LEXICAL PROCESSING DURING NAMING IN CHILDREN WITH COCHLEAR IMPLANTS

by

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This manuscript has been read and accepted for the Graduate Faculty in Speech-Language-Hearing Sciences in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Abstract

LEXICAL PROCESSING DURING NAMING TASKS IN CHILDREN WITH COCHLEAR IMPLANTS

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The speech and language skills of deaf children significantly improve after they receive a cochlear implant (CI). Nevertheless, many do not achieve age-appropriate language skills (Geers, Nicholas, & Sedey, 2003). The primary goal of the present study was to examine lexical access and knowledge in children with CIs.

Twenty children with CIs (9 females, 11 males) and 20 children with normal-hearing (NH; 14 females, 6 males) age 7-10 participated. The CI participants included children with severe to profound bilateral sensorineural hearing loss with at least 8 months of experience with CI prior to participation in this study.

Lexical abilities were examined using two naming tasks, a timed picture-naming task and a phonological and semantic Verbal Fluency (VF) naming task. In the timed picture-naming task, children rapidly named pictures of objects appearing on a computer screen. Reaction times were measured from the onset of picture presentation to the initiation of a verbal response. In the VF tasks, children were given one minute to generate as many words as they could that begin with a given sound (/t/,/l/,/f/) or belong to a certain semantic category (animals, food). All hearing subjects passed an audiological screening.

Children with CIs generated fewer words than the NH children on the VF tasks. Larger group differences were found on the phonological VF task compared to the

semantic VF task. No group differences were found between children with CIs and children with NH on the timed picture-naming task.

Children with CIs seemed to access words less efficiently than NH peers. In contrast, children with CIs did not differ than the NH group in the speed of retrieval and word duration when naming simple pictures. Therefore, the differences between the groups in the VF naming task appear to reflect retrieval difficulties (due to differences in representation or organization) that are apparent under more challenging tasks. The limited early linguistic and auditory experiences of children with CIs alter the typical development of the lexicon and affects lexical organization or representations. If these atypical representations cannot be reconstructed or refined at later stages of development, certain aspects of language knowledge and performance may be atypical even at the advanced ages.

This thesis would not have been possible without the unwavering support and love that I have always received from my parents. I am thankful to them for the practical and emotional backing that they have consistently rushed to provide, and I feel honored to dedicate this thesis to them.

Dedicated with much gratitude to my beloved parents, Abe and Cecile Wechsler

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CHAPTER 1: INTRODUCTION

Language Development in Children with Cochlear Implant

Cochlear implants (CIs) are hearing devices that are implanted by surgery and provide direct electrical stimulation to the auditory nerve. A CI can help provide a sense of sound to a person who is profoundly deaf or severely hard of hearing. The auditory experience provided by a cochlear implant is substantially different from that obtained through natural acoustic stimulation of the auditory system. However, there is now considerable evidence that children are able to make use of the stimulation provided by a CI for speech and language acquisition. The speech and language skills of deaf children significantly improve after they receive a cochlear implant. Nevertheless, some researchers have shown that although implanted children show significant improvement, many do not achieve age-appropriate language skills (Geers, Nicholas, & Sedey, 2003; Nikolopoulos, Dyar, Archbold, & O'Donoghue, 2004). A brief review of recent investigations focusing on the language of children with CIs follows.

A number of studies have used batteries of standardized tests to evaluate the rate and nature of language development following implantation. These studies demonstrated that the rate of language development was greater post-implantation when comparing to pre-implanted rates, greater than the performance of children using hearing aids, and similar to trajectories of normal hearing typically developing children.

Based on the expressive portion of the Reynell Developmental Language Scales, the rate of language development in 70 children (1-7 years, mean implantation age 4.5 years) following implantation exceeded that expected from non-implanted deaf children and was similar to that of children with normal hearing (Svirsky, Robbins, Iler-Kirk, Pisoni, & Miyamoto, 2000).

Similarly, rate of performance gain on the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1981, 1997), a measure of receptive vocabulary, the Clinical Evaluation of Language Fundamentals (CELF; Semel, Wiig, & Secord, 1992, 1995), a general language measure, and in Mean Length of Utterance (MLU) in a group of children with CIs, was roughly equal to that of children with hearing aids with better hearing threshold levels (mean average hearing loss of 78dB versus 106dB in the CI group) (Blamey, Sarant, Paatsch, Barry, Bow et al., 2001). Rates of postoperative improvement were significantly higher than mean pre-operative performance in a group of implanted children, adolescents, and adults (Dawson, Blamey, Dettman, Barker, & Clark, 1995). Similar findings were reported by Tomblin, Barker, Spencer, Zhang, and Gantz (2005) who examined growth curves of expressive language outcomes, measured by a subscale of the Minnesota Child Development Inventory (MCDI) and of the Preschool Language Scale (PLS-3).

Such studies provide important information about the effectiveness of implantation but tell us little about the details of language abilities in these children. Studies examining more specific areas of language (such as syntax and morphology) show that although implanted children were reported to proceed at a faster pace than hearing aid (HA) users (Blamey et al., 2001) or even at the same rate as normal hearing (NH) children (Svirsky et al., 2000), they still do not achieve age-appropriate language scores on more specific language tests. A review of findings examining specific aspects of language in children with CIs follows.

Phonology

Numerous studies have examined the quantity and quality of phonological development of children with CIs. These studies focused on the acquisitions of phonological inventories, such as the acquisition of consonants, vowels and clusters. Children with CIs were found to improve over time in production skills and demonstrated measurable gains in vowel and consonant production. Although the phonetic development of some young-implanted individual children appeared to resemble that of NH children (e.g., a case study reported by Ertmer & Mellon, 2001), many implanted children were reported to fall below phonological development norms (Chin & Pisoni, 2000; Serry & Blamey, 1999). The majority of studies reported that the rate of acquisition of phonetic inventories of young CI users was slower than the rate typically reported in hearing children. Most studies also claim that the order of acquisition of the phonological system follows a similar pattern to that of hearing children. Nonetheless, some studies documented deviation from typical development. For example, Chin (2003) found that many English-speaking children produced non-ambient (non-English) consonants, specifically in the group of the Total communication users, a phenomenon not typical of NH children. Adi-Bensaid and Tubul-Lavy (2009) documented a phenomenon of consonant-free words in Hebrew speaking toddlers, another phenomenon hardly ever found in typically developing children.

Very few studies have focused on the development of phonological representations in children with hearing impairment. The development of phonological representations in typically developing children is assumed to progress from relatively holistic to more segmental representations (Dollaghan, 1994; Storkel, 2004). Children's stored forms differ from those of adults (Ferguson & Farwell, 1975; Locke, 1988). This process of transition from holistic to fine-grained phonological representations has a noticeable refinement by 5-7 years of age and may not develop in this typical manner in hearing-impaired children (Jerger, Lai, & Marchman, 2002b). Moreover, Swingley and Aslin (2000) suggested that young infants' (18-23-month-olds) representations of familiar words are phonetically well-specified. Children with CIs may be at a disadvantage in phonological development since at early stages of development they did not have optimal access to sound either because they were not yet implanted or because of limited access to some speech sounds due to hearing via an implant. Children who lack the perceptual acuity to access the language environment might not form these phonological representations in the same manner as NH children. In other words, access to acoustic-phonetic patterns of speech provides the perceptual foundation for normal oral language development, initially by enabling phonologic representations in the first year of life and subsequently by supplying phonological representations to learn words.

The organization of CI children's lexicons in terms of phonological similarity neighborhoods resembles that of NH children. Kirk, Pisoni, and Osberger (1995) examined effects of lexical characteristics (word frequency and neighborhood density) on word identification in children with CIs. Children with CIs were best at identifying frequent words from sparse lexical neighborhoods. They were sensitive to the acoustic-phonetic similarities between words and seemed to organize words into similarity neighborhoods in long-term memory. Although the study did not compare the performance of children with CIs to that of NH children, their performance seemed to resemble that of NH children and was found to be similar to NH children under degraded listening conditions (Eisenberg, Martinez, Holowecky, & Pogorelsky, 2002).

Phonological awareness skills provide another way to learn about phonological abilities of children with CIs. Only one study thus far has investigated the impact of CI use on the development of phonological awareness (James, Rajput, Brown, Sirimanna, Brinton, & Goswami, 2005). The main finding in this study was that CI use affords some benefit to the development of phonological awareness, namely significant improvement in rhyme awareness over time in the CI group. This study was limited in several ways (e.g., it did not control for receptive vocabulary knowledge and quality and quantity of rehabilitation), but nonetheless provides initial information concerning phonological awareness development in this population and highlights an important area for further research.

Semantics

Most studies examining language in children with CI reported global language scores, making it hard to determine CI children's linguistic abilities specifically in the semantic domain. However, two relevant studies analyzed the vocabulary size of children with CIs using transcriptions of the children's spontaneous language samples (Le Normand, Ouellet, & Cohen, 2003; Ouellet et al., 2001). Quantitative measures of language production showed that children with CIs were delayed in vocabulary development. Children with CIs were significantly impaired in the number of words they acquired from different lexical categories compared to hearing children. However, children post-implantation did seem to follow typical developmental stages of language acquisition. For example, children with CIs seemed to acquire a fairly robust noun category before they developed verb-related knowledge. Ouellet et al. (2001) mentioned that even the best performing CI children performed below the mean of NH children on specific measures of mean length of utterance (MLU; a measure of morphosyntactic complexity) and in vocabulary.

Access to acoustic-phonetic patterns of speech provides the perceptual foundation for establishing representation of speech sounds and integrating them in receptive and expressive oral vocabulary. If smaller and less developed lexicons are established, due to hearing limitations, it is difficult to "catch up" and close the gap, because the incorporation of new words involves reorganization of words in storage and the underlying cognitive domain (Mellon, 2009).

To date, there are no reported studies referring specifically to the semantic level of processing or semantic representations in the CI population. However, two relevant studies involving semantic memory have been reported with moderately hearing impaired children that are “successful hearing aid users” (Jerger, Damian, Tye-Murray, Dougherty, Metha, & Spence, 2006; Jerger, Lai, & Marchman, 2002a). These studies demonstrate similarities in the organization of the lexicon at the semantic level in hearing-impaired children. Hearing-impaired children demonstrated a typicality effect (faster reaction times [RTs]) and fewer errors to typical objects of the clothing category) and a relatedness effect (faster RTs and fewer errors to strong out-of-category objects) similar to normal-hearing children and adults (Jerger et al., 2006). Similarities were also found in a cross-modal picture-word interference paradigm (Jerger, Lai, & Marchman, 2002a). In this study, hearing-impaired children, like NH children and adults, showed a significant semantic interference effect (slowed picture naming in the presence of a semantically related auditory distractor). These studies also highlight the variability among the pediatric hearing-impaired population. The variability in performance can be attributed to the wide age range (5-15 years of age) of the subjects in these studies and to the variation in the hearing status of the participants.

Grammar (morphology and syntax)

Significant delays were also found in the development of grammar. Nikolopoulos, Dyar, Archbold, and O’Donoghue (2004) reported significant delays in grammar acquisition in CI users using the Test for Reception of Grammar (TROG), compared to norms for NH children. CI users also showed inferiority in the use of bound morphemes (Spencer, Tye-Murray, & Tomblin, 1998). Although children with CIs were better compared to HA users in the use of bound morphemes (plurals, third person possessive, past tense, first person possessive and present progressive tense), many CI users did not show a systematic pattern of bound morpheme use in their spontaneous speech. Similarly, Szagun (2004) reported specific deficits in the case and gender marking system in German-speaking children with CIs that were compared to NH children with similar MLUs. In this study, children with CIs were reported to omit case and gender markings more often than the NH participants, and also demonstrated a different error pattern compared to the NH group. Furthermore, there is evidence that English speaking implanted children follow an atypical pattern of morphological development (Svirsky, Stallings, Lento, Ying, & Leonard, 2002) guided by perceptual prominence of some grammatical morphemes.

To summarize, the studies described above highlight the effectiveness of cochlear implantation in improving specific areas of language outcome (e.g., vocabulary and grammar), but, at the same time, demonstrate the existing gap in language performance of CI recipients compared to their normal age-matched peers. Additional support for this conclusion comes from a longitudinal study of a pair of fraternal twins, one who received a CI at twenty months of age and the other who had normal hearing (Seung, Holmes, & Colburn, 2005). Results of this study showed that although primary differences in language development existed between the two twins prior to implantation (20 months of age), nineteen months post-implant activation, the twin with a CI showed receptive vocabulary within the average range, but expressive vocabulary scores remained delayed compared to her chronological age and her twin sister's vocabulary, which was within the average range.

Effect of age at implantation

Age at implantation plays a major role in the trajectory of language outcome. Despite reports of initial lags in language acquisition demonstrated in children with CIs, it seems that some children, implanted at early ages, could eventually catch up to normal hearing peers in some spoken language measures. Tomblin, Barker, Spencer, Zhang, and Gantz (2005) showed that expressive language growth was more rapid in children implanted as infants than children implanted as toddlers. Connor, Craig, Raudenbush, Heavner, and Zwolan (2006) found an advantage for children who had received their implants before the age of 2.5 years in speech production and vocabulary. Nicholas and Geers (2007) stressed the effect of early implantation on language outcomes by 4.5 years of age. The very young CI recipients in this study achieved age-appropriate spoken language scores (measures derived from spontaneous language samples and formal language testing using the PLS-3). Moreover, children implanted at 12-16 months of age did better than children implanted at 24 months of age.

Despite the cumulative findings showing advantages of early implantation, it is not clear whether significant gains in language outcomes are made by children implanted at very young ages (before one year) compared to those implanted during their second year of life (12 to 24 months). Holt and Svirsky (2008) and Dettman, Pinder, Briggs, Dowell, and Leigh (2007) addressed this question. Dettman et al. (2007) reported significant gains in the rate of receptive and expressive language growth, while Holt and Svirsky (2008) found only a small advantage in receptive language development (but not in expressive language or word recognition).

Picture-naming

Picture-naming is commonly used to examine lexical processing (D'Amico, Devescovi, & Bates, 2001; Jescheniak & Levelt, 1994). It has been used in typically developing children and adults, as well as in atypical populations, including language impaired children and adults (Leonard, Nippold, Kail, & Hale, 1983; Miller, Kail, Leonard, & Tomblin, 2001). The timed-picture-naming task yields RT and error data. In typically developing children, performance on naming tasks improves with age (as demonstrated by faster and more accurate results). This improvement has been attributed to maturational changes in processing rate (Kail, 1991). Slower processing speed has been assumed to reflect limitations in processing capacity and resources, including less rapid access to object names (Cook & Meyer, 2008; Miller et al., 2001).

Picture-naming involves a series of stages. These stages include: object recognition, lexical retrieval, formulation, and production (Miller et al., 2001). The object recognition phase includes the visual and conceptual processes leading to the identification of the object. Lexical access is the retrieval of the object name from the mental lexicon. In the formulation and production processes, speakers select and combine the phonemes and the articulatory gestures leading to the production of the picture name. In addition to the perceptual processes used to identify a picture, semantic processing is needed in order to recognize and select the appropriate name, whereas phonological processes are needed so that the picture name can be retrieved or assembled (Nation et al., 2001). In other words, deficits in any of these processes may result in slower picture-naming. Although global RT measures provide limited information regarding specific stages in the naming process, they do provide useful information about normal maturation and about lexical production in atypically developing children. Furthermore, manipulations of this task (e.g., word length, familiarity, etc.) can provide information regarding specific stages in the naming process (e.g., early phonological and semantic stages).

Picture naming has been extensively examined in several clinical populations. Children with reading deficits were slower than good readers across a number of response time measures, including picture-naming (Catts, Gillispie, Leonard, Kail, & Miller, 2002). Similar findings have been reported for children with specific language impairment (SLI) (Leonard et al., 1983; Miller et al., 2001) and for children with moderate hearing impairments in a word-picture interference paradigm (Jerger et al., 2002a; Jerger et al., 2002b). Slower processing may negatively affect language learning (Miller et al., 2001). Furthermore, in a recent study Leonard, Ellis Weismer, Miller, Francis, Tomblin, and Kail (2007) suggested that speed of processing and working memory limitations might be the cause of children's language difficulties. The highly time-dependent nature of registering and interpreting details in the language input make language susceptible to slowed processing.

Reaction time is also influenced by characteristics of the word to be named. These characteristics include word length, frequency, familiarity, age of acquisition, phonological characteristics, etc (D'Amico, Devescovi, & Bates, 2001; Jescheniak & Levelt, 1994). Longer names require more phonological information to be specified in and retrieved from long-term memory. Thus, children's naming tends to be slower and less accurate as word length increases. Children with dyslexia were found to be less accurate than reading-age controls in naming pictures that have long names (three or four syllables) (Nation et al., 2001). This finding is explained by underlying phonological processing deficits characterizing dyslexic children.

Word familiarity and word frequency influence lexical access. Word familiarity affects word duration in adult and child speech. Schwartz (1995) revealed a significant effect of familiarity on the duration of vowels and words produced by young children. Subjects are also typically faster (Almeida, Knobel, Finkbeiner, & Caramazza, 2007) and more accurate (Newman & German, 2005) naming pictures that have highly familiar or frequent names. Recently, Jescheniak and Levelt (1994) replicated the lexical frequency effect discovered in 1965 by Oldfield and Wingfield. They reported naming latencies for pictures with high-frequency names to be 62 ms faster than naming latencies for pictures with low-frequency names, controlled for length and morphological complexity. The common view holds that these frequency/familiarity effects arise as a result of differences in representation or processing of high and low frequency lexical representations (Almeida et al., 2007). High familiarity words are thought to have "stronger" semantic representations (Nation et al., 2001) because they consist of a greater number of attributes or features. Using a delayed picture naming paradigm, Almeida et al. (2007) recently demonstrated that the frequency effect is driven by lexical processes, independently of the picture recognition and articulatory process that take part in picture naming, and therefore validate the frequency effect as a tool to constrain and test theories of lexical access.

Verbal fluency (VF)

VF tasks (also called category production or list-generation tasks) have been used to examine lexical organization in adults and children with typical and atypical language abilities (Sauzéon, Lestage, Raboutet, N'Kaoua, & Claverie, 2004; Troyer, 2000; Weckerly, Wulfeck, & Reilly, 2001). In this task, the subject is given a category (e.g., semantic—*food*; phonological—*f* as an initial sound) and asked to name as many words as possible in that category within a specified time period. The number of words produced for phonological and semantic tasks are compared across groups.

Optimal performance in a VF task involves generating words within a subcategory and, when a subcategory is exhausted, switching to a new subcategory. According to Troyer, Muscovitch, and Winocur (1997), two dissociable components underlie VF performance, clustering and switching. Clustering involves accessing a store of semantically or phonetically related words. An example of clustering in the semantic task *animals*, would include producing a sequence of words from the subcategory of pets, such as *cat, dog, fish*. In the phonological task, a sequence of words beginning with the same two initial phonemes would present a phonological cluster, such as *free, fry, frill*. Clustering is thought to be a relatively automatic process and is related to temporal lobe functioning. The switching component involves the search for new semantic or phonological clusters. Efficient switching allows new words to be produced once exemplars in a given cluster have been exhausted. Switching involves cognitive flexibility in shifting from one subcategory to another and is a relatively effortful process. Switching is related to frontal lobe functioning.

Another important component to evaluate in VF studies is the specific pattern of word production as a function of time on a VF task (i.e., the distribution of the subject's response across the 60 seconds time frame of his response; Hurks, Vles, Hendriksen, Kalff, Feron, Kroes, van Zeben, Steyaert, & Jolles, 2006). Word production in the first 15 seconds of phonological and semantic VF tasks is defined as a measure of automatic information processing, whereas words production in the remaining 45 seconds (in 15-second periods) is taken as a measure of controlled information processing. Successful performance on a VF task thus seems to depend on the effectiveness of both automatic and controlled processing. Hurks et al. (2006) revealed that similar to adult performance, school aged children produced more words in the initial time slice (first 15 seconds) of both phonological and semantic VF tasks, and production decreased as time on task increased.

A number of studies have revealed developmental changes in VF performance from 5 to 16 years (Riva et al., 2000; Sauzéon et al., 2004). Children in the older age groups showed an increase in the number of items retrieved (Kail & Nippold, 1984). Although children improved with age on both semantic and phonological tasks, young children performed better on semantic tasks and phonological improvements were more gradual (Riva et al., 2000; Sauzéon et al., 2004). The differences in performance on these two tasks (phonological and semantic) may be related to the hierarchical organization of the phonological and semantic information in the subject's mental lexicon. Research in the area of semantic categorization has pointed out that words and concepts are internally structured (Mervis & Rosch, 1981). Any object may be categorized at each of several different hierarchical levels: superordinate (e.g., animal), basic (e.g., bird) and subordinate levels (e.g., canary). The basic level is the most general level. Basic level categories are acquired before categories at other hierarchical levels.

Developmental changes were also described for clustering and switching abilities in the VF semantic and phonological tasks. Children in fifth grade (age 10-11) had greater semantic and phonological fluency scores than children in the third grade (age 8-9), concomitant with an increase in the number of clusters but not in cluster size (Koren et al., 2005; Sauzéon et al., 2004). Examining these specific factors in VF performance add a fine distinction to CI children's word retrieval abilities and allow a more accurate and complete description of language capabilities of the pediatric CI population.

Summary and purpose

The speech and language skills of deaf children significantly improve after they receive a cochlear implant (CI). Nevertheless, many do not achieve age-appropriate language skills as measured by standardized and non-standardized instruments. The studies reviewed here demonstrate the benefits of cochlear implantation in children, but do not adequately specify how cochlear implantation alters language processing abilities. Moreover, these studies cannot explain the large variability found in language outcome. Results of research thus far highlight the need to examine more specific aspects of language in order to learn more about the language processing abilities of children with CIs. There is also a need to study language processing in the CI population to learn about the effect of early auditory impairment on language development.

The proposed tasks, timed picture naming and VF naming, would address some of these questions. The proposed studies provide information concerning the language processing mechanisms that underlie the language deficits documented in some of the children using CIs. These methods have not yet been applied to the CI population.

These two measures will be used to further explore phonological and semantic factors in lexical access for naming. Information regarding lexical access at the semantic and phonological levels will be examined in terms of word length and familiarity effects in the timed picture-naming task, and performance on the semantic and phonological VF tasks. I expect to find differences in the speed of processing due to underspecified representations as a result of the periods of deafness existing prior to the acquisition of language and/or reduced language experience that children with CI are afforded. Although previous research suggested that implantation after early stages of language development may enhance expansion of the lexicon (learning more words of different categories, etc.), the representations established prior to implantation may be insufficient for typical language processing and acquisition.

Hypotheses

Children with CIs will show overall slower RTs in the picture-naming task compared to age-matched NH children because of underlying differences in lexical access or organization. The differences found may differentially reflect manipulations of phonological and semantic information (manipulation of the number of syllables in the word and word familiarity rate). The CI group is expected to show more difficulty for words that are longer or less familiar. Thus, the CI group will show greater word length and familiarity effects compared to the NH group due to phonological and semantic limitations. Similarly, the CI group will name fewer words on both semantic and phonological VF tasks. The difference in performance will be greater for the phonological VF task due to impoverished phonological representations, resulting from the limited auditory experience of children in the CI group.

CHAPTER 2: EXPERIMENT 1- TIMED PICTURE NAMING

Methods

Participants

Sixty-six subjects (32 CI and 34 NH) ages 7-12 were recruited for the present study. In order to narrow the age range of the participants in this study, only 40 (7-10 year-olds) were included in the final analysis. All participants underwent language screening. The Clinical Evaluation of Language Fundamentals (CELF-3; Semel, Wiig, & Secord, 1995) language screening was used. In addition, the Test of Nonverbal Intelligence (TONI 3; Brown, Sherbenou, & Johnson, 1997) was administered to NH and CI subjects. Only NH children who passed both a hearing screening (described below) and the CELF language screening were included in the final analysis. All children included in the final analysis had normal IQ scores (above 80 on TONI nonverbal intelligence test). The participants' demographic and SES characteristics (parents' highest education level etc.) matched the distribution of the population in the greater New York City area. English was the primary language of all children tested.

The criteria for CI participants were: severe to profound bilateral sensorineural hearing loss diagnosed before the age of 3 years, with at least six months of experience with CI prior to participation in this study. All the children in the CI group were users of oral communication or total communication. Children who primarily use sign (manual) language were excluded, because they would not be able to perform the verbal naming tasks. The children with CIs were asked to use the typical setting for their CI(s) and hearing aid. The examiner confirmed with the children and their parents that the hearing devices were working properly.

The criteria for hearing participants were: no parentally reported history of speech or language deficits, no reported neurological or emotional disorders and no known visual impairments that cannot be corrected by glasses. All hearing children underwent an audiological screening before initiating the actual experiments. This was conducted in the experiment room, which was a quiet testing room (not in an audiological booth). The passing criterion was 20dB in frequencies 500Hz, 1000Hz, 2000Hz and 4000Hz. Two responses were required in each frequency in each ear in order to pass the hearing screening. Only NH children who passed the hearing screening were included in the final analysis.

The testing protocol order was as follows: Picture naming (Experiment 1), Verbal Fluency (VF; Experiment 2), TONI nonverbal intelligence test and CELF language screening. The order of the testing was maintained the same in most cases. In a few instances this order was not obtained (due to concerns about time limitations that the parent specified, technical reasons or confusion on part of the investigator). Children were given frequent breaks as necessary. A parent questionnaire was filled out on the testing date by the adult accompanying the child, in most cases, the child's mother.

Four children from the CI group were excluded from the final analysis. Three children were excluded due to poor speech intelligibility, which did not permit accurate scoring of their responses. One other child with CI was excluded from the final analysis due to ADHD. (He was receiving medication; he did not complete all of the tasks). Of the remaining subjects, only subjects ages 7-10 years old were included in the final analysis. Each child from the CI group was matched with a child with NH according to age and nonverbal IQ (TONI-3). The children were matched within 4 months of age and 5 points on the TONI standardized score. This matching procedure yielded a total of 40 subjects, 20 CI and NH pairs, who were included in the final analysis for both experiments.

Normal Hearing participants

Twenty NH children (ages 7;0-10;0, M = 8;7, S.D. 1.12) were included. Fourteen were girls and six were boys. The average TONI score was 109.3, S.D. 10.2. Characteristics of the 20 NH participants included in the final analysis are presented in Table 1 below.

Cochlear Implant participants

Twenty children with CIs (ages 7;0-10;2, M = 8;7, S.D. 1.11) were included. Nine were girls and 11 were boys. The average TONI score was 109.7, S.D. 11.5. Seven children used one cochlear implant device in one ear only (right or left), eight had bilateral implants, and five had a combination of a CI in one ear and a hearing aid (HA) in the other (bi-modal amplification). Updated information regarding hearing thresholds with the HA at the time tested for the current study was not available. However, information from the child's chart at the time of implantation for four of the five participants was available for children number 2, 4, 6 and 8 (from Table 2). PTA aided thresholds were 36.3, 50, 30, 93.3 dB respectively. None of the children included in the final analysis had a history of infections or device failure that had caused non-use of the CI for a long period of time. Characteristics of the 20 participants with CIs included in the final analysis are presented in Table 2w.

Table 1. Characteristics of the children in the normal hearing group.

	Gender	Age	TONI score
1	f	9;9	102
2	f	9;5	123
3	f	7;1	105
4	f	7;11	118
5	m	8;1	100
6	f	9;2	121
7	f	7;11	107
8	f	7;2	121
9	m	10;0	103
10	m	9;10	95
11	m	7;10	130
12	m	9;11	90
13	f	9;6	107
14	f	9;7	102
15	f	9;11	107
16	f	7;3	118
17	f	7;4	116
18	f	7;0	112
19	f	8;1	102
20	m	9;6	107

Table 2. Characteristics of the children in the cochlear implant group.

	Gender	Age	TONI	Etiology of HL	Age at HL onset	Age HL identified	Unaided PTA Rt ear	Unaided PTA Lt ear	Age at CI activation	CI Duration	Hearing Device	
											Rt ear	Lt ear
1	f	10;0	115	EVA*	5 months	1;4	73.3	81.6	4;5	5;6	CI	None
2	f	9;2	123	Genetic	Birth	1;7	NI	NI	3;7	5;6	CI	HA
3	m	7;5	94	CMV**	Unknown (<1;0)	1;0	95	93.3	5;0	2;5	CI	CI (1st)
4	f	7;11	118	Genetic (connexin 26)	Birth	1:6	100	85	5;9	2;2	CI	HA
5	m	8;0	100	Genetic	Birth	1;6	NI	NI	7;0	1;0	CI	HA
6	m	8;11	115	Unknown	Unknown	3;0	NI	NI	7;2	1;9	CI	HA
7	m	7;8	93	Genetic	Birth	NI	NI	NI	7;1	0;7	CI	None
8	f	7;0	124	Unknown	Birth	Birth	NI	NI	1;11	5;0	CI	HA
9	f	9;10	107	Wardenburg Syndrome	Birth	Birth	NI	NI	1;10	8;0	None	CI
10	m	10;1	93	Genetic (Connexin 26)	Birth	Birth	NI	NI	2;9	7;4	CI	None
11	m	7;8	118	Genetic (Connexin 26)	Birth	1:4	110	111.6	1;5	6;2	CI (1st)	CI
12	m	9;9	88	Unknown	Unknown	1;0	NI	NI	1;11	7;10	None	CI
13	f	9;5	118	Long QT syndrome	Birth	8 months	NI	NI	2;5	6;11	CI	None
14	m	9;3	105	Genetic	Birth	NI	NI	NI	1;1	8;2	CI (1st)	CI
15	f	10;2	115	Genetic (Connexin 26)	Birth	Birth	NI	NI	1;1	9;1	None	CI
16	f	7;2	125	Genetic (Connexin 26)	Birth	1;7	91.6	86.6	2;10	4;5	CI (1st)	CI
17	f	7;2	115	Unknown	Birth	Birth	103.3	105	3;3	4;0	CI (1st)	CI
18	m	7;0	115	Premature Antibiotics	Unknown (passed hearing screening)	6 months	NI	88.3	2;8	4;4	CI	CI (1st)
19	m	8;1	100	Genetic	Unknown	11 months	103.3	106.6	1;6	6;7	CI (1st)	CI
20	m	9;5	105	Unknown	Unknown	2;11	NI	NI	3;5	6;0	CI	CI (1st)

Note. Age and CI duration are provided in years; months, Pure Tone Average (PTA) in dB.

TONI = Test of Nonverbal Intelligence; HL = hearing loss; PTA = pure tone average; Rt = right; Lt = Left; CI = cochlear implant; HA = hearing aid; EVA = enlarged vestibular aqueduct; CMV = Cytomegalovirus; NI = no information available.

Stimuli and Procedure

Twenty-four black and white line drawings of objects (Snodgrass & Vanderwart, 1980) were presented on a computer screen. The participant was asked to name the pictures as quickly as possible. The dependent measure was reaction time (RT) for intended responses. Since word retrieval ability is influenced by word familiarity (Snyder & Godley, 1992), the words used in this task included 12 high-familiarity words (e.g., ball, dog, carrot, balloon) and 12 low familiarity words (e.g., swan, kite, wagon, camel). Familiarity was based on familiarity ratings from young healthy adults ages 18-22 years (Cycowicz, Friedman, Rothstein, & Snodgrass, 1997). In each group, six words were monosyllabic and six were bi-syllabic. The groups of words were controlled for neighborhood density, based on neighborhood values from the Neighborhood database (Sommers, 2002). The words contained 15 English consonants and 8 English vowels. The 24 pictures were referents of words that represented basic categories that included objects (e.g., items in the house), body parts, toys, animals and food (fruits and vegetables). A complete list of the words appears in the Appendix.

The testing was conducted in a quiet testing room either in the Child Language Lab at the CUNY Graduate Center, or in the Hearing and Learning Center at the Beth Israel Medical Center or at the Hearing and Learning Center of the New York Eye & Ear Infirmary. The child was seated in front of a computer. A voice key-activated response box was connected to a microphone, which was set on the table at a distance of approximately 3 inches from the child's mouth. The voice key detected the child's vocalized response. The object drawings were presented on the computer screen in a random order using E-Prime 1.1 (2003). Responses were collected using E-Prime control programs on a PC computer. Reaction time (RT) was calculated from the onset of the picture presentation to the initiation of a verbal response.

A practice session, with four practice words (bed, car, envelope, glasses), that were not included in the experimental analysis, preceded the actual experiment. The instructions were: “You are going to see pictures on the screen. I want you to tell me what each picture is as fast as you can.” If necessary, the experimenter corrected the child’s performance during this practice procedure (for example, *Don’t use “a/an” before saying the word*). Following the practice session, the actual experiment began. Each picture appeared on the screen until the voice key detected a verbal response and then disappeared. Once the picture had disappeared, a fixation point (+) appeared on the computer screen for 2000 msec, followed by the next picture. The child had 4 sec to produce the word. If no response was detected following a period of 4 sec, the next picture was presented. The investigator noted the child’s verbal response and any interruptions (for example, saying “ah”, coughing etc.). In addition, the sessions were audio recorded and digitized for scoring purposes. The child’s responses were transcribed and scored.

Scoring

Each child received a score for accuracy and a separate score for response time (RT) for each of the 24 trial pictures. For the accuracy score, each response was scored as correct or incorrect. Mispronunciations and misarticulations were included as correct responses, as long as the target word was intelligible. Measurements of RT were collected by E-Prime for each correct response. Since the goal was to compare RTs for the same retrieved words (that include the same phonemes) across both groups, only correct responses of the intended picture were included in the RT measurements. If the child named a picture correctly but added an extra word (e.g., *wishing well* for *well*), the child received a point for the accuracy, but the RT was not included in the analysis, because of the extra word. Similarly, only the naming of the intended words was scored as correct. If the child said *duck* for *swan*, the word *duck* was scored as incorrect. False triggers (interrupting sounds or movements, e.g., cough or body movements that intervened in the RT measurement) and incorrect responses (e.g., *duck* instead of *swan, bird* instead of *penguin*) were excluded from the final RT measurement. Responses that were measured by E-Prime as less than 400 msec were removed (only 10 instances in the CI group and 11 instances in the NH group; 2.0% and 2.2% of the data, respectively).

Interjudge reliability

A second experimenter listened to a randomly selected 20% of the recordings. The experimenter transcribed the responses and provided an accuracy score. Each response was scored as correct or incorrect. Mispronunciations and misarticulations were included as a correct response as noted above. Interjudge reliability, calculated with Pearson product-moment correlation coefficients, was 99% for the accuracy score.

Results

General Analyses: Description of the analyses performed

Linear mixed-model ANOVAs with repeated measures were used. Prior to running the model, the data error variance/covariance matrix was examined to test for the error structure that best fitted the data. The error structure that fitted the data best was unstructured. Tukey's HSD (Honestly Significant Difference) test (Hinton, 2004) was used for post-hoc comparisons. For all analyses, alpha levels were set at 0.05. Cohen’s standardized effect size is reported.

Reaction times were the dependent measures, with “group” serving as a between subject variable and familiarity and word length serving as within subject variables. Correlations with background factors in the CI group and RTs in the picture-naming task were also examined.

These background factors included age, TONI nonverbal IQ, age at implantation and total time of experience with the CI device.

Main effects

Accuracy (percent correct)

In most cases, both group of subjects, CI and NH, named the intended word. The average number of correct responses in the NH group was 20.9 out of 24 pictures presented (87.2% correct, S.E. 0.35) and the average number of correct responses in children with CIs was similar, 19.6 (81.6% correct, S.E. 0.61). The difference between the groups was not statistically significant ($t(1, 39) = -1.9$, $p > 0.05$).

Reaction Time

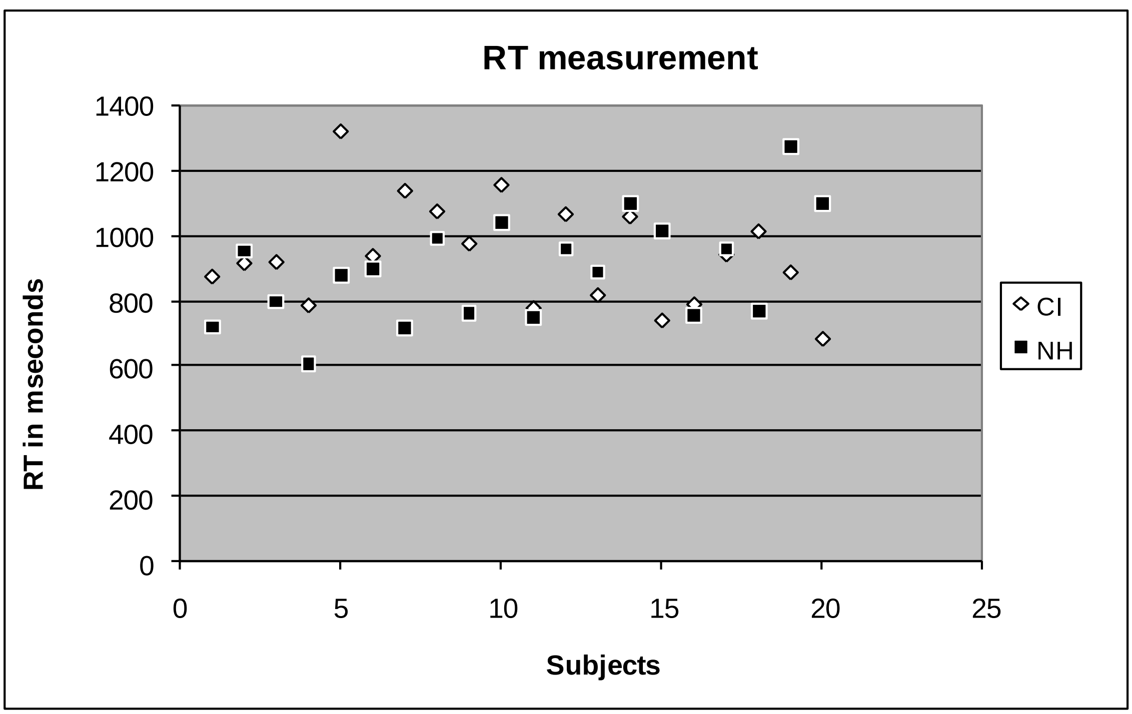
Mean reaction times (in milliseconds) for correct responses for each group are presented in Table 3. No significant main effect was obtained for the picture-naming task. As can be seen in Table 3 below, the CI group overall were slower to name words in the picture-naming task. However, the differences between the two groups (37 milliseconds overall) were not statistically significant ($F(1, 38) = 0.88$, $p > 0.05$, $d = 0.23$). These results suggest that CI children as a group do not differ from the NH group on naming times of single pictures of simple objects.

Although the difference in average reaction times was not statistically significant between the two groups, individual differences were present. Figure 1 below displays individual differences in both groups of participants. As can be seen in Figure 1, the variability in performance in both groups is quite large. Although many children with NH did better that the CI participants, many individuals with CIs performed as well or even better than many hearing participants. Half of the children in the CI group performed better than the average group performance of the children in the NH group.

Table 3. Mean reaction times (in milliseconds) and standard errors (S.E.) on the timed picture-naming task.

	RT (msec)	**S.E.**
CI	956	34.5
NH	919	34.6

Figure 1. Individual data for mean reaction time measurements for correct responses on the timed picture-naming task.



Length and familiarity effects

Average reaction times, in milliseconds, grouped by word characteristics (*word length* and *familiarity*) of the pictures to be named are displayed in Table 4 below. A significant main effect for both *familiarity* and *word length* was found. The differences between high and low familiarity words were significant overall, $F(1, 38) = 45.13$, $p < 0.001$, $d = -1.76$. The difference between short (monosyllabic) and long (bi-syllabic) words was also statistically significant overall, $F(1, 38) = 5.26$, $p < 0.05$, $d = -2.19$. These effects are illustrated in Figures 2 and 3. The interaction between *group* and *familiarity* was not statistically significant ($F(1, 38) = 0.22$, $p > 0.05$). In both groups, the same pattern was found, highly familiar words were faster to be named than less familiar words (parallel lines). However, the interaction between *group* and *word length* was found to be statistically significant ($F(1, 38) = 7.27$, $p = 0.01$). As shown in Figure 2 below, while for the NH group, no difference was found in retrieval time for monosyllabic versus bi-syllabic words (917 versus 921 msec, respectively), the children with CIs were slower by 120 msec to name longer words. In addition, there was a statistically significant interaction between *familiarity* and *word length* across all subjects ($F(1, 38) = 7.48$, $p < 0.01$). As can be seen in Figure 5, overall, across all subjects, highly familiar words, regardless of their length (short or long; monosyllabic or bi-syllabic), were named at similar response times. In contrast, for less familiar words, there was a length effect. Long words of low familiarity were significantly slower to be named than short words of low familiarity.

Neighborhood density

Similar RTs were present for words from sparse and dense lexical neighborhoods. Overall, the average RTs for words from dense lexical neighborhoods was 902 msec (S.D. 170), and the average RTs for words from sparse lexical neighborhoods was 935 msec (S.D. 195). In the CI group, the mean RT for words from dense lexical neighborhood was 902 msec (S.D. 157) and mean RT for words from sparse lexical neighborhoods was 983 msec (S.D. 201). In the NH group, mean RTs were 902 (S.D. 185) and 887 (S.D. 182), respectively.

Table 4. Mean reaction time in milliseconds for the picture-naming task grouped by familiarity level, standard errors in parentheses.

	High familiarity	Low familiarity
CI	843(39.4)	1070 (44.9)
NH	790 (39.4)	1048 (45.2)
OVERALL	817 (27.9)	1059 (33.1)

Table 5. Mean reaction time in milliseconds for the picture-naming task grouped by word length, standard errors in parentheses.

	Short words	Long words
CI	896 (34.4)	1016 (42.4)
NH	917 (34.4)	921 (42.6)
OVERALL	907 (24.4)	969 (31.6)

Figure 2. Interaction between group and word length in the picture-naming task.

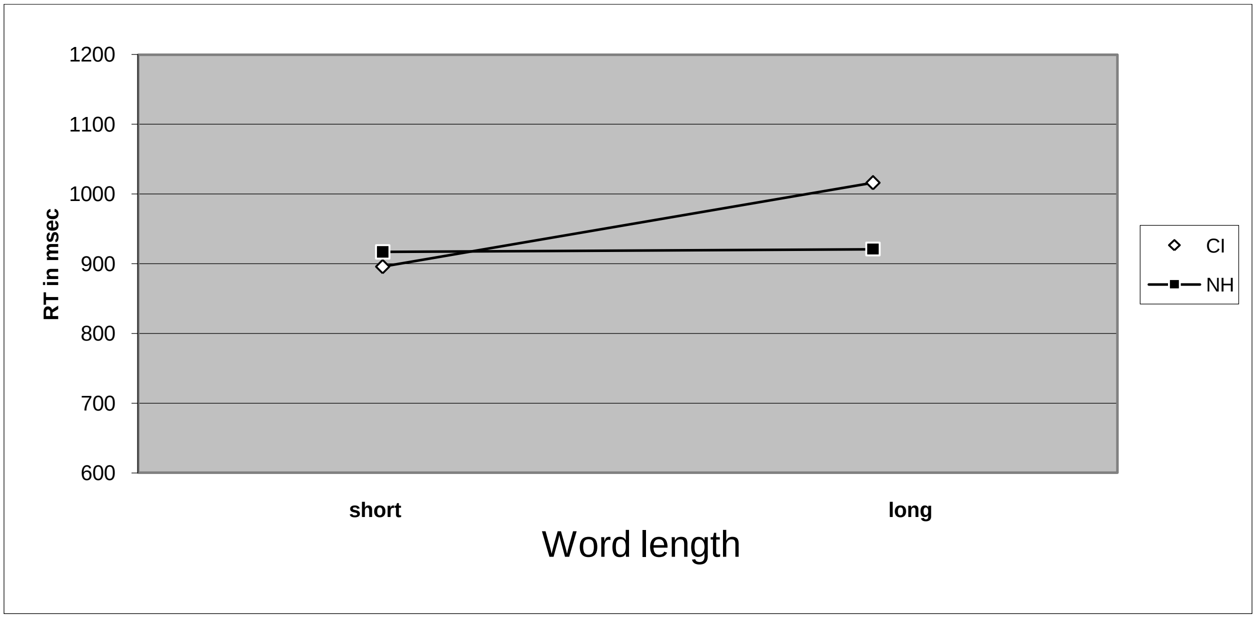
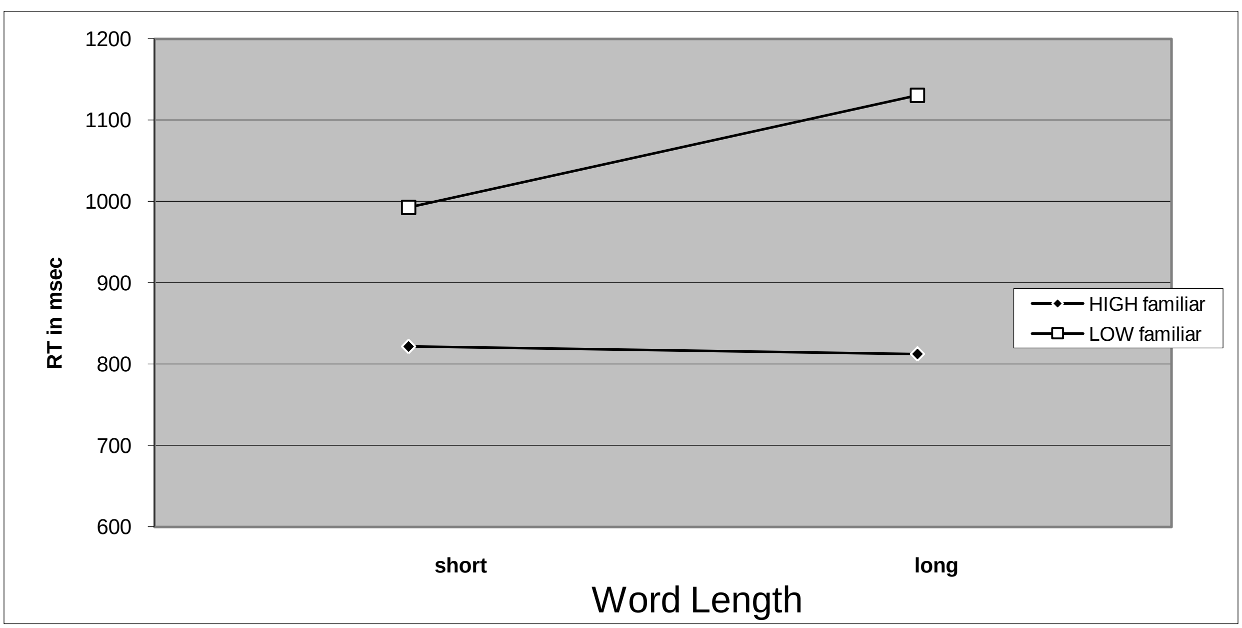


Figure 3. Interaction between familiarity and word length in the picture-naming task, in all subjects.



Correlations with background factors in the CI group

Pearson product-moment correlation coefficients were computed between RT measures and variables related to background factors in the CI group. These correlations are summarized in Table 6. Chronological age of the children in the CI group was not significantly correlated with any of the outcome variables in the picture-naming task. Nonverbal IQ scores (TONI) were negatively correlated with average RT scores. Children who had higher IQ scores had shorter RT measurements, in other words, performed better (faster) on the picture-naming task. These correlations were significant for the short (monosyllabic) highly familiar words and for the long (bi-syllabic) less familiar words of the picture-naming task.

Statistically significant correlations were also found between age at implantation and naming of long (bi-syllabic) highly familiar words and between years of CI use and naming of long (bi-syllabic) highly familiar words. Age at implantation was positively correlated with RTs to long words of high familiarity, in other words, younger implanted children performed better (shorter RTs) in naming long highly familiar words. Similarly, years of CI use was negatively correlated with RTs to long words of high familiarity; children with more years of experience with CI use showed shorter RTs (better performance) in naming long words of high familiarity. In contrast, the correlations between age at implantation and RTs to short words and to RTs of long less familiar words were not statistically significant. Similarly, years of CI use was not statistically correlated with RTs to short words and to the naming of long, less familiar words.

Table 6. Pearson correlation coefficients between background factors related to cochlear implant participants and performance on picture-naming experiment.

	Monosyllabic high familiar	Bi-syllabic high familiar	Monosyllabic low familiar	Bi-syllabic low familiar
Age	r = -0.155	r = -0.291	r = 0.062	r = -0.008
TONI IQ	r = -0.485*	r = -0.346	r = -0.028	r = -0.465*
Age at implantation	r = 0.166	r = 0.432*	r = 0.029	r = 0.010
Years of CI use	r = -0.200	r = -0.471*	r = 0.008	r = -0.012

Note. * $p < 0.05$.

Discussion

Many hearing impaired children using cochlear implants (CIs) show language impairments. However, the specific underlying processes leading to the final language impairment are not fully understood. The proposed study suggested that the nature of this impairment may lie in basic naming abilities that underlie the impaired language development. The hypothesis was that children with CIs will process/retrieve words more slowly because lexical information is stored and retrieved in an atypical manner due to perceptual hearing limitations and reduced linguistic experience.

However, the results of Experiment 1 do not support this hypothesis. Children in the CI group did not differ from the NH group in the picture-naming task. The CI children's naming times for simple single words were similar to those of NH peers. These results imply that the general underlying mechanisms involved in word retrieval and production of familiar single words, that children with CIs identified correctly, are comparable to those of NH children. This cannot however rule out the involvement of word retrieval mechanisms in more complex tasks and in production of phrases and sentences.

It therefore seems that children with CIs follow NH children in some basic abilities, for storing and accessing single basic words in the mental lexicon. If these single words were accessed or stored differently, there would have been significant differences in reaction time.

Nevertheless, it is likely that differences in lexical access and organization do exist and did not appear in the present study due to large individual differences in performance. Moreover, it is possible that group differences will be apparent when examining more general organization of networks of words using different tasks. The picture-naming task may not have been sensitive enough to detect a group difference because of the limited task demands and because of the small number of items used. There is a need to evaluate the children's naming abilities in other tasks (e.g., priming; cross-modal picture word interference) and with less familiar words and later acquired words, to draw firmer conclusions about the structure of the lexicon in the pediatric CI population. Such studies may aid in specifying the nature of deficits and the level of lexical processing at which the difficulty is apparent, and point to the source of the deficit so that intervention could be directed at that source.

The picture-naming task did reveal information that may shed light on the linguistic capabilities of children with CIs. Although no significant group differences were observed in RT measurements, there was a significant interaction of *group* by *word length*: while for the NH group, no difference was found in retrieval time for monosyllabic versus bi-syllabic words, the children with CIs were slower to name longer words.

Familiarity effect in the picture-naming task

Highly familiar words are thought to have "stronger" semantic representations because they include more attributes or features. Shorter naming latencies and more accurate responses have been reported for highly familiar words in typically developing children and adults (Almeida et al., 2007; Leonard et al., 1983; Newman & German, 2005). This familiarity effect is believed to stem from differences in lexical representation and processing. Differences in naming speed for high versus low familiarity words provide information on the semantic process of the naming procedure.

A significant main effect for *familiarity* was found for both groups (NH and CI). The differences between high and low familiarity words were significant overall. In both groups the same pattern was found; highly familiar words were named faster than less familiar words, regardless of their length (short or long; monosyllabic or bi-syllabic). This suggests that children with CIs are sensitive to the general frequency and semantic underpinnings of single words, the primary components of familiarity.

Length effect in the picture-naming task

Longer words require more phonological information to be specified in, and retrieved from long-term memory. Children who have developed a poorly specified phonological system are likely to be particularly disadvantaged in lexical processing of longer words.

In the picture-naming task, a significant main effect for *word length* was found only in the CI group. Children with CIs were slower to name pictures of bi-syllabic words. There was an interaction of *group* by *word length*. For the NH group, no *word length* effect was observed; no difference was found in reaction times for monosyllabic versus bi-syllabic words. In contrast, the children in the CI group were slower by 120 msec to name bi-syllabic words compared to their RT measures for monosyllabic words. The introduction of just one more syllable to the word-to-be-named significantly slowed down the retrieval times of the CI participants. Since children with CIs showed this slow-down for both high familiar and low familiar words, this difference is assumed to reflect difficulties in the phonological domain, either in the retrieval time course and/or in the planning for production phase. This difference may imply that the lexicon of children with CIs is more susceptible to phonological challenges. Future studies involving priming or a picture word interference paradigm could trace the specific loci of this slowness and point more directly to the source of this finding.

CHAPTER 3: EXPERIMENT 2- VERBAL FLUENCY NAMING TASKS

Methods

Participants

The same 40 children, 20 matches of CI and NH pairs, who were described in Experiment 1, participated in the phonological and semantic VF naming tasks (Experiment 2). The criteria for participation and the characteristics of the children in the NH and CI groups were described in detail in the previous chapter.

Stimuli and Procedure

In the VF task, children were given one minute to generate as many words as possible beginning with a particular speech sound or from a specific semantic category. This experiment included a VF phonological task and a VF semantic task. In the VF phonological task, the child was asked to say as many words as possible that begin with a given sound (/t/, /l/, /f/) within one minute. The three phonological subtasks (/t/, /l/ and /f/) were presented in this order. These particular sounds have been used commonly in the literature (e.g., Riva, Nichellli, & Devoti, 2000; Troyer, 2000). Also, these sounds represent a diverse range of speech sound characteristics. These sounds include both voiced and voiceless consonants (/l/ voiced; /f/ and /t/ voiceless). The three phonemes chosen also represent different places of articulation (/t/ and /l/ coronal, /f/ labiodental) and different manners of articulation (/t/ plosive, /l/ lateral, and /f/ fricative). The instructions for the VF phonological task were: “I will tell you a sound, and then I want you to say in one minute, as many words as you can that begin with that sound”.

In the semantic VF task, the child was asked to name as many words as possible that belong to a certain semantic category (*animals*, *foods*) in this order. These categories were chosen because they have been used extensively in previous research, and because these categories are considered basic/familiar categories, which are appropriate for this young group of participants. The instructions for the VF semantic task were: “I will tell you a name of a category, or a name of a group of words, and then I want you to tell me in one minute, as many words as you can that belong to this category.”

The sound /m/ was given as an example for the phonological tasks. The experimenter named possible words (map, movie, morning) and then asked the child to say more words that begin with /m/. The category *clothing* was given as an example for the semantic task. The experimenter demonstrated that the child could say “shirt, socks, shoes”, and asked the child to say more words that belong to the clothing category. The child began when the experimenter said “go”. The experimenter used a stopwatch to measure the one-minute time frame. This session was also audio recorded and digitized for scoring purposes. The investigator listened to the recordings and transcribed the children’s responses.

Scoring

A separate score for each of the five subtasks was obtained. Each correct word received one point. In addition, a total score for the phonological VF task and a separate total score for the semantic VF task were calculated. The total score was the average across the subtasks scores. Repetitions, errors and unintelligible words were not included in the final score. Some examples and more details are provided in Appendix D.

Scoring for the detailed analyses of the verbal fluency responses

Additional detailed clustering and switching analyses of the subjects' responses in the VF tasks were conducted. The rules for defining and scoring clusters were based on Troyer (2000), Troyer et al., (1997), and Koren et al., (2005). The analysis included both semantic and phonological clusters. Semantic clusters consist of words with related meanings that belong to the same subcategory (e.g., sea animals "…seal, dolphin, whale, fish…" or jungle animals "…lion, giraffe, monkey...") according to lists of common subcategories of *animals* and *food* listed in Troyer (2000), Troyer et al., (1997), and Koren et al., (2005). Phonological clusters consist of words that share similar phonemes (e.g., words that begin with /fr/ "…fright, fraud, free, fry…" or phonological neighbors; words with the same initial and final phonemes "…fat, feet, foot, fit…"). Groups of two or more successively produced words belonging to the same semantic subcategory or that share similar phonemes were counted as a cluster.

The analyses also included the number of switches within each subject's response. Switches were defined as transitions from one word, or a group of words (cluster) to the next word (or cluster). Repetitions were included in the cluster and switches analysis. Examples and more details for clustering and switching in the phonological and semantic VF experiment can be found in Appendix D.

Additional analyses included measurements of reaction times to first-retrieved-words in each subtask. Reaction time was measured using Sound Forge 4.5 (1998) from the starting point of the task (press of the stopwatch) to the initiation of the verbal response. The score for the number of words produced during the first 15 seconds of the task was also obtained. This was measured by counting the number of words generated in the initial 15 seconds time frame of the response (setting this point using Sound Forge 4.5, 1998). The score for the proportion of words produced during the first 15 seconds of the child's respond was attained by calculating the percentage of words produced during the first 15 seconds with respect to the total number of words in this subtask. The mean cluster size (MCS) measure was calculated by averaging the cluster size scores across each task. For each of the measures, a separate score was calculated for the phonological task and a separate score was calculated for the semantic task.

Interjudge reliability

An independent rater scored a random 20% of the recordings. Separate scores for the different VF measures were obtained. The VF measures included scores for the number of clusters, the number of switches and the MCS. Interjudge reliabilities, calculated with Pearson product-moment correlation coefficients, were high for the different measures. Interjudge reliability for the total VF score was 99%. The interjudge reliability for the number of clusters was 91%, 94% for the number of switches score and 83% for the MCS score.

Results

General Analyses: Description of the analyses performed

Linear mixed-model ANOVAs with repeated measures were used. Separate ANOVAs for each of the tasks (phonological and semantic) in the VF experiment were conducted. Prior to running each model, the data error variance/covariance matrix was examined to test for the error structure that best fit the data. For the total number of words measure, the error structure that fit the data best was unstructured, for both phonological and semantic total number of words scores. Tukey's HSD (Honestly Significant Difference) test (Hinton, 2004) was used for post-hoc group comparisons of each of the VF subtasks; /t/, /l/, /f/, for the phonological VF and *animals* and *food* for the semantic VF. For all analyses, alpha levels were set at 0.05. Cohen's standardized effect size is reported.

The dependent measures were the number of words. The independent variables were the participants' group (CI and NH) serving as a between subject variable and the subtasks serving as within subject variables. Correlations among variables of interest (such as age, TONI nonverbal IQ, age at implantation and total time of experience with the CI device) and performance on the VF naming task were also performed. The data for the verbal fluency tasks were analyzed separately for the phonological and semantic tasks. The mean group scores and standard errors for the total number of words produced in one minute, are presented in Table 7. The scores for the total number of words and standard errors on phonological and semantic VF subtasks are presented in Table 8.

Linear mixed-model ANOVAs with repeated measures were also performed for the detailed VF measures (clusters, switches, number of words in first 15 seconds, the proportion of words produced in the first 15 seconds, latency to first word and MCS). Prior to performing each statistic, the data error/covariance matrix was examined to ensure the structure that fit the data best. For the cluster measure, number of words in first 15 seconds, the proportion of words produced in the first 15 seconds and MCS measure, the error structure that fit the data best was the Unstructured error structure. For the number of switches measure the structure that fit the data best was the Toeplitz error structure and for the latency to first words measure, the structure that fit the data best was the Compound Symmetry error structure. Tukey's HSD (Honestly Significant Difference) test (Hinton, 2004) was used for post-hoc comparisons. For all analyses, alpha levels were set at 0.05. Cohen's standardized effect size is reported.

Statistical analysis of the number of words produced

Phonological VF Experiment

A significant *group* main effect for the number of words produced was obtained for the phonological VF task. The differences between the NH children and the children with CIs were statistically significant ($F(1, 38) = 10.45$, $p < 0.01$, $d = 1.00$). The children in the CI group named fewer words on average compared to the NH group. No statistically significant *task* main effect was found ($F(2, 37) = 0.04$, $p > 0.05$). Scores for the phonological subtasks (/t/, /l/, /f/) were compared across all participants in this study. As can be seen in Table 8, similar scores were found for all three of the phonological subtasks. Within each group similar scores were obtained across all three phonological subtasks (roughly 6 words per minute in the CI group and 9 words per minute in the NH group). In addition, there was no statistically significant interaction between group and phonological VF tasks, $F(2, 37) = 0.63$, $p > 0.05$.

Semantic VF Experiment

A statistically significant difference was also found for the semantic VF task ($F(1, 38) = 5.06$, $p < 0.05$). The children in the CI group also generated significantly fewer words on the semantic task compared to the NH group. No task effect was found, ($F(1, 38) = 0.96$, $p > 0.05$). Scores for the semantic subtasks (*animals* and *food*) were compared across all participants as well. A similar score was obtained within each group; CI group generated approximately 12 names per minute and NH group named approximately 14-15 words per minute in the semantic VF subtasks (see Table 8). There was no interaction between group and semantic VF task, $F(1, 38) = 1.97$, $p > 0.05$. These results support the fact that the group differences are robust across the different subtasks.

These results confirmed the predictions. The CI group produced fewer words on both semantic and phonological VF tasks. In addition, the predicted difference in performance on the phonological VF task was verified. The performance of the children with CIs was even poorer on the phonological VF task ($p < 0.01$) than on the semantic VF task ($p < 0.05$).

Individual data for phonological and semantic VF experiment

Individual data for the phonological and semantic VF tasks are presented in Figure 4 and Figure 5. As can be seen in the figures below, the variability in performance was large in both groups on these tasks as well. Although the majority of the children with NH did better that the CI participants, some individuals with CIs performed as well as or even better than many hearing participants. The fact that the performance of children with CIs varies widely on language tests, has been well documented in the literature. The heterogeneity of the CI population was observed in this experiment as well. Four of the CI participants performed within one standard deviation of the norm for the NH group on the phonological VF task. Four of the CI participants performed within one standard deviation of the norm for the NH group on the semantic VF task. Only one of these four participants performed within the average range of the NH children in the phonological task as well. There was no obvious single or combined background factor that could be indentified which could characterize these “better performing” children. Of the four successful performers in the phonological task, only one was early implanted, another child had bilateral implants and they all had different sources reported for their hearing loss etiology. Of the four successful performers in the semantic task, two were early implanted and had bilateral implants, one child had one CI and was also early implanted and one child was implanted late (4;5) and nonetheless was also a successful performer on the phonological task. Hearing loss etiology was genetic in three of the four children (Connexin 26 was identified in two of the cases) and the reported etiology for one other child was enlarged vestibular aqueduct (EVA).

Table 7. Mean number of correct words and standard errors (S.E.) on phonological and semantic verbal fluency naming task.

	number of words (S.E.) Phonological VF	**number of words (S.E.) Semantic VF**
CI	6.49 (0.54)	12.25 (0.89)
NH	8.96 (0.56)	15.10 (0.90)

Figure 4. Individual data for the phonological verbal fluency task.

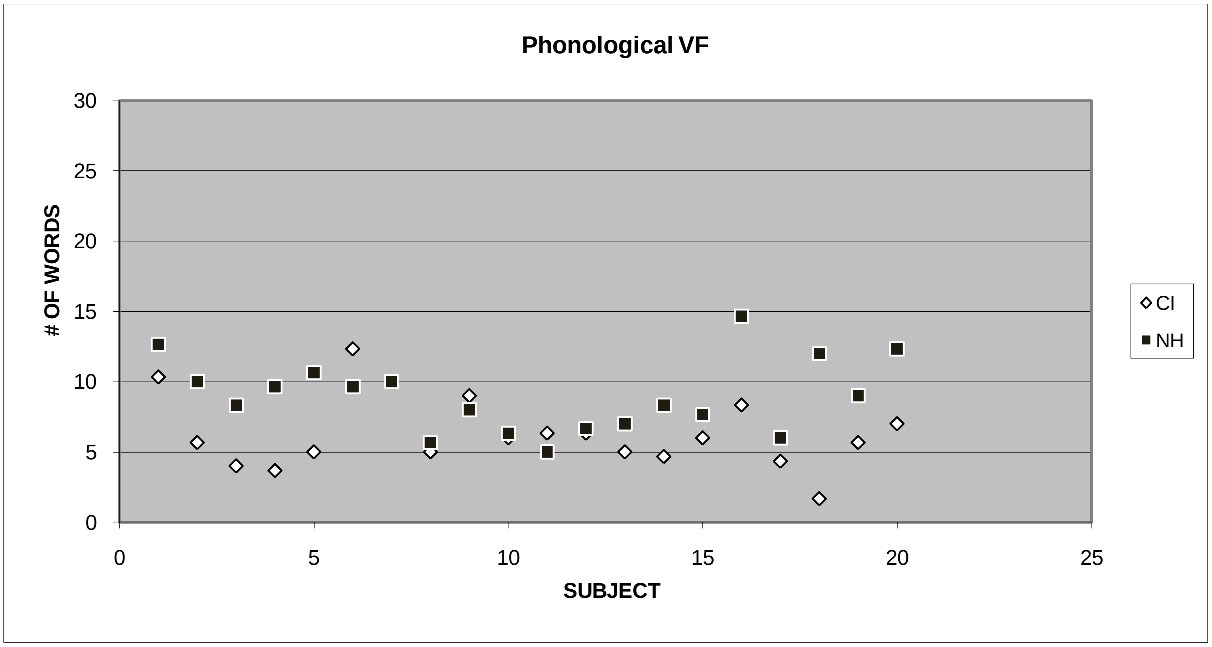


Figure 5. Individual data for the semantic verbal fluency task.

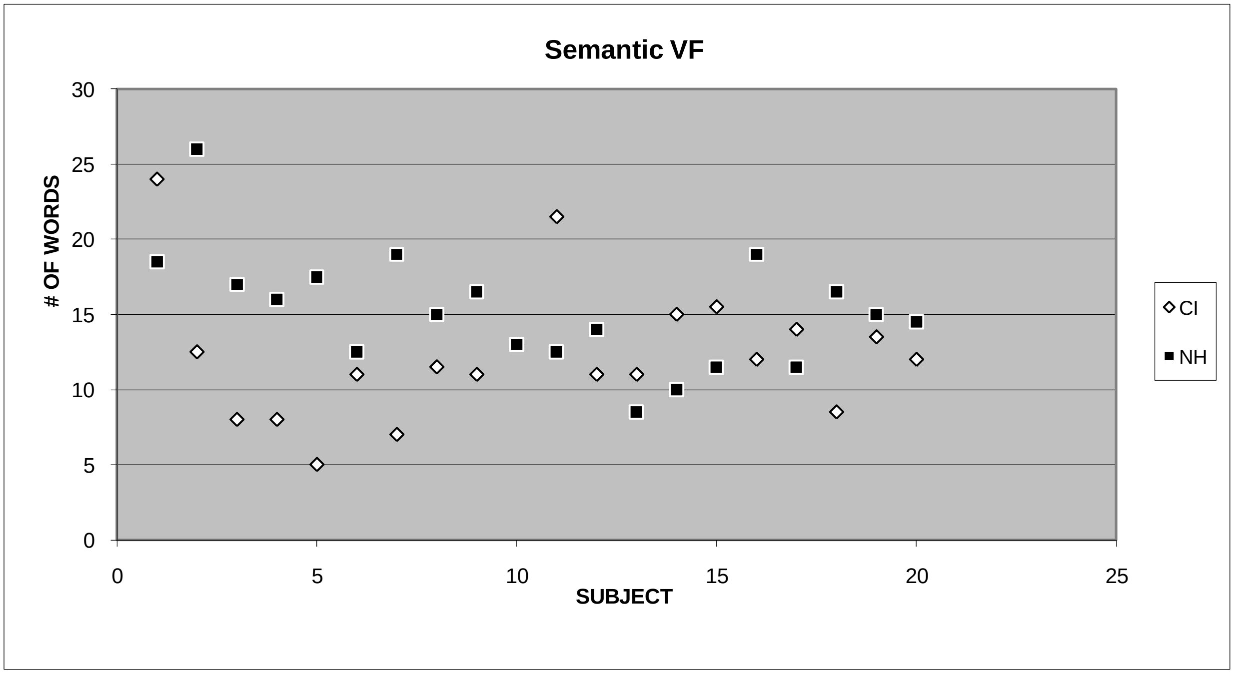


Table 8. Number of words produced in each group for verbal fluency subtasks, standard errors in parentheses.

	/t/	/l/	/f/	Animals	Food
CI	5.85 (0.69)	6.45 (0.70)	6.7 (0.62)	12.4 (1.01)	12.1 (1.03)
NH	9.25 (0.70)	8.85 (0.71)	8.78 (0.64)	14.25 (1.01)	15.63 (1.05)
OVERALL	7.58 (0.48)	7.67 (0.49)	7.74 (0.44)	13.22 (0.68)	14.09 (0.70)

Detailed analyses of the verbal fluency responses

Analyses of clustering and switching were conducted. Clustering analysis included identifying and scoring clusters in the child's response. The analysis of switching examined the number of switches between words and clusters within the VF responses. The detailed analyses also included the number of words generated in the first 15 seconds. Evaluation of performance as a function of time provides additional insight into the cognitive process being performed. As mentioned above, the words named are produced disproportionately across the one minute of performance. Subjects tend to produce more words in the first 15 seconds than in later time intervals (Hurks et al., 2006). Therefore, in addition to comparing the total number of words produced during the first 15-second interval, the relative proportion that this number of words held relative to the total of number of words produced in the whole minute was compared.

Other measures examined in the detailed analysis included measuring latency (RT) to first word generated and the mean cluster size (MCS) of the clusters formed in the VF experiment. Table 9 summarizes these cross group comparisons for this detailed analysis.

Phonological VF Experiment

Number of clusters

Children with CIs showed differences in clustering abilities that come into play in a reduced number of clusters in the phonological VF task. The group difference in the number of clusters generated approached statistical significance ($F(1, 38) = 3.70$, $p = 0.06$, $d = 0.51$), but the effect was very small. The children in the CI group produced fewer clusters on average compared to the NH group. No significant task main effect was found for the number of clusters variable, $F(2, 37) = 3.13$, $p > 0.05$. In addition, there was no statistically significant interaction between group and number of clusters in the phonological VF tasks, $F(2, 37) = 2.42$, $p > 0.05$.

Number of switches

Children with CIs generated significantly fewer switches in the phonological VF task, $F(1, 38) = 7.97$, $p < 0.01$, $d = 0.83$. No significant task main effect was found for the number of switches variable, $F(2, 37) = 1.28$, $p > 0.05$. The interaction group by number of switches was not significant, $F(2, 37) = 0.62$, $p > 0.05$.

Number of words produced in the first 15 seconds

Children with CIs produced fewer words than the NH children in the first 15 seconds of the phonological task, $F(1, 38) = 18.61$, $p < 0.05$, $d = 1.36$. No significant task main effect was found for the number of words in first 15 seconds variable, $F(2, 37) = 0.39$, $p > 0.05$. The interaction group by number of words in first 15 seconds was not significant, $F(2, 37) = 2.91$, $p > 0.05$.

Latency to first word

No group difference was observed for the latency to the first word produced measure, $F(1, 38) = 2.85$, $p > 0.05$, $d = 0.59$. No significant task main effect was found for the latency to first word measure, $F(2, 37) = 0.47$, $p > 0.05$. The interaction group by latency to first word was not significant, $F(2, 37) = 0.85$, $p > 0.05$.

Proportion of words in 15 sec

Children with CIs did not differ from the NH children in the proportion of words produced during the first 15 seconds. The distribution of the words across the 60 seconds of the task was similar in both groups. Both groups produced approximately 40% of the total number of words in the VF phonological task in the first 15 seconds. The children in the CI group generated 40% of the words within the first 15 seconds of the task, and the performance of the NH children was similar, they produced 42% of the words within the first 15 seconds of the task. No group difference was observed for the proportion of words in the first 15 sec, $F(1, 38) = 0.58$, $p > 0.05$, $d = 0.18$. No significant task main effect was found for the proportion of words in 15 sec measure, $F(2, 37) = 0.34$, $p > 0.05$. The interaction group by proportion of words in 15 sec was not significant, $F(2, 37) = 3.43$, $p > 0.05$.

Mean Cluster size (MCS) measure

No group difference was observed for the MCS measure, $F(1, 38) = 2.53$, $p > 0.05$, $d = 0.28$. Both groups formed clusters of similar size, mean cluster size was 2.04 in the CI group and 2.21 in the NH group. Children with CIs appeared to perform similarly to NH children in the formation of clusters. Although the children in the CI group tended to generate fewer clusters in the phonological task, both groups used clusters of similar size. No significant task main effect was found for the MCS measure, $F(2, 37) = 1.17$, $p > 0.05$. The interaction group by MCS was not significant, $F(2, 37) = 0.68$, $p > 0.05$.

Semantic VF Experiment

Number of clusters

No group difference was observed for the number of clusters on the semantic VF task, $F(1, 38) = 2.34$, $p > 0.05$, $d = 0.04$. No significant task main effect was found for the number of clusters variable, $F(1, 38) = 3.13$, $p > 0.05$. In addition, there was no statistically significant interaction between group and number of clusters in the semantic VF tasks, $F(1, 38) = 0.11$, $p > 0.05$.

Number of switches

No group difference was observed for the number of switches measure on the semantic VF task, $F(1, 38) = 2.46$, $p > 0.05$, $d = 0.29$. No significant task main effect was found for the number of switches measure, $F(1, 38) = 2.86$, $p > 0.05$. The interaction group by number of switches was not significant, $F(1, 38) = 0.90$, $p > 0.05$.

Number of words produced in the first 15 seconds

No group difference was observed for the number of words produced in the first 15 seconds of the semantic VF task, $F(1, 38) = 2.53$, $p > 0.05$, $d = 0.52$. No statistically significant task main effect was found for the number of words in first 15 seconds variable, $F(1, 38) = 0.39$, $p > 0.05$. The interaction group by number of words in first 15 seconds was not significant, $F(1, 38) = 0.01$, $p > 0.05$.

Latency to first word

No group difference was observed for the latency to first word measure, $F(1, 38) = 2.69$, $p > 0.05$, $d = 0.33$. No significant task main effect was found for the latency to first word measure, $F(1, 38) = 0.03$, $p > 0.05$. The interaction group by latency to first word was not significant, $F(1, 38) = 0.13$, $p > 0.05$.

Proportion of words in first 15 seconds

Children with CIs did not differ from the NH children in the proportion of words produced during the first 15 seconds, $F(1, 38) = 0.19$, $p > 0.05$, $d = 0.09$. Both groups produced approximately 50% of the total number of the words in the semantic task during the first 15 seconds. (The children in the CI group produced 51% of the total number of words in the semantic VF task in the first 15 seconds. The proportion in the NH group was similar, 50%). No significant task main effect was found for the proportion of words in 15 sec measure, $F(1, 38) = 0.34$, $p > 0.05$. The interaction group by proportion of words in 15 sec was not significant, $F(1, 38) = 1.48$, $p > 0.05$.

Mean Cluster size (MCS) measure

No group difference was observed for the MCS measure, $F(1, 38) = 2.07$, $p < 0.05$, $d = 0.41$). Both groups formed clusters of similar size, mean cluster size was 2.58 in the CI group and 2.73 in the NH group. No significant task main effect was found for the MCS measure, $F(1, 38) = 1.17$, $p > 0.05$. The interaction group by MCS was not significant, $F(1, 38) = 0.24$, $p > 0.05$.

Striking similarities were found in performance of the semantic VF task. No group differences were found in any of the examined measures: number of clusters, number of switches, number of words in 15 sec, latency, proportion of words in first 15 seconds, and MCS. There were also no significant interactions with any of these measures. Children with CIs showed a similar pattern of performance to NH children on the semantic VF tasks, although they performed more poorly in general, as reflected in the total VF semantic score.

Table 9. Summary of cross group comparisons for the detailed analyses of the verbal fluency responses. Standard errors are provided in parentheses, ANOVA significance levels are also presented.

	Phonological			Semantic		
	CI	NH	Significance	CI	NH	Significance
Number of clusters	3.75 (0.50)	4.95 (0.54)	$p = 0.06$	8.55 (0.86)	8.4 (0.61)	$p > 0.05$
Number of switches	12.7 (1.49)	18.1 (1.39)	$p < 0.05$	12.6 (1.25)	14 (0.80)	$p > 0.05$
Number of words in 15 sec	3.06 (0.24)	4.58 (0.26)	$p < 0.05$	5.3 (0.44)	6.25 (0.37)	$p > 0.05$
Latency (RT) in msec to first word	1643 (246)	1037 (204)	$p > 0.05$	2009 (749)	1200 (147)	$p > 0.05$
Proportion of words in 15 sec	40% (3.00)	42% (1.85)	$p > 0.05$	51% (2.74)	50% (1.37)	$p > 0.05$
Mean cluster size	2.04 (0.13)	2.21 (0.14)	$p > 0.05$	2.58 (0.09)	2.73 (0.07)	$p > 0.05$

Correlations with background factors in the CI group

Pearson product-moment correlation coefficients were computed between results of the measures in the VF experiment and variables related to background factors in the CI group. These correlations are summarized in Table 10. Chronological age and TONI nonverbal IQ scores of the children in the CI group were not significantly correlated with outcome variables in the VF experiment. In addition, age at implantation and years of CI use were not significantly correlated with performance on the phonological VF task. However, age at implantation and years of CI use were significantly correlated with performance on the semantic VF task.

As can be seen in Table 10, age at implantation and years of CI use were significantly correlated with performance on the semantic part of the VF task. Age at implantation was negatively correlated with performance on the semantic VF task. Younger implanted children performed better on the semantic VF task (named more words on the semantic task). Similarly, more years of CI use was positively correlated with performance on the semantic VF task. Children who had used their implants for a longer duration of time, performed better on the semantic VF task. These correlations suggest that early implantation is advantageous for certain aspects of lexical performance.

Table 10. Pearson correlation coefficients between background factors related to cochlear implant participants and performance on verbal fluency experiment.

	Phonological VF task	Semantic VF task
Age	r = 0.352	r = 0.335
TONI IQ	r = -0.043	r = 0.328
Age at implantation	r = 0.335	r = -0.463*
Years of CI use	r = -0.109	r = 0.514*

Note. * $p < 0.05$.

Discussion

The second experiment employed a category member generation naming task. In the VF experiment children were asked to name in one minute as many words as they could that begin with a certain sound or that belong to a specific category. Examining performance on the VF experiment allows us to learn about the underlying structure and function of word search mechanisms and the organization of the mental lexicon. Optimal performance on the VF tasks require a systematic search of the mental lexicon; generating words within a subcategory; and, when a subcategory is exhausted, switching to a new subcategory. The performance on phonological and semantic VF tasks relies on the hierarchical organization of words and their attributes in the subject's mental lexicon. Successful performance on a VF task depends on the effectiveness of both automatic and controlled search processes (Hurks et al., 2006). Because typical early lexical development relies heavily on early access to sound, children with CIs were expected to be at a disadvantage and show lower levels of performance, naming fewer words in phonological and semantic VF tasks.

The results of Experiment 2 confirm these assumptions. Significant group differences were found in the number of words generated in the VF experiment. Children with CIs generated fewer words for both the phonological and semantic parts of the VF experiment. Results of the VF task uncover specific differences in the lexical performance of children with CIs compared to NH children, revealed in naming abilities. Children with CIs seem to retrieve words less efficiently during the VF task compared to NH peers. The robust main difference between the groups in the VF task seems more likely to lie mainly in retrieval difficulties rather than speed of planning for production and the production time itself.

Word duration differences between the groups seems unlikely to be the underlying source for the group difference, because rates of production (word duration) for single words measured in the picture-naming task were comparable in the two groups, as reported earlier in the Results section for Experiment 1. Word duration was compared in the two groups in the picture-naming task, rather than on the VF task, because in the picture-naming task, each participant was required to name the same twenty-four experimental words. In the VF task, on the other hand, each participant named different words, which makes it impossible to compare rates of production across words that vary in length and complexity.

It is possible that speech production planning plays a role in the observed differences in VF naming abilities. Due to the limitations of the current study, this hypothesis could not be tested directly. In this study, RT was measured from the onset of picture presentation to the initiation of the verbal response. Since this experiment involves this offline technique, it cannot separate the time course for retrieving word meaning and word form. However, it seems logical to claim that even if a difference in production planning does exist, it is not enough to explain all of the differences in group performance (the robust main effect in the naming VF experiment) for several reasons.

Taking the results from the picture naming and the VF naming experiments, the main issue underlying the difference in performance may be attributed to retrieval. Even if the difference found between CI and NH groups on the picture-naming task is attributed to speech production planning (37 msec difference between the groups in RT), this small difference cannot explain our findings in the VF task in which children with CIs named almost 3 words fewer per minute on average in the semantic VF task.

The results also show that the naming time is influenced by the properties of the category to be named. Thus, children with CIs showed more difficulty retrieving words based on a phonological guide (words that begin with a specific sound) than on a semantic one (words that belong to a specific category). There is no reason to believe that speed of speech planning would be influenced by task demands. Therefore, any difference in performance on VF tasks may be attributed to the search processes required for successful naming, which may be less efficient in children with CIs, due to underlying differences in the representation or organization of the lexicon. Considering all the results, lexical access, representation and organization still remain the major source of the difference in lower naming performance of children with CIs on the VF task. Production planning may play a minor role as well.

Future studies should be designed to explore the time course and the underlying loci of this deficit. More online techniques such as ERPs and priming methodologies are more apt to specify the nature of this breakdown.

Differences in performance on phonological and semantic tasks

In the VF task, there were overall differences in performance between the phonological versus semantic tasks. All subjects (both CI and NH groups) tended to perform better on the semantic than the phonological VF task. These findings are consistent with other studies using phonological and semantic VF tasks (Riva, Nichellli, & Devoti, 2000). The VF phonological task is more difficult than the semantic VF since it requires greater organization and strategic capabilities to search for words in the mental lexicon (Riva et al., 2000).

Larger group differences were observed in the phonological VF task. While children with CIs showed lower performance than the NH group on the semantic VF task, performance on the phonological VF was even more impaired. As predicted, performance in children with CIs reveals limitations in the phonological domain, since the phonological system is vulnerable to delayed exposure to sound and language input.

Differences in the organization of the lexicon between children with CIs and NH children

Retrieval of words belonging to different categories relies on systematic retrieval strategies, as well as on the intactness of the information to be retrieved from long-term memory (Hurks et al., 2006). Efficient performance on VF requires balancing between the size of clusters and the number of switches within the response. In other words, the subjects' performance involves producing words within a certain subcategory, and when that subcategory is exhausted, switching to a new subcategory. Analyzing performance of clusters and switching parameters provides valuable information on the underlying organization of the lexicon (Troyer et al., 1997). Another measures used in the current study included comparing the number of words produced in the first 15 seconds of the VF task.

Differences between the groups emerged when examining the number of switches and clusters formed in the phonological task and when comparing performance during the first 15 seconds of the task. Children with CIs demonstrated significantly fewer switches and also showed a trend (a difference that approached statistical significance, $p = 0.06$) to generate fewer clusters in the phonological VF task. Children with CIs also named significantly fewer words during the first 15 seconds of the phonological VF tasks.

Switching is considered an effortful process and is related to frontal lobe functioning (Hurks et al., 2006). The presence of a hearing impairment is assumed to alter the organization of words in memory. The presence of atypical organization poses even more difficulty in performing challenging and effortful processes. VF tasks are more challenging and, therefore, allow the loci of the breakdown to be revealed. The less efficient performance of the CI children highlights a difference in the efficiency of the organization of the lexicon. It is also possible that children with CIs showed fewer switches due to limitations in executive function, as suggested by Pisoni, Conway, Kronenberg, Horn, Karpicke, and Henning (2008).

Since the difference found between the two groups in naming words for the phonological VF task in one minute remained reliable when the groups were compared on performance in the first 15 seconds only, it may help in determining the nature of the observed limitations; it is not that children with CIs name fewer words because they ran out of words. Apparently, even during the first 15 seconds they displayed a disadvantage in naming performance.

The reduced number of switches, clusters and words generated in the first 15 seconds of the task, demonstrated in the phonological and not in the semantic task, can also be attributed to difference in the efficiency of the organization of the lexicon in terms of phonological features. This stresses the vulnerability of the phonological system to auditory impairment.

Similarities in the organization of the lexicon between children with CIs and NH children

Striking similarities between the two groups were found in the proportion of words generated in the first 15 seconds, in the time to retrieve the first word in the subjects' response and in the mean cluster size (MCS). The proportional distribution of the words across the 60 seconds of the task was similar in both groups. Both groups produced approximately 40% of the total number of words in the VF phonological task and 50% of the total number of words in the semantic VF task in the first 15 seconds of the task. No statistically significant difference was found between the two groups in the RT measurements to the initiation of the first word. Children with CIs also appeared to perform similarly to NH children with respect to the formation of clusters. Both groups used clusters of similar size (no difference was found in MCS). These findings were valid for both phonological and semantic VF tasks. The groups also did not differ in the number of switches, the number of clusters formulated and the number of words in 15 seconds measures in the semantic task.

These findings provide evidence that the automatic and controlled search processes used by both groups are similar. The observed similarities in the distribution of the words across the 60 seconds (generating the same proportion of words during first 15 seconds) imply that long-term memory is organized both phonologically and semantically in a similar manner in the two groups (NH and CI). The similarities found in the MCS can be interpreted as evidence for the fact that children with CIs follow a similar developmental trajectory to that of NH children in the way they form their lexicon, which has been said to be internally structured in several hierarchical levels: superordinate, basic and subordinate. The overall difference between the groups remains, however, in the efficiency of this organization. Although the children with CI perform similarly to the NH children in some key ways, overall, their performance is significantly worse. Based on my current data I postulate that while lexical representations in NH children are narrow and well defined, phonological and semantic representation in children with CIs may be unrefined and less detailed. Therefore, the process of retrieving words in children with CIs is less efficient, takes more time, and yields reduced performance.

CHAPTER 4: GENERAL DISCUSSION

This study was designed to examine specific underlying sources responsible for language deficits in some children with CIs. A deficit in naming has been shown to be a hallmark of language deficits in children and adults with language impairments (Leonard, Nippold, Kail, & Hale, 1983). However, naming is an understudied area of language development in children with hearing impairment and in CI users in particular. In this study, naming experiments were used to identify specific areas in language in which children with CIs differ from NH children.

The present study examined naming abilities using two tasks: a timed picture-naming task, and a phonological and semantic verbal fluency (VF) naming task. Performance of children with CIs was compared to age- and nonverbal IQ-matched NH children. The study had two goals. First, the study was designed to determine whether children with CIs demonstrate limited word retrieval abilities compared to age-matched and IQ-matched normal hearing (NH) peers. The second goal was to identify differences in performance on phonological- and semantic-based naming tasks.

The main hypothesis was that children with CIs would exhibit limited word-retrieval abilities in the naming experiments that stem from poor lexical access and/or organization. The current study uncovered some similarities and differences in the naming abilities of children with CIs and those of NH peers. Children with CIs did not differ from the NH group on the timed picture-naming experiment. No significant group differences were found in reaction-time measures in the picture-naming experiment. In contrast to the findings for the picture-naming task, results of the VF naming task confirmed the prediction. Significant differences were observed in the VF experiment. Children with CIs generated significantly fewer words than the NH group on both phonological and semantic VF tasks.

The findings of this study extend our knowledge of the underlying source of the observed differences in language abilities of some children with CIs, which can be attributed to the access and organization of the lexicon. Since this study involves off-line experiments that do not enable us to track the time course of the different lexical access processes, it is not clear whether the group differences stem from differences in lexical access, storage and/or organization. Further analyses and studies are necessary to determine the source of these differences.

Implications for lexical organization in children with CIs

Phonological organization

Access to acoustic-phonetic patterns of speech provides the perceptual foundation for normal oral language development, initially by enabling phonologic representations in the first year of life and subsequently by supplying phonological representations to learn words. The organization of CI children's lexicons in terms of phonological similarity neighborhoods was found to resemble that of NH children. Children with CIs were shown to be sensitive to the acoustic-phonetic similarities between words and seemed to organize words into similarity neighborhoods in long-term memory in the context of acoustic-phonetic similarities and word frequency (Kirk, Pisoni, & Osberger, 1995; Eisenberg, Martinez, Holowecky, & Pogorelsky, 2002). However, the phonologically-based long-term memory may be less efficient in its organization in children with CIs compared to NH children. Children with CIs may be at a disadvantage in forming these phonologically-based neighborhoods. This may result in underspecified phonological representations that affect the connections between words in memory. This might explain the source of the interaction of *group* by *word length* in the picture-naming experiment and the poorer phonological performance on the VF experiment.

Semantic organization

Quantitative measures of language production showed that children with CIs were delayed in vocabulary development. However, children post-implantation did seem to follow the typical developmental stages of language acquisition. For example, children with CIs seemed to acquire a fairly robust noun category before they developed verb-related knowledge (Le Normand, Ouellet, & Cohen, 2003; Ouellet et al., 2001). To date, there are no studies referring specifically to the semantic level of processing or semantic representations in the CI population. However, two relevant studies involving semantic memory have been reported with moderately hearing impaired children that are "successful hearing aid users" (Jerger, Damian, Tye-Murray, Dougherty, Metha, & Spence, 2006; Jerger, Lai, & Marchman, 2002a). These studies demonstrate similarities in the organization of the lexicon at the semantic level in hearing-impaired children. These results do not aid in specifying or explaining the nature of the semantic delay. One possibility, however, to explain the semantic delay is that the semantic representations and connections within the semantic network are not well specified in children with CIs. This might explain the source for the poorer semantic performance reported in previous research (Le Normand, Ouellet, & Cohen, 2003; Ouellet et al., 2001) and also observed in the semantic VF task of the current study.

Taken together, it seems that the different auditory input provided by a CI alters the typical development of the lexicon and affects lexical organization or representations. This may come into play in the form of unrefined phonological and semantic representations. Pisoni et al. (2008) suggested that the "CIs create highly degraded, "underspecified" neural representations of the phonetic content and indexical properties of speech that propagate and cascade to higher processing levels” (page 61). If these atypical representations cannot be reconstructed or refined at later stages of development, certain aspects of language knowledge and performance may be atypical.

To conclude, children with CIs appear to use similar retrieval strategies to NH children, but their retrieval abilities are less efficient due to poor organization and access to words stored in memory. In other words, although I found absolute differences in the total number of words produced in the VF task, it seems as if the children with CIs are doing basically the same processing as the NH children. They are both forming clusters in order to perform the VF task. They are also both producing the same proportion of words in the first 15 seconds of the task. In other words, their memory organization is similar.

The differences that emerged in this study might be explained by subtle differences that do exist in representations in the mental lexicon. There is evidence that lexical representations of children with CIs might be formed in an underspecified fashion. These less efficient representations, which are set early in life, may not be easily modified later; therefore, the performance of children with CIs remains inferior in this respect. Nevertheless, children with CIs do function as well as hearing children on some simpler tasks, such as the picture naming. It seems that the VF task, which requires a systematic search of many words under time pressure, is more apt to tap lexical access and organization than simple naming tasks that entail the retrieval of only one word at a time.

Several aspects of executive function and frontal lobe activity may be disrupted or delayed in children with sensory impairment and may underlie the differences observed in outcome measures of children with CIs. It is possible that differences were found only on the VF task and not on the picture naming task because the VF task involves some executive function abilities. Since it has been suggested that children with CIs exhibit executive dysfunction (Pisoni et al., 2008), this may have contributed to the reduced performance of the children with CIs on the VF task. On the other hand, as suggested by (Figueras, Edwards, & Langdon, 2008) it is possible that EF are not an intrinsic consequence of deafness, but rather result from delayed language acquisition. In this view, basic word retrieval abilities may be the underlying (linguistic) source for the poorer performance of children with CIs.

Another source for the reduced performance on the VF task may be related to the involvement of working memory abilities in the VF task. Cleary, Pisoni and Geers (2001) demonstrated differences in memory span between children with CIs and age-matched and gender-matched NH children. This atypical working memory development of children with CIs may have influenced the performance of the CI users in the VF experiment in our study as well.

Comparing performance of children with CIs with that of children with HAs with different levels of hearing impairments may shed light on the underlying source of the language impairment. Future research should examine naming abilities of children with various degrees of hearing loss (including minimal and unilateral hearing loss) to that of children with CIs and typically developing NH children, in order to learn the nature of the language impairment.

Effect of age at implantation

The statistical analyses performed for these two experiments included correlations between various factors of interest in the CI group. These factors included age at implantation and duration of CI use as associated with performance outcome (naming abilities). Younger age at implantation and longer duration of CI use were associated with better performance in naming bi-syllabic highly familiar words and also in naming words in the semantic VF tasks.

These results are consistent with earlier studies demonstrating an advantage for early implantation and longer CI use on outcome. Earlier implantation and extended duration of CI use have been repeatedly associated with better speech and language performance (Dettman, Pinder, Briggs, Dowell, & Leigh, 2007; Holt & Svirsly, 2008; Miyamoto et al., 2008; Nicholas & Geers, 2007). Younger age at implantation and more years of CI use are generally associated with better outcomes in receptive and expressive language skills.

There are several possible explanations for the moderate correlations and the non-significant correlations between age at implantation/duration of CI use and the other experimental tasks. These may be related to the nature of the task, the specific subjects in this study and their relatively older ages compared to some other studies.

The nature of the tasks used in the current study may have contributed to the fact that no correlations were found between age of implantation and other experimental tasks. Because the naming tasks examine a specific aspect of language, it is possible that age of implantation is not the most prominent factor affecting the performance on these tasks.

The participants in this study included only a select group of 20 children who were carefully chosen for their ability to fulfill task requirements (good speech intelligibility, specific age range, etc.). This is a relatively select group of CI users. It is possible that with a larger and more heterogeneous group of subjects, age at implantation would have been found to be correlated with other outcome factors as well.

It is also possible that the older age range (7-10 years) of subjects in our study contributed to this finding. Schorr, Roth, and Fox (2008) also found that age at implant was a predictive measure for some (PPVT-III and TAPS-R), but not all, language measures tested. They also found that duration of CI use predicted performance on only one of their language variables (syntax). They attributed their findings to the relatively older age range of children in their study. They suggest that the influence of age at implant may become less obvious in older children, especially when using measures that are not sensitive to subtle differences in linguistic knowledge. This may be valid for my findings as well.

Cleary (2009) noted that several factors contribute to language outcome in hearing-impaired children and that the impact of these variables must be assessed in combination, not in isolation. Also, she highlights the fact that there are many individual differences (such as gender and socio-economic status) that also contribute to language skills displayed by hearing-impaired children. It is therefore possible to say that the effect of age of implantation alone may show only a moderate correlation, because it is not the only factor that contributes to performance outcome.

Early implantation combined with early and intense habilitation could optimize language performance. It is possible that children with CIs need more exposure to words at a certain age to make up for the earlier lack of or reduced exposure to words, before implantation or even after implantation. It is possible that the implant does not convey all of the necessary acoustic information, sufficient for establishing a typical organization of the lexicon. Hearing is compromised especially under degraded listening conditions, such as background noise. In addition, the presence of a hearing impairment may yield a more vulnerable linguistic system. To remedy this deprived system, more exposure to sounds and words may be necessary in order to refine, strengthen, and maximize the connection between words in long-term memory.

Difficulties with word retrieval can be ameliorated by effective word finding strategies. Borovsky and Elman (2006) provide evidence from computational simulations that improvement in category development boosts word learning. Therefore, they suggest that training focused on category development may boost word-learning abilities in children who experience a delay in (input) language learning due to various conditions such as deafness. Several different speech therapy protocols are used for word retrieval impairments in children and adults. Given that the children in the CI group displayed difficulties in naming on phonological and semantic tasks, treatment based on word finding strategies in rehabilitation or habilitation therapy of implanted children may be beneficial. Other approaches could include teaching children groups of words that rhyme or are phonological neighbors so that at a conscious level, the children become more aware of phonological relationships among words. A similar approach could be directed towards semantic features and members of categories underlying nouns. The VF task can also be used as an assessment tool and might be used in intervention to enhance naming abilities and language performance of children with CIs. Further studies should continue to explore and identify specific underlying neuro-linguistic mechanisms and the many factors that impact language acquisition in children with CIs. A better understanding of the language profile of children with CIs and the consideration of the specific factors that interrelate with language abilities of children with CIs are crucial in order to optimize habilitation and enhance linguistic development of pediatric CI users and allow each child to maximize the fullest potential of cochlear implantation.

Appendix A. Stimuli for timed picture-naming experiment

	Word category	**Familiarity score (Cycowitz)**	**Neighborhood density**	**Familiarity rating**	**Number of syllables**
Dog	Animal	3.47	8,8	High	One
Cat	Animal	3.00	30,35	High	One
Corn	Food-vegetables	3.07	14,20	High	One
Ear	Body part	2.67	12,31	High	One
Fish	Animal	2.93	9,13	High	One
Ball	Toys	3.53	21,24	High	One
Apple	Food-fruit	3.20	5,8	High	Two
Balloon	Toys	3.20	2,2	High	Two
Pencil	Objects-Items	3.27	1,2	High	Two
Scissors	Objects-Items	3.33	0,0	High	Two
Table	Objects-Items	2.53	7,9	High	Two
Carrot	Food-Vegetables	3.07	2,3	High	Two
Kite	Toys	3.00	19,20	Low	One
Swan	Animal	2.93	10,11	Low	One
Vase	Objects-Items	2.50	15,16	Low	One
Well	Objects-Items	2.36	22,31	Low	One
Pear	Food-fruit	2.80	22,26	Low	One
Skunk	Animal	2.64	4,5	Low	One
Cherry	Food-fruit	2.63	8,10	Low	Two
Peacock	Animal	2.04	0,0	Low	Two
Penguin	Animal	2.86	0,0	Low	Two
Mushroom	Food-vegetables	2.14	0,0	Low	Two
Wagon	Objects-Items	2.48	0,0	Low	Two
Camel	Animal	2.17	7,8	Low	Two

Continued

Explanation for the different word categories in the description of the words stimuli for the picture-naming task:

Animals- dog, cat, fish, swan, skunk, peacock, penguin, camel

Food (fruit/vegetable)- corn, apple, carrot, pear, cherry, mushroom

Body part- ear

Toys- ball, balloon, kite

Objects in the house and other items- pencil, scissors, table, vase, well, wagon
Appendences

<u>Appendix B.</u> Parent questionnaire- Children with normal hearing (typically developing)

<u>PARENT/GUARDIAN QUESTIONNAIRE</u>

A.

Date: ___________

- Child's Name: ___________
- Date of Birth: _____________ Age: _____________ Grade: _____________
- School:_______________________________________ Town: ____________________________
- Child's Address: ____
- Home Phone Number: __________________________ Work: ______________________________
- Mother’s Name: __________________ Father’s name: ____________________________________
- Mother’s highest education level: _____________ Father’s highest education level: _____________

English______ Spanish_______ Italian_______ Other (please specify) ____

- Mother’s profession:__________________ Father’s profession:_______________________________
- Number of siblings:_______ Age of siblings:___________________________________

Number of people living in the household and their relationship to child: __________________________

B.

- What language(s) are spoken at home? (check all that apply)

  English ____ Spanish ____ Italian ____ Other (please specify) ____
- What is the child’s primary language? ____
- What other languages does your child speak? ____
- What languages can your child understand (although may not speak)? _________________________
- Who are the people the child frequently interacts with? (parents, siblings, grandparents, nanny, babysitter, etc…)

<u>Name</u> <u>Age</u> <u>Relationship</u> <u>Language spoken</u>

- Child's Birthplace: ____________________ ____________________________________
  Town/City State/Country
- Father's Birthplace: ________________ Father's primary language: __________________
- Other languages the father speaks fluently: ____
- Mother's Birthplace: _________________ Mother's primary language:______________________
- Other languages the mother speaks fluently: ____
- Countries (outside the US) in which the child has lived for more than 1 year:

  Country Years

_______________________________ from _______________ to _______________

_______________________________ from _______________ to _______________

_______________________________ from _______________ to _______________

- What is the child's favorite television show? ___________________________________

C.

- Is your child's speech difficult to understand? No _____ Yes _____ (explain) ____
- Do you think your child exhibits a language delay? No _____ Yes _____ (explain) ____
- When did you first notice the language delay? ____
- Is there any history of the following in the family (check all that apply):
  Speech/ language disorders _____ Hearing impairments _____ Learning disorders _____
  Please explain: ____
- Has your child been evaluated by or worked with any of the following? (check all that apply and please explain)
  Ear Nose and Throat (ENT) Doctor _____ Neurologist _____ Psychologist _____
  Audiologist ______ Reading Specialist _____ Speech Language Pathologist _____
  Other ______________ Explain: ____
- Do you think your child hears well? No _____ Yes _____ (explain) _________________________
- Has your child ever had a hearing test in a facility other than school? No _____ Yes _____ (please provide results) ____
- Does the child wear glasses? No ______ Yes _____
- Which hand does your child use most? Left hand _____ Right hand _____ Both equally _____

- Please state the age at which the child reached each developmental milestone:
  Sat up ___________ Walked ___________ Spoke first word __________

D.

- What activities is your child engaged in after school? (meeting with friends, after school courses, playing alone, etc…) ____
- Who does your child like to play with the most? (parents, siblings, neighbors, schoolmates, younger kids, older kids, etc…) ____
- Are there any activities your child hate or avoid participating in? ______________________________
  ____
- Does your child exhibit any antisocial or socially inappropriate behaviors (avoiding interactions, consistently playing alone, etc…)? No ______ Yes ______ (explain) _______________________
- Does your child exhibit any repetitive behaviors or self-stimulating behaviors (rocking or arm flapping, etc…) for no apparent reason? No ______ Yes ______(explain) _________________________
- Does your child maintain eye contact? No ______ Yes ______ (explain) ______________________________________
- Does your child demonstrate outbursts of unprovoked laughter, crying, or aggression? Yes _______ No _______ (explain) ____
- Does your child have quick and drastic mood changes? No ______ Yes ______ (explain) ____
- Has your child been diagnosed with: PDD? No ______ Yes _______ Autism? No _______ Yes ______ Asperger's Syndrome? No _______ Yes ______ ADD/ADHD? No ______ Yes ______

E.

- Does your child evidence any motoric difficulties (writing, drawing, eating, dressing, etc…)?
- No______ Yes ______ (explain) ____
- What outdoor activities does your child enjoy engaging in? ___________________________________
  ____
- What outdoor activities does your child hate or avoid participating in? ___________________________
  ____
- Who dresses your child in the morning? (parent, sibling, dresses himself) _______________________
  ____

Medical History:

- Did the child's mother have any health problems during pregnancy? No _____ Yes _____ (explain)
  ____
- Was your child: Full term _____ Premature _____ Child's birth weight __________
- Has your child ever been hospitalized? No _____ Yes _____ (explain)
  ____
- Does your child have any of the following? (check all that apply)
  Asthma _____ Allergies _____ Frequent ear infections _____
- Does your child take any medication? No ______ Yes ______ (explain)
  ____
- Has your child ever been treated for cleft palate? No _____ Yes _____ (explain)
  ____
- Is there any information you would like to share with us to help us understand your child better?
  ____
  ____
  ____

- Would you or your child be interested in being contacted about participating in future studies? (Please circle one.) Yes No

- This research is supported by a grant from The National Institute on Deafness and Other Communicative Disorders (NIDCD). The NIDCD is committed to including people from all backgrounds in research and therefore asks us to collect the following information. You may choose not to provide this information. (please check one in both categories)

Ethnic Category (please check one)

- ❑ Hispanic or Latino
- ❑ Not Hispanic or Latino

Racial Category (please check one)

- ❑ American Indian/Alaska Native
- ❑ Asian
- ❑ Native Hawaiian or Other Pacific Islander
- ❑ Black or African American
- ❑ White

Appendix C. Parent Questionnaire- Children with CIs

A.

Today's Date: ____________________________
Father's name: ________________ Mother's name: _________________
Child's Name: _________________ Date of birth: _________________________
Name of school: __________ Grade: ____ Age: _____ Sex: f / m (circle one)
Has your child ever skipped a grade or re-taken a grade? _______ If yes, please explain: ____
Home Phone number: ______________________
Cell Phone number: ________________________ Work Phone number: _________________
e-mail: ____
Child's home address ____
____
Mother's highest education level: ____________ Father's highest education level: ___________
Mother's profession: _______________ Father's profession: ____________________________
Number of siblings: ________
Age of siblings: ____
Number of people living in the household and their relationship to child: ___________________

B.

What language(s) are spoken at home? (check all that apply). Please specify the specific dialect used (for example, Mexican/Puerto Rican/Dominican Spanish etc., Mandarin/Cantonese Chinese etc.).
English __ Spanish __ Russian __ Hebrew __ Chinese __ The specific dialect used: __________
Other (please specify) ____________________
What is the child's primary language? ____
What other languages does your child speak? ____
What languages can your child understand (although may not speak)? _____________________
Who are the people the child frequently interacts with? (siblings, grandparents, babysitter, etc…)

Name	Age	Relationship	Language spoken

Child's Birthplace: ____________________ ___________________________________
Town/City State/Country

Father's birthplace: ______________ Father's primary language/s: ________________________
Other languages the father speaks fluently: ____
Mother's Birthplace:_______________ Mother's primary language ________________________
Other languages the mother speaks fluently: ____

Countries (outside the US) in which the child has lived for more than 1 year:

Country		Years		
________________________________	from	________________	to	________________
________________________________	from	________________	to	________________
________________________________	from	________________	to	________________

C.

Information regarding Cochlear-Implant (CI)

Child's age at onset of hearing-impairment: ____

Etiology of hearing loss (if known): ____

Child's age at cochlear implantation: ______ Child's age at initial stimulation (mapping): _____

Implanted ear: left ___ right ___ both ___

If both, which ear was implanted first? Right / left / both at same time

Age at right ear implantation: _______ Age at left ear implantation: _______________

Type of implant processor: ear-level processor _______ body-worn processor _______

Type of implant processor:

Cochlear (Nucleus) ___ Advanced Bionics (Clarion) ___ MED-EL (TEMPO/COMBI40+) ___

Other ________

Model name of the CI your child is currently using (if known): _____________

Speech coding strategy currently using (if known): _____________________

Approximately how many hours during the day does your child use his/her cochlear implant? (circle one)

Less than one hour   1-3   4-8   9-16   16+

Do you feel your child hears well with his/her implant? ___

Do you have any concerns presently regarding your child's cochlear implant? If yes, please explain:
____

Has your child used another type of cochlear implant in the past? If yes, please explain:
____

Has your child in the past ever stopped using his/her implant for any extended amount of time?

If yes, please explain: ____

Does your child regularly use an additional hearing aid in the ear opposite his/her implanted ear?

If yes, please explain: ____

Does your child use an F.M. system? ______ When? ________ How often? ________________

Last mapping date: __________________ Were there any major changes in the map your child uses? ____

Has your child experienced any device failure? __ When __________ How was treated
____

Did your child have Meningitis: ______ If yes, when? ____________ explain:
____

Explain how your child's hearing behavior changed after cochlear implantation:
____
____
____

Does your child use sign language? Yes / No Together with spoken language? Yes / No
Is sign language spoken at home? Yes / No By whom? ________________________
Is sign language used in the child's school? Yes / No By teacher? _____ Other students? _____
Please explain:
What type of manual language is used? (e.g., Signed exact English, Cued Speech, ASL etc.) _________________________________
How often does your child rely on lip-reading? (circle one)
never rarely sometimes fairly often frequently always
Please indicate if your child has been enrolled in the following school settings:
Enrolled in an oral school for children with hearing impairments: from grade ___ to grade: _____
Enrolled in a manual school for children with hearing impairments: from grade ___ to grade: ___
Enrolled in a mainstreamed classroom: from grade _____ to grade: _____
Other, Please describe: ____
Does your child work regularly with a speech-language pathologist? __
In what setting? (check all that apply)
School _____ How often? __________ Private practice _____ How often? __________ Other: ____
Is your child currently involved in any specific therapy type? _____ Please describe: ____

How often does your child find speech spoken by unfamiliar talkers difficult to understand? (Circle one)
never rarely sometimes fairly often frequently always
Have you noticed any types of speakers that your child finds especially difficult to understand? (e.g., male talkers, female talkers, non-native speakers, young children etc.) _____ Please explain: ____
How comfortable is your child with audio-only telephone communication? ____
How difficult is it for your child to recognize a family member only from the sound of his/her voice? ____
Does your child play a musical instrument? _____ Which? __________ For how many years? ___________

D.

Is there any history of the following in the family (check all that apply):
Speech/ language disorders _____ Hearing impairments _____ Learning disorders _____
Please explain: ____
Has your child been evaluated by or worked with any of the following? (check all that apply and please explain): Neurologist ___ Psychologist ___ Reading specialist _____ Physical therapy _____ Occupational therapy _____ Other __________ Explain: _________________________________
Approximately at what age did your child start to read? _________________________________
Does the child wear glasses or contact lenses? No __ Yes __ Is he/she wearing them today? ____
Has your child been diagnosed as being colorblind? ______________________________________
Which hand does your child tend to use when drawing/writing? Left / Right / Both equally
Please state the age at which the child reached each developmental milestone:
Sat up __________ Walked __________ Spoke first word __________

E.

What activities is your child engaged in after school? (meeting with friends, after school courses, playing alone, etc…) ____

____

Who does your child like to play with the most? (siblings, neighbors, schoolmates, younger kids, older kids, etc…) ____

____

Are there any activities your child hate or avoid participating in? __________________________

____

Does your child exhibit any antisocial or socially inappropriate behaviors (avoiding interactions, consistently playing alone, etc…)? No ___ Yes ___ (explain) ____________________________

____

Does your child exhibit any repetitive behaviors or self-stimulating behaviors (rocking or arm flapping, etc…) for no apparent reason? No ___ Yes ___ (explain) _________________________

Does your child maintain eye contact? No ___ Yes ___ (explain) __________________________

Does your child demonstrate outbursts of unprovoked laughter, crying, or aggression? No ___ Yes ___ (explain) ____

Does your child have quick and drastic mood changes? No ___ Yes ___ (explain) ___________

____

Has your child been diagnosed with: PDD? No ___ Yes ___ Autism? No ___ Yes ___

Asperger's Syndrome? No ___ Yes ___ ADD/ADHD? No ___ Yes ___

F.

Does your child evidence any motoric difficulties (writing, drawing, eating, dressing, etc…)?

No ___ Yes ___ (explain) ____

What outdoor activities does your child enjoy engaging in? _______________________________

____

What outdoor activities does your child hate or avoid participating in? _____________________

____

Who dresses your child in the morning? (parent, sibling, dresses himself)? __________________

____

What is the child's favorite television show? ____

<u>Medical History</u>:

Did the child's mother have any health problems during pregnancy? No _____ Yes _____ (explain) ____

Was your child: Full term __ Premature __ (number of weeks _____)

Child's birth weight ______________

Has your child ever been hospitalized? No ___ Yes ___ (explain) _________________________

____

Does your child have any of the following? (check all that apply)

Asthma _____ Allergies _____ explain: ____

Has your child ever had an ear infection? _________

If so, in which ear(s)? _____ first occurrence? _____ frequency of occurrence: _____

Did your child have a draining ear (pus, blood, etc.)? ____________________________________

Did your child complain of noises in his ear, such as ringing or pulsing (tinnitus)? ____________
Is your child able to locate the direction from which sound is coming? _____________________
Does your child favor one ear? ___ If so, which ear? ___________
Does your child have difficulty hearing in noise? _______________________________________
Does he ask frequently "what" or ask you to repeat yourself? _____________________________
Is your child sensitive to loud noises?____
Does your child take any medication? No _____ Yes _____ (explain)____
Has your child ever been treated for cleft palate? No __ Yes __ (explain) ___________________

Is there any information you would like to share with us to help us understand your child better?
____
____
____

Would you or your child be interested in being contacted about participating in future studies?

(Please circle one) **Yes** **No**

This research is supported by a grant from The National Institute on Deafness and Other Communicative Disorders (NIDCD). The NIDCD is committed to including people from all backgrounds in research and therefore asks us to collect the following information. You may choose not to provide this information.

Please check one in both categories:

Ethnic Category (please circle one)

1. Hispanic or Latino
2. Not Hispanic or Latino

Racial Category (please circle one)

1. American Indian/Alaska Native
2. Asian
3. Native Hawaiian or Other Pacific Islander
4. Black or African American
5. White

Appendix D. Scoring Rules for the verbal fluency task

Scoring rules were based on Troyer et al., 1997; Troyer, 2000 and Koren et al., 2005.

Verbal fluency experiment

Any correct response received 1 point.

Repetitions, errors, unintelligible words and names of general categories did not receive a point.

If the child named a words that start with the sound /f/, but is spelled with "ph" (example: phone), the word was scored, because the task is based on the sound /f/ and not spelling for the letter f.

If the child named words that start with the "th" sound, although spelled with a "t" (example: the, three), the child did not receive a point, because the task was the sound and not spelling.

Private names, science fiction, slang and abbreviations (e.g., TV) were accepted. "Baby words" (e.g., "lolly" for lolly pop) were accepted as well.

If the child named an additional word by just adding plural, he received only one point. For example: friend, friends = 1 point; fence, fences = 1point (no extra point for just adding "s").

Change of tense, adding "ed" (example: tap, tapped or lye, lied) or "ing" (laugh, laughing) or (eat, eats)- the child received only one point (no extra point for just adding "ed" or "ing"). However, irregular changes of tense or plural, provided an extra point. For example: foot, feet = 2 points; teach, taught = 2 points; goose, geese = 2 points.

Changes from noun to adjective, provided an extra point.

For example: luck, lucky = 2 points; talk, talkative = 2 points; fame, famous = 2 points.

If the child named two words, in which the second word is the same as the first word, but just added a word to the previous word, without changing the entity of the first word, for example, for the category food: chili, chili dog, he received only one point. Similarly, lolly, lolly pop = 1 point. Similarly, if the child named: four, four hundred, four thousand = he received only 1 point. But: Four, fourteen = 2 points; five, fifth = 2 points, because these are irregular changes.

In the VF a*nimals* task, feminine and muscular received two points; adult and infant received two points. For example: hen, rooster = 2 points; cat, kitten = 2 points; lion, lioness = 2 points.

If a child named general categories (supra ordinate) (examples; apes, fruit) and did not name in his response words that belong to these general categories, for example monkey (apes), apples (fruit), he received one point for this response (one point for "apes" and one point for "fruit"). However, if he named a general category and did name words that belong to this category, such as monkey (apes); or for the fruit example: banana, apple etc, he received points for the words he named, but NOT an additional point for the general word, the category name (supra ordinate). For example: "cake, meat, fruit, apple, banana, orange" = 5 points (fruit not counted); but "cake, meat, fruit" = 3 points (fruit counted).

Also, in the *animals* task, minor changes did not receive an extra points, changes that make a greater change did receive points. Example: bear, polar bear = 2 points; goat, mountain goat = 2 points.

When scoring the *animals* category, the word "human" or "people" were accepted.

Scoring rules for clustering and switching (verbal fluency experiment)

Repetitions were included in the cluster and switches counts.

Scoring rules for clusters

Clusters were defined as groups of two or more successively produced words that share phonological or semantic characteristics.

Groups of two or more successively produced words belonging to the same semantic subcategory or members of the same phonological category were counted as a cluster.

Each word in the cluster, counted for one point.

Semantic clusters consisted words with related meanings or that belonged to the same subcategory. (Example: coffee-cake; dolphin-whale)

For example, in the *animal* category, subcategories of aquatic animals or jungle animals may have been present. (e.g., in the child's respond to the a*nimals* subtask, the child may have said "…seal, dolphin, whale, fish…lion, giraffe, monkey...", in other words, an aquatic animals semantic cluster of the size of 4 (seal, dolphin, whale, fish) and a jungle-animals cluster of size 3 (lion, giraffe, monkey).

The same word was counted twice if the word belonged to two consecutive clusters.

Example: "dog cat tiger lion cheetah". Cat was counted twice. First, dog and cat were counted as a pet cluster and the second time cat was counted as part of the zoological category feline, which included cat, tiger, lion, cheetah etc.

Foods from same ethnic group were counted together as a cluster. For example, burrito, fajita… Mexican; egg roll, rice, sweet & sour sauce… Chinese; pizza, pasta… Italian.

Phonological clusters consisted of words that share similar phonemes, either beginning (phonologically) with the same two initial segments (CV or CC), or words sharing first and last sound, or words that rhyme. (Example: free-fry; fat-foot; like-life). For example if in the "f" category (words that begin with /f/) the child said "…fight, fright…fat, feet, foot…" he was scored to have one phonological cluster of size 2 (fight, fright) and one phonological cluster of size 3 (fat, feet, foot).

In the cluster scoring, errors, wrong words or general words were included.

Additional examples for clusters are included in Troyer et al., 1997 (p.145-6), Troyer, 2000 (p. 377-8) and Koren et al., 2005 (p. 1102).

Scoring rules for switches

Switches were defined as transitions from one correct word to another or to a cluster, or from a group of words (cluster) to the next word/group of words. For example, if in the child's respond to the *animals* task, the child named: "seal, dolphin, whale, fish, ant, penguin, lion, giraffe, monkey". The child named a total of 9 animals. Seven of the animals that the child named were part of a cluster that could be identified (*aquatic animals* and *jungle animals*). Two animals were named individually (ant, penguin), these animals were not part of the clusters identified. In this example, the child named an *aquatic animals* cluster of the size of 4: "seal, dolphin, whale, fish", then the child named "ant" and "penguin" (not part of a cluster). Since "Ant" and "penguin" were not part of a specific cluster, they were scored as a single word. Then the child named a cluster of 3 *jungle animals*: "lion, giraffe, monkey". In this example, we counted a total of 3 switches: one from the *aquatic animals* cluster to the "ant", a second switch from "ant" to "penguin" and a third switch from "penguin" to the *jungle animals* cluster.

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