MEDICINSKA FAKULTETEN
Lunds universitet

Department of Logopedics, Phoniatrics and Audiology
Department of Clinical Sciences, Lund

Vocabulary Development and Object Shape Recognition in Children with Cochlear Implants

Gazal Sayed

Speech and Language Pathology Programme, 2020
Master's Thesis (one year), 30 credits

Supervisors:
Birgitta Sahlén
Kristina Borgström
Malin Lindgren

Abstract

Purpose: The purpose of the study was to describe vocabulary development in children with cochlear implants (CI) and compare vocabulary development during a period of two to three years after CI activation to that in children with normal hearing. The association between expressive and receptive vocabulary development and object shape recognition is explored.
Method: The study included 15 participants (Girls: N= 9, Boys: N=6) who were recruited from an audiological clinic in southern Sweden and a summer camp. Object shape recognition, receptive and expressive vocabulary were assessed longitudinally with tests and a questionnaire at three different time points after the CI activation.
Results: The measure of productive vocabulary of children with CI varied from equivalent to hearing age peers' results to below hearing age peers' within the time period of the study. Two to three years after the CI activation, the group of participants had receptive vocabulary skills at or very close to their hearing age equivalent score.
Conclusion: Object shape recognition did not predict vocabulary development within the current time frame but may turn out to be a predictor in later follow-ups of the participants with CI as shown in earlier studies of children with normal hearing. Smart attention training in young CI users as a complement to currently offered language intervention program may have the potential of supporting vocabulary development.

Keywords: Cochlear implants, object shape recognition, vocabulary, longitudinal study

Table of Contents

Introduction 1

Background 1
- Cochlear Implants 1
- Early Word Learning and Object Shape Recognition (OSR) 2
- Vocabulary Development in Children with Cochlear Implants 4
- The relationship between Receptive and Productive Vocabulary 5
- Aims 5

Methods 6
- Participants 6
- Inclusion Criteria 6
- Description of the Participants 6
- Missing Data 7
- Materials 7
  - Object Shape Recognition (OSR). 7
  - Productive Vocabulary. 8
  - Receptive Vocabulary. 8
- Procedure 8
- Ethical Statement 10

Results 10
- Descriptive Data 10
- Object Shape Recognition 12
- Productive Vocabulary Growth (SECDI) 12
- Receptive Vocabulary Growth 14
- Correlations between the test of Object Shape Recognition, SECDI and Reynell IV. 15
- Summary of Results 16

Discussion 18
- Object Shape Recognition in Relation to Vocabulary Development 18
- Productive Vocabulary Growth at T1, T2 and T3 19
- Receptive Vocabulary at T3 20
- Receptive and Productive Vocabulary 21
- Methodological Discussion 21
- Future Research 22
- Conclusions 22

References 24

Attachments 27
- Attachment 1. 27
- Attachment 2. 28
- Attachment 3. 29

Introduction

Children diagnosed with severe – to – profound hearing loss (SPHL) may receive cochlear implants (CI) when they are as young as five months old as a result of early and improved neo-natal hearing screenings implemented at hospitals according to the Swedish Agency for Health Technology Assessment and Assessment of Social Services (2004). The implementation of hearing screening for newborn infants is crucial for identification of hearing loss and intervention at the optimal time, in order to facilitate access to spoken communication and in most cases, spoken language acquisition. Cochlear implantation at an early age is a significant factor for a child's language development (Karltorp et al., 2019; Hansson, Ibertsson, Asker-Árnason & Sahlén, 2018; Geers, Nicholas, Tobey & Davidson, 2016). However, even with an early implantation of unilateral or bilateral CI, children are at risk for language learning problems such as delayed vocabulary development (Duchesne, Sutton & Bergeron, 2009).

Vocabulary development is central for language proficiency. Researchers representing different scientific disciplines, have studied early word learning from different perspectives. Landau, Smith and Jones (1988), conducted a study on what potentially could support the developing child in early word learning from the perspective of developmental and cognitive psychology. The starting point of their research was to form an understanding of which dimensions (shape, size, colour or texture) mattered the most when children learn the names of novel objects. These dimensions were chosen because they are well-known perceptual properties that are detectable by typically developing children. The findings showed that a child's attention at the age of 18 and 24 months becomes more selective towards the shape of an object than towards other perceptual aspects of an object, when acquiring novel object names, a phenomenon known as *the shape bias* (Landau, Smith & Jones, 1988). Shape bias then in turn facilitates the child's ability to identify and categorise objects of the same shape, also known as the *object shape recognition (OSR)* (Smith, 2003).

The *Attentional Learning Account* of word learning, posits that the development of shape bias and OSR in turn boosts further word learning by tuning the child's attention to the most relevant feature of objects, sometimes referred to as *smart attention* (Colunga & Smith, 2008; Smith, Colunga & Yoshida, 2010; Smith, Jones, Landau, Gershkoff-Stowe & Samuelson, 2002). This is thought to be one important mechanism behind the vocabulary spurt.

Children with cochlear implants represent a group that requires support and intervention in order to facilitate language learning. The present study is a descriptive study of a small group of early implanted children with CI, with an aim of investigating their early vocabulary development. Three measures of vocabulary (measures of object shape recognition, receptive and expressive vocabulary) are used to capture aspects of the participants' vocabulary development at the different occasions in time (T1, T2, T3). The long-term aim of the initiative is to develop a vocabulary intervention program based on *smart attention* training in young CI users as a complement to currently offered language intervention programs.

Background

Cochlear Implants

A cochlear implant (CI), is a two-part device with an external part and an internal part that is surgically implanted in the cochlea. The external part is worn behind the ear and consists of a microphone and a speech processor. The microphone picks up the sound, which is then transmitted via the speech processor and converted into neural signals to stimulate the auditory nerve. This process triggers the brain and allows it process the auditory input (Pisoni et al., 2008). In spite of considerable technical development during the last decades, hearing in individuals with CI is not fully restored but considered compromised compared to that of individuals with normal hearing (NH) (Pisoni et al., 2008). However, there is now ample evidence suggesting that a cochlear implant and, specifically, bilateral cochlear implants, provide the child with significantly better speech perception and sound localization, which, in turn, supports spoken language development (Välimaa, Kunnarit, Laukkanen-Nevalt, Lonkas & the National Clinical Research Team, 2017).

In Sweden, all infants in the maternity ward are offered a hearing test, otoacoustic emissions (OAE) (SBU, 2004). In case of atypical findings, the family is offered a follow-up appointment at the audiological clinic for further investigation of the infant's hearing. This process secures an efficient process of identification of hearing loss and, the timely and correct fitting with hearing aids (HA). However, based on the type and degree of hearing loss assessed by a multi-professional team at the audiological clinic, CI may be a more suitable option a for child's language development. A CI user's so called hearing age is sometimes reported together with the chronological age in research studies. Hearing age is counted from the day the CI is activated. However, the hearing age of a child with SPHL is hard to exactly estimate, because a child with SPHL may, for example, have hearing residues or could have lost his hearing suddenly or over time (Vavatzanidies, Mürbe, Friederici & Hahne, 2018).

Early Word Learning and Object Shape Recognition (OSR)

Caregivers watch their newborn infants develop language skills in a span of just a few years. It all begins with coos and babbles and, around the age 9 – 12months children develop joint attention, the social cognitive skill that supports the child in the use of communicative gesture followed by the combination of gesture with a word (Tomasello, 2006; Hoff, 2014). Children's language comprehension skills are in a constant state of development during that time and, expand from the recognition of the names of their favourite toys and onto the understanding of simple instructions such 'give me a hug'. The development of vocabulary is a complex process based on the interaction of a range of social, cognitive and linguistic skills (Bloom, 2000).

Vocabulary development requires verbal and non-verbal cognitive skills. One of the most anticipated language milestone by caregivers is the first word; which typically appears sometime between 10 and 15 months of age (Hoff, 2014, p.138). The first word is typically uttered after various perceptual and cognitive skills have developed, starting from the ability to analyse and store auditory input, repeating and segmenting the phonological utterances and making associations between the word and its meaning. The speech segmentation problem is an important part of vocabulary development that every toddler faces (Hoff, 2014, p.154). Evidence has shown that toddlers who can successfully identify the stream of speech have gone through the process of first learning the rhythm of their language and then using that rhythm to segment reoccurring speech sequences in spoken language (Hoff, 2014; Theissan & Saffran, 2007). At the same time, toddlers are analysing and storing the auditory input to be able to repeat the phonological utterances and steadily associating the utterance with its meaning (Nettebladt & Salameh, 2007). Between the ages of 15 to 24 months, children with NH reach a 50-word productive vocabulary, which can be classified in: nouns, verbs and adjectives. During this stage, nouns are the largest category in the vocabulary (Hoff, 2014, pp.141-142).

As children start learning new words, and specifically novel nouns, they eventually develop a so called shape bias, which is an increase in attention and preference towards the shape of an object, and an understanding that objects with the same name often are alike in shape. Children typically develop a shape bias sometime between 18 and 24 months

(Gershkoff-Stowe & Smith, 2004). During the same time, the vocabulary spurt takes place, which is the sudden significant increase in a child's productive vocabulary, after the child has acquired a vocabulary size of 50 words (Dapretto & Bjork, 2000). It seems that shape bias functions as both a cause and an effect of word learning. Thus, shape bias develops due to word learning, and in the same time increases the growth of the productive vocabulary. In other words, when children learn the name of a new object, they then extend that name to other objects that are similar in shape (Golinkoff et al., 2012). Shape bias enables the child to identify the main common characteristics between several object exemplars in order to place them in one category. This, in turn increases the generalization process of word learning and the organisation of the lexicon.

OSR is similar to shape bias, in the sense that both abilities have the object shape in focus and, both have been found to be related to early word-learning (Periera & Smith, 2009; Yee, Jones & Smith, 2012). However, the main difference between these two abilities is that OSR is the specific ability of recognising an object from its overall shape. A common example that is found in a child's environment is a chair which comes in various forms such as a desk chair, armchair, deck chair and in many other forms, but all have a similar shape. Children who have developed OSR will therefore be able to identify novel chairs from their shape, regardless of colour or texture (Yee et al., 2012). Smith et al. (2002) have conducted an intervention study where children in structured interaction with caregivers during eight weeks were taught to direct their attention towards shape in novel and unknown objects, with non-word names. It was found that this training positively supported the participants' vocabulary acquisition and increased the rate at which they learned new words.

In a study conducted by Borgström, Torkildsen and Lindgren (2015a), to investigate the vocabulary development in 20 – to – 24-month-old children with NH, event-related potentials (ERP) of object shape recognition were found to be associated with the size of the child's vocabulary. ERP were measured when children performed an object recognition test and, showed that children with larger productive vocabularies were better able to match the word with object shape than children with smaller productive vocabularies. Of the 77 children in that study, 36 children participated in a follow-up study by Borgström, Torkildsen, Sahlén and Lindgren (2019), to further investigate their language development five years later. The ERP of robust object shape recognition at 20 to 24 months was found to strongly predict future productive and receptive language skills, and was a better predictor than early vocabulary size alone.

Petersson and Strahl in their masters' thesis (2018) conducted a study on 32 children at 26 – to – 32 month of age with, according to care-givers, typical language development and NH. They investigated vocabulary development in relation to early OSR ability. This study was a follow-up of a study of the 39 children that were tested by Strahl's unpublished report (2017) at age of 20 – 24 months. Petersson and Strahl (2018) found that as a group, there was a significant correlation between the participants' productive vocabulary size at 20 – to 24 months of age and at 26 – to 32 months. However, no significant correlation between OSR and the participants' vocabulary was found. Furthermore, the authors investigated the relationship between a questionnaire that was administered to caregivers at two different times, in which the caregivers estimated their children's productive vocabulary. The authors found that the caregiver's assessment of their children's productive vocabulary correlated with the participants' performance on the receptive language test.

There are great individual differences in vocabulary development among children. This can be due to the fact that there is a difference for both internal and external factors that contribute to each child's language development. The internal or within-child factors are the factors unique to the child: executive functions, working memory, shape bias and OSR are all internal factors that help shape the vocabulary development of a child (Hoff, 2014, p.153).

External factors also differ from one child to another in their role of contribution to the child's vocabulary acquisition. External factors can be described as the environmental factors that influence a child's vocabulary acquisition. Language is learned in a social context and language exposure represent an external factor. A rich and relevant language stimulation surrounding a child will increase the rate of a child's ability to learn new words, compared to a child with more limited language exposure (Hoff & Naigles, 2002). The interactions between caregivers and their children are significant to the child's vocabulary development, because these interactions provide linguistic and contextual input that are essential to the child in order to learn both the labels and meaning of new words. However, the quality of the linguistic input that caregivers provide varies (Chen, Castellanos, Yu & Houston, 2019).

Socioeconomic status (SES) often measured as care-givers education, is an external factor that has been found to predict the size of vocabulary in children: Children born in families with higher SES tend to develop a larger vocabulary (Fernald, Marchman & Weisleder, 2013). Finally, the birth order of a child is also an external factor that contributes to word learning; first-born children tend to have larger vocabularies than later-born children (Berglund, Eriksson & Westerlund, 2005).

Vocabulary Development in Children with Cochlear Implants

Auditory input is a fundamental source for infants to develop a spoken language. Children born with SPHL get limited auditory experience compared to children with NH from the time they are foetuses in the womb (Partanen et al., 2013). Cochlear implants may be the solution for infants with SPHL to improve sound perception and acquire a spoken language.

In spite of a range of advances during the last two decades, infants with SPHL still exhibit more problems developing spoken language than hearing peers (Geers et al, 2015; Hansson et al, 2018). Children born with SPHL, similarly to children with NH, start with coos and babbles in their first months of life (Löfkvist et al., 2019). There is however, a difference between children with NH and children with SPHL in the quantity of babbling they produce and the quality of the sound productions. Children with NH by the age of 9 to 10 months, produce clear syllabic babbling but babbling in children with SPHL is limited and less intelligible (Stoel-Gammon & Otomo, 1986; Hoff 2014, p.334). Despite having the ability to develop joint attention and share interactions with another person, children with SPHL do not advance in their communicative skills in the same manner as children with NH (Lederberg, 2003; Hoff, 2014, p.334). The limitations in babbling, which is seen as a pathway towards word production, negatively affects their lexical development in children with SPHL (Löfkvist et al., 2019). The vocabulary development of children with SPHL is delayed and develops at a slower rate compared to children with NH. However, even in this group, there are a range of individual differences that contribute to the growing vocabulary knowledge. (Löfkvist et al., 2019).

Studies have found that children with CI at group level demonstrate an overall different vocabulary growth than children with NH, even with implantation prior to 30 months of age (Lund, 2016). The individual differences can be due to the differences in auditory input the toddler receives, the quantity and quality of verbal and non-verbal interactions between the caregiver and the child, the quality of language being used by caregivers and the speed toddlers have in directing their attention towards the caregivers' utterances (Chen, Castellanos, Yu & Houston, 2019). As a group, most researchers agree that children with CI are delayed in their early vocabulary development (Lund, 2016). The process of word-learning in children with CI may even be different than that in children with NH. Children with CI may for example be less skilled at quick incidental learning. Children with NH have the ability to recall and use a new word after incidental exposure, which is the ability to pick up new words just by hearing it once, even if it was not directed to the child.

However, for children with CI this becomes much harder. The quality of the auditory input, especially if the environment is noisy, is not sufficient enough for a CI user to pick up a new word incidentally (Löfkvist, Almkvist, Lyxell & Tallberg, 2013). Children with CI receive a degraded signal of the phonological representations, thus affecting their sensitivity towards duration, pitch and stress (Pisoni et al., 2008). Moreover, incidental exposure is most efficient when a child already has a big vocabulary size (Lund & Douglas, 2016).

The environment surrounding a child with hearing loss is as in children with NH, crucial to the vocabulary growth and provides support for novel word-learning. Children with NH can acquire new words though the auditory-visual signal integration. However, there is evidence that children with SPHL have deficits in spontaneously integrating the auditory and visual signals together, thus limiting the multimodal process of learning new words (Bergeson, Houston & Miyamoto, 2010; Lund, 2016). It is important to note that children with CI are not considered to be deficient in language-learning per se. They have the potential to acquire vocabulary over time, just like children with NH, although the process may be different. Thus, it seems difficult for a child with CI to catch up on a year or two of learning without being delayed (Lund, 2016).

The relationship between Receptive and Productive Vocabulary

According to Rescorla and Turner (2015), receptive and productive vocabulary development are strongly associated. Children with a limited productive vocabulary size at 24 months of age are described as *late talkers*; even though they often catch up to children in their age group, their performance on language assessment tests are often lower than the performance in peers with typical development (Roos & Weismer, 2008). The productive vocabulary size of 24 months old children is a significant predictor of children's performance on other language competencies at later stages (Rescorla & Turner, 2015). Fölster and Hansson (2016) found in their master's thesis that children's productive vocabulary size at 20 to 24 months of age was a significant predictor of other linguistic abilities e.g. phonological awareness, lexical access and word retrieval 6 to 7 years later. They even found that the OSR ability of children at 20-24 months of age correlated with their language skills 6-7years later and, children who performed worse than the rest of the group on the OSR test, had language difficulties later. Fölster and Hansson (2016) even recommended the use of OSR test and the Swedish Early Communicative Development Inventories (SECDI) together at around the age of 2 years for a better identification of children with risk for language disorder. SECDI has already been established as a reliable assessment tool and, caregivers have a good estimation of their children's vocabulary (Fenson et al., 1993). OSR is a cognitive ability that requires perceptual cognitive ability, smart attention, and does not depend solely on auditory input, which makes it a skill that can support children with SPHL when they receive their CI or other suitable hearing aid. Thus far, there is evidence of a significant relationship between the early productive vocabulary, OSR and later receptive vocabulary. To the author's knowledge no earlier studies have explored whether there is a similar relationship between OSR and the development of vocabulary in children with CI. Therefore, it is interesting to explore whether OSR skills can predict CI-users' vocabulary skills.

Aims

- To describe the development of three aspects of vocabulary development (object shape recognition, expressive and receptive vocabulary size) in children with CI at different time points during the first 2–3 years after cochlear activation.
- To compare the individual profiles of vocabulary growth in children with CI to vocabulary development in children with NH.

- To explore how the three measures of vocabulary development are related to each other concomitantly as well as longitudinally.

Of particular interest in this study is object shape recognition skills in children with CI. Our specific research question is therefore:

- Can object shape recognition predict the vocabulary development, both receptive and expressive, 2-3 years after the cochlear activation?

Methods

Participants

The majority of the children who participated in the present study were recruited from an audiological clinic in southern Sweden. Some children were recruited from a summer camp held by the Swedish Organization for Children with Cochlear Implants or Hearing Aids (Barnplantorna). The summer camp invites children with CI and their families from all over Sweden for one week every other year. To this camp researchers and clinicians involved in relevant research projects are also invited to recruit families and to present their research projects. All families with a child with CI in Sweden are enrolled in clinical services from a CI-team at an audiological clinic offering regular check-ups, approximately every six months until the age of 18 years. The assessment procedure used in this study is implemented at the actual audiological clinic at the test occasions chosen for the present study, T1, T2 and T3.

Inclusion Criteria

To be included in the present study, the following criteria had to be met: a diagnosis of severe to profound hearing loss; and a cochlear implantation before the age of 32 months.

Description of the Participants

In total, 15 children participated, three from the summer camp and 12 from the audiological clinic. The present study included 15 participants (Girls: N= 9, Boys: N=6) with severe to profound hearing loss: Fourteen of the participants had bilateral CI and one participant was bimodally aided with a CI and HA. The mean age of the CI activation for the participants was 15 months (one year and three months, M=15 months, standard deviation, SD = 6.55) All participants were fitted with HA prior to the implantation. The hearing age in this thesis corresponds with the age at which the CI activation took place.

Caregivers gave their written consent to participate at the initial testing at the clinic or at the summer camp, to be contacted for follow-ups by the clinician/research team and to participate in the present study. The written consent also included that the clinician/research team may access the participants' medical records for information such as the date of activation and type of operation (unilateral/bilateral). All caregivers filled out a questionnaire regarding familial aggregation of language disorders and other neurodevelopmental disorders, languages used at home and caregivers' level of education. Of the 15 participating children, Swedish was the first language (L1) for 11 children and sign language or another spoken language than Swedish was the first language for the other four children. All the participants attended preschools where spoken Swedish was the primary language. There was familial aggregation of language and/ or language-related disorders in five of the families. One of the families had a family history of hereditary neurodevelopmental disorder.

Almost all of the participants (80%) had experienced typical motor development and did not have any other diagnosed neurodevelopmental disorder. Three of the participants (20%) had a diagnosed neurodevelopmental disorders. The educational level of the caregivers included in this thesis are divided into three categories: nine years of education or less (elementary school), 12 years of education (high school) and more than 12 years of education (university degree). Eleven of the participants' mothers (73.3%) had completed more than 12 years of education, while three had only completed the nine years of elementary school that are mandatory in Sweden. Forty percent of the participants' fathers had completed more than 12 years of education. The difference between mother and fathers as for university degree roughly corresponds to the difference between men and women in Sweden with university degree (Statistics Sweden, 2020).

Missing Data

Even if written consent for the study was received from all families for further follow-up assessments there are missing data as can be seen from Figure 1 and Table 2. At test occasion 2 (T2) and 3 (T3), three participants were not able to be present and, from some families the speech and language pathologists (SLPs) did not, in spite of several reminders, receive the SECDI questionnaire. The study started off with a total of 15 participants at the first occasion (T1). Two of the participants were, however, identified as outliers in the OSR test result at T1 and, were therefore excluded from the data set.

Table 1. Demographic characteristics of the participants as reported by their caregivers.

		N	**Percent**
Gender	Girls	9	60%
	Boys	6	40%
Heredity for Language Disorder	Yes	5	33.3%
	No	10	66.7%
Preschool	Mainstream	5	33.3%
	Preschool for children with HL*	10	66.7%
Mother's Education	≤ 9 years (Elementary school)	3	20%
	12 years (High school)	1	6.7%
	> 12 years (University)	11	73.3%
Father's Education	≤ 9 years (Elementary school)	1	6.7%
	12 years (High school)	8	53.3%
	> 12 years (University)	6	40%

**Preschool for children with HL is for children with (CI or HA) and the teachers have special education to support the student's specific needs.*

Materials

In the following, the tests and the questionnaire used at test occasions T1, T2 and T3 are presented as well as principles for analysis and scoring.

Object Shape Recognition (OSR). The object shape recognition test was identical to the test used by Strahl (2017, unpublished report), adapted from the experimental task used in Borgström et al. (2015). The test was divided into three parts to measure the child's ability to identify objects: the first was a practice section and consisted of six example pictures of objects and animals; the second was the OSR section and consisted of 14 black silhouette pictures of different objects and animals; the last part functioned as a control condition and included 14 pictures of the same items, but this time as regular pictures. The child was only asked to point to the item (control picture or silhouette) corresponding to the word uttered by the SLP (e.g. "where is the duck?"); no verbal answer was required from the child. A final score was then calculated corresponding to the ratio between correct silhouette pictures and correct regular pictures. This way the test produced a measure of each child's ability to recognize object shape independent of their general receptive word knowledge (which of course includes recognition of the labelled objects). If the child pointed correctly a score of one was given and if the response was incorrect or the participant showed obvious signs of not comprehending the question, no points were given. This test was used on the first and second test occasions as it was suitable for the age group of the participants at T1 and T2.

Productive Vocabulary. The caregivers filled out the Swedish Early Communicative Development Inventories (SECDI), the Swedish version of the MacArthur- Bates Communicative Development Inventories (Fenson et al., 1993). SECDI is a checklist of 710 words from different categories that are common in children's early vocabularies, and the version used was 'Words and sentences' which is the check-list designed for children aged 16 – 26 months (Berglund & Eriksson, 2000). To measure the participant's productive vocabulary, their caregivers administered the SECDI forms on all three test occasions (see timeline Figure 1). Caregivers were offered both verbal and written instructions on how to check off the words that filled the criteria for their child's productive vocabulary. Each word checked off by the caregivers in the SECDI counted as one point; and the maximum points a child could achieve was 710 points (Berglund et al., 2000).

Receptive Vocabulary. To measure the participant's receptive vocabulary, the study used Reynell IV which has been standardised for Swedish-speaking children in ages two to seven years old (Lundeborg Hammarström, Kjellmer & Hansson, 2016). Reynell IV is divided into two parts: receptive and productive (Lundeborg Hammarström et al., 2016). It was only administered at T3 (see timeline, Figure 1) and the receptive part, was the part used for the participants in this study. To achieve results that represented the child's ability well, the test administrator took into consideration the limitation of CI and how it could affect the child's understanding of verbal instructions. Therefore, the tests were administered after two to three years of hearing with CI and the test administrator had experience of administrating language tests on children with CI. It was found by Petersson and Strahl (2018) to be suitable in terms of time and concentration required from young children to continue the test. For every correct response from the child, a score of one was awarded and total score possible was 72. The results were then matched to the existing normative data for the chronologically age matched children, and provided a standardised percentile score. According to the test's manual, no repetition of the instruction was allowed, but the SLP provided a repetition of the instruction if instructions seemed not to be properly perceived or if the child was distracted. This was in line with the recommendations by Petersson and Strahl (2018), who found that the results were more reliable of the child's receptive abilities after repeated instructions and, gave a score of 0.5 for a correct response after repeated instruction. This way of scoring was therefore, also used in the present study.

Procedure

In Figure 1 a timeline for the procedure is presented. The data was collected on three different occasions- T1, T2 and T3. T1 took place 12 months after the CI activation, T2 took place at an average of 18 months after the CI activation and, finally T3 took place at an average of 31 months after the CI activation.

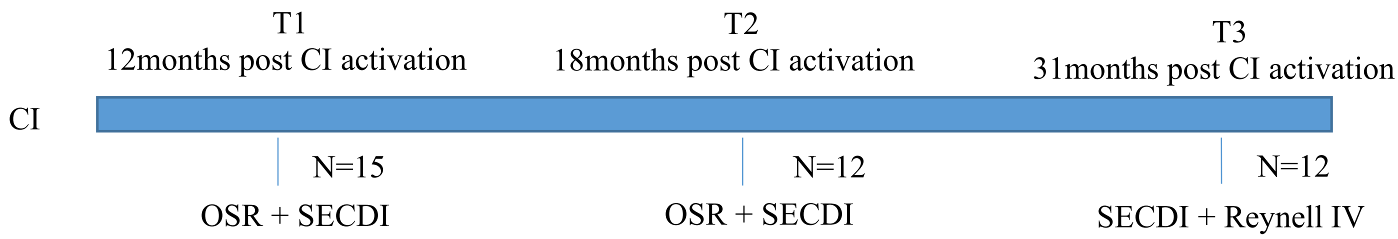

Figure 1. A timeline of the test occasions (T1, T2 and T3) with the tests/questionnaire administered at the different time points with an average of, 12 months, 18 months and 31months after the cochlear activation, along with number of participants participating at each time point.

The testing took place in a quiet room at an audiological clinic or at the summer camp in Sweden where the tests were administered by SLPs in the research team. To become familiar with the procedure and the administration of the tests and questionnaires the author of the present thesis attended one testing by the SLP at the clinic and tested one child with CI in his home.

For this thesis the author was provided with data of the participants included from the audiological clinic. From the clinic the author received an Excel file where all personal information was deleted, and included only data such as age at implant, age at activation, type of implant and processor and other demographic data as the age of the participants at the different test occasions, the primary language used at home and the type of preschool participants attended. The clinic also had access to the data collected during the summer camp, since some of the SLPs from the clinic administered the tests at the camp. In an effort to try and maintain the same number of participants throughout the test occasions, the supervisor of the present thesis had contact with the SLPs in the participants' home clinics who administered the SECDI and Reynell IV for two of the participants at T2 and T3, to make it easier for these participants and their families to continue in the present study.

Table 2 shows the participants' mean chronological age and mean hearing age and the total number of participating children at the three test occasions.

*Table 2***.** *The number of participants (N) for which we have information and the chronological and hearing age in months (mean and SD) of the participants at the time of the CI-activation and on the different test occasions. The total number of participants varies due to the absence of some of the participants at the time of the test administration.*

	N	**Mean (months)**	**SD (min-max)**
Age at CI- activation	15	15	6.5 (8-30)
Chronological Age at T1	15	27	7.1 (20-47)
Hearing Age at T1	15	12	2.1 (8-16)
Chronological Age at T2	12	32	7.0 (27-51)
Hearing Age at T2	12	18	2.2 (17-24)
Chronological Age at T3	12	47	11.5 (35-76)
Hearing Age at T3	12	31	8.7 (26-50)

Statistics and Data Analysis

All the collected data in the present thesis was analysed in version 25 of the software program IBM SPSS (Statistical Package for the Social Sciences). Since none of the variables were normally distributed, the correlations between the SECDI (T1, T2 and T3), the OSR test and Reynell IV were analysed using Spearman correlations (rho), with an alpha level of 0.05. The test results of the different tests administered were transferred to Excel in order to create illustrative graphs of the productive vocabulary growth of the participants.

Ethical Statement

The ethical committee of the Logopedics, Phoniatrics and Audiology at Lund University has approved the present study in January 2020. All the caregivers of the participants gave their written consent and were informed about the purpose and method of the thesis. All of the collected data was analysed in a pseudorandomised order and the author of this thesis had no knowledge of which code belonged to which child. Throughout the test administrations, the child's needs were taken into consideration and the test administration did not exceed 45 minutes, however it could be experienced as tiring for some participants. Furthermore, the tests took place at the planned appointments for the follow-up of the children with CI, thus, they were not required to come to the clinic just for the present study. However, the aim of the study, to develop an intervention program as a complement to currently offered language intervention programs was a motivating reason for the caregivers' participants to participate in the present study.

Results

The results of the participants will first be presented at the group level, followed by the individual development based on the three measures used: object shape recognition, productive vocabulary and receptive vocabulary. Finally, the correlations between the different measures will be presented.

Descriptive Data

The test results from the present thesis are presented in Table 3, which shows the descriptive statistics of the SECDI, the OSR tests and the Reynell IV tests conducted on the different test occasions. The results from the SECDI administered at T1, T2 and T3 were compared to the normative data of NH children's "Productive Vocabulary" between the age of 16 and 28 months from Berglund and Eriksson (Berglund & Eriksson, 2002). The mean hearing age and the mean chronological age of the participants at every test occasion were calculated and, then, compared to the 50th percentile score of the children with NH of that age. At T1, the mean hearing age was 12 months and, due to the absence of norm data from that age group, the results were compared to the norms for SECDI "Words and gestures", a very similar checklist for younger children. Both at T1 and T2, children with CI had a vocabulary size that exceeded the vocabulary size of hearing age peers. However, as presented in Table 3, the participants' productive vocabulary size at T3 was below the normal range of hearing age and chronological age peers. At T3, the participants' hearing age and chronological age was above 28 months and the norm data was therefore estimated by presuming a continued constant growth rate. This is of course not entirely correct, but was necessary in order to have data to compare to. Given this we can sum up, that only at the first two test occasions, the participants with CI had a mean SECDI score that was higher than their hearing age norm but lower than their chronological age norm.

Fifteen participants completed the object shape recognition test at T1, however two of the participants were identified as outliers, with scores higher than 1.00. A score higher than

1.00 was likely due to a guessing technique that the children adapted during the test and therefore these children were excluded from the data set for T1. The same participants, however, scored an adequate score six months later T2, and were therefore included in the analysis that followed at T2. For an estimation of the object shape recognition results, the results in the present thesis were compared to the results of the children with NH collected in Strahl's unpublished report (2017). The children with NH in her study were between the ages of 26 and 29 months at the time of the test and had a mean score of 0.88, which was higher than what the children with CI scored at T1 (0.78), with a mean chronological age of 27 months.

Of the thirteen participants who performed Reynell IV at T3, only two participants scored above the 10th percentile (compared to their chronological age) and, the rest had Reynell IV scores below the norm (between 0 and 8th percentile). In contrast, their age equivalence scores of the children with CI revealed that 66% of the participants performed adequately when compared to their hearing age.

In the following sections, the word *predict* will be used to explain the longitudinal correlations between the vocabulary measures. There was no regression analysis done in the present study.

Table 3. Descriptive statistics of the test results conducted in the present thesis. The rows with the SECDI scores include the age in months (m) and, the norm data of the chronological age and hearing age peers from Berglund and Eriksson (2000). The row with the OSR score includes the reference score on the OSR test from Strahl's (2017) report of children between the age of 26 – 29 months.

	N	Median	Min	Max	Mean	Std. Dev.
SECDI T1 (Total points =710)	15	53	0	529	104	144
Norm Score						
Hearing age (12m)					5	
Chronological age (27m)					375	
SECDI T2 (Total points =710)	9*	112	15	394	135	136
Norm Score						
Hearing age (18m)					35	
Chronological age (32m)					650	
SECDI T3 (Total points =710)	12	476.50	187	695	443	175
Norm Score						
Hearing age (31m)					650	
Chronological age (47m)					900	
OSR T1	13**	0.85	0.00	1.00	0.78	0.27
Reference Score					0.88	
OSR T2	11	0.90	0.00	1.00	0.80	0.30
Reynell IV percentile T3	13	1.00	0	42	6.08	11.36
Reynell IV (Total points =72)	13	36	1	57	35.08	16.45

**N=9 SECDI was not returned to the audiological clinic.*
***N=13 Total number of participating children at the T3.*

Object Shape Recognition

Figure 2 shows how children with CI performed on the OSR test compared to the children with NH from Strahl's (2017, unpublished report). Only T1 is illustrated because the children from the reference group were between the age of 26 – 29 months matching the mean chronological age of the participants from the present thesis at T1. The linear regression line follows the OSR performance of children with CI versus children with NH from Strahl's report (2017). Five of the participants from Strahl's unpublished report (2017) had a chronological age that matched the participants of the present study, therefore only five reference scores (x) are presented. Children with CI were not able to identify as many pictures as children with NH in the same chronological age group and had lower performance score on both parts than the participants from Strahl's unpublished report (2017).

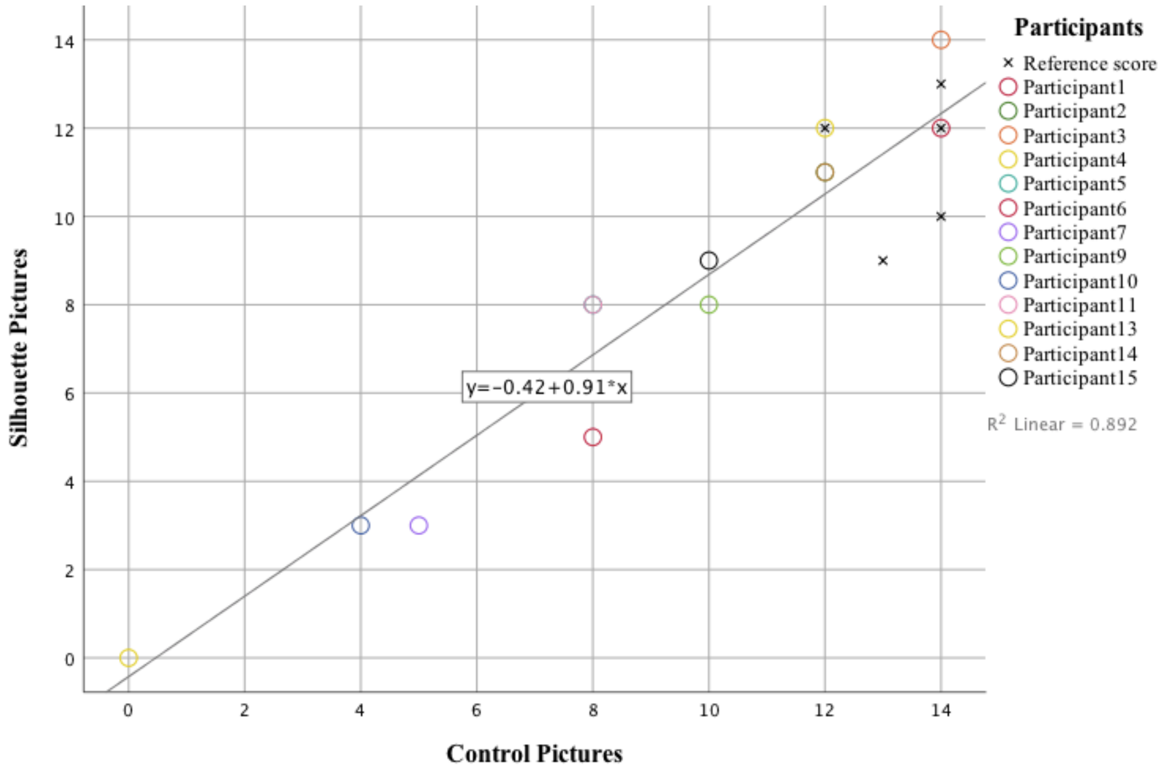

Figure 2. A scatter plot representing the participants' performance on both sections (silhouette and control) of the OSR test at T1. Every circle in the graph represents the participants' score from the study and, reference score (x) represents the performance of the five participants from the reference group of Strahl's report who had a matching chronological age to the children in the present study (2017).

Productive Vocabulary Growth (SECDI)

Figure 3 shows the participants' individual productive vocabulary growth. Some participants went through a significant development phase in their productive vocabulary between T1 and T2; others had a more significant development phase between T2 and T3. Two participants, presented as "Participant6" and "Participant15", were the children with the highest SECDI scores at T3. Both participants, 6 and 15, are boys who come from Swedish-speaking families and for whom spoken Swedish is the primary language used at home. Both participants attended preschool for children with hearing loss and their mothers have university degrees. Participant 6 had a hearing age of 27 months and a chronological age of

51 months at T3. As for receptive vocabulary, he scored in the 42th percentile on Reynell IV, which was adequate for his chronological age. Participant 15 had a hearing age of 26 months and a chronological age of 35 months at T3. Participant 15 had score equivalent to percentile 12 in Reynell IV, which puts him above the hearing age norm. Participants 6 and 15 differ in their vocabulary size in the beginning of the SECDI administration, however both seem to go through a vocabulary spurt between T2 and T3. The other children with SECDI scores among the normal and lower range varied in their vocabulary development: some moving gradually, with others going through an increase in vocabulary size after T2. In general, children with CI had a productive vocabulary size similar to that of children with the same hearing age at T1 and T2. Then at T3, the vocabulary size became smaller than both hearing age and chronological age peers. When comparing the productive vocabulary size of children with CI to children with NH of the same chronological age throughout the three test occasions, it was smaller.

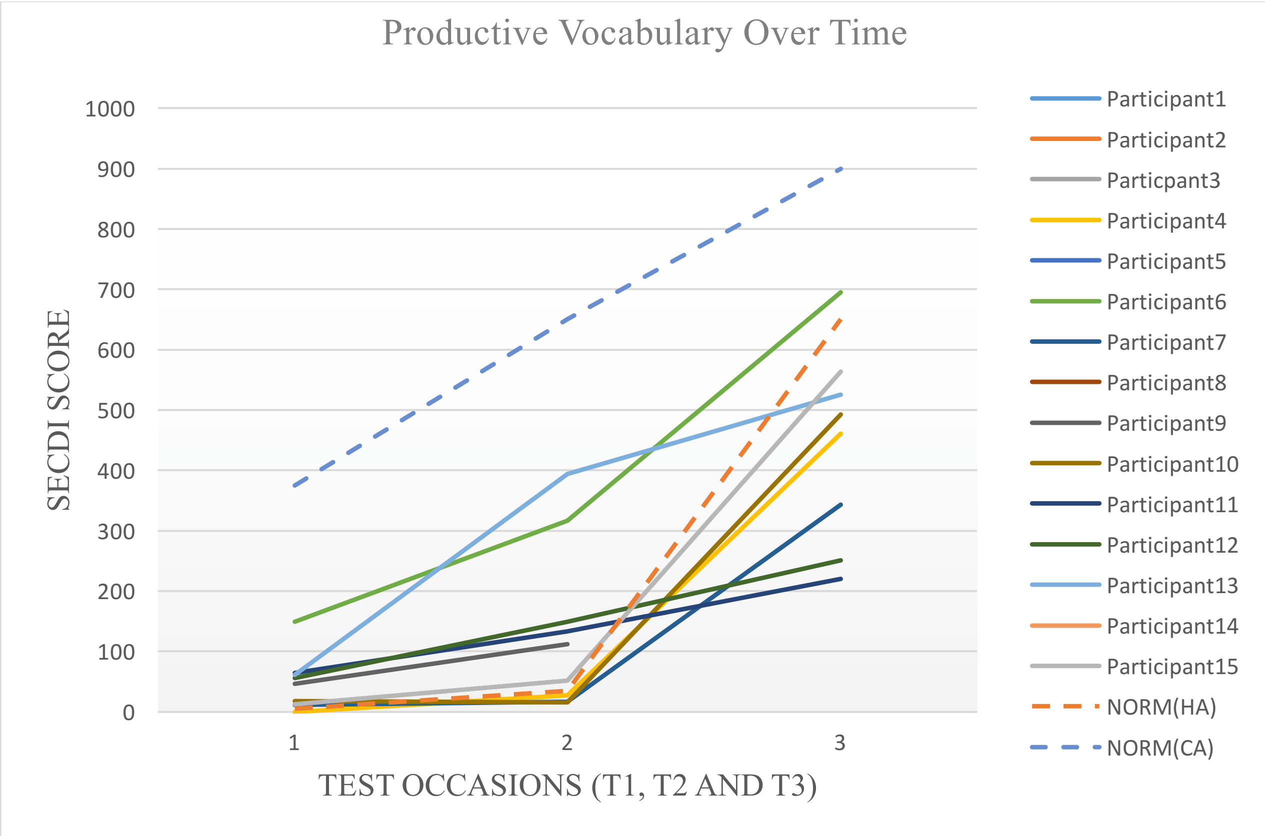

Figure 3. Individual profiles of the participants' productive vocabulary at T1(N=15), T2(N=9) and T3(N=12). Every line represents a participants' productive vocabulary over the three test occasions (T1, T2 and T3). (--) The blue dotted line represents the productive vocabulary from the norm data of children with NH of the same chronological age (CA) as the participants. (--) The orange dotted line represents the productive vocabulary from the norm data of children with NH of the same hearing age (HA) as the participants.

Receptive Vocabulary Growth

Figure 4 and 5 show the performance of the participants on their receptive vocabulary assessment (Reynell IV) at T3 in relation to their chronological age peers and hearing age peers' performance from the norm data.

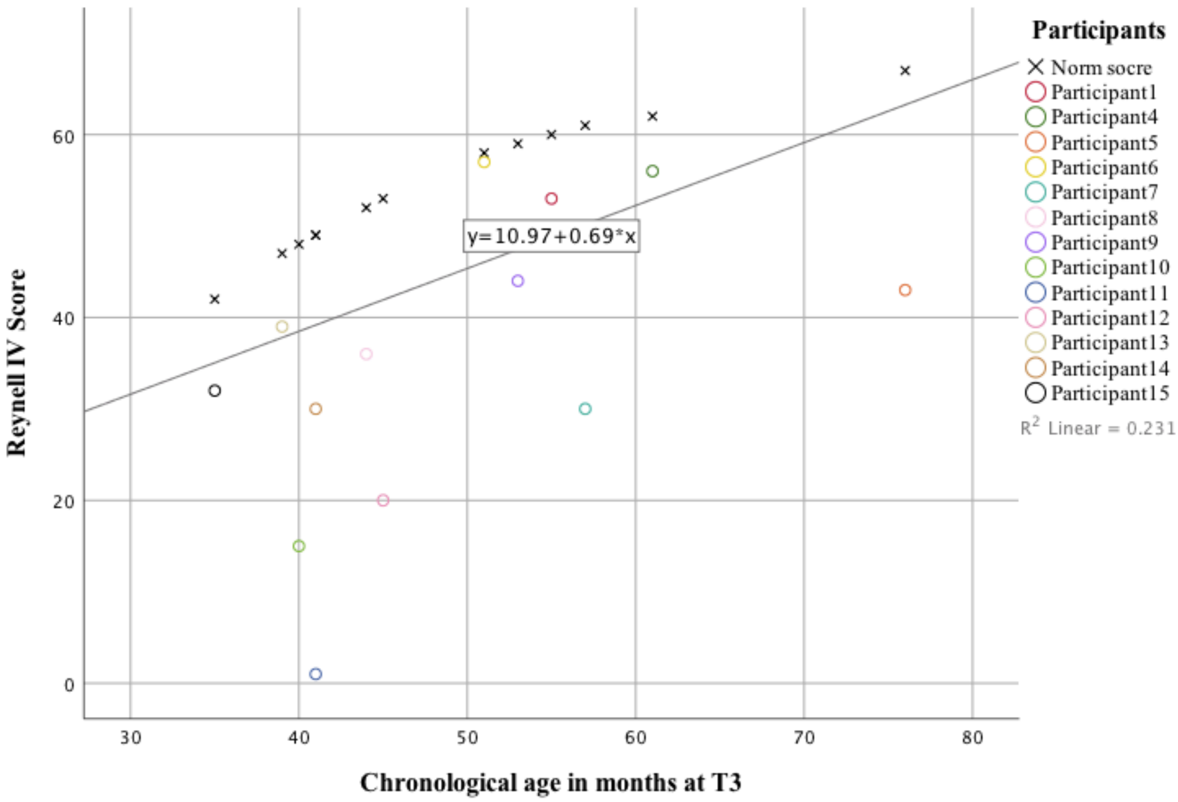

Figure 4. A scatter plot representing the receptive vocabulary measured using (Reynell IV) of the participants at T3, in relation to the norm data of their chronological age peers. Every circle represents a participants' Reynell IV score from T3. (x) represents the Reynell IV scores of the norm data for children in the same chronological age group as the participants. The regression line represents the participants' score on Reynell at T3.

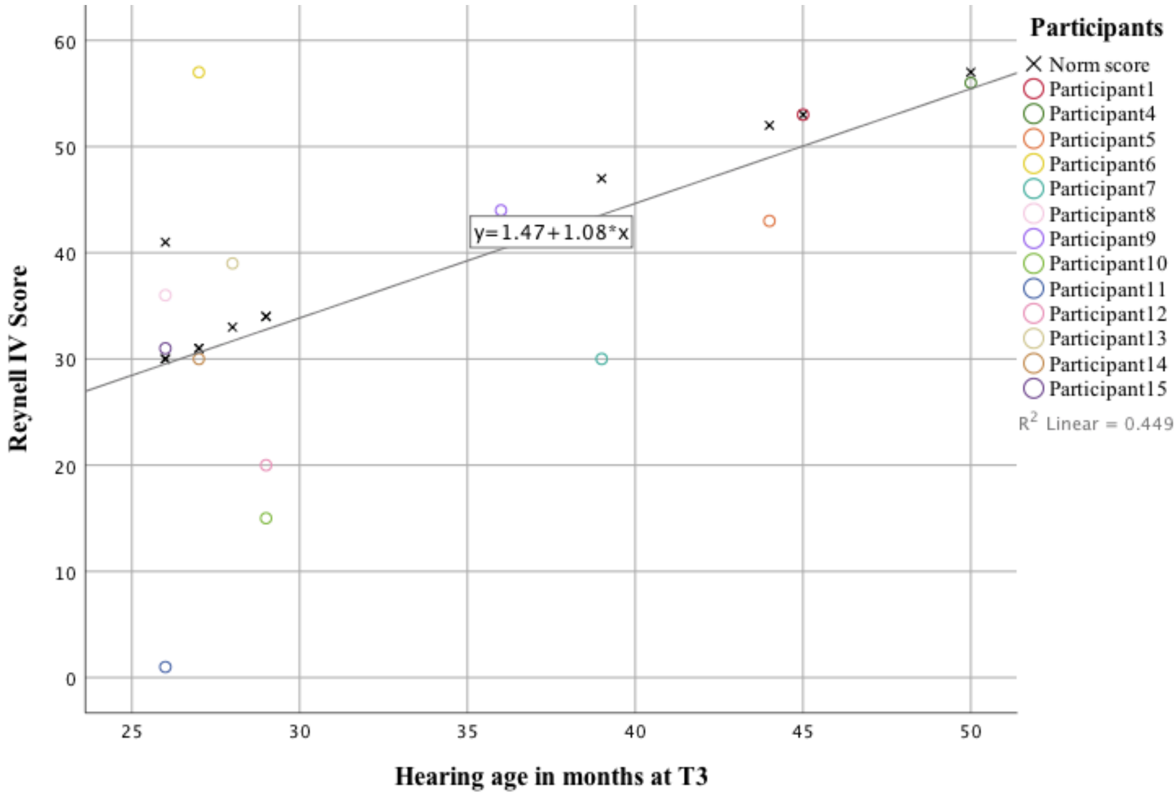

Figure 5. A scatter plot representing the receptive vocabulary measured using Reynell IV at T3, in relation to norm data of their hearing age peers. Every circle represents a participants' Reynell IV score from T3. (x) represents the results of the norm data for children in the same hearing age group as the participants. The regression line represents the participants' score on Reynell at T3.

Figure 4 and Figure 5 illustrate the clear difference in the performance of the participants, when compared to children of the same chronological age versus children of the same hearing age. When compared to children of the same chronological age, the majority of the participants' performance were below the norm. The regression line fitted to model the data in Figure 4 indicates that participants older in age performed better on Reynell IV, however, they still did not match the chronological age peers. The regression line in Figure 5, on the other hand shows that 66% (8 of 12) of participants' performance on the receptive vocabulary test (Reynell IV), was equivalent or close to the norm data for the same hearing age.

Correlations between the test of Object Shape Recognition, SECDI and Reynell IV

In Table 4, the correlation analysis between SECDI at T1, T2 and T3, the OSR test at T1 and T2 and the receptive vocabulary (Reynell IV) at T3 is presented.

Table 4. Calculations of correlations between SECDI (T1, T2 and T3), object shape recognition (T1 and T2) and Reynell IV (T3).

	1	**2**	**3**	**4**	**5**	**6**
SECDI T1						
Spearman's rho						
p-value						
N						
SECDI T2						
Spearman's rho	**.800**					
p-value	0.010					
N	9					
SECDI T3						
Spearman's rho	.196	.238				
p-value	.542	.570				
N	12	8				
OSR T1						
Spearman's rho	**.815**	**.790**	-.043			
p-value	.001	.020	.906			
N	13	8	10			
OSR T2						
Spearman's rho	.439	.457	.450	.334		
p-value	.177	.255	.192	.379		
N	11	8	10	9		
Reynell IV T3						
Spearman's rho	-.191	.420	**.654**	-.231	.369	
p-value	.532	.260	.021	.494	.264	
N	13	9	12	11	11	

The results from the productive vocabulary measure, the SECDI, correlated significantly with the results of the OSR test at T1 (rho=0.81, p=0.01, N=13). Performance on the OSR test at T1 also predicted the results of the SECDI at T2 (rho=0.79, p=0.02, N=8). There was no significant correlation between the OSR at T2 and the SECDI at T2 and T3. There was no significant statistical correlation between the SECDI at T1 and T2 in relation to the Reynell IV at T3. However, the productive vocabulary assessment using the SECDI at T3 correlated significantly with the receptive vocabulary assessment using Reynell IV at T3 (rho= 0.65, p=0.07, N=12). The results of the OSR test at T1 and T2 did not show any significant effect on receptive vocabulary assessment using Reynell IV at T3 and there was no significant correlation between the OSR test and Reynell IV. The caregivers filled out the SECDI questionnaire at all three time points and the correlation analysis showed a significant correlation between the SECDI at T1 and T2 (rho=0.80, p= 0.01). No significant correlation was found between the SECDI at T1 and T3 and the SECDI at T2 and T3.

Summary of Results

- Children with CI performed below the mean score of children with NH on the OSR test from the reference group in Strahl's unpublished report (2017).
- Participants with CI seem able to catch up to the mean productive vocabulary size of norm data for the same hearing age. However, their productive vocabulary size was smaller than that of the norm data for the same chronological age.

- Children with CI performed on the receptive vocabulary assessment, Reynell IV, adequately in comparison to hearing age children. However, the majority's performance was below the norm data of chronological age scores.
- Two to three years after CI activation, children's productive vocabulary size was significantly correlated to their receptive vocabulary skills.
- Children who had better object shape recognition abilities and larger productive vocabularies at T1 tended to still have relatively larger productive vocabularies six months later at T2.
- Although OSR ability was related to concurrent productive vocabulary size at T1 and six months later, it did not predict language skills (productive or receptive) at T3, in children with CI. Thus, there seems to be an association between OSR and vocabulary skills concomitantly but weak evidence for a longitudinal association e.g. 2-3 years after CI activation.

Discussion

The overall purpose of the present study was to describe the vocabulary development, both receptive and expressive and, the object shape recognition ability of a group of children with CI. The first aim was to explore how three aspects of vocabulary (OSR, expressive and receptive vocabulary) develop during the first 2-3 years after the cochlear activation. To sum up, the performance of the participants on the tests and questionnaire that were used at T1, T2 and T3 displayed a wide individual variation in the vocabulary development. An interesting finding was that at 18 months after the CI activation (T2) the participants seemed to go through a vocabulary spurt (see Figure 3); which seemed to take place irrespective of the productive vocabulary size, and which varied considerable at T2.

The second aim was to compare the vocabulary development in children with CI to that of children with NH. The results from the tests and questionnaire were compared to existing chronological age and hearing age norms and reference data from studies of children with NH. The productive vocabulary size according to caregivers at T1 and T2 exceeded the vocabulary size of hearing age norms, but at T3 the productive vocabulary size was below the range of hearing age peers. From the assessment of the receptive vocabulary at T3, the results indicated that during the time frame of the present study, children with CI performed very close or equivalent to children of the same hearing age. However, in relation to the chronological age norm data, the participants' performance was not on par with children with NH.

Thirdly, an exploration of how the three measures of vocabulary were associated to each other and, specifically whether OSR at T1 or T2 could predict vocabulary development two years later, was made. A correlation analysis was conducted in order to explore the relationships both concomitantly and longitudinally. The findings from this study showed that the OSR ability was not significantly correlated to later vocabulary skills and could neither predict the child's performance on the receptive test (Reynell IV) nor the productive vocabulary (SECDI) at T3. The participants' productive vocabulary as estimated by their caregivers significantly correlated with their performance on the receptive vocabulary assessment at T3. The following section will discuss the results in depth.

Object Shape Recognition in Relation to Vocabulary Development

A specific research question in the present study was whether OSR can predict vocabulary development in children with CI. Previous studies evaluating OSR in relation to vocabulary development have suggested that OSR can predict a typically developing child's vocabulary skills at a later age (Smith et al., 2002; Gershkoff-Stowe & Smith, 2004; Borgström et al., 2019). The findings from Borgström et al (2019) suggests that the ERP of OSR at 20 to 24 months (2015) was a significant predictor of the children's vocabulary skills 4-5 years later (Borgström et al., 2019). The present study is the first to explore whether there is a similar relationship between OSR and the development of vocabulary in children with CI over a shorter period of time, 2-3 years after CI activation and by using a physical version of the same test without the ERP measurement. The findings from the present thesis found no significant correlation between the participants' performance on the behavioural OSR test and the vocabulary development 2–3 years later. Our finding is, however, in line with Petersson and Strahl's (2018) results in their master's thesis, where they investigated whether the OSR in 26–29-month-old children could predict their vocabulary six months later. They found that this particular OSR test did not predict their participants' vocabulary skills within this short period (Petersson & Strahl, 2018). Considering the results from the two earlier studies on children with NH, the question is motivated, whether OSR can predict vocabulary development in a longer time period in children with CI.

Although the performance of the participants with CI on the OSR test in this study did not predict their productive and receptive vocabulary 2-3 years later, it is important to note the concomitant relationship, showing that, at T1, there was a significant correlation between SECDI and OSR (rho= 0.815, p=0.01, N=13), as presented in Table 4. Thus, children with CI with a larger productive vocabulary size performed better on the OSR test than children with a smaller productive vocabulary size. This result is consistent with the findings in the study of Smith (2003), showing that children with a vocabulary size exceeding 100 words were able to perform better on OSR tasks than those with vocabulary size below 100 words. The participants in this study had an average of 104 words at T1. The importance of OSR ability in children between the ages of 18 and 24 months is not limited only to predict their vocabulary size; this ability is primarily considered to support children in their word learning at a particular stage of vocabulary development (Golinkoff et al., 2012). In the present study, the children with CI with better OSR performance and larger vocabulary at T1 continued to have larger vocabularies at T2 as can be seen in the correlation analysis in Table 4 (rho=0.790, p=0.020, N=8). This suggests that the OSR can predict vocabulary development later on, even in children with CI.

To relate the performance of children with CI on the OSR test to children with NH, the participants' results were compared to the results of chronological age children with NH from Strahl's unpublished report (2017). It is important to bear in mind that this comparison is not based on standardised data, the scores from the Strahl's report were considered only as a reference for the present thesis. The comparison made here only suggests that children with CI performed worse than few children with NH on the OSR test. There was an improvement noted in the scores between T1 and T2, from a mean ratio score of (0.78) to (0.80), but it was still lower than the (0.88) of the children with NH. This was a somewhat an unexpected result, because the participants from the present study were older than the children with NH and possibly more cognitively mature. Even with limited auditory input their visual perceptual skills and cognitive maturity could be expected to have their supported their OSR ability. This was in fact shown in a previous study by Vavatzanidies et al. (2018) where they found that the cognitive faculties supported children with CI after the implantation and they were able to display a semantic processing in the form of N400 effect at the hearing age of 12 months which was considered even earlier than that of children with NH and of the same hearing age. The N400 effect is an ERP measurement that was used when testing the participants' semantic processing. When a child incorrectly matches a label to its object, an increase negativity takes place and this is referred to as N400 effect (Vavatzanidies et al., 2018).

Due to the small sample size of participants in the present thesis, all results should be considered with caution. The sample size may have been a reason for the lack of significant correlations between the scores from the OSR test and the other measures.

Productive Vocabulary Growth at T1, T2 and T3

Children with CI displayed a wide variation in their productive vocabulary development according to the caregivers' estimation (SECDI). There are several individual related factors that have been associated with improved vocabulary growth in children with CI, such as the with the CI implant and time for activation, their mothers' level of education and the quality of auditory input the child receives after the CI activation (Välimaa, et al., 2017; Chen et al., 2019). However, different studies seem to agree that children with CI remain below the norms of chronological age peers when it comes to the development of productive vocabulary in the first few years after the CI activation (Lund, 2016). Välimaa et al (2017) studied the development of early vocabulary in 20 Finnish children who had received bilateral CI at a mean age of 12 months. The results showed that 55% of the participants, during the first year of CI use, had significantly lower scores compared to the norms of children with NH (Valimaa et al., 2017). The findings of the present thesis indicate that the participants' productive vocabulary as reported by their caregivers was below the chronological age norms at all test occasions. However, at T1 and T2 the participants' productive vocabulary was larger than the norm data for children of the same hearing age. A possible explanation for the larger vocabulary size at T2 and T2, may be that caregivers so shortly after the CI activation have great expectations about word production. They may be very observant at early signs of what they perceive as word productions and may therefore overestimate their children's productive vocabulary.

On the three test occasions, there was a great individual variation in the participants' productive vocabulary size (SECDI). This was the case even at T3 where the participants had a mean hearing age of 31months, and the vocabulary size varied between 476 and 695 words (STD =175). This great variation has also been emphasized in previous studies and was explained by various factors such as quality of auditory input and language level used by caregivers in a study by Chen, Castellanos, Yu and Houston (2019). Another finding in the present study was that, at T2, when the participants had a mean hearing age of 18 months, most of the participants had a score that exceeded 100 words and the mean productive vocabulary score was 135 words. This could suggest that the children with CI went through a vocabulary spurt at a mean time period of 18 months after the CI had been activated.

The small size of participants and wide variation in age allowed us to analyse the individual vocabulary development of the participants (Figure 3). An encouraging trend was observed: 14 out of 15 participants at T1, 12 months after CI activation, were able to exceeded the norm score of hearing age peers in SECDI. However, unexpectedly at, T3 the participants' mean vocabulary size (SECDI) suddenly dropped below the normal range of hearing age peers as presented in Table 3. The developmental process of productive vocabulary may be different in children with CI compared to children with NH. There may also be periods of receptive vocabulary growth with few words uttered that is not captured in the caregivers' estimation of productive vocabulary at a certain time point. Periods of receptive development might only be mirrored in word production after a longer period of time. Löfkvist et al. (2013), investigated the vocabulary development of 34 Swedish-speaking children with CI and compared them to children with NH. They found that the participants at the age of 6 to 9 years had a productive vocabulary equivalent to chronological age children as measured by Boston Naming Test (BNT). It would be interesting to investigate the present group of children at a later age, in order to explore whether their productive vocabulary have caught up with that of children with NH.

Receptive Vocabulary at T3

One of the aims of the present study was to describe the development of three aspects of vocabulary development: OSR, productive and receptive vocabulary. So far, we have described the OSR and productive vocabulary. Finally, the receptive vocabulary was assessed, at T3, when the children had a mean hearing age of 31 months and had been exposed to auditory language for a reasonable amount of time to be able to perform a formal receptive language test such as Reynell IV. The results showed that the participants' scores were very close or equivalent to the hearing age norms. However, in relation to chronological age norms, the participants did not catch up within 2-3years of CI use with chronological age peers. In spite of advances in CI, a child's hearing is not restored to the normal levels and CI users receive degraded levels of auditory input which could lead to difficulty in the comprehension of verbal instructions. This was also why Reynell IV was administered at T3 after the child have had two to three years of CI use. Furthermore, the receptive tests are not developed specifically for children with CI, the SLP testing the child supported participants by offering repetition of the instructions if the child seemed distracted or showed signs of not perceiving the instructions accurately.

Receptive and Productive Vocabulary

After describing the development of the three aspects of vocabulary development (OSR, productive and receptive vocabulary), we explored how these three aspects were related to each other, both concomitantly and longitudinally. As for the concomitant relationships, we found that the participants' productive vocabulary was significantly related to their receptive vocabulary skills when measured at T3, 2-3 years after the CI activation. Children with a larger vocabulary size also performed the highest on Reynell IV. Longitudinally, there is evidence that early vocabulary size is strongly related to the receptive vocabulary skills and to other language competencies at a later age (Rescorla & Turner, 2015; Fölster & Hansson, 2016). Thus, there is reason to believe that the use of the SECDI questionnaire can facilitate the identification process of children with CI that require intervention, with the purpose of reducing, the well-known gap (Hansson et al., 2018) for linguistic skills between children with CI and chronological age peers with NH by the time of school start.

A finding was that at T3, the participants' receptive skills as measured by the formal test Reynell IV, seemed better than their productive vocabulary skills as measured by SECDI, in relation to hearing age peers. It should be noted that the measures are quite different, one is a parental estimation and one is formal test of very young, sometimes not optimally participating young children. Interpretations should therefore be cautious. A discrepancy could, however, be explained by the fact that the majority of the participants and their caregivers have received audio-verbal therapy (AVT), a family-centred intervention that focuses on the communication between the caregivers and their child up to the age of three years (AG Bell Academy, 2012). The focus is on caregivers' responses to the child's initiatives, their use of child-directed spoken language and support of the child's listening skills. Thus, the intervention provides a lot of support for the receptive aspect of the vocabulary development.

Methodological Discussion

A common trend in longitudinal studies is that participants tend to miss some test occasions throughout the time frame of the study for various reasons. In addition to that, the use of a questionnaire, which, sometimes, is not sent back to the clinic, also leads to missing data. Both factors lead to missing data from some of the participants who could have added significant results to the study.

The participants from the present study were recruited from an audiological clinic in southern Sweden and a summer camp for children with CI. Seventy-three percent of the participants' mothers had a university degree and, 33% of the families had heredity for language disorders. Both percentages are considered high and may have contributed to the performance of the participants. For example, the two participants who had the highest scores in SECDI and Reynell IV, both had a mother with a university degree, which supports studies showing that children who come from higher SES have larger vocabulary (Fernald, Marchman & Weisleder, 2013). Heredity for language disorders is also an additional risk factor for a child with hearing loss and therefore important to take into consideration when administering language tests.

The present study has chosen to study children's performance on an OSR test, which was adapted from an experimental task from Borgström et al. (2015) and was identical to the test used in Strahl's unpublished report (2017). The test was measured using ratio scores. Ratio scores were considered the most suitable, in terms of measuring and capturing the specific ability of children to recognise objects shapes and not measuring and capturing comprehensions skills of the child. However, the ratio scores have limitations. For example, a participant who was able to match all 14 silhouette pictures and all 14 control pictures scored 1.0 on the test. A participant who matched 9 silhouette pictures and 9 control pictures also scored 1.0. This means that the second participant did not have the object names in his vocabulary and therefore, could not recognise the rest of the objects in the test. This has led us to question the reliability of the ratio score used in the present thesis, because it could have affected the interpretation of the correlation analysis. However, it was important to use that score in order to ensure the validity of the test and to test the ability in recognising shape independent of the comprehension of the objects' label. It is also important to note that the OSR stimuli used in this test is quite different to the stimuli used in most of the literature on the shape bias and shape recognition, in which three-dimensional objects is the standard. It is therefore possible that it does not capture the same recognition process as the other studies.

The OSR has no norm data; however, we have used data from Strahl's unpublished report (2017) and Petersson and Strahl's (2018) master's thesis as reference data for the present thesis. This was necessary for the analysis of the results, but, the age group from this study and Strahl's unpublished report (2017) was not entirely the same. Using the reference data gave us a general idea of the performance of children with CI on the OSR test but the comparison cannot be said to be completely accurate and interpretations must be very careful.

SECDI has shown significant results in the present thesis. However, it only has norm data for the ages between 16 to 26 months. The participants' age in the present study varied beyond that age group. Both the participants' hearing age and chronological age were taken into consideration in relation to the norm data and there was a wide variation in age. At T2 all the participants had a hearing age that was between 16 and 26 months, however, their chronological age at that time did not have matching norm data. The same applies to T1 and T3 and this could have reduced the confidence in the interpretation of the participants' performance.

There is a lack of valid and reliable assessment tools for spoken vocabulary development in young children NH and in children with CI. In a recent study by Karltorp et al. (2019), the language development of Swedish children with CI was studied in relation to the age at which the CI operation took place. The authors used the Reynell IV with norm data from an English paediatric population and the Peabody Picture Vocabulary Test was used with norm data from the American version of the test. This may question the validity and reliability of the results in studies lacking norms or reference data for Swedish-speaking children and strongly calls for the development of a reliable tests for children with CI. Receptive vocabulary assessment tools must take into consideration the special needs children with CI may have (Lund, 2016).

Future Research

This is the first study to investigate the OSR ability in children with CI and, the research is still considered to be in its early stages. More research on the OSR ability is of importance. Knowledge is needed about whether it can predict later language skills and if it can be used in intervention in children with CI. It is therefore recommended to continue the development of an OSR test to develop a stronger level of reliability and validity. The training of smart attention and shape recognition may have potential, especially for children that require that kind of boost in order to acquire adequate vocabulary skills.

Conclusions

The present study has explored the vocabulary development of young children with CI at three occasions during a period of two to three years after the CI activation. We can conclude from our findings that there was a great variation observed in the participants' vocabulary development throughout study's time frame. The participating children's receptive vocabulary scores did not reach the level of chronological age peers but they achieved scores very similar to their hearing age peers. As for the productive vocabulary, based on the caregivers' estimation, the participants' vocabulary size two to three years after the CI activation, was smaller than the vocabulary size of chronological age and hearing age peers. The study also had a special interest in the object shape recognition, and it was found that it could predict neither the children's performance in the receptive test (Reynell IV) nor the productive vocabulary size (SECDI) within this relatively short period of time of two to three years. However, it may turn out to be a predictor of vocabulary in later follow-ups of the participants with CI, as shown in earlier studies of children with NH. Vocabulary development is central for language proficiency and school success; therefore, it is crucial to continue following the vocabulary development of children with CI.

Acknowledgments

I would like to express my great appreciation to my supervisors, Birgitta Sahlén, Kristina Borgström and Malin Lindgren who have been so generous with their time and guided me through every stage of this thesis and, especially in the presentation of our results. Tack! I would like to say thank you to all the families who have participated in the study and to the CI-team in Lund who have allowed me to take part and use their collected data. Finally, I want to thank my family for all their support!

References

Alberg, J., Wilson, K., & Roush, J. (2006). Statewide Collaboration in The Delivery of EHDI Services. *The Volta Review*, *106*(3), 259-274. AG Bell Academy for Listening and Spoken Language (2012).

Adamson, L.B., Bakeman, R., & Deckner, D. F. (2004). The Development of Symbol-Infused Joint Engagement. *Child Development, 75*(4), 1171-1187. https://doi.org/10.1111/j.1467-8624.2004.00732.x

Berglund, E., Eriksson, M., & Westerlund, M. (2005). Communicative Skills in Relation to Gender, Birth Order, Childcare and Socioeconomic Status in 18-month-old Children. *Scandinavian Journal of Psychology, 46*(6), 485- 491. https://doi.org/10.1111/j.1467-9450.2005.00480.x

Bergeson, T. R., Houston, D. M., Miyamoto, R. T. (2010). Effects of Congenital Hearing Loss and Cochlear Implantation on Audiovisual Speech Perception in Infants and Children. *Restorative Neurology and Neuroscience,* 28, 157-165. Doi:10.3233/RNN-2010-0522

Bloom, P. (2000) How Children Learn the Meanings of Words. MIT Press, Cambridge

Borgström, K., Torkildsen, J. v. K., & Lindgren, M. (2015a). Event- Related Potentials During Word Mapping to Object Shape Predict Toddlers' Vocabulary Size. *Frontiers in Psychology*, 6(43). doi: 10.3389/fpsyg.2015.00143

Borgström, K., Torkildsen, J. v. K., Sahlén, B., & Lindgren, M. (2019). Brain Measures of Toddlers' Shape Recognition Predict Language and Cognitive Skills at 6-7 Years. *Frontiers in Psychology, 10*(1945). doi: 10.3389/fpsyg.2019.01945.

Chen, C., Castellanos, I., Yu, C., & Houston, D.M. (2019). Parental Linguistic Input and Its Relation to Toddlers' Visual Attention in Joint Object Play: A Comparison Between Children with Normal Hearing and Children with Hearing Loss. *International Congress of Infant Studies,* 1-24. doi: 10.111/infa.12291.

Colunga, E., & Smith, L. B. (2008). Knowledge Embedded in process: The Self-Organization of Skilled Noun Learning. *Developmental Science, 11*(2), 195-203. Doi:10.1111/j.14677687.2007.00665.x

Dapretto, M., & Bjork, E. (2000). The Development of Word Retrieval Abilities in the Second Year and its Relation to Early Vocabulary Growth. *Child Development, 71,* 635-648.

Dixon, W. E. & Smith, P. H. (2000). Links Between Early Temperament and Language Acquisition. *Mernill- Palmer Quarterly, 46*, 417-440.

Duchesne, L., Sutton, A. & Bergeron, F., 2009, Language Achievement in Children Who Received Cochlear Implants Between 1 and 2 Years of Age: Group Trends and Individual Patterns. *Journal of Deaf Studies and Deaf Education, 14*, 465-485.

Fernald, A., Marchman, V. A., & Weisleder, A. (2013). SES Differences in Language Processing Skill and Vocabulary Are Evident at 18 months. *Developmental Science, 16*(2), 234-248. https://doi-org.ludwig.lub.lu.se/10.1111/desc.12019.

Fölster, A., & Hansson, J. (2016). Tidigt Ordförråd och Formigenkänningsförmåga Kan Förutsäga Språkliga Förmåga i 6 – 7 Års Åldern (Master's thesis). Lund: Instutionen för kliniska vetenskaper, Lunds universitet. http://lup.lub.lu.se/student-papers/record/8889473.

Ganger, J., & Brent, M. R. (2004). Reexamining the Vocabulary Spurt. *Developmental Psychology, 40*(4), 621-632. https://doi-org.ludwig.lub.lu.se/10.1037/0012-1649.40.4.621

Geers, A. E., Nicholas, J., Tobey, E., & Davidson, L. (2016). Persistent Language Delay Versus Late Language Emergence in Children with Early Cochlear Implantation.

Journal of Speech, Language, and Hearing Research. 59(1), 155-170. Doi:10.1044/2015_JSLHR-H-14-0173
Geshkoff-Stowe, L., & Smith, L. B. (2004). Shape and The First Hundred Nouns. *Child Development, 75*(4), 1098-1114/j.1467-8624.2004.00728.x
Goliknkoff, R.M., Pasek-Hirsh, K., Bloom, L., Smith, L.B., Woodward, A.L., Akhtar, N., … Hollich, G. (2012). Become a Word Learner: A Debate on Lexical Acquisition. *Oxford University Press.* Doi: 10.1093/acprof:oso/978019530324.001.0001
Hansson, K., Ibertsson, T., Asker-Árnason, L., & Sahlén, B. (2018). Language Impairment in Children with CI: An investigation of Swedish. *Lingua,* 213, 63-77. Doi:10.1016/j.lingua.2018.07.001.
Hoff, E. (2014). *Language Development* (5th ed.). Wadsworth, Cengage Learning.
Hoff, E., & Naigles, L. (2002). How Children Use Input to Acquire Lexicon. *Child Development, 73,* 418-433. https://doi.org/10.1111/1467-8624.00415
Jones, S.S., & Smith, L.B. (2005). Object Name Learning and Object Perception: A Deficit in Late talkers. *Journal of Child Language, 32*(1), 223-240. doi: 10.1017/S0305000904006646.
Karltorp, E., Eklöf, M., Östlund, E., Asp, F., Tideholm, B., Löfkvist, U. (2019). Cochlear Implants Before 9 Months of Age Led to More Natural Spoken Language
Development Without Increased Surgical Risks. *Acta Peadtiatrica (Oslo, Norway; 1992).* 2020;109:332-341. Doi:10.1111/apa.14954.
Landau, B., Smith, L., & Jones, S. (1988). The importance of Shape in Early Lexical Learning. *Cognitive Development, 3,* 299-321. Doi:https://doi.org/10.1016/0855-2014(88)90014-7
Lundeborg Hammarström, I., Kjellmer, L. & Hansson, K. (2016). Swedish translation: *The New Reynell Developmental Language Scales. London* Stockholm: Hogrefe.
Lund, E., & Douglas, W. M. (2016). Teaching Vocabulary to Preschool Children with Hearing Loss. *Exceptional Children, 83*(1), 26-41.
Löfkvist, U., Bäckström, K., Dahlby-Skoog. M., Gunnarsson, S., Persson, M., Lohmander, A. (2019). Babbling and Consonant Productive in Children with Hearing Impairment
Who Use Hearing Aids or Cochlear Implants- a Pilot Study, *Logopedics Phoniatrics Vocology.* Doi: 10.1080/14015439.2019.1695929
Löfkvist, U., Almkvist, O., Lyxell, B. & Tallberg, I. M. (2013). Lexical and Semantic Ability in Groups of Children with Cochlear Implants, Language Impairment and Autism Spectrum Disorder, *International Journal of Peadiatric Otorhinolaryngology, 78*(2),
253-263.https://doi.org/10.10106/j.ijporl.2013.11.017.
Nettebladt, U., Salameh, E-K. (Red). (2007). *Språkutveckling och språkstörning hos barn. Del 1, fonologi, grammatik, lexikon*. Lund: Studentlitteratur AB.
Partanen, E., Kujala, T., Näätänen, R., Liitola, A., Sambeth, A., & Huotilainen, M. (2013). Learning-Induced Neural Plasticity of Speech Processing Before Birth. *Proceedings of the National Academy of Sciences, 110*(37), 15145-15150. doi: 10.1073/pnas.1302159110
Periera, A.F., & Smith, L.B. (2009). Developmental Changes in Visual Object Recognition Between 18 and 24 Months of Age. *Developmental Science, 12*(1), 67-83. doi: 10.1111/j.1467-7687.2008.00747.x
Petersson, E., Strahl, S. (2018). Ordförrådsutveckling hos 26 – 32 månader gamla barn i relation till tidigt formigenkänningsförmåga, *Master's thesis.* Lund: Instuitionen för kliniska vetenskaper, Lunds universitet. http://lup.lub.lu.se/student-papers/record/8951861
Pisoni, D., KroneBerger, W., Conway, C., Horn, D., Karpicke, J. & Hennings, S., (2008). Efficacy and Effectiveness of Cochlear Implants in Deaf Children. In M. Marschark

and P. Hauser (eds), *Deaf Cognition: Foundations and Outcomes (New York, NY: Oxford University Press).*
Roos, E. M., & Weismer, S. E. (2008). Language Outcomes of Late Talking Toddlers at Preschool and Beyond. *Perspectives on language learning and education, 15*(3), 119-126. https://doi.org/10.1044/lle15.3.119.
SBU Alert. Allmän hörselscreening av nyfödda. Version 1. Stockholm: Statens beredning för medicinsk utvärdering (SBU); 2004. http://www.sbu.se
Statistikmyndigheten SCB (2020). Utbildningsnivån i Sverige. Retrieved 2020 May 20 from https://www.scb.se/hitta-statistik/sverige-i-siffror/utbildning-jobb-och-pengar/utbildningsnivan-i-sverige/.
Smith, L.B., (2003). Learning to Recognize Objects. *Psychological Science, 14*(3), 244-50. doi: 10.1111/1467-9280.03439.
Smith, L.B., Colunga, E., & Yoshida, H. (2019). Knowledge as Process: Contextually Cued Attention and Early Word Learning. Cognitive *Science: A Multidisciplinary Journal, 34*(7), 1287-1314. Doi:10.1111/j.1551-6709.2010.01130.x
Smith, L.B., Jones, S. S., Landau, B., Gershkoff-Stowe, L., & Samuelson, L. (2002). Object Name Learning Provides On-The-Job-Training for Attention. *Psychological Science, 13*(1), 13-19. Doi:10.1111/1467-9280.00403
Strahl, S. (2017). Development of Object Shape Recognition and Language in Toddlers. Unpublished manuscript.
Thiessan, E. D. & Saffran, J. R. (2007). Learning to learn: Infants' Acquisition of Stress-Based Strategies for Word Segmentation. *Language Learning and Development, 3,* 73-100. https://doi.org/10.1080/15475440709337001
Tomasello, M. (2006). Acquiring Linguistic Constructions. In W. Damon, R.M. Lerner (Series Eds.). D. Kuhn & R. S. Siegler, *Handbook of child psychology: Vol. 2. Cognition, perception and language* (6th ed., pp.255-298). Hoboken, NJ: Wiley
Vavatzanidis, N. K., Mürbe, D., Friederici, A. D. & Hahne, A. (2018). Establising a Mental Lexicon with Cochlear Implants: an ERP study with Young Children. *Scientific Reports 8,* 910. https://doi.org/10.1038/s41598-017-18852-3
Välimaa, T., Kunnari, S., Laukkanen-Nevala, P., Lonka, E. & the National Clinical Research Team. (2017), Early Vocabulary Development in Children with Bilateral Cochlear Implants. *International Journal of Language & Communication Disorders,* 53: 3-15. doi:10.1111/1460-6984.12322
Yee, M., Jones, S.S. & Smith, L.B. (2012), Changes in Visual Object Recognition Precede the Shape Bias in Early Noun Learning. *Frontiers in Psyhology, 3(*533). Doi: 10.3389/fpsyg.2012.00533

Attachments

Attachment 1.
Samtyckesblankett

- Härmed lämnar vi tillstånd till att vi och vårt barn deltar i undersökningen. Vi har inhämtat information skriftligt och muntligt om undersökningen. Vi är medvetna om att resultaten kommer publiceras i vetenskapliga sammanhang på gruppnivå. Alla resultat behandlas så att obehöriga inte kan ta del av dem och kodnyckeln förvaras på ett säkert ställe och kommer inte att hanteras av någon annan än vi som är ansvariga för studien. Om barnet eller ni väljer att inte medverka eller avbryta era deltagande har detta inga konsekvenser, och undersökningen innebär inga risker.
  OBS Det krävs underskrift från bada vårdnadshavarna.

1. Vårdnadshavares namn: . . . .

2. Vårdnadshavares namn: . . . .

Mailadress: . . . .

Telefonnummer: . . . .

Barnets namn: . . . .

Barnets födelsedatum: . . . .

Vårdnadshavares namnteckning, ort och datum
. . . .

Vårdnadshavares namnteckning, ord och datum
. . . .

Attachment 2.
Information till vårdnadshavare angående deltagande i studie och frågeformulär

Som en del av ett examensarbete i logopedi på Lunds universitet genomför jag (Gazal Sayed) under handledning av Brigitta Sahlén, Kristina Borgström och Malin Lindgren en studie gällande ordförrådsutveckling och formigenkänning hos barn som tidigt opererats med cochleaimplantat (CI). Vår förhoppning med denna studie är att bidra till ökad kunskap inom behandling som är viktig för barn med CI och hur man kan förstärka deras lexikala utveckling.

Formigenkänningsförmåga innebär att barnet kan kategorisera föremål utifrån deras form. När barn lär sig vad föremål kallas, och vilka olika specifika föremål som kallas för samma sak till exempel olika stolar som ser olika ut, så måste de på något sätt lista vad de relevanta likheterna är. Barnets förmåga att kategorisera utifrån form kan leda till att barnet utökar sitt ordförråd. Syftet med den här studien av barn med CI är att studera formigenkänning och ordförrådsutveckling vid olika tidpunkter. Dessutom vill vi undersöka relationen mellan vårdnadshavares skattning av sina barns ordförråd och barnens resultat på ett formigenkänningstest vid tre tillfällen med ungefär sex månaders mellanrum. Studien kan eventuellt bidra till ökad kunskap inom behandling som är viktig för barn med CI. Barnets språkliga förmåga kommer också att testas för att se om det finns något samband med formigenkänning.

Om ni väljer att delta i studien innebär det att barnet träffar mig i cirka en timme i barnets hemmiljö. De deltagande barnen kommer att få göra ett språkligt test som testat barnets förmåga att benämna olika bilder och förstå ord. Angående tider för testning är jag flexibel och kan komma hem till er när det passar er bäst.

Det enskilda barnet och dess resultat från samtliga tester är pseudonymiserade . Allt material kommer att avidentifieras genom att varje barn får en siffra och kodnyckeln förvaras på ett säkert ställe och kommer inte att hanteras av någon annan än vi som är ansvariga för studien. Ni som vårdnadshavare kan få ta del av sammanställningar av våra resultat när studien är klar. Barnets och ert medverkande är frivilligt och barnet eller ni kan när som helst avbryta deltagandet utan att det får några konsekvenser. Materialet kommer att förvaras i ett låst skåp på Avdelningen för logopedi, foniatri och audiologi, Lunds universitet. Studien är godkänd av Etiska kommittén vid Avdelningen för logopedi, foniatri och audiologi, Lunds universitet.

Om ni önskar ytterligare information eller har ni frågor gällande studien är ni välkomna att kontakta oss via telefon eller e-post. Om ni vill delta är vi tacksamma, och vi ber er då att svara på några frågor som följer nedan och skriva under godkännandet.

Med vänliga hälsningar,

Gazal Sayed, logopedstudent

Birgitta Sahlén, handledare
Leg logoped, professor i logopedi

Kristina Borgström, handledare
Psykolog, forskare i neuropsykologi

Malin Lindgren, handledare
Leg logoped

Attachment 3.
Frågeformulär

Svara på följande frågor genom att ringa in det svar som passar bäst och vidareutveckla gärna på raderna! Stort tack för dina svar

1. Finns det någon i barnets familj/släkt som har eller haft svårigheter med språk, läsning eller skrivning?
   Ja Nej
   Om ja, vilket släktskap har personen med barnet? och vilka svårigheter? . . . .
   . . . .

2. Finns det någon i barnets familj/släkt som har hörselnedsättning?
   Ja Nej
   Om ja, vilket släktskap har personen med barnet? och beskriv nedsättningen:
   . . . .

3. Använder ni något annat språk eller några andra språk i familjen än svenska?
   Ja Nej
   Om ja, vilket/vilka? . . . .

4. Anser du att ert barn haft typisk motorisk utveckling?
   Ja Nej
   Om nej, beskriv hur: .. . .

5. Finns det någon i familjen/släkten som har en neuropsykiatrisk diagnos såsom Autism, ADHD, Tourettes syndrom eller språkstörning?
   Ja Nej
   Om ja, beskriv problemen:. . . . .

6. Går ert barn på förskola?
   Ja Nej
   Om ja, hur gammalt var barnet när den började: . . . .

   Om ja, ungefär hur många timmar per vecka tillbringar barnet på förskolan: . . . .
   . . . .

7. Har ert barn syskon?
   Ja Nej
   Om ja, vilket nummer i syskonskaran har det medverkande barnet? . . . .

8. Högsta slutförda utbildning vårdnadshavare 1 och 2: (grundskola, gymnasium eller högskola/universitet)

1. . . . .
2. . . . .

9. Vilken är din nuvarande sysselsättning vårdnadshavare 1 och 2:

1. . . . .
2. . . . .