both the CI and SLI children. The majority of the SLI children (~ 73%) fall significantly below their TD peers on MLU and the production of finite verbs, irrespective of age. This is only the case for a subgroup of the CI children (~ 38%) who fall significantly below their TD peers on both variables. This subgroup consisted primarily of the 4 and 5-year-old CI children, rather than the 6 and 7-year-olds.

The CI and SLI children compared to each other in the production of subject-verb agreement errors. In terms of the type of errors in the production of subject-verb agreement morphemes, CI and SLI children showed similar distributions of substitution and omission of subject-verb agreement morphemes. Omissions occurred more often than substitutions.

3. The acquisition of past tense

TD children

With respect to the acquisition of regular past tense in TD children, the results of chapter 6 indicated these children acquire the regular past tense morpheme between the ages of 5 to 7. This is supported by three findings:

- The production of target-like regular past tense morphemes increased more rapidly as compared to target-like irregular past tense.
- The production of target-like regular past tense was significantly positively correlated with the production of past tense on nonce verbs.
- The production of target-like regular past tense was almost significantly positively correlated with the production of overgeneralizations.

The acquisition of the regular past tense was not affected by the frequency of occurrence of the past tense forms of the regular verb in the adult target speech. In contrast, the irregular past tense was predicted by the frequency of occurrence of the irregular past tense form in the adult target speech.

CI children in comparison to TD children

In chapter 6 it has been shown that CI children produce significantly less target-like regular past tense inflections than their TD peers. There is little evidence that CI children acquire the regular past tense morpheme between the ages of 5 and 7. First of all, CI children did not increase more rapidly in the production of target-like regular past tenses as opposed to the target-like irregular past tenses. Secondly, no correlation was found between the production of target-like regular past tense and past tense of nonce-verbs. The CI children fell significantly behind on their TD peers in the production of past tense forms of nonce-verbs. And thirdly, CI children produced less overgeneralizations as compared to their TD peers.

At the age of 7, the CI children compared to their TD peers in the production of target-like irregular past tense. The production of these tense morphemes was not affected by the frequency of occurrence of the irregular past tense form in the adult target speech. Nor were frequency effects found for the regular verbs.

SLI children in comparison to TD children

The results in chapter 6 showed that, at all ages, SLI children produced significantly fewer target-like regular past tenses as compared to their TD peers. The SLI children showed some evidence of acquiring the regular past tense morpheme. First of all, they increased more rapidly in the production of target-like regular past tense as compared to the irregular past tense. And secondly, the correlation between the production of target-like regular past tense and overgeneralizations and past tense formation of nonce-verbs reached a level of significance. However, the SLI children remained significantly behind their TD peers in the production of past tenses of nonce-verbs. Moreover, they produced fewer overgeneralizations as compared to their TD peers.

At the age of 7, the SLI children compared to their TD peers in their production of target-like irregular past tense. The production of the irregular past tense was not affected by the frequency of occurrence of the irregular past tense form in the adult target speech. Frequency effects were also not found for the regular verbs.

CI children in comparison to SLI children

No significant group differences have been found between the CI and SLI children on the production of target-like past tenses of regular, irregular and nonce verbs. However, the SLI children demonstrated an increase in target-like past tense production on all types of verbs, whereas the CI children hardly increased in target-like past tense production.

The CI and SLI children were comparable to one another in the type of non-target-like past tense productions. The CI and SLI children produced more present tense forms or null responses to the stimuli presented in this task than did their TD peers.

4. Age at implantation and hearing age

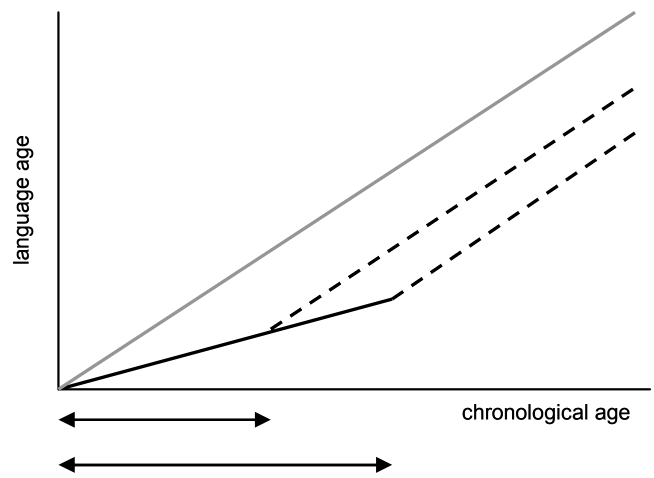
One of the core findings of the present dissertation is the clear effect of hearing age on the children's finite verb production with age at implantation as an indirect factor. The variation in outcomes on MLU and the percentage of subject-verb agreement errors is not explained by age at implantation or by hearing age. In addition, no effects of age at implantation or hearing age have been found on the production of past tenses.

Age at implantation and effects on language learning

Several accounts have been given in the literature to explain the beneficial effects of early implantation. One of these suggests that early implantation reduces the time span of auditory deprivation. The effect of length of auditory deprivation on language growth is presented in Figure 1. This Figure presents the language growth as a function of chronological age. The diagonal in the graph indicates the language growth for TD children. The two other language growth curves are hypothetical curves for two CI children implanted at different ages.

It has been shown that the development of cortical function can be altered by a period of auditory deprivation. Electrophysiological measures of the auditory cortex indicate that the CI, which gives access to auditory input, partially restores the cortical function. The extent to which restoration of the cortical function occurs depends on the time span of auditory deprivation (Ponton & Eggermont, 2001). Age-appropriate cortical responses were found for children implanted early in life (<3.5 yrs) as compared to children implanted later in life (>7 yrs) (Sharma et al., 2005). Geers (2004) reported that 80% of the children implanted within the first year of life reached age-appropriate scores as opposed to 43% implanted after the age of 2. She attributes these findings to a shorter period of auditory deprivation.

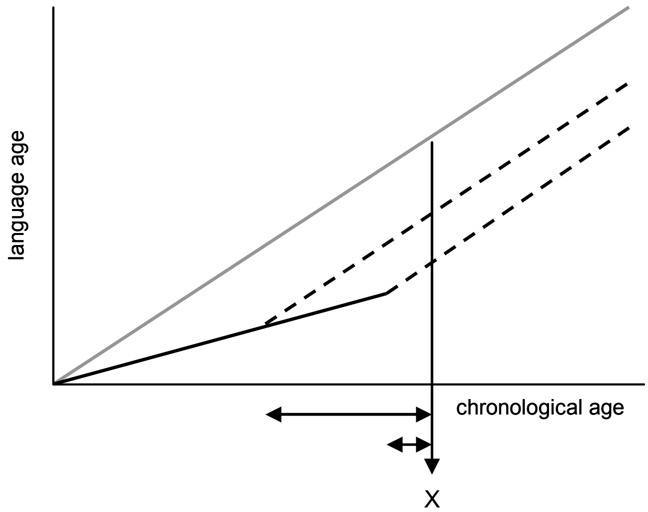
Figure 1. Language growth as a function of chronological age. The grey diagonal presents the language growth for the TD children. The two other language growth curves in this graph present two hypothetical language growth curves for CI children. The transition point from a solid line to a dashed line is the age at implantation. The arrows indicate the time period of auditory deprivation.



Another account attributes the benefits of early implantation in CI children to longer exposure to and experience with auditory speech input. The effect of length of auditory speech input on language growth is presented in Figure 2. If we assess language at point x, than the CI children differ in the length of auditory speech input. Significant correlations have been found between the production of morphology and the length of auditory experience, with better outcomes for children who received their implant early in life (Spencer et al., 1998; Tomblin et al., 1999).

However, the effects of auditory deprivation and auditory experience in the development of language are difficult to disentangle, because they are (partially) correlated. The time span of auditory experience is the chronological age minus the age at implantation. As a consequence, children who receive their implant early in life have, by definition, longer experiences with auditory speech input at moment x. Categorizing CI children according to their age at implantation does not resolve this problem.

Figure 2. Language growth as a function of chronological age. The grey diagonal presents the language growth for the TD children. The two other language growth curves in this graph present two hypothetical language growth curves for CI children. The transition point from a solid line to a dashed line is the age at implantation. The arrows indicate the time span of auditory speech input. The x present the point of testing.

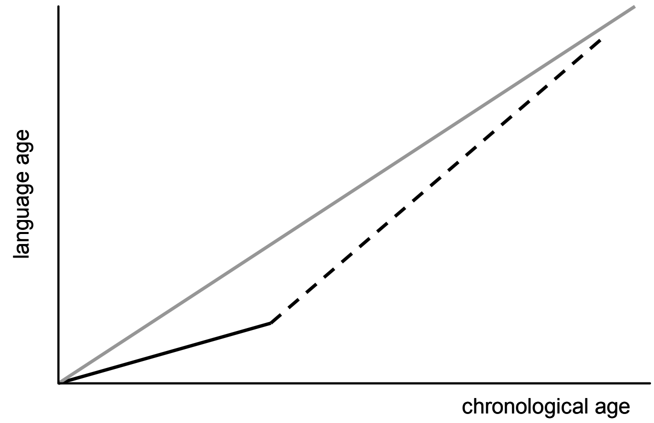


A third account that has been proposed in the literature is that children who received their implant early in life have faster than normal language learning rates (Svirsky et al., 2004, Tomblin et al., 2005, Nicholas & Geers, 2007). Such a language growth curve is presented in Figure 3.

Evidence for faster than normal language growth has been found in studies using hierarchical linear modeling, in which language growth is modeled according to different variables. The fact that the growth curves are based on predicted scores rather than actual scores is a weakness of this type of data analysis.

Stronger evidence for faster than normal language learning rates has been found in longitudinal language research. Coene et al. (to appear/a) found that CI children implanted before 15 months of age are more likely to have accelerated language development (i.e. above 1.0) as compared to children implanted after this age.

Figure 3. Language growth as a function of chronological age. The grey diagonal presents the language growth for the TD children. The other growth curve in the graph presents a hypothetical language growth curve for a CI child. The transition point from a solid line to a dashed line is the age at implantation.

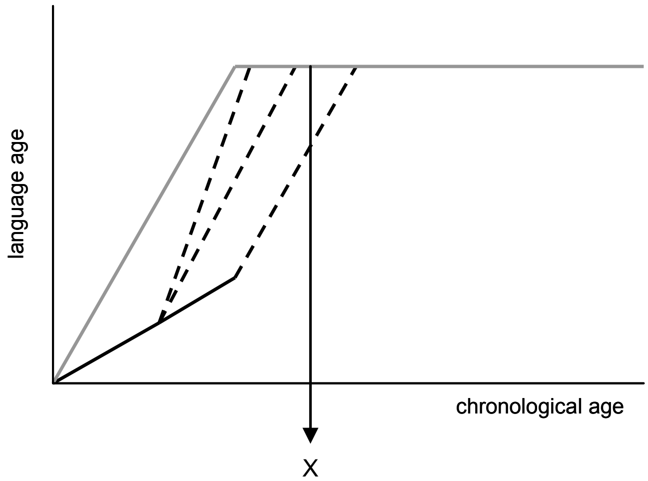


Reaching the ceiling

The result of this dissertation contributes to the general finding that hearing age, which is confounded with age at implantation, results in better language achievement. However, in the above-mentioned accounts it is assumed that language development proceeds linearly with age. However, the development of various language aspects reach ceiling performance. This ceiling performance is presented in Figure 4. The grey line indicates the language development and the plateau in language performance for the TD children. The other language growth curves are hypothetical curves for two CI children implanted at different ages. This account does not exclude faster than normal language growth rates, therefore one growth curve is branched off.

For TD children, the acquisition of finiteness has reached a plateau by the age of 4. This study indicates that aural language experience may be a crucial variable in the development of finiteness, rather than chronological age and age at implantation alone. It means that CI children are likely to catch up with their hearing peers provided they have had a similar duration of aural language experience. This finding contributes to the characteristics of the above-mentioned delayed subgroup of CI children on the acquisition of finiteness. This delayed subgroup seems to consist of younger CI children who had shorter spans of aural language experience.

Figure 4. Language growth as a function of chronological age. The grey line presents the language growth for the TD children before test moment x. The solid grey line presents the ceiling performance of CI children. The three other language growth curves in this graph present hypothetical language growth curves for CI children with different ages at implantation.



5. Perceptual salience

The results of the present study have shown that CI , HA and SLI children have difficulties in the production of subject-verb agreement morphemes and regular past tense morphemes. With respect to the errors of verbal morphemes, our findings show that CI and HA children did not omit significantly more target-like bound verb morphemes (e.g. *–s*) as compared to inflected verb forms in obligatory contexts (e.g. *works*), in which the latter is perceptually more salient than the former. In terms of acquisition, this can be seen as evidence that CI and HA children are able to acquire both types of morphology irrespective of its perceptual prominence.

For both CI and SLI children, the most common subject-verb agreement error is the omission of the low salient 3rd person singular morpheme (chapter 5, section 5.2.). Less frequently, they use a singular form in a plural context. The latter type of agreement error includes the omission of the plural verb morpheme. As the plural morpheme (*-en*) in Dutch contains a vowel, it may be taken to be perceptually more salient than the 3rd person singular morpheme (*-t*). The results show that both CI and SLI children are more likely to omit the 3rd person singular morpheme as compared to the plural verb morpheme. This is in accordance with the Surface Account.

However, two findings of this dissertation seem to challenge the role of perceptual salience in the acquisition of verb morphemes for CI children: The first finding concerns an analysis of the omission of the circumfix of past participles. The circumfix of the past participles in Dutch includes a relatively salient prefix (*ge-*) and relatively low salient suffix (*-t*) (e.g. gewerkt). The results of this analysis indicated that SLI children omitted the suffix more often as compared to the prefix. However, the CI children omitted the prefix more often than the suffix. The latter finding does not correspond with the prediction of the Surface Account.

The second finding concerns the discrimination of regular past tense in an oddity paradigm with the present tense as the background sound and the regular past tense as the 'odd' sound to be discriminated (e.g. werk '*work*' – werkte '*worked*'). Crucially, this was one of the instances that occurred in a quiet, clinical environment. As can be observed, present and past tense forms are a minimal pair that differ only with respect to the absence or conversely the. presence of a low salient phoneme (voiceless plosive + *schwa*). The fact that CI children are able to discriminate between the present and past tense form of regular verbs is not reflected in their production of the past tense form.

Morpheme-in-Noise Perception Deficit Hypothesis (MIND)

We conclude that the observed difficulties in the acquisition of verbal grammatical morphemes cannot be attributed to the low perceptual salience of these morphemes per se. Therefore, we have proposed an alternative hypothesis (chapter 6, subsection 8.2), which places the deficit in a suboptimal perception of low salient grammatical morphemes.

For people with hearing impairments, suboptimal perception of grammatical morphemes occurs in noisy environments due to the loss of temporal fine structure (TFS) in the cochlea. In normal-hearing people, fluctuations in the TFS enable them to decide whether a speech signal is part of the target speech or noise. CIs are not able to restore the information obtained from TFS, therefore, CI users are limited in perceiving speech in noise (see chapter 2, subsection 2.2).

In everyday life, CI children encounter noisy environments. This leads us to hypothesize that CI children do not adequately perceive grammatical morphemes in everyday speech. As processing, and consequently acquisition, are dependent on perception, the qualitatively reduced auditory speech input has an important impact on the development of grammar, in particular on those morphemes that are perceptually low salient.

Reduced auditory speech input versus reduced input

Leonard and colleagues (1997) have argued that the incomplete processing of perceptually low salient morphemes has the same consequences on language development as reduced input frequency. Following this line of reasoning, sequential bilingual (L2) children, i.e. children who learn their L2 with reduced adult target speech input (Pearson et al., 1997), should compare to SLI and CI children in their development of grammatical morphology. To test this, we have included the results of a group of 12-year-old L2 children on the elicitation task (i.e. past tense morphology) in chapter 6, subsection 8.4.

The 12-year-old L2 children compared to the 5 and 6-year old SLI children in their production of the regular past tense morpheme. The 12-year-old L2 children outperformed the CI children in their production of the regular past tense morpheme.

On the basis of these results, we conclude that reduced input can have stronger effects on the acquisition of grammatical morphemes as compared to the incomplete processing of perceptually low salient morphemes. The effect of reduced auditory speech input has stronger effects on the acquisition of grammatical morphemes than reduced overall input. The results of the L2 children therefore underline the importance of qualitatively sufficient auditory input in the acquisition of grammatical morphemes.

6. Future research

The MIND hypothesis

The MIND hypothesis is an interesting hypothesis for future research. In chapter 6, we advocated that a perception task should be developed in which different types of perceptually low salient morphemes are discriminated when offered in quiet and noisy conditions. For Dutch, appropriate morphemes would include e.g. regular past tense /*-te*/and /*-de*/, possessive *-s* (Jans boek – *John's book*), plural *-s* (tafel *table*– tafels *tables*) and 3rd person singular agreement morpheme *-t* (werkt *works*).

We also proposed that this type of perception task has the potential to reveal group differences between the CI and HA children (see Eisenberg et al., 2004). Speech perception in noise is improved by increasing the information obtained from TFS. Classical HAs, which only amplify sound, allow the use of TFS for those frequencies that are not affected by sensorineural hearing loss. In most cases, these frequencies with hearing preservation are in the lower frequency range. In contrast, CIs only provide those frequencies that are processed by the electrodes. If CI users have residual hearing in the lower frequencies, the device does not allow them to use the TFS information from these frequencies.

Research to date has indicated that acoustic stimulation of the residual low-frequency hearing of CI users improves speech recognition in noise. Better speech-in-noise recognition has been shown for CI users who received electrical/acoustical stimulation (EAS) (Gantz et al., 2005) as well as for CI users who wear a Hearing Aid (HA) in the opposite ear (Dunn et al., 2005, Ching et al., 2005, Coene et al., to appear/b). According to this view, it is expected that EAS will also enhance the perception, and consequently also the production of low salient morphemes in young deaf children.

Delayed language and cognitive maturation

It has been shown that language development is the most important factor in the development of Theory of Mind (ToM) in children who are deaf (Shick, De Villiers, De Viliers & Hoffmeister, 2007; Remmel & Peters, 2008; Peters, Remmel & Richards, 2009). ToM refers to the ability to attribute mental states, such as beliefs, wishes and intentions, to both oneself and others. The ToM development opens the way for children to social understanding and to develop their social cognitive abilities. The impact of ToM development is also evident in their academic achievements (Binnie, 2005). Building on these insights, future research should be directed towards the effects of delayed language development on the development of social cognitive abilities and academic skills.

7. Clinical implications

Finally, we will focus on a number of possible clinical implications resulting from our analyses.

Based on commonly used language tests, the oral grammar of early implanted CI children is generally taken to compare to that of TD hearing peers. An in-depth analysis of the language samples of a population of early implanted children, however, revealed a number of persistent problems in the acquisition of grammatical morphemes. These difficulties remain unnoticed when using global language tests only. Therefore, the language assessment of CI children should include a more detailed analysis based on a number of variables targeting morpho-syntactic development;

The acquisition of grammatical morphemes is dependent on sufficient auditory perception of these morphemes. Auditory speech perception is decreased when CI children are placed in noisy environments. It has been shown that children encounter noise levels ranging from 34 to 73dB in their classrooms (Knecht et al., 2002). Teachers and speech-language therapist should be aware of the negative effects of noise in the acquisition of language. This also underlines the importance of FM systems in classrooms. An FM system provides direct access to the teacher's voice by means of a transmitter worn by the teacher and a receiver plugged into the processor of the child's CI. This reduces the negative effects of noise on the perception of speech.

It has been shown for TD and SLI children that their perception of morphemes decreases when these morphemes are presented at a faster rate (Ellis Weismer et al., 1996; Hayiou-Thomas et al., 2004). This implies that slower speech rates are beneficial in the development of morphemes for TD, CI and SLI children.

APPENDICES

Appendix to CHAPTER 4

Initials, gender and age at testing for the TD and SLI children participating in the reliability/validity study of the STAP test.

	initials	*gender*	*age*	
6 yrs				
TD children	CHA	V	6;01.13	
	ELL	V	6;02.26	
	MAG	V	5;11.27	
	NIN	V	6;03.26	
	NON	V	6;02.26	
	NOT	M	6;09.26	
	SEP	M	6;00.07	
	TIN	V	6;02.04	
	ELL	V	6;09.24	
	IAN	V	6;09.15	
	JAN	M	6;09.29	
	JAS	M	6;10.05	
	ANN	V	6;04.20	
	LOW	M	6;03.21	
				Corpus
CI children	BER	M	6;00.10	B&K
	PIM	M	6;00.13	B&K
	HES	M	6;00.24	B&K
	JEL	M	6;01.13	B&K
	JOE	M	6;01.26	B&K
	RAM	M	6;02.10	B&K
	JOO	M	6;07.22	B&K
	CAT	V	6;10.04	Leiden
	SAN	M	6;05.01	Leiden
	RUB	M	6;08.27	Leiden
	SYB	M	6;06.10	Leiden
	ELK	V	6;03.14	Leiden
	KOE	M	6;05.19	Leiden
	JOR	M	6;11.17	Leiden
	RUB	M	6;05.06	Leiden

Appendix to CHAPTER 5

Table 1. Summary of the unaided and aided hearing thresholds averaged over 500, 1000 and 2000Hz as measured for the best ear for the CI and HA children.

	age	*CI-children*			*HA-children*		
		M	SD	range	M	SD	range
unaided	4 years	109	13	82-120	78	9	70-95
threshold	5 years	108	12	85-120	62	14	42-82
dB(HL)	6 years	114	9	92-120	61	18	42-81
	7 years	113	10	87-120	64	19	40-93
aided	4 years	34	9	20-55	31	3	27-37
threshold	5 years	33	5	25-42	31	4	27-37
dB(HL)	6 years	31	6	25-42	24	11	12-33
	7 years	34	9	20-42	27	3	22-28

Table 2. Means, standard deviations and ranges for obligatory contexts for finite verbs and omission of finite verbs in these contexts, and for total number of finite verbs production and the number of verb morpheme errors.

	Finite verb production in obligatory contexts		*bound verb morpheme production*	
CI children	Obligatory Contexts	Finite verb omission	Total number of finite verbs	Verb morpheme errors
4yrs M(SD)	41.8 (*7.49*)	2.67 (*3.24*)	41.3 (*12.76*)	2.53 (*3.44*)
Range	28 – 50	0 – 10	17 – 56	0 – 14
5yrs M(SD)	45.6 (*4.24*)	2.36 (*2.24*)	45.3 (*7.62*)	1.86 (*1.29*)
range	38 – 50	0 – 9	32 – 59	0 – 4
6yrs M(SD)	48.7 (*1.25*)	1.30 (*1.49*)	50.8 (*5.37*)	3.30 (*3.47*)
range	47 – 50	0 – 5	43 – 59	1 – 12
7yrs M(SD)	47.9 (*3.72*)	1.11 (*1.27*)	53.6 (*7.14*)	2.56 (*2.65*)
range	40 – 50	0 – 3	42 – 63	0 – 9
HA children				
4yrs M(SD)	43.9 (*3.07*)	3.80 (*3.62*)	40.5 (*6.50*)	3.20 (*3.05*)
range	39 – 48	0 – 11	27 – 49	0 – 10
5yrs M(SD)	42.2 (*4.82*)	1.78 (*2.17*)	43.1 (*8.98*)	3.22 (*2.86*)
range	34 – 49	0 – 7	27 – 56	0 – 8
6yrs M(SD)	42.7 (*6.35*)	0.50 (*0.55*)	44.8 (*8.57*)	2.17 (*2.64*)
range	33 – 49	0 – 1	30 – 53	0 – 7
7yrs M(SD)	45.5 (*3.21*)	1.33 (*2.34*)	47.7 (*7.55*)	2.33 (*2.58*)
range	40 – 48	0 – 6	35 – 56	0 – 6

Table 3. Initials of each subject in the CI group with their gender, age at testing, their Age At Implantation (AAI) in months, the type of device they are using, their unaided Hearing Loss (HL) and aided Hearing Loss in dBHL.

initials	*gender*	*age*	*AAI*	*device*	*unaided HL*	*aided HL*
4 yrs						
LOU	V	4;00.30	11	Nucleus Sprint	120	35
STE	M	4;02.09	15	Nucleus 24	120	38
AMB	V	4;00.09	13	Nucleus 24	120	38
ANN	V	4;00.02	7	Nucleus 24	120	30
EMM	V	4;.00.03	10	Nucleus 24	115	25
JOR	M	3;11.27	18	Nucleus 24	113	35
KLA	M	3;11.27	17	Nucleus 24	93	35
MIG	M	3;11.30	9	Nucleus 24	120	38
ROX	V	3;10.26	6	Nucleus 24	117	23
TES	V	4;00.10	19	Nucleus 24	112	55
YAR	V	4;00.14	9	Nucleus 24	103	42
FEM	V	4;00.21	17	Nucleus 24	115	20
AIS	V	4;10.24	35	Digisonic SPk	92	32
REN	M	4;08.30	18		91	27
SEP	M	4;11.25	18	Nucleus Sprint	82	32
5 yrs						
LIN	V	5;04.06	35	Nucleus Sprint	113	28
ANN	V	5;00.11	7	Nucleus 24	120	27
EMM	V	4;11.25	10	Nucleus 24	115	25
JOR	M	4;11.27	18	Nucleus 24	115	42
KLA	M	4;11.30	17	Nucleus 24	113	32
MIG	M	5;00.04	9	Nucleus 24	120	37
ROX	V	5;01.08	5	Nucleus 24	117	28
TES	V	5;00.08	19	Nucleus 24	112	42
YAR	V	5;00.07	9	Nucleus 24	103	32
JAM	M	5;10.10	28	Nucleus 24	85	40
LAU	V	5;08.14	34	Digisonic SP20	113	35
VAL	M	5;04.30	28	Nucleus 24	92	33
JON	M	5;09.28	22		-	32
VES	M	5;07.03	8	Nucleus 24	90	32
6 yrs						
AMB	V	6;00.11	13	Nucleus 24	120	35
JOR	M	6;01.19	18	Nucleus 24	115	42
EMM	V	6;00.10	10	Nucleus 24	115	25
KLA	M	6;01.09	17	Nucleus 24	113	28
AXE	M	6;00.28	43	Digisonic SPk	120	38
HANg	V	6;00.29	9		-	33
HANr	V	6;08.23	10	Nucleus 24	92	25
MIG	M	6;00.15	9	Nucleus 24	120	27
ROX	V	6;00.26	5	Nucleus 24	117	27

TES	V	6;01.02	19	Nucleus 24	112	33
7 yrs						
AMB	V	7;01.09	13	Nucleus 24	120	35
EMM	V	7;00.27	10	Nucleus 24	115	20
JOR	M	7;01.14	18	Nucleus 24	115	42
KLA	M	7;00.18	17	Nucleus 24	113	28
LIA	M	7;01.17	25	Nucleus Sprint	87	40
MIG	M	7;02.08	9	Nucleus 24	120	40
ROX	V	7;00.19	5	Nucleus 24	117	22
TES	V	7;00.07	19	Nucleus 24	112	42
BRE	M	7;09.03	23	Digisonic SP20	115	35

Table 4. Initials of each subject in the HA group with their gender, age at testing, their unaided Hearing Loss (HL) and aided Hearing Loss in dBHL.

	initials	*gender*	*age*	*unaided HL*	*aided HL*
4 yrs					
	EVI	V	4;07.27	95	37
	BRU	M	4;01.08	81	33
	CLA	V	4;01.05	70	28
	HAN	V	3;11.27	70	27
	LAN	M	3;11.20	70	28
	LOU	M	4;00.07	82	30
	ZEN	M	4;01.22	-	-
	MOR	V	4;08.25	82	30
	MAR	V	4;07.26	70	32
	SEP	M	4;11.25	-	-
5 yrs					
	CAR	V	5;11.24		
	HAN	V	5;00.27	70	27
	JES	M	5;00.11	68	28
	LOB	V	5;00.21	57	33
	LOU	M	5;02.20	82	37
	ANO	V	5;00.21	-	-
	ELI	V	5;02.21	42	-
	LOT	V	5;02.14	-	-
	VAL	M	5;00.13	55	30
6 yrs					
	BRU	M	6;00.19	81	33
	HAN	V	6;00.29	70	27
	GWE	V	6;03.04	-	-
	ELI	V	6;09.08	42	-
	JIN	V	6;04.15	50	12
	SEP	M	6;10.03	-	-
7 yrs					
	BAS	M	7;04.05	72	-
	HAN	V	7;00.04	70	27
	JUL	V	7;10.00	40	28
	JUS	V	7;00.16	93	28
	LOB	V	7;02.03	57	28
	MAT	M	7;11.19	52	22

Table 5. Initials of each subject in the SLI-group with their gender, age at testing, and corpus (B&K = Bol & Kuiken and Leiden = collected for this study).

	initials	*gender*	*age*	*corpus*
4 yrs				
	RIN	V	4;01.16	B&K
	PIE	M	4;07.20	B&K
	REN	M	4;08.21	B&K
	MON	V	4;09.08	B&K
	COB	M	4;05.03	Leiden
5 yrs				
	WIL	V	5;01.02	B&K
	DIA	V	5;01.04	B&K
	LIE	V	5;03.07	B&K
	PAS	M	5;04.28	B&K
	MAR	M	5;11.22	B&K
	NIE	M	5;05.06	Leiden
	KUR	M	5;10.00	Leiden
	TIN	V	5;07.23	Leiden
	PAL	V	5;03.05	Leiden
6 yrs				
	BER	M	6;00.10	B&K
	PIM	M	6;00.13	B&K
	HES	M	6;00.24	B&K
	JEL	M	6;01.13	B&K
	JOE	M	6;01.26	B&K
	RAM	M	6;02.10	B&K
	JOO	M	6;07.22	B&K
	CAT	V	6;10.04	Leiden
	SAN	M	6;05.01	Leiden
	RUB	M	6;08.27	Leiden
	SYB	M	6;06.10	Leiden
	ELK	V	6;03.14	Leiden
	KOE	M	6;05.19	Leiden
	JOR	M	6;11.17	Leiden
	RUB	M	6;05.06	Leiden
7 yrs				
	PJO	M	7;00.18	B&K
	SJO	V	7;01.26	B&K
	KEE	M	7;04.19	B&K
	SOF	V	7;08.19	Leiden
	WIL	M	7;06.08	Leiden
	GIA	M	7;05.10	Leiden
	YEN	V	7;00.02	Leiden
	SEL	V	7;01.24	Leiden
	JUL	V	7;06.07	Leiden

Appendix to CHAPTER 6

Past tense elicitation task

Elicitation movie **Bob and Boris are building a sandcastle**

SCRIPT past tense elicitation task (stimuli in bold)

Practice items

Bob **gooit** de bal.
'Bob throws the ball'
Gisteren toen gooide Bob de bal
'Yesterday, Bob threw the ball'

Boris **loopt** naar school.
'Boris walks to school'
Gisteren toen liep Boris naar school.
'Yesterday, Bob walked to school'

Script

Dit is Bob.
'This is Bob'

En dit is Boris.
'And this is Boris'

1. 'Hallo' **zegt** Bob.
   'Hello' says Bob'
   Gisteren toen zei Bob 'Hallo'.
   'Yesterday, Bob said 'hello'

Boris zegt hallo terug.
'Boris says hello to Bob'

Bob en Boris zijn elkaars beste vrienden.
'Bob and Boris are each others best friends'

2. Vandaag **spelen** zij in de speeltuin.
   'Today they ***play*** *in the playground'*
   Gisteren toen speelden zij in de speeltuin.
   'Yesterday, the played in the playground'

3. Bob **schommelt** even.
   'Bob ***swings*** *for a while'*
   Gisteren toen schommelde Bob.
   'Yesterday, Bob swung for while'

4. Boris **legt** zand in de emmer.
   'Boris puts sand in the bucket'
   Gisteren toen legde Boris zand in de emmer.
   'Yesterday, Boris put sand in the bucket'

5. Ondertussen **jopt** Bob naar onderen.
   'Meanwhile, Bob jops down'
   Gisteren toen jopte Bob naar onderen.
   'Yesterday, Bob jopped down'

6. Bob **brengt** een schep naar Boris.
   'Bob brings a shovel to Boris'
   Gisteren toen bracht Bob een schep naar Boris.
   'Yesterday, Bob brought a shovel to Boris'

7. Boris **glijft** achter het kasteel.
   'Boris glijfs behind the castle'
   Gisteren toen gleef Boris achter het kasteel.
   'Yesterday, Boris gleef behind the castle'

8. Samen **prommelen** ze naar voren.
   'Together, they prommel to the front'
   Gisteren toen prommelden zij samen naar voren.
   'Yesterday, they prommeled to the front'

Het kasteel ziet er al heel mooi uit.
'The castle look very nice already'

Bob heeft dorst gekregen van het harde werken.
'Bob got thirsty from all the hard work'

9. Dus **stoppen** zij eventjes.
   'So they stop for a minute'
   Gisteren toen stopten zij eventjes.
   'Yesterday, they stopped for a minute'

Ze gaan limonade drinken.
'They are going to drink lemonade'

10. Boris **tegt** de limonade.
    'Boris tegs the limonade'
    Gisteren toen tegde Boris de limonade.

'Yesterday, Boris tegged the limonade'

Dat vinden ze wel lekker!
'That's what they like!'

11. Oh oh, Bob **wotst** teveel.
'[interjection], Bob wots to much'
Gisteren toen wotste Bob teveel.
'Yesterday, Bob wotsed to much'

12. En oh nee! Daar **valt** het glas van Boris.
'[interjection] The glas of Boris is falling'
Gisteren toen viel het glas van Boris.
'Yesterday, the glas of Boris fell'

13. De toren van het kasteel **breekt**.
'The tower of the castle breaks'
Gisteren toen brak de toren.
'Yesterday, the castle brook'

Nu is het zandkasteel kapot.
'Now the sandcastle has broken'

14. Bob **kijkt** ernaar.
'Bob is looking at it'
Gisteren toen keek Bob ernaar.
'Yesterday, Bob looked at it'

Allebei schrikken ze.
'They are both shocked'

15. Boris **schopt** het glas weg.
'Boris kicks the glas away'
Gisteren toen schopte Boris het glas weg.
'Yesterday, Boris kicked the glass away'

Zij maken de toren opnieuw.
'They rebuild the tower'

Ze zijn hard aan't werk.
'They work hard'

16. Oeps! Ze **botsen** tegen elkaar aan.
'[interjection] the bump into each other'
Gisteren toen botsten ze tegen elkaar aan.
'Yesterday, they bumped into each other'

Bob en Boris lachen hard.
'Bob en Boris are laughing'

17. Dan **grallen** ze verder.
'Then they gral further'
Gisteren toen gralden ze verder.
'Then they gralled further'

Nu zit de toren er weer op.
'Now the tower has been rebuild'

Het kasteel is klaar.
'The castle is finished'

Oh nee, nog niet. Boris stopt er nog een vlag bij.
'[interjection], not yet. Boris puts a flag in the castle'

18. Bob **schrijft** hun namen erop.
'Bob writes their names on it'
Gisteren toen schreef Bob hun namen erop.
'Yesterday, Bob wrote their names on it'

Nu is het helemaal klaar.
'Now it's all finished'

Ze zijn er moe van geworden.
'They are very tired'

En nu naar huis!
'Lets go home!'

Table 1. Frequency counts for each N-CDI regular and irregular verbs. Counts are based on child spontaneous speech (present and past tense forms) and adult spontaneous speech (=CGN).

N-CDI verb	*reg/irreg*	*children*		*CGN*
		present	*past*	*past*
spetteren *(to splash)*	regular	0	0	0
trommelen *(to drum)*	regular	2	0	0
knuffelen *(to cuddle)*	regular	4	0	0
botsen *(to bump)*	regular	4	1	0
vegen *(to wipe)*	regular	0	0	1
schoppen *(to kick)*	regular	1	0	1
poetsen *(to clean)*	regular	3	0	1
zoenen *(to kiss)*	regular	0	0	2
schommelen *(to swing)*	regular	5	0	2
wassen *(to wash)*	regular	13	0	2
wandelen *(to walk)*	regular	1	0	3
tekenen *(to draw)*	regular	29	0	3
duwen *(to push)*	regular	11	1	4
dansen *(to dance)*	regular	13	0	6
lachen *(to laugh)*	regular	10	2	15
leggen *(to lay something down)*	regular	34	0	18
fietsen *(to cycle)*	regular	17	0	19
stoppen *(to stop)*	regular	26	0	23
gooien *(to throw)*	regular	28	0	27
draaien *(to turn)*	regular	11	0	28
spelen *(to play)*	regular	110	0	103
huilen *(to cry)*	regular	12	0	1
tonen *(to show)*	regular	7	0	7
leggen *(to put something away)*	regular	-	-	18
blazen *(to blow)*	irregular	1	0	3
breken *(to break)*	irregular	2	0	5
bijten *(to break)*	irregular	3	0	5
schrijven *(to write)*	irregular	4	0	41
slaan *(to hit)*	Irregular	4	0	32
brengen *(to bring)*	irregular	5	0	29
helpen *(to help)*	irregular	6	0	21
trekken *(to pull)*	irregular	11	0	44
zingen *(to sing)*	irregular	12	0	35
zwemmen *(to swim)*	irregular	12	0	3
drinken *(to drink)*	irregular	17	0	20
nemen *(to take)*	irregular	18	2	121
vliegen *(to fly)*	irregular	21	5	38
lezen *(to read)*	irregular	25	0	77
springen *(to jump)*	irregular	27	0	16

krijgen *(to get)*	irregular	35	0	680
rijden *(to ride)*	irregular	40	0	120
rennen *(to run)*	irregular	41	0	3
roepen *(to shout)*	irregular	43	0	37
geven *(to give)*	irregular	46	0	140
slapen *(to sleep)*	irregular	56	1	44
eten *(to eat)*	irregular	63	0	33
vallen *(to fall)*	irregular	87	7	234
zeggen *(to say)*	irregular	91	19	3676
zien *(to see)*	irregular	169	2	827
kijken *(to look)*	irregular	362	1	160
gaan *(to go)*	irregular	375	48	2987

Table 2. Initials, gender and age at testing for the participating TD children in the past tense elicitation task.

	The Netherlands			*Belgium*		
	initials	*gender*	*age*	*initials*	*gender*	*age*
5 yrs						
	MON	V	4;11.29	CHA	V	5;04;00
	LYN	V	5;01.07	JAN	V	5;05;12
	LOT	V	5;10.24	KYA	M	5;03.10
	ASH	V	5;04.12	FLO	M	5;10.05
	ZAH	V	5;07.08	SYL	V	5;07.00
	DOR	V	5;11.26	DOO	V	5;11.08
	MAA	M	5;08.30	REN	M	5;05.14
	ELI	V	-	JOA	M	5;08.16
	WOU	M	5;10.20	YAM	M	5;04.03
	JOE	M	5;02.27	GEN	V	5;09.24
	ROS	V	5;11.16	JAN	M	5;05.29
	VER	V	5;04.12	NAT	M	5;07.18
				MAU	V	5;08.27
				JES	M	5;03.23
6 yrs						
	LUU	M	6;03.19	LIN	V	6;10.15
	MAR	M	6;06.25	KLA	V	6;10.12
	MYR	V	6;10.09	BEN	M	6;09.16
	LAU	V	6;11.24	MAR	V	6;01.09
	JOL	V	6;09.14	ACH	M	6;06.08
	YAR	M	6;06.28	FAB	M	6;10.20
				YOR	M	6;02.12
				MAT	M	6;07.09
				MATT	M	6;09.01
				DAR	M	6;08.19
				NIE	M	6;05.04
				SEP	M	6;08.10
				YAN	V	6;11.17
				RIE	V	6;11.22
				MAR1	V	6;03.04
				MAR2	V	6;03.04
				KOB	M	6;10.04
				NOA	M	6;04.04
7 yrs						
	ROM	V	7;01.13	WOU	M	7;00.02
	ESM	V	7;01.22	CHA	V	7;00.05
	LOE	V	7;00.26	MAR	V	7;02.16
	JET	V	7;09.21	EMM	V	7;04.27
	ANN	V	7;02.10	LUC	M	7;05.20
	DAP	V	7;00.07	RUG	V	7;07.18

JOL	V	7;07.14	JAN	V	7;00.24
FRA	M	7;05.18	CAM	M	7;05.07
MAT	M	7;07.11	ANO	V	7;04.20
LUC	V	7;01.13	JAN	V	7;00.17
ESM	V	7;10.26	MEL	V	7;07.00
GER	V	-			
MAT	M	7;07.11			

Table 3. Initials, gender, age at testing, age at implantation (in months) and unaided hearing loss (in dBHL) for the participating CI children in the past tense elicitation task.

	initials	*gender*	*age*	*AAI*	*unaided HL*
5 yrs					
	BRI	V	5;04.14	47	88
	EVI	V	5;11.02	59	95
	LOU	V	5;06.07	11	120
	NOU	M	5;07.25	13	-
	STE	M	5;07.28	15	120
	BIL	M	5;05.11	39	-
6 yrs					
	FEM	V	6;00.11	17	115
	REN	M	6;02.26	43	91
	VAL	M	6;10.05	28	92
	LAU	V	6;07.23	33	113
	STIJ	M	6;04.21	10	-
7 yrs					
	JON	M	7;03.07	22	103
	LIA	M	7;11.28	25	87
	ANN	V	7;08.13	7	120

Table 3. Initials, gender, age at testing and hearing levels (in dBHL) for the participating SLI children in the past tense elicitation task.

	initials	*gender*	*age*	*HL*
5 yrs				
	JAN	V	5;03.30	18
	FEL	M	5;11.05	10
	CED	M	5;01.01	12
	LEN	V	5;02.05	20
	TYN	M	5;09.00	-
	RAC	V	5;01.12	-
	LAN	M	5;11.20	13
	RAF	M	5;06.03	12
6 yrs				
	STE	M	6;02.26	13
	FLY	V	6;01.10	-
	MAR	V	6;04.16	8
	ALY	V	6;05.23	-
	ZIT	V	6;10.30	10
	LIN	V	6;10.30	12
	BOJ	V	6;02.25	13
	LEO	V	6;06.27	13
	NAT	V	6;01.16	8
7 yrs				
	BRE	V	7;02.30	12
	DYL	M	7;06.09	12
	ELK	V	7;08.23	12
	KYE	M	7;01.09	12
	BRI	V	7;04.21	-
	TIN	V	7;01.03	20
	RUB	M	7;10.19	10
	ORT	M	7;01.19	12

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SAMENVATTING

in het Nederlands

Introductie

Een goed gehoor en een efficiënte verwerking van het auditieve spraaksignaal zijn essentieel in de ontwikkeling van gesproken taal. Kinderen die vanaf de geboorte slechthorend zijn, lopen daarom het risico vertraging op te lopen in hun taalontwikkeling. Om deze vertraging zo klein mogelijk te houden, worden zeer snel na de diagnose 'slechthorendheid' gehoorapparaten aangemeten. Een gehoorapparaat versterkt het geluid, waardoor het hoorverlies deels wordt gecompenseerd en voor kinderen met een mild tot matig hoorverlies is dit voldoende om de taalontwikkeling te stimuleren.

Indien het hoorverlies te groot is, zal het versterken van geluid door middel van een gehoorapparaat niet leiden tot voldoende spraakverstaan. Voor deze ernstig slechthorende en dove kinderen is er het cochleair implantaat (CI). Dit implantaat zet het geluid om in elektrische pulsen, die via een geïmplanteerde elektrode de auditieve zenuw stimuleren. Deze directe stimulatie geeft een sensatie van auditieve waarneming. Het is gebleken dat elektrisch gestimuleerde auditieve waarneming positief bijdraagt aan de taalontwikkeling van dove en ernstig slechthorende kinderen.

Recenter onderzoek toont aan dat, wanneer de taal wordt opgedeeld in verschillende domeinen (zoals fonologie, morfologie, etc.), de ontwikkeling van elk van deze domeinen niet gelijk verloopt. Zo ondervinden dove kinderen met een cochleair implantaat meer moeite met de ontwikkeling van grammatica in vergelijking met het lexicon. Met name op het gebied van de grammaticale morfologie lijken deze kinderen hun horende leeftijdsgenootjes moeilijk te kunnen bijhouden.

Het doel van deze studie is om meer inzicht te krijgen in het effect van een cochleair implantaat op de ontwikkeling van grammaticale morfologie. In deze studie hebben we ons geconcentreerd op de ontwikkeling van verbale morfologie van dove kinderen met een cochleair implantaat in de leeftijd van 4 tot en met 7 jaar. Daartoe is de verbale morfologische ontwikkeling van deze kinderen vergeleken met die van horende, normaal ontwikkelende kinderen, slechthorende kinderen met gehoorapparaten, en kinderen met taalstoornissen.

De ontwikkeling van verbale morfologie is vervolgens nader geanalyseerd in relatie tot de leeftijd van implantatie en hoorleeftijd, en in relatie tot perceptuele saillantie van verbale morfemen.

Methode

De ontwikkeling van verbale morfologie bij dove kinderen met een cochleair implantaat werd onderzocht aan de hand van spontanetaaldata en een experimentele elicitatietaak. De spontanetaaldata zijn geanalyseerd op gemiddelde zinslengte (d.i. een maat voor algemene taalproductiviteit), en een kwantitative en kwalitatieve maat voor de productie van verbale morfologie. De kwantitatieve variabele bestond uit de som van het aantal finiete werkwoorden in een spontanetaalopname van 50 uitingen; de kwalitatieve variabele bevatte de som van het aantal fouten in subject-werkwoord congruentie (bijv. *zij *slaap/slaapt*) en omissies van het vervoegde werkwoord in een verplichte context (bijv. *ikke *(ben) naar de film geweest*). Voor de analyse van spontanetaaldata werd een genormeerde taaltest gebruikt. Zodoende kon er een vergelijking worden gemaakt met horende, normaal ontwikkelende kinderen.

Onderzoek naar de ontwikkeling van verledentijdsmorfologie in het Nederlands wordt bemoeilijkt door de lage frequentie van deze verledentijdsvormen in spontaan taalgebruik. Eerder dan een verleden tijd (bijv. *fietste*) gebruikt de spreker een voltooid tegenwoordige tijd (bijv. *heb gefietst*) De ontwikkeling van de verledentijdsmorfologie is daarom onderzocht aan de hand van een elicitatietaak. In deze taak werden verledentijdsvormen van zowel bestaande regelmatige (bijv. *werk – werkte*) als onregelmatige (bijv *breek – brak*) werkwoorden uitgelokt. Er werden ook een aantal niet-bestaande werkwoorden opgenomen in de elicitatietaak (bijv. *joppen – jopte*). Deze werkwoorden geven de mogelijkheid om te kijken in hoeverre kinderen in staat zijn om aan een nieuwe werkwoordsstam een regelmatig verledentijdsmorfeem toe te voegen (/*-te*/ en /*-de*/) of om niet-bestaande werkwoorden te vervoegen naar analogie van bestaande onregelmatige werkwoorden.

Verbale morfologie in spontanetaaldata: congruentie

De analyse van de spontanetaaldata liet een verschil zien tussen met name jonge kinderen met een cochleair implantaat (4 en 5 jaar) en hun horende normaal ontwikkelende leeftijdsgenootjes. Deze jonge dove kinderen produceerden kortere zinnen en minder finiete werkwoorden dan de normaal

ontwikkelende kinderen. Ongeveer 73% van de taalgestoorde kinderen liet eenzelfde patroon zien als de jonge kinderen met een cochleair implantaat.
De oudere kinderen met een cochleair implantaat (6 en 7 jaar) produceerden langere zinnen en meer finiete werkwoorden in vergelijking met de jongere kinderen met een cochleair implantaat. Dit betekent dat zij de kloof met hun horende leeftijdsgenootjes hebben kunnen dichten op de *kwantitatieve* ontwikkeling van verbale morfologie. Voor hun leeftijdsgenootjes met een taalstoornis is dit evenwel niet het geval. Voor deze laatste groep werd namelijk geen toename gevonden in de productie van finiete werkwoorden. Op 6- en 7-jarige leeftijd produceerden de taalgestoorde kinderen significant minder finiete werkwoorden dan de kinderen met een cochleair implantaat. Ook de kinderen met hoortoestellen kenden een minder grote toename in hun productie van verbale morfologie in vergelijking met de kinderen die een cochleair implantaat droegen. Dit leidde echter niet tot significante verschillen tussen beide groepen slechthorende kinderen.

De resultaten voor de *kwalitatieve* variabele toonde aan dat kinderen met een cochleair implantaat, evenals kinderen met een taalstoornis en slechthorende kinderen met hoortoestellen, meer congruentiefouten maakten dan hun horende leeftijdsgenootjes. Bovendien werd voor geen van de groepen een afname gevonden in het aantal congruentiefouten naarmate de kinderen ouder werden. Dit wijst op persisterende problemen in de productie van verbale congruentiemorfemen.

Verbale morfologie in de elicitatietaak: verledentijdsproductie

De resultaten van de elicitatietaak laten zien dat zowel de kinderen met een cochleair implantaat als de kinderen met een taalstoornis achterlopen in hun verwerving van het regelmatige en onregelmatige verledentijdsmorfeem. Beide klinische groepen produceerden significant minder correcte verledentijdsvormen van regelmatige werkwoorden in vergelijking met hun horende normaal ontwikkelende leeftijdsgenootjes. Hetzelfde resultaat werd gevonden voor de productie van verledentijdsvormen van niet-bestaande werkwoorden. De normaal ontwikkelende kinderen hadden een voorkeur voor een regelmatige vervoeging van deze werkwoorden. De dove en taalgestoorde kinderen gaven vaak een tegenwoordigetijdsvorm of gaven helemaal geen respons. Voor zowel bestaande als niet-bestaande werkwoorden bleven significante verschillen bestaan tussen de klinische groepen en hun horende normaal ontwikkelende leeftijdsgenootjes tot de leeftijd van 7 jaar.

In de literatuur is geopperd dat de productie van overgeneralisaties, waarbij het regelmatige verledentijdsmorfeem wordt aangehecht aan de stam van onregelmatige werkwoorden (bijv. *breek – breekte*), aangeeft dat de regel voor verledentijdsmarkering is verworven. In deze studie werd voor de kinderen met een cochleair implantaat en kinderen met een taalstoornis een positieve samenhang gevonden tussen de productie van correcte regelmatige verledentijdsvormen en overgeneralisaties. Dit zou kunnen duiden op het ontstaan van een regel voor verledentijdsmarkering. Echter, de percentages correcte regelmatige verledentijdsvormen voor niet-bestaande werkwoorden was laag voor de kinderen met taalstoornissen en zeer laag voor de kinderen met een cochleair implantaat. Indien een regel inderdaad verworven zou zijn, dan zou men verwachten dat deze regel frequenter zou worden gebruikt bij dergelijke werkwoorden.

Wat betreft de *onregelmatige* verledentijdsvormen, lieten zowel kinderen met een cochleair implantaat als taalgestoorde kinderen een minder grote achterstand zien ten opzichte van de normaal ontwikkelende kinderen. De 5- en 6-jarige kinderen uit beide klinische groepen produceerden significant minder onregelmatige verledentijdsvormen dan hun normaal ontwikkelende leeftijdsgenootjes. Op de leeftijd van 7 jaar werd geen significant verschil gevonden in de productie van onregelmatige verledentijdsvormen. De discrepantie tussen de verwerving van regelmatige en onregelmatige werkwoordsmorfologie wijst dus in richting van een grammaticale stoornis voor beide klinische groepen.

De rol van leeftijd van implantatie en hoorleeftijd

De resultaten van zowel de spontanetaaldata als van de elicitatietaak zijn nader geanalyseerd in relatie tot leeftijd van implantatie. In de literatuur is systematisch een positief effect aangetoond van vroege implantatie op de taalontwikkeling. Dit houdt in dat kinderen die hun implantaat krijgen voor hun tweede verjaardag betere resultaten vertonen wat hun gesprokentaalontwikkeling betreft dan kinderen die hun implantaat krijgen na hun tweede verjaardag. Het onderliggende idee is dat dankzij vroege implantatie een kind optimaal gebruik kan maken van de sensitieve periode voor taalontwikkeling. Tijdens deze periode zijn kinderen zeer ontvankelijk voor taal, omdat het brein in deze periode optimaal plastisch is. Naarmate kinderen ouder worden neemt deze plasticiteit af en dus ook de ontvankelijkheid voor taal.

In de taalontwikkeling van kinderen met een cochleair implantaat speelt naast leeftijd van implantatie bovendien nog een tweede factor een belangrijke rol. Indien de taalproductie wordt gemeten van deze kinderen met eenzelfde chronologische leeftijd, dan is er een variatie binnen de groep voor hun zogenaamde 'hoorleeftijd'. Zo heeft een 4-jarig kind, dat zijn/haar implantaat ontving op 1-jarige leeftijd, drie jaar lang toegang gehad tot auditieve spraakinput. Zijn/haar leeftijdsgenootje dat pas op 3-jarige leeftijd zijn/haar implantaat kreeg heeft slechts één jaar spraakinput gehad. Uit de literatuur is bekend dat een hogere hoorleeftijd positief bijdraagt aan de taalontwikkeling.

Daarom is in deze studie het effect van hoorleeftijd, naast leeftijd van implantatie, ook meegenomen.

Een opmerkelijk resultaat in deze studie is dat hoorleeftijd belangrijker lijkt te zijn voor de productie van finiete werkwoorden dan leeftijd van implantatie en chronologische leeftijd. Kinderen met een cochleair implantaat bereiken het productieniveau van hun normaal horende leeftijdsgenootjes na 3.5 jaar van auditieve spraakinput, ongeacht hun chronologische leeftijd. Voor de taalmetingen op jonge leeftijd (d.i. tot ca. 5 jaar) betekent dit dat er ook een indirect voordeel is met betrekking tot de vroege leeftijd van implantatie: vroeg geïmplanteerde kinderen hebben immers op zeer jonge leeftijd reeds een relatief lang ervaring met spraakinput opgedaan.

Verder komt uit deze studie ook naar voren dat normaal horende kinderen een plateau bereiken in hun taalontwikkeling. Dit is bijvoorbeeld te illustreren aan de hand van hun zinslengte in woorden. Tot de leeftijd van 4 jaar neemt het gemiddeld aantal woorden per zin gestaag toe, maar neemt daarna niet verder toe. Ook bij kinderen met een cochleair implantaat ziet men een dergelijke groeicurve, die echter later van start gaat en stabiliseert. Dit impliceert dat eens deze kinderen een stabiele zinslengte hebben bereikt (ongeveer rond hun vijfde levensjaar), er voor deze taalmaat geen effect meer zal worden gevonden van leeftijd van implantatie en hoorleeftijd.

Er werd geen effect gevonden van leeftijd van implantatie of gehoorleeftijd op het maken van congruentiefouten. Een gedetailleerde analyse laat zien dat dit komt doordat kinderen met een cochleair implantaat geen duidelijke daling vertonen in het aantal fouten tussen 4 en 7 jaar, terwijl dit bij normaalhorenden wel het geval is. Deze resultaten kunnen het best worden verklaard in het kader van de perceptuele saillantie van verschillende werkwoordsmorfemen en de impact ervan op de taalverwerving bij het dove kind.

De rol van perceptuele saillantie en de Morfeem-in-Ruis perceptiestoornis hypothese

Bij horende normaal ontwikkelende kinderen wordt de verwerving van grammaticale morfemen deels bepaald door hun perceptuele saillantie. Dit houdt in dat morfemen die meer opvallen in het spraaksignaal eerder worden verworven dan morfemen die minder opvallen. Een morfeem zal meer opvallen wanneer het syllabisch is, een klemtoon krijgt en een langere duur heeft. Voor de verbale morfologie houdt dit in dat een ongebonden complex morfeem zoals het finiete werkwoord (bijv. *werkt*) meer zal opvallen dan het gebonden 3^{e} persoons enkelvoudmorfeem (*-t*) alleen. Om eenzelfde reden zal ook het gebonden verbale meervoudsmorfeem (*-en*) (bijv. *werken*) meer opvallen dan het gebonden morfeem (*-t*). Het is aannemelijk dat bij slechthorende kinderen de invloed van perceptuele saillantie nog groter is dan bij hun horende leeftijdsgenootjes.

De resultaten van deze studie laten evenwel geen effect zien van perceptuele saillantie op de verwerving van verbale morfologie bij de kinderen met een cochleair implantaat. Deze kinderen lieten perceptueel laag saillante gebonden morfemen net zo vaak weg als het gehele finiete werkwoord en dit veranderde niet gedurende het taalverwervingsproces. Wanneer perceptuele saillantie een rol zou spelen, dan zouden de omissies van het gehele finiete werkwoord sterker moeten dalen ten opzichte van de gebonden morfemen.

Ook de vergelijking tussen gebonden morfemen met een lagere vs. hogere graad van perceptuele saillantie kon geen duidelijke verschillen aantonen in frequentie van omissie van deze morfemen. Enerzijds lieten kinderen met een cochleair implantaat wel vaker het 3^{e} persoons enkelvoudsmorfeem weg in vergelijking met het meervoudsmorfeem, hetgeen de rol van perceptuele saillantie lijkt te bevestigen. Anderzijds werd echter het prefix van het voltooid deelwoord (d.w.z. *ge-* in bijv. *gewerkt*) vaker werd weggelaten dan het suffix (d.w.z. *-t* in bijv. *gewerkt*) – terwijl het prefix juist perceptueel saillanter is dan het suffix.

Teneinde uit te sluiten dat het louter om een perifeer probleem zou gaan, nl. dat dove kinderen met hun cochleair implantaat bepaalde gebonden werkwoordsmorfemen niet kunnen waarnemen en onderscheiden, werden minimale paren (bijv. *werkt* – *werkte*) aan hen aangeboden in stilte. Hieruit bleek dat zij deze morfemen wel degelijk kunnen onderscheiden, zij het in een ideale testsituatie.

Deze laatste observatie heeft geleid tot de *Morfeem-in-Ruis perceptiestoornis hypothese*. Deze hypothese houdt in dat de geobserveerde problemen in de verwerving van grammaticale morfemen bij cochleair-implantaatgebruikers moet worden toegeschreven aan de suboptimale perceptie in moeilijke luistersituaties. Anders geformuleerd: de *Morfeem-in-Ruis perceptiestoornis hypothese* stelt dat slechthorenden als gevolg van hun gehoorverlies belangrijke informatie in het spraaksignaal missen, met name de perceptueel zwak saillante werkwoordsmorfologie. Het onderliggende idee is dat de temporele fijnstructuur van het spraaksignaal niet goed doorgegeven wordt en dat juist deze informatie essentieel is wanneer men spraak wil verstaan in situaties met veel stoorlawaai. Dove kinderen met een cochleair implantaat verwerven taal in rumoerige situaties, zoals een klaslokaal waar de ruis kan oplopen tot 60dB. Hierdoor hebben zij meer kans om niet-saillante grammaticale morfemen te missen in het spraaksignaal. Aangezien voldoende spraak input en verwerking een voorwaarde zijn om het taalverwervingsproces te voltooien, is het aannemelijk dat het missen van deze morfemen negatieve gevolgen heeft voor de verwerving ervan.

Conclusie

Deze studie toont aan dat het cochleair implantaat dove en ernstig slechthorende kinderen in de leeftijd van 4 tot en met 7 jaar in staat stelt verbale morfologie te ontwikkelen. Hoewel zij aanvankelijk een achterstand vertonen in de productie van finitie werkwoorden ten opzichte van hun horende leeftijdsgenootjes, zijn zij uiteindelijk in staat de kloof te dichten. Wanneer de kloof wordt gedicht, is afhankelijk van de duur van de periode waarin een kind met een cochleair implantaat toegang heeft tot auditieve spraakinput (d.w.z. de hoorleeftijd). Leeftijd van implantatie is hierin een indirecte factor.

Wat betreft de productie van finiete werkwoorden overtreffen kinderen met een cochleair implantaat niet alleen de kinderen met taalstoornissen, maar ook de slechthorende kinderen met klassieke hoortoestellen. Dit is opmerkelijk, aangezien deze laatste groep een kleiner hoorverlies heeft en daarom dus een betere uitgangspositie heeft wat betreft gesproken taalontwikkeling dan de dove en ernstig slechthorende kinderen met een cochleair implantaat.

Ondanks de goede resultaten op de productie van verbale morfologie, maken kinderen met een cochleair implantaat toch meer fouten in het gebruik van verbale morfemen dan hun normaal ontwikkelende leeftijdsgenootjes. Hierin lijken zij dan weer juist op hun leeftijdsgenootjes met taalstoornissen en op hun slechthorende leeftijdsgenootjes met hoortoestellen. De problemen in de correcte productie van verbale morfemen is niet te wijten aan perceptuele saillaintie. Daarom zal toekomstig onderzoek zich moeten richten op mogelijke additionele factoren die van invloed zijn op de verwerving van verbale morfemen. Aanvullende tests voor de perceptie van verschillende typen van morfemen in ruiscondities kan meer uitsluitsel geven over de voorgestelde Morfeem-in-Ruis perceptiestoornis hypothese.

CURRICULUM VITAE

Annemiek Hammer was born in Hengelo on the 20th of August 1981. She attended the Greydanus College in Enschede and Zwolle from 1993 to 1999. In 2000 she started with language and culture studies at Utrecht University. During these years she took many courses in phonetics and linguistics and became particularly interested in clinical linguistics. To follow her interest she continued with linguistics and speech language pathology at the University of Nijmegen. In 2006, she obtained her bachelor Linguistics and master Speech Language Pathology. While writing her MA-thesis, she applied for the research position for the VIDI-project *The morphosyntactic development of children with cochlear implants. A comparison with children using hearing aids, normally hearing children and children with SLI*. She started as a PhD-student in December 2006 and finished her dissertation in February 2010.