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Master's Thesis

Comprehension of Pronouns and Reflexives by Children with a Cochlear Implant

I.G.E. Wessel
3641503

Supervisie:
Prof. Dr. M.B.H. Everaert
Prof. Dr. F.N.K. Wijnen

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Author: Inge G. E. Wessel

Student number: 3641503

Supervisor Utrecht University:

Prof. Dr. M.B.H. Everaert

Prof. Dr. F.N.K. Wijnen

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Abstract

A cochlear implant (CI) is a surgically-inserted prosthetic hearing device that helps to restore auditory functioning in deaf people. Hearing loss before the onset of language has been shown to have a deleterious effect on speech and language development in children. Therefore, it is of the utmost importance to develop effective clinical interventions for deaf children. However, no specific language test exists that can fully characterize how children with a CI develop the perception of spoken language. The tests currently used in clinics are speech tests that usually fail to capture the complexity of language and its development. There is not a test which fully captures the complexity of language. Therefore, we need to develop specific comprehension tests for children with a CI. In order to create such a test, it is first necessary to determine the level of speech and language proficiencies of children with a CI, how these children differ from non-hearing-impaired children, and how they develop over time.

This study is the first component of a longitudinal study which will monitor CI children with respect to their hearing levels, their speech and linguistic skills, and their cognitive development. In this first study, we will focus on a specific linguistic phenomenon, namely the Delay of Principle B Effect (DPBE). The inability to correctly interpret pronouns and reflexives seems to be a good indicator of atypical or delayed language development. Moreover, this ability can be tested in a relatively short time. Therefore, we hypothesize that the interpretation of pronouns and reflexives could be useful tools to monitor language development in CI children.

In this study, ten CI children were tested using a picture verification task. Ten age- and gender-matched non-hearing-impaired children (NHI) served as the control group. Children with and without a CI, between the ages of 5 and 13 years were chosen, as previous research shows that this is the range during which pronouns and reflexives should be fully acquired (Başkent et al., in press). We have raised the upper limit of the age range because we expected delay with these milestones amongst the CI children. Two different speech rates (normal and slowed) were used (van Rij et al. 2010), as children with a CI may benefit from a slower speech rate.

We hypothesized that children with a CI and non-hearing impaired (NHI) children will have different milestones in the perception of reflexives and pronouns. The results confirmed this hypothesis. In identifying pronouns and reflexives, children with a CI made more mistakes than did NHI children. This supports the first hypothesis.

In earlier research, van Rij et al. (2010) concluded that children between the ages of 5 and 6;3 years benefited from a slower speech rate in the perception/comprehension of pronouns. Based on this finding, we hypothesized that a slower speech rate would have a positive effect on the pronoun comprehension score. In this study, contrary to what we expected, the children's pronoun comprehension did not improve when a slower speech rate was used. Rather, the scores of tests using a slower speech rate were lower. The test scores in the normal speech rate condition were much better. However, we should acknowledge that the slowed speech samples sounded very unnatural, and this perhaps contributed to poorer performance in general. Because of the lower scores on the test using a slower speech rate, the second hypothesis is falsified?

In conclusion, based on the comprehension test, we can state that children with a CI have delayed milestones in comprehension of pronouns and reflexives compared to NHI children. In interpreting pronouns and reflexives, children with a CI make more mistakes than do NHI children. The children do not benefit from a slower speech rate with pronouns interpretation. The clinical instrument seems to be a good test to use; however, a larger group needs to be tested in order to provide more reliable results and a more specific overview of how children with a CI develop linguistic skills.

A recommendation for further research is to make the slowed-down speech sound more natural, so that the children are/can be tested in comparable circumstances. I would also recommend that researchers search for more tests that measure specific language and literacy difficulties over a wider age range.

Acknowledgement

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1. Introduction

Speech perception skills in children with a cochlear implant (CI) are often measured using a language production test like that of Schlichting (Schlichting et al.,1995)) or the language comprehension test Reynell (Reynell, J. (1977)). These tests usually fail to give an reliable results of the speech and language development of children with a CI. In order to fully understand their achievements, it is essential to have a good overview of CI-children's speech and language skills, as well as of the development of these skills. Here, we will focus on the comprehension of reflexives (English *himself/herself*, Dutch *zichzelf*) and pronouns (English *him/her*, Dutch *hem/haar*), an area which has been well-studied for normal-hearing children. We will describe an experiment on this particular patient population. Towards developing such a test, we propose to use the comprehension of pronouns (him/her) and reflexives (himself/herself).

Based on the literature (See Baauw, 2002 for an overview), we may assume that normal-hearing children show adult-like comprehension of reflexives at the age of 5, while their comprehension of pronouns reaches adult-like levels after that. That is, these specific skills – grasping the referents of pronouns and reflexives – are acquired at different ages. The aim of this study is to add to establishing a baseline measurement of these children's complete understanding of pronouns and reflexives.

This thesis is a follow-up of Başkent et al. (2013). The baseline data were collected from non-hearing impairment (NHI) children who were tested using acoustic simulations of CIs. To capture the linguistic milestones, the test from van Rij et al. (2010) will be used. In this study, we will look at two different groups of participants: non-hearing-impaired children (control group), and children with cochlear implants (unilaterally and bilaterally implanted). The target sentences will contain pronouns and reflexives, and two speech rates will be used (normal speech rate and slowed speech rate). The different speech rates are included to explore whether children with a CI benefit from slower speech rates.

Previous studies have found that children with a CI have an overall delay in speech and language development, compared to NHI children (Kirk et al., 2002). Therfore, we hypothesize that children with a CI and NHI children will have different linguistic milestones for the comprehension of reflexives and pronouns.

Love (2009) and van Rij et al. (2010) investigated pronoun comprehension of pronouns at a slowed speech rate amongst NHI children. There is no a priori reason to expect different results for children with a CI. The slowed speech rate had a positive effect on the interpretation of pronouns. This study's second hypothesis is, therefore, that a slowed speech rate will have a positive effect for both groups on the pronoun comprehension score.

1.1 Cochlear implants

A cochlear implant (CI) is a surgically-inserted prosthetic hearing device that helps to restore auditory functioning in deaf people. CIs are of great benefit for children and adults who were born deaf or who have become severely hearing-impaired. The CI not only allows deaf people to hear sounds in their environment, but also helps them understand speech, facilitating communication and better social interaction (Schorr et al., 2009).

Figure 1 shows a CI positioned in the ear. The main components of a CI are a microphone (1), a speech processor (2), a transmitter (receiver/stimulator) (3) and an electrode array (4) (EHSC, 2013).

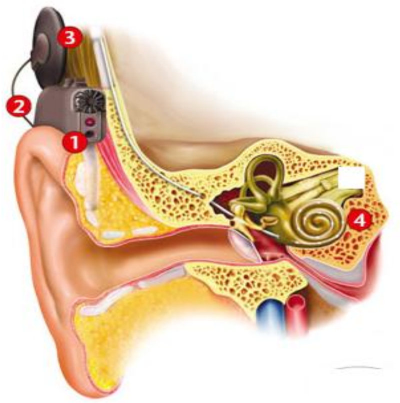

Figure 1: Ear shown with a CI (EHSC,2013)

The microphone picks up sounds from the environment and transmits them to the speech processor, which converts the analogue sound into digital pulse trains that are modulated according to the sound waveforms. The transmission of the digital pulses through the scalp occurs between the transmitter and receiver coils. These digital signals from the speech processor are then transmitted to the electrodes. The electrode array stimulates the auditory nerve using digital current pulses (Adunka & Kiefer, 2005).

1.2 Speech and language development with implants

Over the past years there has been research into children with CIs (Tyler et al., 1997). When a child is born deaf, it has a deleterious effect on the development of speech and language. Studies have shown that 4 months old children develop phonetic perception when they are exposed to spoken language (Kuhl et al., 1992). Children are able to recognize their own name when they are 9 months old and also begin to produce words (Jusczyk, et al., 1999; Jusczyk & Luce, 2002). By the age of 10-12 months the child can integrate different types of word segmentation cues; at 16 months a child uses vowel-initial words; and by 17 months the child is making two-word sentences. Children who are born deaf are not exposed to spoken language. This has consequences for their speech and language development. In order to facilitate the development of hearing ability and speech understanding and language development, it is better to equip the child with a CI as early as possible; ideally between 6 and 12 months of age (Dettman et al., 2007; O'Donhohue et al., 2000; Nicolas & Geers 2008).

It is desirable that hearing-impaired children should be equipped with a CI as early as possibly, in order for speech understanding and language development to develop normally. Although, the CI must be implanted before the age of six (Baumgartner et al., 2002; Nicholas & Geers 2007). After the age of six (when the critical language period has elapsed), children are more likely to show a delay in speech and language development in comparison to NHI children (Kirk et al., 2002; Baumgartner et al., 2002). One of the benefits of early CI implantation is that these children develop linguistic skills faster, and some CI children may even catch up to the language level of NHI children (Vermeulen, et al. 1999). The results in Baumgartner et al.'s (2002) study showed that when children receive a CI before the age of three, the likelihood that they will catch up with NHI children is very high. Of course, this may differ from child to child, but this study gives a general picture of the CI children's development after implantation. Nevertheless, different critical periods in the speech and language development occur in different stages and different ages.

Although it is best to implant the CI as early as possible for the natural development of speech understanding and language, there are considerable additional risks during an implantation before the age of one. These risks are related to anaesthesia complications

– for instance, the child can get a cardiac arrest during the implantation (Young, 2002). Because of the advantages and disadvantages of implantation at an early age, the correct implantation age remains a topic of debate in the field.

Nowadays, children also be implanted bilaterally with two CIs, either sequentially or simultaneously. “Sequentially” means the second CI will be implanted later than the first, in a second surgical procedure. It is also possible to implant CIs at the same time during a single surgery (simultaneously) (Ramsdem et al., 2012).

There is increasing evidence that deaf children who receive a bilateral implantation have a better speech and language development than deaf children who receive only one CI. Bilaterally-implanted children demonstrate better perception of speech in noise (Deun van, et al., 2010; Litovsky et al., 2006; Wie, 2010, Steffens et al., 2009), better lateralization (Bascura et al., 2009) and better localization (Bascura et al., 2009; Grieco-Calub & Litovsky 2010, Deun van, et al., 2010) of sounds and spoken language. Bilateral CI implantation also has a positive effect on expressive and receptive spoken language in prelingual deaf children (Boons et al., 2012).

2. Delay of Principle B Effect

It is important to fully explore language development in children with a CI. When more data are available on how children with a CI develop, speech therapists will have a better understanding of what they must pay attention to during the development of language skills, and will be able to offer better aid to children with a CI. There is a body of research regarding the development of language skills amongst children with a CI; for example, the development of production and perception of spoken language by children who have a CI. However, the tests currently used in the clinics are language tests (Reynell (Reynell, J. (1977)) and Schlichting (Schlichting et al.,1995)) , which usually fail to capture the comprehension of language and its development amongst children with CIs.

We need to develop new comprehension tests specifically for children with a CI, but in order to do so, we first need to understand the speech and language skills and comprehension of children with a CI and how these develop over time, and compare these results to those of NHI children. To understand the development of those skills there will be a test used from van Rij et al (2010). She tested the comprehension of the Principal B effect in children.

2.1 Theories about the Delay of Principle B Effect

There exist a number of theories that try to explain why the Delay of Priciple B Effect (DPBE) occurs. Chomsky (1981) formulated the Binding Theory, given in the following three principles:

Principle A: A reflexive must be bound in its governing category.
Principle B: A pronoun must be free and not bound in its governing category.
Principle C: An r-expression cannot have an antecedent that c-commands it.

This thesis focuses only on Principles A and B. For instance:

Sentence 1, Principle A, sentence with a reflexive: *The elephant is hitting himself with a hammer.*

Sentence 2, Principle B, sentence with a pronoun: *The elephant is hitting him with a hammer.*

In sentence 1 *himself* can only refer can refer to *elephant* (Figure 2).
For children is it unclear where *him* refers to. Him cannot refer to *elephant* nor the *hammer*, because the subject of in is not describe in this sentence. It refers in this case to the crocodile (Figure 3). The child have problems with determining proper coreference.

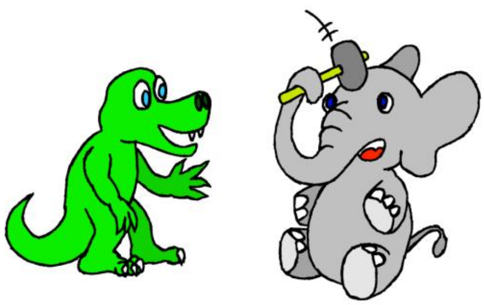

Figure 2: **Example picture**

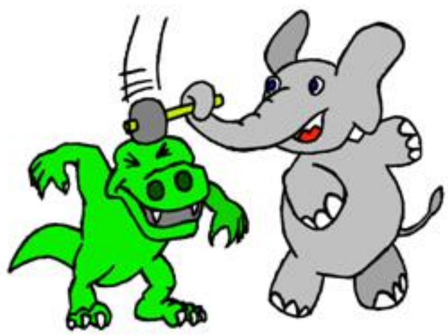

Figure 3: **Example picture**

However, it was observed early on that children showed delayed acquisition of Principle B. This is called the DPBE.Chien & Wexler (1990) and Thornton & Wexler (1999) put forward a deficiency in the pragmatic account. Reinhart (2006) had another explanation; there is a limitation of working memory (WM) in young children as a result of which the DPBE occurs. These explanations are related to comprehension and not to production. An alternative explanation comes from Hendriks & Spenader (2005/2006). Their explanation lies in asymmetrical grammar. Conroy et al. (2009) put forward that the DPBE does not exist, arguing instead that the supposed delay is a product of flawed methodology. However, Hendriks & Spenader (2005/2006) showed that DBPE does exist and other papers criticized it (Conroy et al.(2009), Spenader et al. (2009)). Several of these explanations will be discussed below. Van Rij et al. (2010) showed that when speech rate is slowed down, the comprehension of pronouns improves.

Chien & Wexler (1990) studied the comprehension of pronouns and reflexives amongst 120 children between 2;6 and 6;6 years old. Only children with English as their native language were included. They did four experiments to test children's ability to apply Principles A and B of the binding theory. The experiment used two methods; a Truth Value Judgement Task (Figures 4 and 5) and an Act-Out task. Each participant was tested in an empty classroom by two experimenters. One experimenter observed and recorded the responses of the child and the other one performed the experiment. Each experiment was divided into two sections: a training section and a testing section.

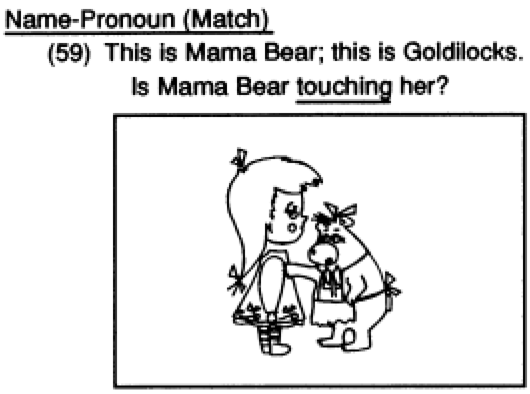

Figure 4: *Yes/No* Judgement task (Chien & Wexler, 1990)

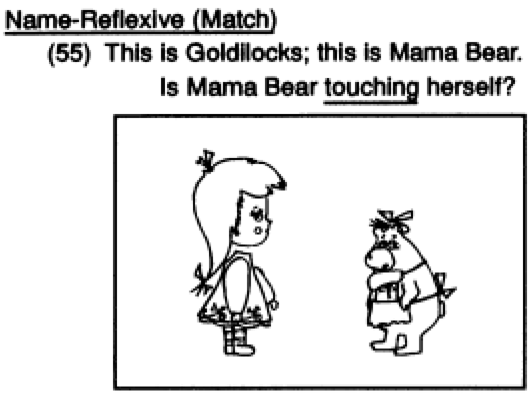

Figure 5: *Yes/No* Judgement task (Chien & Wexler, 1990)

During the testing section, the children were shown a picture of Mama Bear and Goldilocks facing each other. The children heard a sentence, *Is Mama Bear touching her?* Children around the age of five answered this question with *yes* around 50% of the time during these tests. As compared to *herself* children answered this question with *yes* around 80% of the time during the test.
The study showed that children had no problem with the interpretation of the word "herself" (Principle A), but had difficulties with the interpretation of the word "her" (Principle B). Children's poor performance on pronominal coreference has been found for many other languages (Russian, Dutch, Icelandic; see Baauw 2002 for discussion). Since the impossibility of coreference in *Is Mama Bear touching her* has been regarded as a violation of Principle B, it has been argued that the DPBE is the result of extra-syntactic factors, children having problems with the application of a pragmatic principle (Chien & Wexler's Principle P or Grodzinsky & Reinhart's Rule I) that rules out coreference between two elements. But Chien & Wexler also studied examples like *Every girl is pointing at her* in which 'coreference' is not an issue. It turned out condition B was obeyed. Chien & Wexler therefore concluded that children have knowledge of Principle A, and principle B. However, in cases like exemplified in figure 2 principle B does apply.

Thornton & Wexler (1999) continued the study of children's application of Principles A and B. From this study, they concluded that problems with the application of Principle B are related to a deficiency in pragmatic skills. The child does not know how to interpret sentences with a pronoun in the case of coreference, but in quantificational construction (*Every girl is pointing at her)* the DPBE disappears.

Reinhart (2006) claims that there is innate knowledge of Principles A and B. Reinhart sees the limited WM of the children as the source of children's problems with Principle B. She argues that children will apply Principles A and B correctly when their WM capacity starts to increase.

Spenader et al. (2009) proposed an alternative explanation. They concluded that the DPBE is an effect of the limitation of the child's grammatical knowledge. The lack of grammatical knowledge does not affect the interpretation of sentences requiring only the application of Principle A. However, this lack of knowledge does come into play when the child interprets sentences requiring the application of Principle B. For example(figure 6): "*The elephant is hitting him with a hammer.* Him cannot refer to crocodile nor hammer."

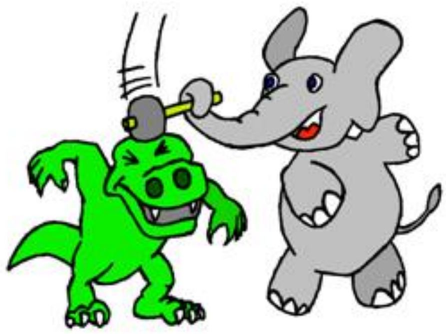

Figure 6: **Example picture**

Van Rij et al. (2010)

van Rij et al.'s (2010) hypothesis is that normally developing children (from 4;1 to 6;3 years) would show improved comprehension of pronouns when presented with a slowed speech rate. van Rij et al. (2010) show that the DBPE is caused by children's insufficient linguistic processing speed. They expected that when the speed rate of a sentence is lower, children will be able to interpret pronouns more easily. The conclusion of this study is that normally developing children benefit from slower speech rates.

Details of the study

Van Rij et al. (2010) developed a test for measuring the milestones of pronoun and reflexive comprehension in typically developing children from 4;1 to 6;3 years.
The study consisted of two blocks, one using a normal speech rate and the other a slowed speech rate. The stimuli were sentences with pronouns or reflexives. Each block consisted of sixteen pictures with accompanying sentences; eight sentences containing a pronoun and eight sentences containing a reflexive. The children sat behind a computer and were shown a picture. At the same time they heard a sentence. They needed to

decide whether the sentence they heard was an accurate description of the picture they saw. On the keyboard there were two smileys: a green smiley with a happy face and an orange smiley with a frowning face. When the sentence matched the picture, the child had to press the green happy smiley. When the sentence did not match (i.e. when there was a mismatch), the child had to press the orange frowning smiley. Van Rij et al. (2010) expected that children's results would be better when speech was slowed, because they would have more time to process the pronoun or reflexive in the sentence.

Başkent et al. (2013)

Başkent et al. (2013) used a similar method to that of van Rij et al. (2010). They used acoustic CI-simulations with NHI children between 5-8 years (56 participants), 10-11 years (15 participants) and adults (22 participants). The purpose of the study was to provide a baseline for pronoun and reflexive perception amongst CI children. They explored the effects of spectral degradations on CI processing using noise band vocoder simulations with NHI children.

Details of the study

The setup of the study was the same as the study conducted by van Rij et al. (2010), with one difference in the conditions of the sentences. The participants were tested in two blocks: normal speech and degraded speech (CI-simulation). People who have a CI use 4 to 8 spectral channels to listen to speech, and this causes a degradation of the speech signals delivered through the CI (Dorman et al., 1998).

The study's results showed that younger children (5-8 years) showed adult-like performance in comprehension of reflexives only. Older children (10-11 years) showed an adult-like performance in comprehension of both reflexives and pronouns. There was no difference in the scores obtained for normal speech and for the 8-channel degradation. However, in the 4-channel degradation, the performance deteriorated, but the relative patterns between age groups stayed similar to that of eight channel/no degradation. The study also showed that degraded speech had differing/differential effects on the interpretation of the two types of sentences. When presented with degraded speech, adults made more mistakes with pronouns, but not with reflexives. This study's expectations for the comprehension test scores of CI children are based upon the above results.

2.2 Effect of speech rate on pronoun comprehension

Not many studies have investigated pronoun comprehension in slowed speech rates (Love,T. , Walenski, M. & Swinney, et al. (2009)) and van Rij et al. (2010) both tested participants in a slowed speech rate condition. Love et al. (2009) showed that pronoun comprehension scores increased from 40 to 71 percent with a slowed speech rate, but there was no improvement in reflexive comprehension. However, Love et al. (2009) tested participants with aphasia. So we cannot compare this with NHI and CI children.

Van Rij et al. (2010) also conducted a study on the comprehension of pronouns and reflexives amongst normally developing children using a slowed speech rate, and concluded that there is a significant effect on pronoun comprehension. There is a relevant comparison between the this thesis and that of van Rij et al. (2010). Therefore, the assumption is made that the children in this study will also perform better when presented with the slowed speech rate stimuli compared to the normal speech rate stimuli.

3. Methods and Materials

3.1 Participants

A total of 20 children aged 5 to 13 years were tested. Full understanding of the referential properties of pronouns and reflexives in NHI children is attained between the ages of 5 and 8 years. However, because the goal of the present study is to investigate and quantify delays in achieving these milestones, the age range employed here is wider. All participants were monolingual Dutch speakers. The study population consisted of 2 groups: ten children (5 male, 5 female) with a CI and ten children (5 male, 5 female) with normal hearing. The children with a CI had been born deaf, had a hearing syndrome or auditory neuropathy, or had had meningitis. A participant have a normal hearing when the average pure-tone threshold for one ear was smaller than 20 dB. All participants of both groups were matched according to age and gender so that each NHI child served as a control to a CI child.

All participants showed normal cognitive development, were generally in good health and were monolingual speakers of Dutch. Subjects were excluded from the study when they were non-native Dutch speakers, native Frisian speakers or bilingual speakers; or if they had cognitive disabilities, (multiple) developmental problems and/or physical disabilities. Although all participants showed normal cognitive development, two cognitive tests were used to investigate their working memory (WM). The scores on the working memory test may be correlated with the scores on the comprehension test.

The participants with CIs were recruited through the University Medical Centre Groningen (UMCG).The participants with normal hearing were recruited through primary schools. Each participant received a small present when they finished the tasks. The parents of the children received a voucher and a travel allowance. This study was approved by the Medical Ethical Committee of the UMCG.

3.2 Procedure

The main test focused on the comprehension of reflexives and pronouns presented at normal and slowed speech rates. After the comprehension test, children were shown a picture on a computer screen and had to decide whether the sentence they heard was an accurate description of the picture. In addition, a hearing test was conducted, as well as several tests that measured linguistic skills and working memory capacity.

3.3 Main Task

Every participant was tested in the normal and slowed speech rate conditions. The order of the conditions was randomized. The participants were tested individually in a quiet room at school, in the hospital or at home, with one experimenter. When the child preferred one of the parents to be there during the test, this was arranged. Most of the children were more comfortable when the parent was in the same room.

The participants were instructed to press the green button with a smiley face when they decided that the sentence they heard was a correct description of the picture. When the sentence was not a correct description of the picture, the participant had to push the orange button with a frowning face. During the test, the participant could take as much time as needed to give a response. They could also request to hear the sentence again one time. Before starting with the real test, the participant received practice items so he/she could get used to the speech rate of the sentences. The conditions were presented in 2 blocks of 20 sentences; 8 sentences with a pronoun, 8 sentences with a reflexive, and 4 control items.

The participant sat in front of the laptop. Then, The researcher introduced a hand puppet (a pig), she said that the puppet mixed up the pictures and the corresponding sound bites in the computer game. The participant had to help the pig to place the pictures and the sentences in the right order again, because the pig do not understand the sentence.

The participant heard a sentence through loudspeakers. At the same time, the participant was shown a picture on the laptop screen and had to decide whether the sentence was a correct description of the picture. If the picture corresponded with the sentence he/she pushed the green button. Otherwise he/she had to pushed the orange button. When the participant pushed the orange button (mismatch answer,) he/she had to explain to the hand puppet why the sentence was not a correct description of the picture. As a result, the investigator knew whether the child was able to perform the test and understood what he/she had to do.

All the sentences were presented at the same sound intensity level of 60 dB. However, this does not mean they are perceived with the same intensity by CI children. The experimenter asked after each test sentence if the volume was suitable. If needed, the child could adjust the sound intensity on the CI one time.

3.4 Hearing thresholds

To measure the hearing thresholds of the NHI participants, the children were tested using pure-tone audiometry. This was performed using a portable clinical audiometer using eight different octave frequencies (0.25, 0.50, 0.75, 1, 2, 4, 6, 8 kHz) on both ears. The hearing thresholds from the CI participants were obtained from the hospital. The hearing thresholds of the CI participants were measured in a silent and isolated room. The hearing thresholds of the NHI participants were measured in a normal, quiet (but not sound-isolated) room.

3.5 Additional Linguistic and Cognitive Tasks

The Development of the Grammar and Phonology Screening (GAPS, Gardner, H. (2006)) test was used as an additional linguistic test, and the digit span forward (FW) and digit span backward (BW) were used as WM tests.

The GAPS was used to assess key markers of specific language and literacy difficulties in young children. The GAPS is designed to be a short, reliable assessment of young children's language abilities between the ages of 3 and 6. This screening test was developed to detect the extent to which the grammatical and phonological competences of SLI-children are impaired (Gathercole & Adams, 1993; Conti-Ramsden, 2003).

The GAPS is an English screening tool, translated into Dutch. In the test a picture of an alien is used. His name is Bick (Figure 7). The experimenter explains to the child that the alien cannot understand adults. He only understands children. The GAPS involves two different tasks: sentence repetition and non-word repetition. In the sentence repetition section, pictures are used. The child is shown a picture and with every picture the experimenter says a sentence. The child has to repeat the sentence.

In the non-word section, the experimenter explains to the child that the words in this test do not exist. The experimenter reads the non-words out loud and the child has to repeat them.

Between the ages of 4;10 and 5;5 years, children are generally able to repeat 9,3 out of 11sentences correctly. Children are able to repeat on average 10,3 sentences correctly when they are 5;6 to 5;11 years old, and children between 6;0 and 6;5 years repeat 10,5 sentences correctly. The maximum score for this part of the test is 11 points, corresponding with 11 sentences.

Between the ages of 4;10 and 5;5 years, normally developing children are able to repeat on average 6,8 out of 9 words correctly. They are able to repeat 7,1 words correctly when they are 5;6 to 5;11 years of age, and children between 6;0 and 6;5 years also repeat 7,1 words correctly. The most a participant can score in this part of the test is 9 points.

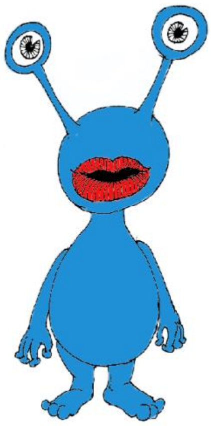

Figure 7: Bick

A subtest of the Clinical Evaluation of Language Fundamentals (CELF-4 (Kort et al. 2012)) was used to measure digit span. This test has been designed for children between 5 and 18 years old. The digit span consists of two types of test(s): repetition forward and repetition backward. The experiment started with two test items to check whether the participants understood the task and whether they are able to do the task. The experimenter started by mentioning 2 digits, and when the child repeated the digits twice correctly, the experimenter went on with 3 different digits and so on. The child had to repeat these different digits, and if the repetition was correct, the experimenter started with a new series of digits. For instance: the experimenter said 3-5, and the child repeated 3-5. Then the experimenter said 7-2, and the child said 7-2. But if the child made a mistake with the same number of digits twice, the experimenter stopped the test. The number of digits correctly repeated at that point was the outcome of the test. The digit span BW works the same as the digit span FW, but the child has to repeat the digits backwards. For instance: the experimenter said 3-8, and the child repeated 8-3. Then the experimenter said 7-4, and the child said 4-7. The best score a child can achieve in the digit span FW section is 16, and 14 in the digit span BW section.

3.6 Design

This study used a between-subjects design. It was purely behavioural and observational. There were two independent variables: group (two levels: control group, CI users) and age. The dependent variables was type of sentence (two levels: pronouns, reflexives) and speech rate (two levels: normal, slowed).

3.7 Stimuli

The stimuli consisted of two types of sentences: one type included a pronoun and the other type included a reflexive. Each sentence contained the reflexive *zich(zelf)* 'himself' or the pronoun *hem* 'him' (van Rij, 2010; Başkent et al., 2013). Each time before the test sentence was presented, the children heard an introduction-sentence; for example, *"Look, the crocodile and the elephant are in the garden."* After this sentence, the participant heard the test sentence; for example *"The crocodile is hitting himself with a hammer."* Then the child had to decide whether that sentence described the picture correctly or not. The verbs used were: *bijten* 'to bite', *kietelen* 'to tickle', *schminken* 'to make up', *wijzen naar* 'to point to', *slaan* 'to hit' and *vastbinden* 'to tie up'. All the sentences were pre-recorded. The normal speech rate condition had a mean rate of 4.0 syllables per second. The slowed speech rate condition was digitally stretched 1.5 times, with a mean rate of 2.7 syllables per second. All the sentences were calibrated and presented at 60 dB, using the ear simulator Kemar in the silence room of the hospital.

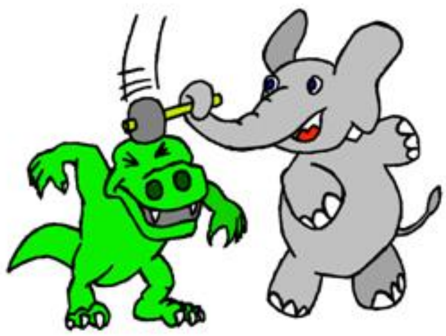

Figure 8: Example picture

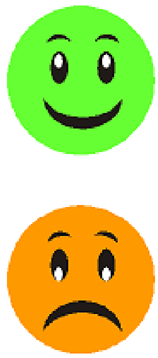

Figure 9: Response buttons

3.8 Apparatus

A Lenovo D590 laptop was used to present the pictures, Logitech free-field speakers were used to play the sentences. They were calibrated at 60 dB. There were two response buttons (Figure 9) on the keyboard (green smiling face and orange frowning face).

3.9 Statistics

To measure the effects of group and age, sentence type and speech rate, a repeated measures ANOVA was used. An independent sample t-test was used to measure the difference between the hearing thresholds of the right and left ears. A p-value of .05 or lower is considered statistically significant.

d' (d-Prime) was used to control for the yes-bias of the answers, as small children have a tendency to say "yes" more often than "no". d' is a measure of sensitivity for detecting a signal. The hit rate and false alarm rates were used to calculate d' in Matlab. When the correct answer was 'yes', and the child gave the answer 'yes', it was a hit. Conversely, when the correct answer was 'no', but the child answered 'yes', it was a false alarm.

4. Results

4.1 Characteristics of the participants

First, we compared the participant characteristics between the two subject groups to make sure that they were compatible (Table 1). The mean age in both groups was similar, as was aimed for – 9;2 years for the CI group and 9;1 years for the NHI group. A t-test showed that this age difference was not significant (t = 0.00, p = .918), The gender distribution in both groups was identical. As a result, the groups were comparable in age and gender.

Table 1 gives an overview of the participants of the study. The mean age, standard deviation and p-values from the t-test are given. Age, hearing loss were, GAPS scores and Digit span scores calculated by means of a two-sample t-test.

	CI (n = 10)	NHI (n = 10)	p-values
Age			
months	111 ± 0,6	109 ± 0,6	0.92
Range	62 → 156	59 → 156	
Gender			
Male	5	5	-
Female	5	5	-
Hearing loss (dB)			
Right	25,4 dB ± 7,7	2,3 dB ± 4,0	0.00
Left	30,2 dB ± 3,5	3,3 dB ± 4,9	
Intelligence quotient (IQ)			
Score	100 ± 15	100 ± 15	0.00
Range	85 → 115	85 → 115	
GAPS words (0-9)			
Score	5.7 ± 2.9	9 ± 0	0.002
Range	0 → 9	9	

GAPS sentences (0-11) Score Range	 8.3 ±3.9 0 → 11	 10.8 ± 0.4 10 →11	 0.060
Digit span forward (0-16) Score Range	 6,4 ± 1,5 4 → 8	 8,3 ± 2,9 4 → 12	 0.086
Digit span backward (0-14) Score Range	 3.0 ± 1,7 0 → 6	 5.1 ± 3,1 0 → 10	 0.077

Table 1: Subjects' characteristics

4.2 Pure tone thresholds

The audiograms in Figure 10 show the mean results of the CI group and NHI group. The children with a CI were tested in free field recently at the hospital, and NHI children were tested with noise cancelling headphones.

Figure 7 This figure shows the mean hearing thresholds per group. The higher the threshold is, the worse the subject's hearing is. The mean hearing threshold level is significantly different between the NHI and CI groups (right ear: t=3.58, p=0.00; left ear: t=1.83, p= 0.00). For the CI group, the mean score is between 23 dB and 36 dB. For the NHI group, the mean score is between 1 dB and 6 dB.

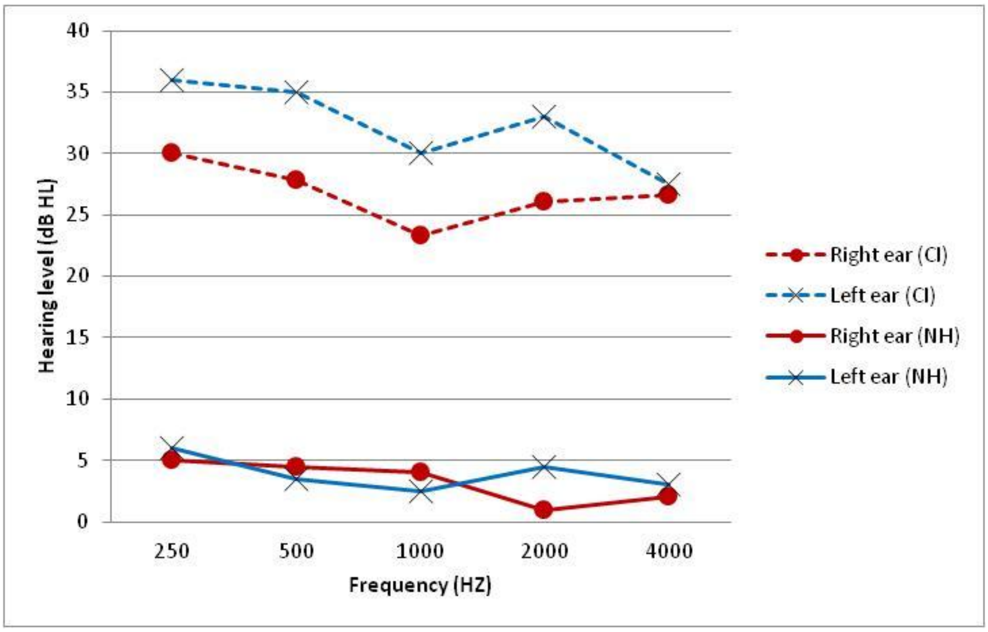

Figure 10: Hearing thresholds for CI and NHI groups

4.3 Sentence types

Figure 11 shows the pronoun condition results. The average percentages of correct responses per group the normal speech rate and the slowed speech rate conditions are shown. The data show that the scores are better in the normal speech rate condition than in the slowed speech rate condition. Figure 12 shows the reflexive condition results. It shows that the percentages of correct responses do not differ between the two speech rate conditions.

Figure 11 also shows the error bars. These bars indicates the group standard deviations (in percentages) around the mean. These are the mean pronoun scores of both groups, in the normal and slowed speech rate conditions. The error bars in Figure 12 indicates the group standard deviations (in percentage) around the mean. These are the mean reflexive scores for both groups, in the normal and slowed speech rate conditions.

It seems that CI children experience more problems in comprehending the sentences with pronouns than the hearing children have on pronoun comprehension. Overall, the NHI children perform better than the CI children.

A repeated measures ANOVA was performed on the data, with group (CI and NHI children) as a between-subjects factor, and type of sentence (pronouns/reflexives) as a within-subjects factor. According to Figures 11 and 12, there is only a significant ($p = .05$ or lower) effect of the type of sentence ($F=17.4$, $p=.001$) – and this is a significant effect.

Another repeated measures ANOVA was performed on the data, with group (CI and NHI children) as a between-subjects factor and the speech rate (normal/slowed) as within-subjects factor. In this situation there is only a focus on the speech rate. There is significant effect of speech rate condition ($F= 5.2$, $p=.035$).

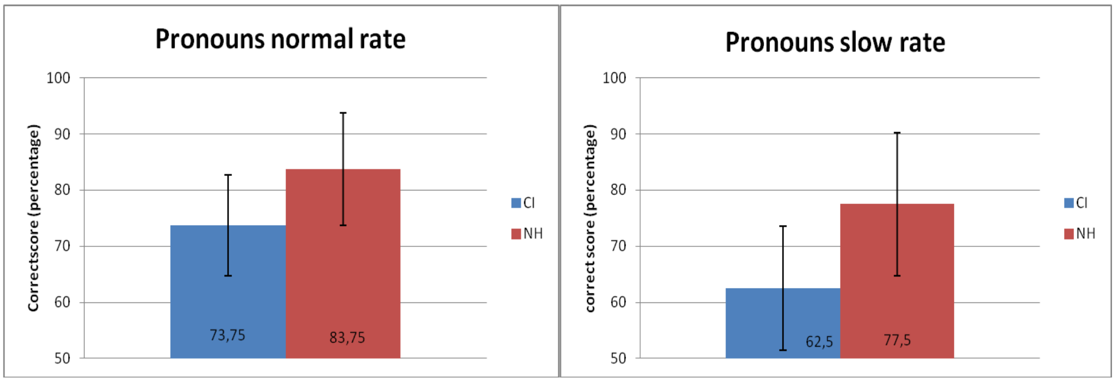

Figure 11: Mean correct scores pronouns

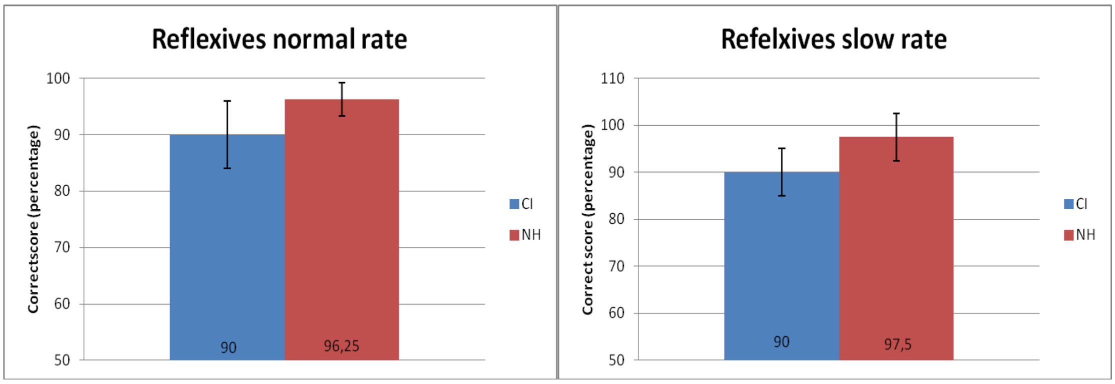

Figure 12: Mean correct scores reflexives

In table 13 is an overview of the overall score between reflexives an pronouns and between CI children compared to normal children. NR means normal speech rate and SR means slow speech rate.

As you can see in figure 13 the scores on the reflexives sentences are almost equal to each other. So we have to conclude that all children have no benefit from a slower speech rate. By pronouns the correct score even degrees with a slower speech rate. Overall you can see that NHI children perform better on the test.

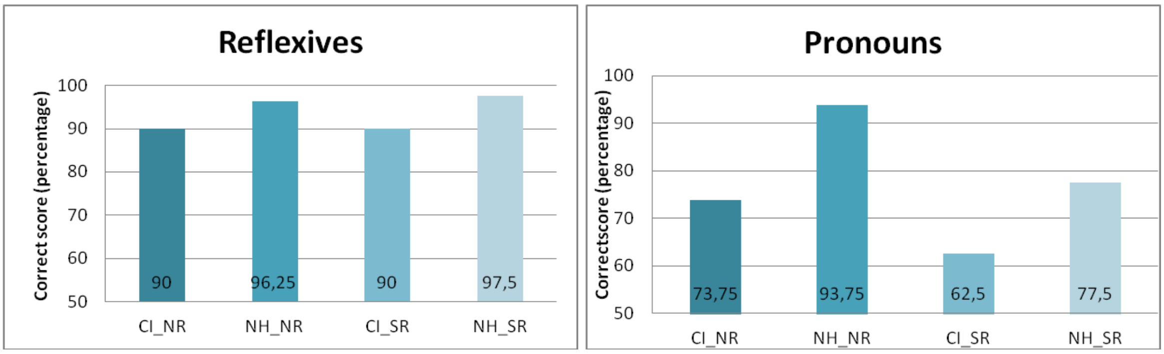

Figure 13: Overall scores reflexives and pronouns.

4.4 d-Primes

The experimental task was a Truth Value Judgement Task. To overcome the yes-bias of children, the results were analyzed and presented in d-prime (d'). Figure 13 presents the sensitivity measured for pronoun comprehension. Scores between the 0 and 1 mean that the hit and false alarm rates are almost equal. A large d' value suggests a high sensitivity. The sensitivity to the pronouns in the slowed speech rate is not very high. Figure 14 shows the d' of the reflexives. There is a slight difference.

The d' scores of CI children for pronouns and reflexives are lower than those of NHI children (Figures 13 and 14). The scores for sensitivity to pronouns in CI children decreased particularly in the slowed speech rate condition (Figure 13). The score for sensitivity to reflexives in NHI children decreased in the slowed speech rate condition.

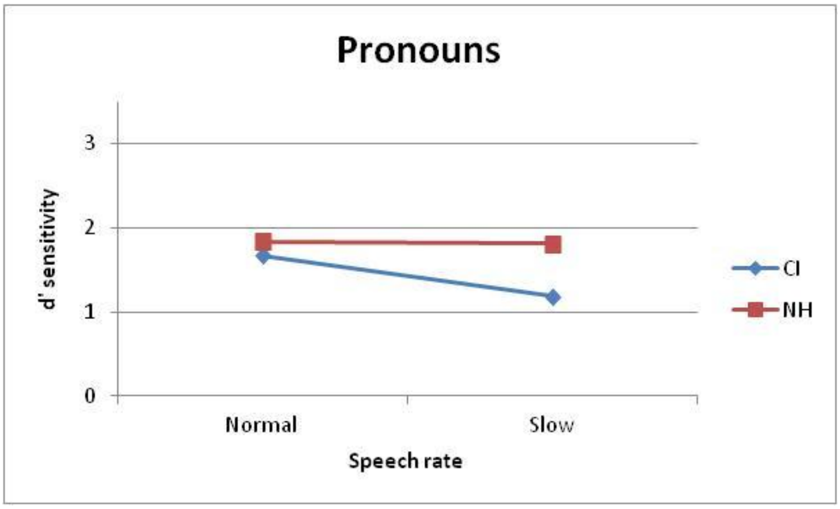

Figure 13: Mean d' scores for pronouns

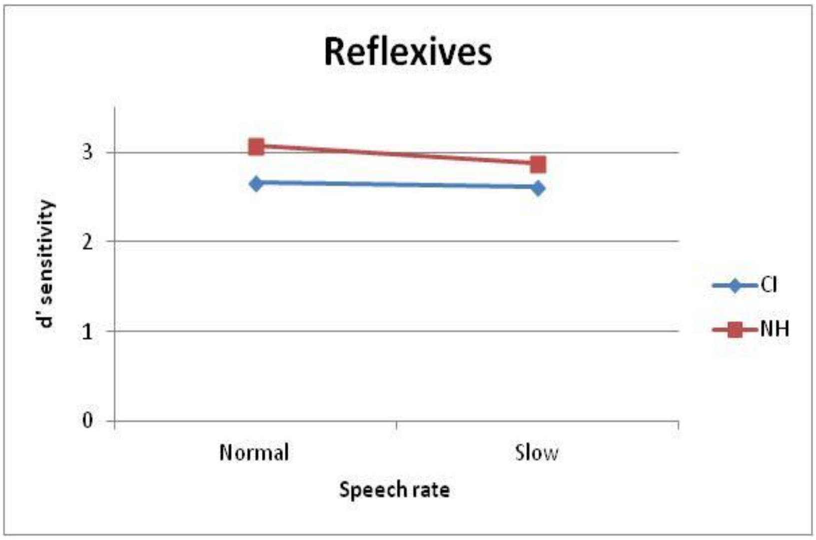

Figure 14: Mean d' scores for reflexives.

4.5 Cognitive tests

Table 2 gives an overview of the participants' scores on the additional linguistic (GAPS) and cognitive (digit span) tests. One of the participants was not able to repeat the words and sentences of the GAPS test. This participant belonged to the CI group. In addition, two participants were not able to repeat the digits backwards. One of these subjects belonged to the CI group, and the other to the NHI group. The results of the NHI and CI children were compared using t-tests, small difference was found, but not significant: GAPS sentences (t= 19,60, p= .060), digit span forward (t= 5,6, p= .086) and digit span backward (t= 2,06, p= .077). The two groups' results on the GAPS words were significantly different (t= 27,2, p= .002).

Table 2 shows the mean value with standard error. Every participant undergoes the same test in the same order.

	CI (n = 10)	NHI (n = 10)	p-values
GAPS words (0-9)			
Score	5.7 ± 1.1	9 ± 0	.002
Range	0 → 9	9	
GAPS sentences (0-11)			
Score	8.3 ± 1.2	10.8 ± 0.1	.060
Range	0 → 11	10 →11	
Digit span forward (0-16)			
Score	6,4 ± 0.5	8,3 ± 0.9	.086
Range	4 → 8	4 → 12	
Digit span backward (0-14)			
Score	3.0 ± 0.5	5.1 ± 1.0	.077
Range	0 → 6	0 → 10	

Table 2: Cognitive and linguistic outcomes

4.6 Results per individual participant GAPS and digit span

In Tables 3 and 4, an overview of the results of individual participants is given, presented per group. These tables represent the results of the normal speech rate condition, together with the scores of the GAPS and digit span tests (explained at page 15) .

Table 3 gives an overview of the the individual scores for all the CI children. The scores for pronouns and reflexives and for the GAPS and digit span tests are presented. Table 4 gives also individal scores for NHI children. Percentages are percentages of the correct interpretation.

ID	Age (months)	Gender	Pronouns (%)	Reflexives (%)	GAPS sentences (0-11)	GAPS words (0-9)	Digitspan FW (0-16)	Digitspan BW (0-14)
CI 1	156	Male	75	100	11	8	8	4
CI 2	153	Male	100	100	11	8	8	6
CI 3	142	Male	62.5	87.5	11	6	8	4
CI 4	141	Female	87.5	100	11	4	4	2
CI 5	127	Male	100	75	11	8	7	4
CI 6	92	Male	75	100	4	3	7	4
CI 7	90	Female	50	87.5	5	7	6	2
CI 8	82	Female	50	100	9	4	6	2
CI 9	66	Female	62.5	62.5	0	0	4	0
CI 10	62	Female	75	87.5	10	9	6	2

Table 3: CI group; normal speech rate

ID	Age (months)	Gender	Pronouns (%)	Reflexives (%)	GAPS sentences (0-11)	GAPS words (0-9)	Digitspan FW (0-16)	Digitspan BW (0-14)
NHI 1	156	Male	100	100	11	9	10	9
NHI 2	150	Male	100	100	11	9	8	4
NHI 3	138	Male	100	100	10	9	10	10
NHI 4	146	Female	100	100	11	9	10	5
NHI 5	121	Male	87,5	75	11	9	11	5
NHI 6	86	Male	62,5	100	11	9	5	2
NHI 7	88	Female	100	100	11	9	12	8
NHI 8	81	Female	75	100	11	9	9	4
NHI 9	69	Female	37,5	100	11	9	4	4
NHI 10	60	Female	75	87,5	10	9	4	0

Table 4: NHI group; normal speech rate

In the following tables (Tables 5 and 6), an overview of the scores in the slowed speech rate condition per participant, per group is given of the pronouns and reflexives.

ID	Age	Gender	Pronouns	Reflexives
CI 1	156	Male	50 %	100 %
CI 2	150	Male	87,5	100
CI 3	138	Male	25	100
CI 4	146	Female	87,5	100
CI 5	121	Male	87,5	100
CI 6	86	Male	50	100
CI 7	88	Female	37,5	62,5
CI 8	81	Female	62,5	87,5
CI 9	69	Female	62,5	75
CI 10	60	Female	75	75

Table 5: CI group; slowed speech rate

ID	Age	Gender	Pronouns	Reflexives
NHI 1	156	Male	87.5 %	100 %
NHI 2	150	Male	100	100
NHI 3	138	Male	100	100
NHI 4	146	Female	100	87.5
NHI 5	121	Male	87.5	100
NHI 6	86	Male	62.5	87.5
NHI 7	88	Female	100	100
NHI 8	81	Female	87.5	87.5
NHI 9	69	Female	37.5	100
NHI 10	60	Female	37.5	100

Table 6: NHI group; slowed speech rate

4.7 Correlation between WM and reflexives.

Figure 15 and 16 provides the coefficient of determination between the reflexives and the WM parts Gaps sentences (GS) and Gaps non-words (GNW) for the CI children. The r^2 in figure 15 is 0.26. The r^2 in figure 16 is 0.08. The r^2 of figure 15 results in a correlation value (r) of 0.50 and the r^2 of figure 16 results in a r of 0.28. The value of de R can vary between the -1 and +1. Zero means there is no linear relationship, +1 is a perfect positive linear. As you can see in the results above there is no perfect strong linear relationship.

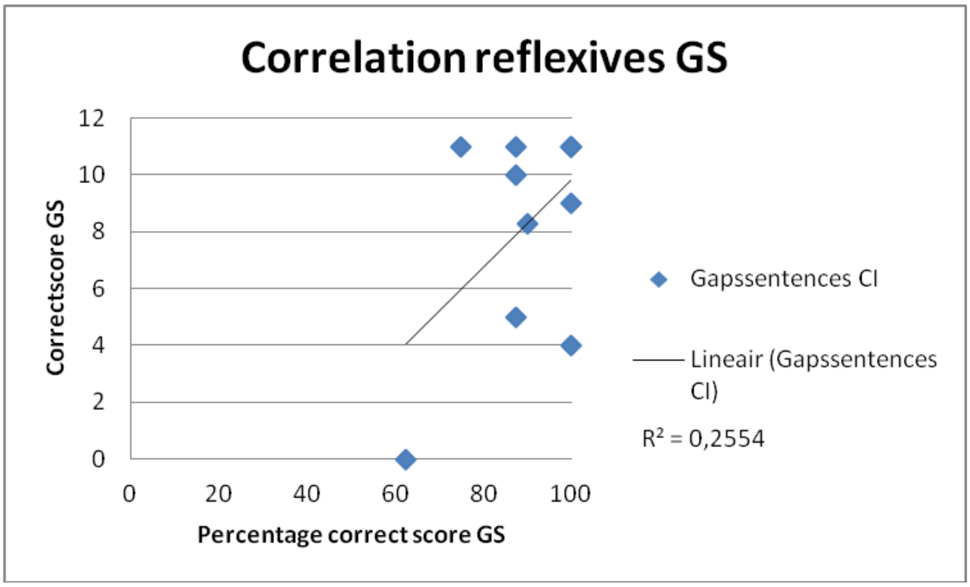

Figure 15: Correlation between reflexives and GS

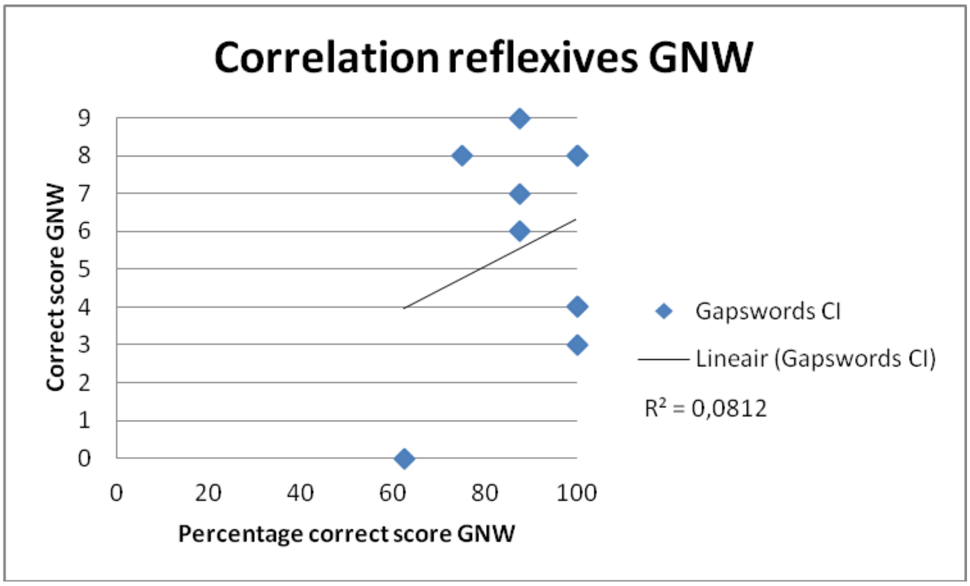

Figure 16: Correlation between reflexives and GNW

5. Discussion

The aim of this study was to investigate whether children with a CI have different linguistic milestones in the comprehension of the pronouns and reflexives compared to NHI children.

These were the hypotheses:

I. NHI children and children with a CI have different linguistic milestones in the comprehension of pronouns and reflexives.

II. When a slowed speech rate is used, the pronoun scores and reflexives in both groups will be better than those obtained when a normal speech rate is used.

Comparing the two groups' pronoun and reflexive comprehension scores shows that the NHI children performed better than the CI children. It seems that, compared to NHI children, the children with a CI have a delayed milestone in the comprehension of pronouns and reflexives.
However, the scores need to be compared to those of Başkent et al. (2013), because this study is a follow-up to that one. The scores of the present study differ from those of Başkent et al. (2013). The results of the Başkent et al. (2013) were roughly 50% for pronouns and 80% for reflexives in slow speech condition.

5.1 Comparison Başkent et al. (2013)

The children in the present study scored better on every part of the comprehension test. That was unexpected, because the experimental setup of the two studies was almost the same. However there were slight differences. The participants in Başkent et al. (2013) were tested at schools, without their parents nearby; and they also listened to degraded speech (CI simulation). It is possible that the children who had to listen to degraded speech had to focus more on the form of the sentences than on their content. Furthermore, it is possible that the children in our study were more cooperative, because one of the parents was there during the test, or because they felt more comfortable being tested at home. However this can also be a pitfall; that is, the subconscious approval or disapproval conveyed by parents' body language during testing could have had some effect. Another difference between the two studies was the testing location. The children were tested at home or in the silence room in the hospital. To ensure more comparable results in future follow-up studies, we will try to reduce such confounds by testing children without the parents being visible to the child, testing the children in the silence room at the hospital, and also by trying to match all children in more than just age and gender by taking into account socio-economic factors.

5.2 Slow speech

Van Rij et al. (2010) showed that slowing down the speech rate had a positive influence on the pronoun perception scores. The results of our test showed a slight difference between results in the normal and slowed speech rates, but not in the way we expected. Amongst the CI children, the scores decreased when the speech rate was slowed (from 75% to 65%). It seems that children with a CI do not benefit when the speech rate is slowed down. However, when we consider speech rate more closely, the slowed speech that was used does not sound natural. The children commented that it was a strange voice, and a bit boring to listen to. Van Rij et al. (2010) stretched their sentences by 1.5 times. This means that the words were stretched, and the silences between the words as well. It is possible that when only the silent periods between the words are extended, the sentence will sound more natural to the children, and their scores might increase. This is also an area in which future studies might be improved.

5.3 Results WM

Reinhart (2006) attributes children's comprehension problem of DBPE to their limited WM. Reinhart (2006) believes that the ability to compute coreference in the proper circumstance is correlated with a smaller WM. We used the digit span test to investigate whether our participants had a WM problem. It seems there is no reason to assume that there is a connection between the comprehension test scores and the two cognitive tests used, digit span FW and digit span BW. We compared the results of the NHI and the CI children using singular t-tests. A small but not significant difference was found: digit span forward ($t= 5,6$, $p= .086$) and digit span backward ($t= 2,06$, $p= .077$). The scores varied, as the participants (particularly in the CI group) who scored well on the comprehension test did not always score well on the digit span FW and digit span BW tests. The cognitive test results of the NHI group and the CI group showed a larger difference. The CI children had a lower mean score than the NHI children. In general, the NHI children performed better than the CI children in the cognitive tests .

The NHI children made almost no errors in the GAPS sentences, and in the GAPS non-words repetition they made no errors at all. It is difficult for children with a CI, especially younger children, to repeat sentences and non-words. When the CI children have to repeat non-words, they transfer the non-words into words who does exist. On the GAPS non-word repetition, children with a CI made more mistakes than NHI children. The results were significantly different between the two groups ($t= 27,2$, $p= .002$).

On the GAPS sentences subtest, children with an CI from 10;6-13;0 years scored the same as the NHI children. We compared the results of the NHI and CI children using singular t-tests. The results showed a small but not significant difference: ($t= 19,60$, $p= .060$). Children with a CI found it also difficult to repeat the sentences. Overall, they performed well, but they forgot some details, like the 't' at the end of 'drinkt'. It does not seem that this is related to speech production skills, but it seems that the CI children cannot hear some subtle things, and this test may therefore be too specific se for CI children.

Some children with a CI repeat non-words as real words. They do not recognize the non-word, and children with a CI find it difficult to recall words that do not exist. The test results show that it is difficult for CI children to repeat non-words ($t= 27,2$, $p= .002$), even when they are informed beforehand that the words do not exist. Some of the children were very unsure whether the word that they had repeated was the word the experimenter had said to the child. It seems like the children with a CI had more specific language and literacy difficulties.

It must be taken into account that the GAPS test is designed for children between three and six years old. Maybe there are other tests that measure specific language and literacy difficulties for a wider age range.
In the introduction, Reinhart's explanation of the DBPE was mentioned. From our results, it does not seem that the comprehension problem is a WM problem, because there is no strong correlation ($r = 0,50$ on the GS test/$r = 0,28$ on the GNW test) between

the scores on the cognitive test and those on the comprehension test. When a slowed speech rate was used, the scores on the comprehension test did not increase.

5.4 Milestones

So, our test results confirmed that children with a CI have delayed milestones for the comprehension of pronouns and reflexives compared to NHI children. In perceiving pronouns and reflexives, children with a CI made more mistakes than NHI children. The results in this thesis did not confirm that children showed better pronoun comprehension when a slower speech rate was used. Actually, the scores in the slowed speech rate condition were lower than those in the normal speech rate condition. Furthermore, the results did not confirm that WM limitations are the cause of the DPBE.

5.5 Recommendations

Suggestions for the future research are: 1) The slowed speech rate should be made to sound more natural. 2) Children need to be tested in circumstances that are comparable to those used in Başkent et al. (2013). A good way to achieve this would be to test participants in the silence room at the hospital in Groningen. In this study, the tests were conducted at different locations, and the children could have been distracted by different factors, resulting in a less reliable result. 3) Testing a larger group will provide more reliable results and a more specific overview of how children with a CI develop linguistic skills. However, it would be even better to follow the children over a period of 5 years, so as to have a complete overview of their development. 4) The possibility of using other tests that measure specific language and literacy difficulties for a wider age range should be investigated – the use of such tests would increase reliability. The tests that were used for this study were specified for use on subjects up to the age of six. For children that were older, these tests did not present a challenge. The results of these tests will therefore give an inflated measure of participants cognitive skills.

6. Conclusion

As predicted, the comprehension test found that children with a CI have delayed milestones in mastering the correct meaning of pronouns and reflexives compared to NHI children. In perceiving pronouns and reflexives, children with a CI made more mistakes than NHI children. Children with a CI have a slower development of the comprehension of pronouns and reflexives compared to NHI children.

The children with a CI and the NHI children did not benefit from a slower speech rate in the comprehension of pronouns. In fact the scores in the slowed speech rate condition were lower than those in the normal speech rate condition. A reason might can say that, for these groups of children, the slowed speech rate sounded too unnatural. But we have to keep in mind that the comprehension of pronouns is more difficult than the comprehension of reflexives. The group of participants of this thesis was very small.

A reason might can say that, for the NHI children the slowed down rate sounded too unnatural. But we have to keep in mind that the comprehension of pronouns is more difficult than the comprehension of reflexives. And also the group of participants of this thesis was very small.

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