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Cognition and communication in children/adolescents with cochlear implant

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If the person you are talking to doesn't appear to be listening, be patient. It may simply be that he has a small piece of fluff in his ear.

Winnie the Pooh

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To my family

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ABBREVIATIONS AND DEFINITIONS

CI	Cochlear implant
HI	Hearing impairment
SPHI	Severe to profound hearing impairment
Deaf	A sociocultural term referring to persons who are members of the deaf community and use sign language as their main communication (Lane, 2005)
BEHL	Best ear hearing level
Prelingual SPHI	Severe to profound hearing impairment acquired before 36 months of age
Postlingual SPHI	Severe to profound hearing impairment acquired after 36 months of age
Congenital SPHI	Severe to profound hearing impairment at birth
CIP	Conversational partner to the child/adolescent with CI
HC	Hearing children
HCP	Conversational partner to the hearing child/adolescent
SLI	Specific language impairment
SNR	Signal to noise ratio
PCC	Percent consonants correct
PSA	Percent suprasegmental accuracy

LIST OF PUBLICATIONS

This thesis is based on the studies reported in the following papers, referred to in the text by their respective Roman numerals.

I. Ibertsson, T., Willstedt-Svensson, U., Radeborg, K. & Sahlén, B. 2008. A methodological contribution to the assessment of nonword repetition - a comparison between children with specific language impairment and hearing impaired children with hearing aids or cochlear implants. Logopedics Phoniatrics Vocology 33:168-178.

II. Ibertsson, T., Hansson, K., Mäki-Torkko, E., Willstedt-Svensson & Sahlén, B. 2008. Deaf teenagers with cochlear implants in conversation with hearing peers. International Journal of Language and Communication Disorders 44: 319-337.

III. Ibertsson, T., Hansson, K., Mäki-Torkko, E., Asker-Árnason, L., & Sahlén, B. 2009. Speech recognition, working memory and conversation in children with cochlear implant. Deafness and Education International 11:132-151.

IV. Ibertsson, T., Asker-Árnason, L. Hansson, K., Lyxell, B. & Sahlén, B. The complex relationship between reading, writing and working memory in seven teenagers with cochlear implant. Manuscript.

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INTRODUCTION

A cochlear implant (CI) stimulates the auditory system and provides auditory input to individuals with severe to profound hearing impairment (SPHI). Worldwide, approximately 120.000 children and adults have received a CI (Wilson and Dorman, 2008). The first child to receive a CI in Sweden was implanted 1991 and up to date approximately 600 children in Sweden have been implanted (Barnplantorna, 2009).

CIs have made it possible for children with SPHI to develop skills related to spoken communication in a way not possible before, even though the hearing capacity is not restored to normal levels (Svirsky, Robbins, Kirk, Pisoni and Miyamoto, 2000; Geers, Brenner, Nicholas, Tye-Murray and Tobey, 2003a). However, our knowledge about the development in a number of areas in children/adolescents with CI is still lacking. There is still a major lack of knowledge about why some children/adolescents with CI typically develop cognitively and linguistically and some not, and how they cope with real life conversations with hearing peers.

The purpose of this thesis was to explore the interaction between cognition and language (i.e. working memory capacity and phonological processing) and more complex skills such as the ability to interact with hearing peers, and some aspects of reading and writing in children/adolescents with CI.

Figure 1 illustrates that hearing with CI affects working memory capacity as well as skills related to different language levels; phonology, grammar and lexicon. These skills are in turn prerequisites for the development of more complex skills such as conversation, reading, writing and arithmetic. Speech recognition and speech intelligibility are also complex skills, since long explored by researchers in the field of paediatric audiology and also widely included in clinical audiological assessments of outcomes in children with CI.

All the skills in Figure 1 influence each other and interact in a complex and non-hierarchical fashion. The interaction between functions showed in bold in Figure 1 are in focus in this thesis.

Traditionally these skills have been explored and assessed in areas such as audiology, linguistics, speech pathology and cognitive psychology. An interdisciplinary approach to research in children with hearing impairment (HI), including children with CI, is not only necessary but it is perhaps the only fruitful way to accumulate theoretical knowledge about the population. The formalization of such an interdisciplinary field, with the proposed label Cognitive Hearing Science, was recently advocated in a overview by Arlinger, Lunner, Lyxell and Pichora Fuller (2009).

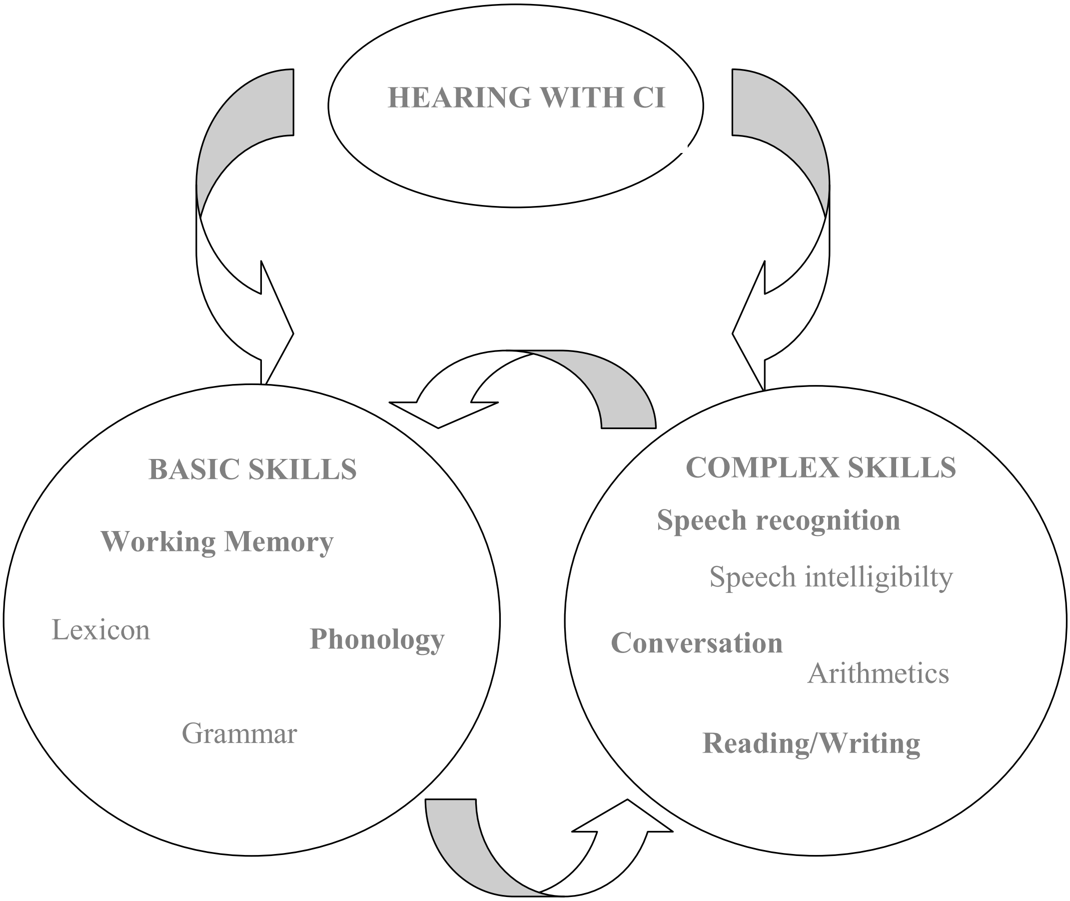

Figure 1. Illustration of the basic and complex skills influenced by hearing with a CI

Children with CI represent a very heterogeneous group. They vary with respect to a number of factors, such as age at implant, duration of deafness, aetiology of hearing impairment (HI) and communication mode. The participants in this thesis were all recruited as a part of follow-up at the Department of Audiology, Lund University Hospital. The participants in study I were aged five to eight years and the participants in study II, III and IV were aged nine to nineteen. A few steps were taken in order to restrict variability in some respects. Before being tested, the participants were judged by a speech language pathologist to be cooperative in test situations. They were, according to medical records, assessed by a psychologist and were found to have an IQ within normal limits. They were unilaterally implanted and all used the Nucleus 22 implant and the speech processors were programmed by the same technical audiologist. All 26 participants used oral language as their main communication mode at home. However, in study I, where the children were younger, four children were placed in special schools for children with HI and they, as well as three others, used sign language to various degrees.

BACKGROUND

The auditory system and hearing impairment

When an acoustic signal reaches the outer ear a series of events takes place in the auditory system, i.e. the outer ear, the middle ear, the inner ear, the central auditory pathways, and the auditory cortex. First, the tympanic membrane starts to vibrate, and these vibrations are then transmitted through the three ossicles to the oval window. Fluids in the three canals of the cochlea start to move, leading to a displacement of the basilar membrane that is responsible for analysing the signal into different frequencies. The hair cells on the basilar membrane bend and stimulate the ganglion cells and the nerve fibres. These are organized according to the frequency at which they are most sensitive. The hair cells located in the basal turn of the cochlea respond to high frequency sounds while those located in the apex of cochlea respond to low frequency sounds. The acoustic nerve transmits the impulses to groups of neurons in a complex system of pathways and they finally reach the auditory cortex. An injury somewhere in the auditory system leads to a hearing impairment (HI) and to a distorted signal in the auditory cortex.

Prevalence, aetiology, classifications and definitions

It is estimated that over 250 million people in the world have an HI (WHO, 2009); permanent childhood hearing impairment has a prevalence of 1 to 2 per 1000 individuals (Fortnum and Davis, 1997; Mäki-Torkko, 1998). The most common type is *sensorineural HI* (Parving, 1983) where the injury is located either in the cochlea, along the auditory nerve or along the central auditory pathways. According to Mäki-Torkko (1998), 90 % of all permanent HI are sensorineural.

The cause of HI is known in approximately 60% of all cases (Fortnum, Marshall and Summerfield, 2002). Of those 41.9 % have a genetic cause of HI, whereas 12.9 % have a syndromal cause. Fortnum and Davis (1997) and Fortnum et al. (2002) has also reported that approximately 30-40 % of all children with HI have another clinical or developmental problem, and about half of these have more than one problem.

There are many different classifications of HI, mainly referring to the degree of HI and the time of onset. One commonly used classification of the degree of HI was proposed by an EU expert group (Stephens, 1996). This classification is based on the average hearing at 0.5, 1, 2 and 4 kHz in the best hearing ear $\text{BEHL}_{0.5\text{-}4\ \text{kHz}}$. According to this classification, a *severe HI* is defined as a $\text{BEHL}_{0.5\text{-}4\ \text{kHz}} \geq 70$ dB HL but < 95 dB HL and a *profound HI* as $\text{BEHL}_{0.5\text{-}4\ \text{kHz}} \geq 95$ dB HL. The time of onset of HI can be classified as a *congenital* (from birth) or an *acquired* HI. According to Fortnum et al. (2002) about 80% of all children with SPHI have a congenital HI. Furthermore, HI is sometimes classified as a *prelingual* vs *postlingual* HI. In the literature on children with CI, prelingual is often defined as an acquired HI before 36 months and postlingual as acquired HI after 36 months of age (Wie, 2005).

In this thesis, the term *SPHI* will be used to describe children/adolescents with a severe to profound hearing impairment for whom hearing is not sufficiently restored by hearing aids and who therefore have been implanted with a CI.

Cochlear implants

Device

The current multi-channel CIs consist of an external and an internal unit. The external part of the CI has a *microphone* that picks up the sounds and a *speech processor* that codes the frequency of the signal, much like a healthy cochlea analyses the input signal into its frequency components, and then transmits the coded signal through a *transmission system* to the internal unit that is surgically implanted in the temporal bone behind the ear. The internal unit consists of a *receiver* and an *array of electrodes,* placed in the scala tympani. *The receiver* receives the signals transmits them to the array of electrodes.

The most commonly used cochlear implant systems used today are; NUCLEUS from Cochlear, MED-EL from Medical Electronics, and CLARION from Advanced Bionics. These three systems have a different number of electrodes which are stimulated depending on the frequency of the signal. Electrodes near the base of the cochlea are stimulated with high-frequency signals, while electrodes near the apex are stimulated with low-frequency signals. The type of signal processing used for coding speech signals is defined as a *speech coding strategy.* Most common current strategies aim to mimic the frequency distribution in a healthy cochlea, i.e. the speech signal is divided into several frequency channels corresponding to the tonotopic organisation of the cochlea.

Hearing with a CI

A CI cannot be regarded as a device/system comparable to the auditory system in hearing individuals. Although the children with CI receive auditory input, the hearing is not restored to normal levels. Therefore, the auditory cortex receives a degraded signal that, according to Pisoni et al. (2008), hampers the development of phonological representations in long-term memory which are thus likely to be imprecise. The consequence of imprecise phonological representations is that other systems than those related to verbal auditory processing also will be affected, i.e. the imprecise phonological representations “cascade to higher processing levels” (Pisoni *et al.*, 2008:58).

A long lack of auditory input may also have caused the cells predisposed for hearing to develop in other functions instead of being unused, which means that a neural reorganization of the auditory system has taken place (Wilson and Dorman, 2008). For example, Finney, Fine and Dobkins (2001) found signs of visual stimuli activating cells originally destined to process auditory stimuli in individuals with a childhood SPHI. Therefore, when a child receives a CI some reorganisation has probably already taken place, which in turn influences the nature of hearing with a CI.

The brain becomes less plastic with increasing age. According to Gilley, Sharma and Dorman (2008) this supports the notion of a sensitive period during which the system is maximally plastic. This has had a major impact on the question of when a child with congenital SPHI should receive a CI. Sharma, Dorman and Sparhr (2002) report that there seems to be a sensitive period of 3.5 years for children with CI since children implanted during the first 3.5 years had similar cortical responses to auditory stimulation as hearing children.

Criteria for candidacy

The criteria that have to be fulfilled in order to receive an implant have changed over the years. In the early days of CI, the audiological criterion was that only adults with postlingual SPHI with no benefit from hearing aids would be included. Later on, children with postlingual SPHI were included, and then also children with congenital or prelingual SPHI. Today, even individuals with residual hearing, but with limited benefits from the amplification provided by hearing aids, are candidates for a CI.

For non-audiological criteria, the clearest change has been the introduction of CI to children with multiple handicaps. For example, children with CHARGE syndrome (Lanson, Green, Roland, Lalwani and Waltzman, 2007) and children with autism spectrum disorder (Donaldson, Heavner and Zwolan, 2004) are possible candidates for CI. In fact, there are very few absolute contraindications for CI. They include complete obliteration of the cochlear nerve (cranial nerve nr 8) or cochlear agenesis (Bouchard, Ouellet and Cohen, 2009).

Candidacy for CI is usually defined as SPHI where optimally fitted hearing aids do not provide enough benefit for speech and language development. Before the decision on surgery is made, the candidate is thoroughly assessed by a multi-professional team. The audiological assessment includes a verification of the degree and type of HI, and also the degree of hearing aid benefit. Computer tomography (CT) or magnetic resonance imaging (MRI) is used to evaluate the status of the cochlea, the temporal bone, the facial nerve, the cochleovestibular nerve. Speech and language pathologists assess communication development. Psychosocial assessment of the child and the family is included, and technical and medical information is given.

Age at implant

Today, the Food and Drug Administration (FDA) in the US approves of children being implanted at 12 months of age (Wackym, Firszt and Runge-Samuelson, 2005) but due to the many screening programs children are implanted at an even younger age. The question of whether the earlier the better is not as straightforward as one might think, in particular not when it comes to operating children younger than 12 months of age due to the risks involved. According to Valencia, Rimell, Friedman, Oblander and Helmbrecht (2008), young children have an underdeveloped mastoid tip, a thin skull, a thin skin and a higher risk of complications after anaesthesia. The authors conclude that the risks of implanting children as young as 7 months are minimal and the operation can be considered safe if the surgical team involved is experienced. Comparing children with CI, who received their implant at 6 months of age, with children implanted at the age of 12 months, Holt and Svirsky (2008) found that the advantages from implanting children at 6 months of age were rather small and therefore argue that the risks of the treatment should be taken into consideration.

Age at implant and its impact on language and communicative will be discussed further under the section language and communication in children with CI.

Unilateral/Bilateral implants

Hearing people rely on two ears for better localisation of sound and speech recognition, especially in noise. These are the two areas many unilateral CI users are experiencing difficulties with. Therefore, more and more individuals receive bilateral implantations. Up to date, approximately 150 children in Sweden have been implanted bilaterally (Barnplantorna, 2009). Bilateral implantation has been reported to benefit both sound localisation (Litovsky, Johnstone and Godar, 2006) and speech recognition in quiet and in noise (Scherf, van Deun, van Wieringen, Wouters, Desloovere, Dhooge *et al.*, 2007).

After surgery

The initial stimulation takes place 3-4 weeks after the surgery. According to Firszt and Reeder (2005) the clinicians obtain both different behavioural responses from the child and results from objective measures acquired in the operating room. By increasing and decreasing the stimulation levels both thresholds and comfort levels are set. Reliable responses are searched for in as many apical and basal channels as possible. The thresholds and the comfort levels are then used to develop an initial speech program (Firszt and Reeder, 2005).

During the years after implantation, a close co-operation between the family and the CI team is essential. This can mean several appointments on a yearly basis and the most frequent contacts are with the technical audiologist, the pediatric audiologist and the speech /language pathologist. Later on regular follow-ups are scheduled once or twice a year but additional contacts are made if needed, and the rehabilitation is always planned based on the needs of each individual child and his/her family.

Communication mode and school-setting

A communication mode is the means by which communication with and by the child with CI occurs (Gravel and O'Gara, 2003). When studying children with CI in Sweden, it is important to be aware of the many differences in school settings and communication modes compared to countries outside Sweden and Scandinavia. In 1981, sign language was acknowledged as the official language of the deaf in Sweden. The term *deaf* is considered a sociocultural term which refers to persons who are members of the deaf community and use sign language as their main communication mode (Lane, 2005). In Sweden, all children born with SPHI are offered the opportunity to be exposed to sign language in re/habilitation.

In Sweden today, there are five possible educational settings for children with CI. Some children are individually integrated in mainstream schools for hearing children and some attend classes for children with HI integrated in mainstream schools. Children with CI may also attend a special school for children with HI where they are instructed in oral language. Further, they may attend a special school for children with SPHI where different options (sign language and oral language with supportive sign) are provided depending on the child's linguistic and communicative abilities.

Studies have for a long time reported that different communication modes and school settings influence the language acquisition in children with CI. For example, the amount of time a child with CI has spent in mainstream education, with an oral communication approach, is a significant predictor of language outcome (Geers and Brenner, 2003; Uchanski and Geers, 2003). Archbold, Nikipoulous and Lloyd-Richmond (2009) have also found a link between mainstream education placement and long-term use of CI, so that children who are placed in mainstream education use their implant/s more. However, recent studies argue that communication mode cannot be viewed as something static and that it is no longer a question of either oral communication or sign language, since children with CI change their communication modes over time (Watson, Archbold and Nikolopoulos, 2006; Wheeler, Archbold, Hardie and Watson, 2009). A successive transition between communication modes, not an abrupt change, has also been reported in some studies, suggesting that children with CI use sign to a lesser extent as their oral communication develops (Wheeler *et al.*, 2009).

Psycho-social aspects of hearing-loss

Numerous studies have emphasized the difficulties individuals with SPHI, without CI, encounter in areas of psycho-social well-being, such as self-esteem (see Nicholas and Geers, 2003 for a review). As for children with CI, studies report that they seem to have good self-esteem, not different from hearing peers (Filipo, Bosco, Barchetta and Mancini, 1999; Nicholas and Geers, 2003; Sahli and Belgin, 2006).

In Sweden, one study has assessed the well-being in children with CI (Preisler, Tvingstedt and Ahlström, 2005). This study reported that the Swedish children, operated during the 90´s, viewed themselves as "bicultural", which the authors interpret as a strong argument for ensuring that sign language continues to play the same role in the future as in the past. This will be a difficult goal to achieve, since more and more children with SPHI and CI are mainstreamed.

Speech recognition and speech intelligibility in children with CI

The measure of speech recognition skills is an important part of the assessment for the planning of re/habilitation (Gatehouse, 1998). A large part of the research on the development of children with CI has up to date focussed on the development of speech recognition and speech intelligibility after implantation (Pisoni *et al.*, 2008). Wie, Falkenberg, Tvete and Tomblin (2007) report that 79 of the first implanted children in Norway had an average score of 63% on a mono-syllabic word recognition test without noise. However, it is when listening in noise that the real challenges occur for children with CI. Pisoni et al. (2008) suggest that the differences individuals with CI report in more complex listening conditions (noise) reflects the fundamental differences in perceptual processing between normal hearing and hearing with a CI.

The assessment of speech intelligibility after implantation is also part of clinical follow-up. In children with CI, speech intelligibility is often measured using a listener rating scale (Allen, Nikolopoulos and O'Donoghue, 1998; Loundon, Busquet, Roger, Moatti and Garabedian, 2000). In a study on 18 Finnish children with prelingual SPHI with CI Huttunen (2008) found that intelligible speech was reached after a period of 5 years of CI use. It is of great importance to remember that both speech recognition and speech intelligibility measures are complex measures since both are influenced by sensory factors (or motor, in the cases of speech intelligibility) as well as by a range of contextual, linguistic and cognitive factors.

Factors influencing outcome

As mentioned earlier, children with CI show large variations in outcome, almost regardless of the measures of outcome. This variation is most likely a consequence of differences in the functioning of the auditory pathways, the reorganization after sensory deprivation, brain plasticity, CI systems, processing strategies, school settings and communication modes, a range of demographic factors (age at diagnosis, age at implant etc), and self-esteem or well-being of the child with CI. Furthermore, more specific factors such as the educational level of the family (Geers, Moog, Biedenstein, Brenner and Hayes, 2009), prelinguistic skills (Tait, Lutman and Robinson, 2000), gender (Geers, Nicholas and Sedey, 2003b) and parental involvement (Spencer, Gantz and Knutson, 2004) have been reported as important factors for the outcome.

An important predictor of the outcome is cognition. Focus in the present thesis is on one specific aspect of cognition, i.e, working memory capacity. Pisoni et al., (2008) suggest that working memory capacity might be a more significant contributor than demographic factors, such as age at implant and duration of deafness, and different medical and educational factors to the benefit from CI. This has been supported by findings on Swedish children with CI (Willstedt-Svensson, Löfqvist, Almqvist and Sahlén, 2004; Asker-Árnason, Wass, Ibertsson, Lyxell and Sahlén, 2007)

Working memory

Theories and tools

Working memory is a memory system that represents the capacity to process and store information simultaneously over a brief period of time (Daneman and Carpenter, 1980b; Repovs and Baddeley, 2006; Alloway, Gathercole, Kirkwood and Elliott, 2009) and can be viewed as the link between sensory input and permanently stored information. Individual differences in working memory capacity have important consequences for the ability to acquire knowledge, and new skills, and to perform complex activities. Children and adolescents thus have to rely on working memory skills in a number of activities that are part of classroom activities. Among these are to understand and remember instructions, in reasoning, in problem-solving (Alloway *et al.*, 2009), in reading (Baddeley, 2003; Cain, Oakhill and Bryant, 2004; Gathercole, Alloway, Willis and Adams, 2006; Savage, Cornish, Manly and Hollis, 2006), in writing (Kellogg, 1990; Alamargot, Lambert, Thebault and Dansac, 2007), and in mental arithmetic (DeStefano and LeFevre, 2004).

Several theories or models have been proposed to explain the function and/or structure of working memory (Baddeley and Hitch, 1974; Daneman and Carpenter, 1980a; Towse, Hitch and Hutton, 1998; Engle, Kane and Tuholski, 1999; Daneman and Hannon, 2007). One set of models are particularly focused on functionality and the processing component of the working memory system (Towse *et al.*, 1998; Engle *et al.*, 1999; Daneman and Hannon, 2007) which is responsible for the simultaneous processing and storage of information in competing task demands (Towse *et al.*, 1998; Daneman and Hannon, 2007; Alloway *et al.*, 2009). This aspect of working memory capacity will be referred to as *general working memory capacity* in this thesis. The assessment tools employed within this theoretical framework have typically been reading span tasks (Daneman and Carpenter, 1980a), backward digit span tasks (Burkholder and Pisoni, 2004) and competing language processing tasks (Gaulin and Campbell, 1994; Towse *et al.*, 1998).

Another influential working memory model is the multi-component model (Baddeley and Hitch, 1974; Baddeley, 2003; Repovs and Baddeley, 2006). This model consists of four components that serve different functional purposes. The components are denoted; the central executive, the phonological loop, the visuo-spatial sketchpad and the episodic buffer. The central executive has executive as well as some storing capacity and is responsible for the control and allocation of attention and coordination of information from the two slave-systems (the phonological loop and the visuo-spatial sketchpad). The phonological loop is responsible for the storing and rehearsing of sound- and speech-based information and the visuo-spatial sketchpad serves the same purpose for visual stimuli. The phonological loop is subdivided into two subcomponents. One is a temporary storage system which maintains phonological information for approximately two seconds. The second subcomponent of the phonological loop is a subvocal rehearsal system where phonological information is rehearsed by a process called inner speech, in order to store and refine the phonological information. In this thesis the function of the phonological loop will be referred to as phonological working memory or phonological short-term memory (Baddeley, 2003; Repovs and Baddeley, 2006). The fourth component, the episodic buffer is a component recently proposed by Baddeley (2000). It is a multimodal store that integrates information into unitary episodic representations and can be viewed as an interface between working memory and long-term memory. There is a considerable number of assessment tools used to tap phonological working memory capacity. The common denominator for them is that they assess the ability to imitate completely novel verbal stimuli or strings of phonemes (referred to as nonwords), as in nonword repetition tasks or in tasks assessing serial recall of nonwords. The argument for using nonwords is that they do not activate lexical representations in long- term memory. Therefore it is important that their word-likeness is very low.

A series of operations, occurring just within a few seconds, are needed in order to repeat a nonword. They include the reception of the spoken information, the encoding of the spoken sound pattern and the construction of new phonological representations in long term memory, based on one single exposure to the stimulus (Dillon, Burkholder, Cleary and Pisoni, 2004). Finally, the new phonological representation must undergo output processing, i.e. motor planning and articulation, in order to end up in overt speech (Burkholder-Juhasz, Levi, Dillon and Pisoni, 2007).

Phonological working memory capacity has been shown to play a significant role in the acquisition of language during childhood, both in maternal language development and when learning foreign languages (Baddeley, 2003; Gathercole, 2006; Repovs and Baddeley, 2006) Repovš & Baddeley, 2006) and has therefore been referred to as a language learning device (Baddeley, Gathercole and Papagno, 1998) and is one of the best predictors of language impairment in young hearing children (Simkin and Conti-Ramsden, 2001).

The present thesis is anchored in the two above mentioned theoretical working memory constructs. Two working memory tasks were selected, the competing language processing task, the CLPT (Gaulin and Campbell, 1994), and a nonword repetition test (Sahlén, Reuterskiold-Wagner, Nettelbladt and Radeborg, 1999) anchored in the multi-component model. The term *phonological processing* is at times used in this thesis as an umbrella term for the performance on tests of nonword repetition and nonword discrimination. When referring to other studies (mainly in paper IV) the term sometimes also includes performance on tests assessing phonological representations in long-term memory (i.e. phonological awareness tasks).

Questions have been raised as to whether nonword repetition really is a reliable index of phonological working memory since speech production problems in children may mask their phonological working memory capacity in a nonword repetition task (Sahlén *et al.*, 1999). Researchers in the area of specific language impairment (SLI) have therefore developed assessment tools with minimal demands on speech output. One example is the nonword discrimination task developed by Reuterskiöld Wagner, Sahlén and Nyman (2005). A significant association between nonword discrimination and nonword repetition has been found in typically developing children and in children with language impairment (Nyman, 1999; Reuterskiöld Wagner *et al.*, 2005), indicating that the tasks measure a common factor in hearing children.

Working memory in children with CI

Working memory capacity in children with CI is not very well understood. General working memory capacity is less examined than phonological working memory capacity in children with CI (Lyxell, Sahlén, Wass, Ibertsson, Larsby, Hallgren *et al.*, 2008). Burkholder and Pisoni (2004) have studied performance on backward digit span tasks that are assumed to tax general working memory capacity and report that children with CI performed at a lower level than hearing children on backward digit span tasks. Using a sentence completion and recall task, Wass, Ibertsson, Lyxell, Sahlén, Hallgren, Larsby et al. (2008) found that children with prelingual SPHI with

CI had a lower level of performance on this measure of general working memory capacity than their hearing peers. However, the differences between the children with CI and hearing peers were much more obvious on the measures tapping phonological working memory capacity than on measures of general working memory capacity. These findings are also in line with findings on children with mild/moderate sensorineural HI (Hansson, Forsberg, Löfqvist, Mäki-Torkko and Sahlén, 2004).

In an extensive series of studies Pisoni and co-workers have explored nonword repetition in children with CI (Carter, Dillon and Pisoni, 2002; Cleary, Dillon and Pisoni, 2002; Dillon, Pisoni, Cleary and Carter, 2004; Dillon *et al.*, 2004b; Dillon, Cleary, Pisoni and Carter, 2004c; Burkholder-Juhasz *et al.*, 2007). They conclude that children with CI have lower phonological working memory capacities than hearing children. The same has been found in Swedish children with CI (Wass *et al.*, 2008).

Furthermore, Pisoni and his co-workers have showed that, if nonword repetition is scored in a binary way (correct or incorrect imitation of a nonword) children with CI perform at floor. Cleary et al. (2002) found that children with CI only produce five percent of the nonwords without any errors and thus propose that a binary analysis cannot be used as a valid procedure to measure performance. This is supported in a study by Willstedt-Svensson et al. (2004) who studied 15 Swedish children with congenital SPHI with CI, aged 5;4-11;5. They found that only four percent of all nonwords were repeated correctly. In addition, Burkholder-Juhasz et al. (2007) argue that when scoring for both segmental and suprasegmental accuracy a more useful set of results is received.

Nonword repetition skills in children with CI vary substantially (Cleary *et al.*, 2002). Interestingly, significant correlations have been found between nonword repetition and speech perception (Cleary *et al.*, 2002; Dillon *et al.*, 2004c) speech intelligibility (Carter *et al.*, 2002; Cleary *et al.*, 2002; Dillon *et al.*, 2004a), nonword discrimination (Asker-Árnason *et al.*, 2007), novel word learning (Willstedt-Svensson *et al.*, 2004), vocabulary (Cleary, Pisoni, & Iler Kirk, 2000), composite measures of receptive language (Dawson, Busby, McKay and Clark, 2002), reading skills (Dillon and Pisoni, 2006; Asker-Árnason *et al.*, 2007), communication mode, age at deafness and speaking rate (Dillon *et al.*, 2004) have been reported.

Language and communication in children with CI

Language

The mastery of spoken and written language is one of the most challenging tasks in childhood development (Briscoe, Bishop and Norbury, 2001). Hearing is an important prerequisite for language development. Therefore children with SPHI are at severe risk for language problems.

Children with SPHI with CI show large individual variability in language outcome (Schorr, Roth and Fox, 2008) and variability across different language skills (Geers *et al.*, 2009). Studies on children with CI have explored phonology (Carter *et al.*, 2002), vocabulary (Connor, Craig, Raudenbush, Heavner and Zwolan, 2006; Geers, Nicholas and Moog, 2007; Geers *et al.*, 2009; Hayes, Geers, Treiman and Moog, 2009) and grammar (Svirsky, Stallings, Lento, Ying and Leonard, 2002; Young and Killen, 2002; Willstedt-Svensson *et al.*, 2004; Schorr *et al.*, 2008). It is however, difficult to draw any conclusions as to whether children with CI perform as hearing peers or not since the empirical results are inconclusive.

One significant contributor to language development in children with CI is age at implantation (Hay-McCutcheon, Kirk, Henning, Gao and Qi, 2008). Some studies report that children with prelingual SPHI with CI, implanted at a younger age, acquire language at a similar rate as hearing peers, due to the early auditory input (Kirk *et al.*, 2002; Svirsky, Teoh and Neuburger, 2004; Nicholas and Geers, 2007; Hayes, Geers, Treiman and Moog, 2009). Others report that there are small or no differences in language outcome between children with CI implanted early and those implanted late (Geers *et al.*, 2003b; Geers, 2004). According to Geers et al. (2003b) this lack of difference between early and late implanters might be explained by the fact that children regarded as early implanted were not young enough at implantation (aged two or three years at implantation).

Reading skills

A number of different skills are necessary for the development of reading ability. Many authors strongly emphasize the role of phonological processing in early literacy development (Bishop and Adams, 1990; Marshall, Snowling and Bailey, 2001; Muter, Hulme, Snowling and Stevenson, 2004; Vellutino, Fletcher, Snowling and Scanlon, 2004), whereas others also stress the role of language comprehension. For example, Hoover and Gough (1990) claim that in the early stages of learning to read oral language comprehension is as essential as phonological processing. Reading comprehension will, according to their view, be impaired if either language comprehension skills or decoding skills is poor. The role of language comprehension in reading has also been discussed by Barth, Catts and Anthony (2008) who suggest that the role of language comprehension in reading might become more important as the children grow older due to the need to search for meaning when reading.

Reading can be assessed by a large number of different tasks. These tasks are often divided into decoding tasks and reading comprehension tasks. Poor decoding skills may make reading effortful and slow, or fast and inaccurate, and limit children’s recognition and comprehension of words, which in turn hamper their reading comprehension (Chard, Stoolmiller, Harn, Wanzek, Vaughn, Linan-Thompson *et al.*, 2008). In early reading development hearing children’s decoding is mostly based on phonological decoding strategies. Decoding based on orthographic decoding strategies usually develops later. A skilful reader can use both strategies and smoothly shift to a phonological decoding strategy when needed for unknown words or parts of words.

The auditory input transmitted through a CI enables children with CI to build more stable phonological representations in long-term memory than children with SPHI without CI. However, as mentioned earlier, the hearing is not restored to normal levels and the auditory cortex, as described by Pisoni et al. (2008) receives a degraded signal. This makes the phonological representations imprecise and weakens the phonological processing. This in turn may cause limited possibilities to use a phonological decoding strategy when reading, and children with CI could therefore be at risk for poor reading development (James, Rajput, Brinton and Goswami, 2008).

The combined empirical results from studies of children with CI show however, that they perform relatively well on measures of reading comprehension (Moog, 2002; Geers, 2003; Spencer, Barker and Tomblin, 2003; Asker-Árnason *et al.*, 2007; Vermeulen, van Bon, Schreuder, Knoors and Snik, 2007). For example, Asker-Árnason et al. (2007) report that 63% of the children with prelingual SPHI with CI, aged seven to thirteen in their study performed as their hearing peers (within 1 SD) on tests assessing reading comprehension. This is in line with findings from Geers (2003) who studied eight to nine year old children with CI and reported that 52% of the children scored within the average range of hearing children their age. However, according to Geers, Tobey, Moog and Brenner (2008), the reading development in children with CI might slow down and plateau as they get older. Despite long-term use of CI, teenagers with CI, aged 15 to 18, did not reach the reading levels of hearing age matched students (Geers *et al.*, 2008).

Considering that children with CI seem to be poor at phonological processing, e.g. on nonword repetition and nonword discrimination, it is rather surprising that they can develop fairly good reading comprehension. According to Lyxell at al. (2008) one explanation might be that children with CI use decoding strategies that are different from those used by hearing children. Although this remains to be demonstrated empirically, they may rely more on orthographic decoding strategies than on phonological decoding strategies. It has been proposed that even poor readers among hearing children make less use of phonological decoding strategies, especially if the task can be solved through visual strategies (Catts and Kamhi, 2005). Perhaps this is true for children with CI as well, as proposed by Lyxell et al. (2008) and Marschark, Rothen and Fabich (2007) who argue for alternative routes to reading development besides phonological processing and phonological decoding strategies in children with SPHI.

Writing skills

Many of the factors that influence reading skills also affect writing skills (Catts and Kamhi, 2005). So far, there are few studies of writing skills in children with CI. Spencer et al. (2003) studied the writing skills in children with SPHI and CI and compared the results to hearing age matched peers. They concluded that the children with CI showed immature writing as they used shorter, less complex sentences with grammatical errors. Simpler syntax was also found in a study by Marchark, Mouradian and Halas (1994) in children with SPHI without CI.

The studies mentioned above only focussed on the written product of written narration. Asker-Árnason, Wengelin and Sahlén (2008), in addition to analyzing the written product, also analysed the writing process (pauses, editings and text flow) in a study including 18 children with SPHI and CI aged from 11 to 19 years, using a key-stroke logging program , the Scriptlog (Strömqvist and Karlsson, 2002). The authors found that the children with CI had fewer spelling errors than hearing controls but, in some cases, less complex grammar. The most striking and robust difference between the children with CI and their hearing peers was that the children with CI used more content words and more pause time when writing a narrative. According to Asker-Árnason et al. (2008), the higher percentage of content words found in their study suggests a less sophisticated language use.

Working memory has been found to influence the ability to write narratives in children with SPHI, without CI (Alamargot *et al.*, 2007). The writing of a narrative requires the simultaneous planning of the story and the formulation of sentences, lexical retrieval, spelling etc. In short, these operations demand the ability to simultaneously process and store information or general working memory capacity (Kellogg, 1996). There is thus reason to expect an association between written narrative skills and working memory capacity in children/adolescents with CI.

Communication

Conversational skills

There is little knowledge about how children/teenagers with CI cope in everyday verbal interaction with hearing peers. This is, however, an area that is important to explore given that many of these children are placed in educational settings where they are frequently interacting and collaborating with hearing peers. In these situations conversational skills are critical (Gottman, 1983).

The approach adopted for this investigation and analysis is inspired by Conversation Analysis (CA) (Hutchby and Wooffitt, 2008). According to this theory, conversation is a joint and mutual activity, viewed as a collaborative act. CA emanates from sociology and the work of Harvery Sacks, inspired by Ervin Goffman and Harold Garfinkel (Hutchby and Wooffitt, 2008). Within CA there is a special interest for exploring conversations where one of the participants has an impairment affecting communication (Perkins, 2007). The manifestation of the impairment is seen “as evidence of interactive solutions to underlying problems, rather than as primary deficits per se“ (Perkins, 2007: 4). The manifestation of an impairment such as HI thus affects all participants in a conversation and it is therefore important to consider the conversation as a whole and not only to focus on the behaviour of the participant with the impairment.

All contributions in a conversation are context dependent, determined by earlier contributions as well as preparing for and determining following contributions (Linell, 1998). Furthermore, the linguistic constructions used are often co-constructed by the conversational participants (e.g., in question-answer pairs, or when the participants complete each other’s utterances (Bockgård, 2000; Lindström, 2008).

Another manifestation of collaboration occurs when the participants in a conversation try to avoid or remedy misunderstandings. This phenomenon, i.e., conversational repairs, has often been the focus in CA studies. According to Schegloff, Jefferson and Sacks (1977) repairs are used by participants in a conversation to address problems in hearing, speaking or understanding. In conversations between two partners misunderstandings can occur for a number of reasons. That is, the speaker does not give enough information, s/he may not speak intelligibly enough, or wrongly assumes common ground with his/her conversational partner. Misunderstandings can also stem from the listener not paying enough attention, lacks motivation, or has comprehension or hearing problems (Lloyd, 1999). According to Schegloff et al. (1977), repairs can be categorized into four different types depending on who initiates (self or other) and who makes (self or other) the repair. If one of the participants in a conversation has not heard and/or understood the message the situation can be solved by using an "other-initiated self repair", that is to ask the partner to repeat or to clarify the message. Other-initiated self-repairs, or requests for clarification, are viewed as critical for the information exchange in conversations with typically developing children (Garvey, 1984).

Mutual adaptation and understanding might be more difficult to achieve in dialogues between children with HI, using a hearing aid, or a CI, and their conversational partners due to the HI. If the mutual understanding fails due to poorer speech recognition or speech intelligibility in the child with HI, the conversation is likely to be influenced, and the participants must take action to either address or to solve possible misunderstandings that may occur by using requests for clarification. According to Erber (1996), the use of requests for clarification decides the degree of success individuals with HI achieve in conversations, and could therefore be an important indicator of conversational skills in children with HI, with or without CI. Arnold, Palmer and Lloyd (1999) report that children with HI aged 5-9 years, without CI - wearing hearing aids, produced significantly fewer requests for clarification than hearing children. Lloyd, Lieven and Arnold (2005) suggest that children with HI might use fewer requests for clarification, either as a sign of developmental lag, a poor understanding of the experimental situation or because of a sense of learned helplessness due to prior experiences of conversation failures (Lloyd *et al.*, 2005).

A low use of requests for clarification has also been found in other clinical populations, such as children with language impairment (Brinton and Fujiki, 1982; Leinonen and Letts, 1997; Reuterskiöld Wagner, Nettelbladt and Sahlén, 2001) and children with learning disabilities (Donahue, Pearl and Bryan, 1980).

Requests for clarification can be categorised into non-specific (neutral or "what"/"huh") and specific requests (Gallagher, 1981; Tye-Murray, Witt and Schum, 1995). By using non-specific requests for clarification, the partner will not receive any indication of which part of the message that was not understood or not heard. Specific requests (e.g., "What colour did you say his hair has?") specifies exactly what was missed, thus offering the opportunity for the partner to focus on that in a repetition or rephrasing. According to Erber (1996) and Gagné, Stelmacovich and Yovetich. (1991), the use of specific requests for clarification is believed to be more effective, especially for individuals with HI, but the empirical pattern seems to be reversed. The most common type of request for clarification in individuals with HI, without CI, is a non-specific request for clarification (Caissie and Rockwell, 1994; Caissie and Wilson, 1995; Tye-Murray and Witt, 1996).

The use of requests for clarification can be assessed in either spontaneous conversations or in more structured ones. One example of a structured assessment is a referential communication task. Lloyd et al. (2005) regard referential communication tasks as analogous to classroom communication, because in such a task it is crucial to make oneself understood as well as to understand the information received. We believe that referential communication tasks foremost can be regarded as analogous to problem solving activities which occur daily in educational settings. The task used in the present work is an elaborated version of a referential communication task originally designed by Glucksberg and Krauss (1967). In this task, the challenge is for the speaker to describe something or someone, i.e. the referential array, so that the listener can identify what s/he is describing. The child needs to not only understand which information s/he has to give but also which information s/he needs to leave out, i.e. to be selective. A "good" listener, in a task like this, must be able to make use of the information received and understand when a message is not clear or good enough and then to ask for additional information, i e. to request for clarification. Therefore the referential communication task is a useful method to use in order to study the use of requests for clarification. Lloyd et al. (2005) also suggest that referential communication tasks might be useful for teachers and clinicians in order to stimulate children to think more about both speaking and listening skills, e.g. to have the listener's need in mind when communicating. They also suggest that it is especially interesting to study conversations between children with HI and age- matched peers, since an adult might to a higher extent dominate the conversation.

As illustrated in Figure 1, conversational skills are complex skills, just like reading and writing. It is therefore of interest to relate conversational skills to basic skills, like working memory as well as to other complex skills, like speech recognition in noise.

AIMS

The purpose of this thesis was to explore the interaction between cognition and language (i.e. working memory capacity and phonological processing) and more complex skills such as the ability to interact with hearing peers and some aspects of reading and writing in children/adolescents with CI.

Each of the studies had the following specific aims:

*Study I***:** To develop a procedure for assessing segmental and suprasegmental accuracy in a nonword repetition test, and to explore the accuracy as a function of syllable length in three groups of children; children with CI, children with mild to moderate HI with hearing aids, and hearing children with SLI.

Study II: To develop a procedure for assessing conversational skills, and to apply the procedure to characterize conversations between children/adolescents with CI and hearing peers (from a dialogical as well as from an individual perspective).

*Study III***:** To explore the relationship between speech recognition in noise, working memory capacity, and conversational skills, measured as the use of requests for clarification in a referential communication task.

Study IV: To investigate intra-individual associations in some aspects of reading, writing and working memory in teenagers with CI.

METHODS

Participants

Children with CI

Study I. Thirteen children with CI participated in study 1; four were males and nine females. Eleven children had a congenital SPHI and two children had prelingual SPHI. They were aged 5;2-8;11 and had regularly used their implant for at least one and a half year (from 18 to 78 months). According to medical records the aetiology of HI was unknown in eight cases; four had hereditary sensorineural HI, and one had HI caused by ototoxic medicine.

Study II, III, IV. Eighteen children/adolescents with CI older than 7 years were invited to participate in these studies. Of these eighteen children, five declined participation for two different reasons: the parents referred to geographical reasons or to heavy pressure on the family. Thus, thirteen children/adolescents accepted the invitation, seven males and six females. Seven of the children had prelingual SPHI and six postlingual SPHI. They ranged in age from 9 to 19;1 years at the time of testing and had regularly used their implant for at least four years (4;2 to 13;9 years). The duration of deafness ranged from 4 months to 4;2 years. According to medical records, the aetiology of HI was unknown in six cases; two had hereditary sensorineural HI, four had HI caused by infectious disease and in one case the cause was inner ear anomaly. Seven of the participants had progressive HI.

Due to the time-consuming procedure to collect and analyze conversational data eight of these children/adolescents participated in study II, all thirteen in study III. Seven teenagers were selected to participate in study IV. They were selected since they had the appropriate ages for participation in the reading and writing assessments (the remaining six were all too young).

The children/adolescents with CI were compared with children with mild to moderate HI, with hearing aids, and with children with SLI in study I and with hearing children/adolescents in study II and III.

Children with mild to moderate HI

Thirteen children with mild/moderate HI aged 5;4-8;11 (mean age 6;11) participated in study I. They all wore a hearing aid in at least one ear and had a symmetrical, bilateral, sensorineural HI with an average BEHL of 48.55 dB. These children were recruited from ENT clinics in southern Sweden. They all had normal nonverbal IQ and were all monolingual speakers of Swedish and educated in an oral setting. Three attended a special school for children with HI but the rest (N=10) attended mainstream schools.

Children with SLI

The third group participating in study I were thirteen children with a diagnosis of SLI aged 5;1-7;0 (mean age 5;10). They were all recruited through speech and language pathologists in southern Sweden. All the children with SLI passed a hearing screening and had nonverbal IQ within normal limits. They were monolingual speakers of Swedish with hearing parents. They attended a mainstream school but the majority had individual support from a special teacher.

Hearing children

Eight hearing children/adolescents with typical language, age and gender matched to the participants with CI participated in study II. Four were boys and four were girls aged 11-19 years. In addition, 16 hearing children/adolescents, each selected by a participant with CI or by their matched controls participated (CIP and HCP respectively). Four of the partners of the children/adolescents with CI were boys and four were girls, all aged 11-19 years and of the partners to the matched controls three were boys and five were girls, all aged 11-19 years. All hearing children/adolescents, except the participants with CI were recruited from different schools in the southern Sweden and were monolingual speakers of Swedish.

Tests, assessments and analyses

The tests and assessments together with information on which domain and specific area they assess as well as in which of the four studies each of them has been used are presented in Table 1. All tests were performed orally.

Table 1. All tests and assessments together with information on which domain and specific area they assess.

Specific area	*Test/assessment*	*Measure*	*Used in study:*
Speech recognition in noise	Hagerman sentences	Signal to noise ratio (SNR)	III, IV
General working memory capacity	The Competing Language Processing Task (CLPT)	Recall of words	III, IV
Phonological processing skills	The nonword repetition test	Segmental accuracy:	I, III, IV
		Suprasegmental accuracy:	I
		Segmental accuracy as a function of number of syllables:	I
		Suprasegmental accuracy as a function of number of syllables:	I
	The nonword discrimination test	Accurately discriminated minimal nonword pairs	I, III, IV
Conversation with a hearing peer	Referential communication task	Number of words	II
		Number of turns	II
		Time used to solve the task	II, III
		Number of requests for clarification	II, III
		Different types of requests for clarification	II,III
Reading	Duvan: decoding skills	Word identification by sounds (WIS): accuracy and speed	IV
		Word identification by Letters (WIL): accuracy and speed	IV
		Vocabulary	IV
	Duvan: Self-estimated skills	Self-estimated reading skills	IV
		Self-estimated reading interest	IV
Writing	Scriptlog: Product	Story grammar	IV
		Spelling	IV
		Content words	IV
	Scriptlog: Process	Pause time	IV
		Editings	IV

Speech recognition in noise

A Swedish standardised test *Hagerman sentences* was used to assess speech recognition in noise. *Hagerman sentences* measure the signal to noise ratio (SNR) in which an individual recognises 50% of a number of sentences correctly (Hagerman and Kinnefors, 1995). The test consists of a trial list and ten lists, each containing ten sentences. Each sentence consists of five words that throughout the test occur in the following order: proper name, verb, numeral, adjective and noun. According to Hagerman and Kinnerfors (1995), normally hearing adults have a mean of –7.8 dB. Ibertsson (2002) reports a mean of –3.2 dB for 20 adult CI users. Hagesäter and Thern (2003) report that fifteen hearing children aged 7 had SNR on *Hagerman sentences* that ranged from –5.3 to -1.3 dB, with a mean of –3.89 dB.

Nonword repetition skills

A *nonword repetition test* (Sahlén *et al.*, 1999) was used to assess phonological working memory. The participants were asked to repeat 24 nonwords of increasing syllable length. The nonwords were constructed according to Swedish phonotactic rules. The stimuli were not balanced in terms of linguistic characteristics such as syllable structure, consonant or vowel features, or stress patterns. The children were told that they had never heard the words before and that they should imitate the items to the best of their ability. They were also instructed that they should guess if they were uncertain.

The responses were recorded and later transcribed phonemically. The children's ability to imitate nonwords was scored according to the following:

- Segmental accuracy was assessed in study I, III and IV. Each consonant correctly repeated in the correct position of the nonword was scored as 1. A maximum score of 111 was possible and percent consonants correct (PCC) was computed.

- Suprasegmental accuracy was also assessed in study I. The children were given a score of 1 if they repeated the same number of syllables as the target nonword and a score of 1 if they used the correct stress pattern, a total score of 2 for each word. A maximum score of 48 was thus possible and percent correct syllables and stress (PSA) was computed.

In study, I both segmental and suprasegmental accuracy was assessed as a function of number of syllables. Altogether, this analysis yielded scores for both total segmental and suprasegmental accuracy for all nonwords in the nonword repetition test (total PCC and total PSA) as well as for each syllable level.

Nonword discrimination skills

The ability to discriminate phonemes was measured with the *nonword discrimination test* (Reuterskiöld Wagner *et al.*, 2005). This test consists of 16 nonword pairs created with eight of the nonwords from the nonword repetition test. Each nonword was presented in two conditions, once together with an identical nonword (e.g., i'fu:m-i'fu:m) and once together with a similar nonword differing by only one phoneme (e.g., i'fu:m-i'bu:m). The task was to indicate, by saying 'same' or 'different', whether two presented nonwords were identical. In order to receive the maximum score, the child had to make the correct decisions about all of the non-words, in both conditions. The maximum score was 8.

General working memory capacity

The capacity to simultaneously store and process information in competing processing demands was assessed with the *Competing Language Processing Task, the CLPT* (Gaulin and Campbell, 1994), using a Swedish version developed by Pohjanen and Sandberg (1999). This test consists of 42 sentences constructed as semantically acceptable or semantically unacceptable propositions, divided in 2x6 sets where each set consists of 2-6 sentences. The participants were first asked to judge whether the proposition was semantically acceptable or not by saying 'yes' or 'no', and then to recall the last word in each sentence in the set. For every word correctly recalled, a score of 1 was given. A maximum score of 42 was possible.

Conversational skills with hearing peers in a referential communication task

As described earlier, the children/adolescents with CI chose a hearing peer of their own to participate in a referential communication task. The child/adolescent with CI and his/her hearing peer were seated right opposite each other on each side of a 30 cm high screen. By using a rather low screen the conversation between the child/adolescent and his/her hearing peer were thought to be more similar to "real life" conversations since visual cues (such as the possibility to lip-read, or to use gestures) were not altogether eliminated. For the participants, the task was to describe a set of pictures depicting faces. One set of pictures was placed in a predetermined pattern in front of one child (*the speaker*), another in a pile in front of the other child (*the listener*). The task for the speaker was to describe each face (e.g., 'He has green eyes, red hair and a hat') and its position so that the listener could identify each face and arrange his/her set of pictures in the same way as the set in front of the speaker. When a first set of pictures was described the children/adolescents changed roles and a new set of pictures was presented with the same instructions.

Each participant with CI was also matched for age and gender to a hearing child/adolescent. These participants, as the child/ adolescents with CI, chose a peer of his/her own to solve the referential communication task with. Just as the children/ adolescents with CI and their partners, they acted as both speaker and listener. The following two types of comparisons were made, see Table 2.

Table 2. Two types of comparisons between the two types of pairs and dialogues. HC indicate the hearing child and P the partner.

Comparisons between the two types of conversational pairs	pair 1: HC-HCP -	pair 2: CI-CIP
Comparisons between the dialogues focusing on the individually matched children	dialogue 1: HC-CI	dialogue 2: HCP-CIP

This allowed us to study both the influence of the HI in a conversation in order to find out to what extent the handicap influences the conversation, and also to compare the children/adolescents with individually matched hearing peers.

Each conversation was recorded with a digital camera and then transcribed orthographically using Codes for the Human Analysis of Transcripts (CHAT) conventions (MacWhinney, 2000). The CLAN program (MacWhinney, 2000) was used for quantifications of number of words and turns, as well as for coding and quantification of requests for clarification.

To assess the use of requests for clarification, a categorisation of all requests for clarification used by the participants was made and a classification system was developed. Both the total number of requests and the distribution of different types of requests for clarification were analysed for both the speaker and the listener. The requests for clarification were first classified into the main categories of non-specific and specific requests for clarification. The specific requests for clarification were further classified into different sub-categories inspired by studies by Caissie and Gibson (1997), Caissie and Rockwell (1993) and Tye-Murray et al. (1995). The subtype classification was based on whether they requested elaboration or not and whether the request added new information or not. This is illustrated in Table 3.

Table 3. The classification of different requests for clarification.

Type of question	Specific	Elaboration	Request adds new information
Non-specific	-		
Request for elaboration	+	+	-
Request for repetition	+		-
Request for confirmation of given information	+	-	-
Forced choice	+	-	-
Request for confirmation of new information	+	-	+
Control question			

The following measures were computed for study II:

- The number of words used by both types of conversational pairs and by each participant in the role as both speaker and listener
- The number of turns produced by both types of conversational pairs and by each participant in the role as both speaker and listener
- The time spent to solve the task for both types of conversational pairs and for each dialogue
- The total number of requests for clarification used in the two types of conversational pairs and by each participant in the role as both speaker and listener
- The distribution of seven different types of requests for clarification (in %) in each type of conversational pair and made by each participant in the role as both speaker and listener.

The following measures were computed for study III

- The time spent to solve the task for the conversational pairs where one of the participants had a CI
- The total number of requests for clarification used by the children/adolescents with CI in the role as listener
- The distribution of the three most frequent types of requests for clarification used (in %) in children/adolescents with CI in the role as listener.

Reading skills

Three different subtests, all without requirement of oral responses, from a more comprehensive reading test, *the Duvan* (Lundberg and Wolff, 2003) were used to assess different aspects of decoding skills. In one of the tests, orthographic decoding strategies are taxed for written word identification. The two other tests tax phonological decoding strategies and semantic/lexical processing skills.

Word identification by sounds (*WIS*) taps phonological decoding skills and consists of 60 series of words, each containing three incorrectly spelled words presented visually. One of the words would sound like a real word and the participant is told to mark out this word and to process as many series as possible within two minutes. Two different analyses were made:

- Speed was measured as the percentage of processed series out of 60 in two minutes.
- Accuracy was measured as the percentage of correct responses in processed series.

Word identification by letters (WIL) is tapping orthographic decoding strategies and consists of 100 series of words; each containing three words that would sound like real words when read out, but only one of the three is correctly spelled. The participant is told to mark the word with correct spelling and to process as many series as possible within two minutes.

- Speed was measured as the percentage of processed series out of 100 in two minutes.
- Accuracy was measured as the percentage of correct responses in processed series.

In the *Vocabulary* task, 14 series of four words were presented visually to the participant who was asked to identify a synonym to the first word in each series. The three alternatives in each series are phonologically similar. The performance was quantified as percent correct responses out of 14.

Self-estimated reading skills were assessed using a questionnaire, also from the Duvan. The child was asked to evaluate the degree of correctness of 15 statements on a 4-point scale. The percentage was counted based on a maximum of 60 points.

Self-estimated reading interest was assessed by asking the participants to evaluate the degree of correctness of 5 statements on a 4-point scale and the percentage was counted based on a maximum of 20 points.

Writing skills

A key-stroke logging program ScriptLog (Strömqvist and Karlsson, 2002) was used to assess different aspects of writing. This program saves a record of all key-board events and this makes it possible to investigate not only the final text, or the product, but also all temporal aspects of the writing process.

The children wrote a narrative, which was elicited by means of a selection of pictures from a so-called Frog story (Mayer and Mayer, 1975). The pictures appeared on the screen, one by one, and the child could write in an empty space on the screen.

The writing product was assessed with the following measures:

- *Story Grammar* by using a slightly revised version of a model by Stein and Glenn (1979). Points were given for the inclusion of seven different areas: the setting of the story, complicating action, reaction, strategies, solving the problem, evaluation, and resolution. A maximum score of 15 was possible.
- *Spelling* was assessed by counting the percentage of misspelled words out of the total amount of words.
- The proportion of *content words*, or different nouns, adjectives and verbs out of the total number of words.

The writing process was assessed with the following measures:

- *Pause time* was counted by studying all pauses of two seconds or more and then the percentage of pause time was calculated.
- *Editings* were counted by subtracting the number of letters in the final text from the number of letters in the linear text.

Statistical analyses

In study I two-tailed t-tests and a series of analysis of variance (ANOVAs and ANCOVAs) were used in order to explore group differences, interactions between variables, and the influence of age and gender. Due to small number of participants and large variation non-parametrical methods were used in study II and III. The Wilcoxon signed-rank test was used in study II to compare conversational pairs and CI with HC, and the Spearman rank order correlation in study III to study associations between different variables.

THE INVESTIGATIONS

(I) A methodological contribution to the assessment of nonword repetition – a comparison between children with specific language impairment and hearing impaired children with hearing aids or cochlear implants

Aim
To develop a procedure for assessing segmental and suprasegmental accuracy in a nonword repetition test, and to explore the accuracy as a function of syllable length in three groups of children; children with CI, children with mild to moderate HI, with hearing aids and hearing children with SLI.

Subjects
Three groups of children were included in the study, children with CI aged 5;2-8;11 (mean age 7;5 years), children with HI wearing hearing aids aged 5;4-8;11 (mean age 6;11 years) and children with SLI aged 5;1-7;0 (mean age 5;10 years).

Results
All the children were more accurate imitating suprasegmental features than segmental features in nonwords. Comparing group means of both segmental and suprasegmental accuracy, the children with HI performed at better level than the children with SLI, who in turn outperformed the children with CI. Segmental and suprasegmental accuracy decreased with syllable length of the nonwords in all three groups.

We used a mixed ANCOVA for comparing segmental accuracy as the dependent variable with age as a covariate. Group and gender were used as between-group factors and number of syllables as within-group factor. No significant effect of group, gender, or number of syllables was revealed. The same analysis was used for comparing suprasegmental accuracy. The results showed significant effects of group and number of syllables. On a combined measure of segmental and suprasegmental accuracy, a mixed ANOVA where age and gender were taken into consideration, showed that the main effects of both group and syllable level remained.

In order to further study age effects, the children in each group were also divided into younger and older children. A mixed ANOVA, with the sum of segmental accuracy and suprasegmental accuracy as the dependent variable, and group and age categories as between-group factors, revealed a significant main effect for group. In the groups of children with HI and CI, older children performed better than younger children. This was not the case in the SLI group.

For all participants, as one group, we found a positive relationship between nonword discrimination and nonword repetition. However, when looking at each group separately, the correlation was significant only for the children with CI.

Conclusions and implications

It is important to include suprasegmental accuracy in the analysis and scoring of nonwords. Children with CI who do not develop as expected linguistically may be identified early if a combined measure of segmental and suprasegmental accuracy is used. It is important to assess both aspects of nonword repetition longitudinally since poor improvement can be a clinical marker of language impairment.

(II) Deaf teenagers with cochlear implants in conversation with hearing peers

Aim

To develop a procedure for assessing conversational skills, and to apply this procedure to characterize conversations between children/adolescents with CI and hearing peers (from a dialogical as well as from an individual perspective).

Subjects

Two types of conversational pairs were created to participate in a referential communication task. Eight pairs consisted of a child/adolescent with CI and a hearing peer, chosen by the participant with CI. The other eight pairs consisted of a hearing child/adolescent, who was age- and gender- matched to a child/adolescent with CI, who also chose a hearing conversational partner. All participants were aged 11-19.

Results

The variables studied were the number of words and turns produced, the time needed to solve the task, the number of requests for clarification, and the distribution of different types of requests for clarification.

The conversations where one of the participants was a child/adolescent with CI did not differ from conversations between hearing children/adolescents with respect to number of words, number of turns, or the time needed to solve the task.

The conversations between a child/adolescent with CI and a hearing peer contained significantly more requests for clarification than the conversations between two hearing peers. Furthermore when studying the distribution of different types of requests for clarification we found that the conversations where one of the children/adolescents had a CI contained a significantly higher proportion of *requests for confirmation of new information* than the conversations between two hearing individuals. The pairs consisting of two hearing children/adolescents instead used significantly more *requests for confirmation of already given information* than the pairs where one of the participants had a CI.

When comparing children/adolescents with CI with the individually matched hearing children/adolescents no difference was found for number of words and turns. The children/adolescents with CI did, however, make significantly more requests for clarification than the individually matched peers in the role as listener. The children/adolescents with CI also tended to use more *requests for confirmation of new information* than the matched hearing individuals and significantly fewer *requests for confirmation of already given information.* There was also a tendency for the individuals with CI to use fewer *requests for elaboration* than for the other participants.

Conclusions and implications

The results from both a dialogical and an individual perspective show similar patterns. The children/adolescents with SPHI wearing CI are active and collaborative conversational partners in a referential communication task together with a well-known conversational peer. They talk as much and they contribute to solving the task as efficiently as their hearing peers.

Participants with CI use more requests for clarification, and also other types of requests for clarification, than their hearing peers. The interpretation is that children/adolescents with CI use requests for clarification in ways that permit them to manage the conversation and leading it forward. By doing so they are more in control of the responses given by the conversational partner.

Certain conditions in our study seem to facilitate the participation in conversation. Such conditions might be a calm and quiet environment, a task that is structured and without time limits, and that the partner is well known to the individual with CI. This is something professionals working with children/adolescents with SPHI could take into account.

(III) Speech recognition, working memory and conversation in children with cochlear implants

Aim
To explore the relationship between speech recognition in noise, working memory capacity and conversational skills, measured as the use of requests for clarification in a referential communication task.

Subjects
Thirteen children/adolescents with SPHI with CI, aged 9-19 participated.

Results
We found significant correlations between speech recognition and the number of requests for clarification and the time needed to solve the task. That is, individuals with better speech recognition used fewer requests for clarification and solved the task faster.

General working memory capacity was positively and significantly associated with the proportion of requests for confirmation of new information and negatively with the proportion of requests for confirmation of already given information.

The influence of different time factors such as age, age at diagnosis, duration of deafness and time with CI on the measures of speech recognition in noise, working memory and conversational skills was evident in only one significant correlation, namely between chronological age and speech recognition in noise.

Conclusions and implications
Both speech recognition in noise and general working memory capacity seem to contribute to conversational skills but in different ways. Speech recognition influences more general aspects of conversation skills, i.e. number of requests for clarification and the time used to solve the task, whereas general working memory capacity seems to contribute to the type of requests for clarification used in the role as listener. Our results indicate that children with better working memory capacity used types of requests for clarification that helped them lead the conversation forward and take control of the conversations, whereas children with poorer working memory capacity used types of requests for clarification in order to secure the progress of the conversation by avoiding questions where there is less control of the answers given by the partner, perhaps in order to avoid misunderstandings.

(IV) The complex relationship between reading, writing and working memory in seven teenagers with cochlear implant

Aim
To investigate intra-individual associations in some aspects of reading, writing and working memory in teenagers with CI.

Subjects
Seven teenagers aged 14 to 19 years participated.

Results
The teenagers with CI performed on a par with (or better than) hearing teenagers on reading tasks tapping orthographic decoding strategies (from the Duvan test battery). They were as fast as hearing peers on the reading tasks tapping both phonological and orthographic decoding strategies, i.e. they processed as many series of words within two minutes as their hearing peers.

Three out of seven teenagers were more hampered than hearing teenagers in reading tasks tapping phonological decoding strategies. These three also had the lowest scores on nonword repetition. The participants' own estimations of reading skill and reading interest were as high as in hearing teenagers even for the three participants who had poorer results on tests tapping mainly phonological decoding strategies.

There seems to be a relationship between the aspects of reading and writing that were measured but it does not appear very clear-cut. Two of the three participants with poor performance on a decoding task taxing phonological decoding strategies wrote less elaborate narratives. They also used a higher proportion of content words (and lower proportion of function words) and achieved lower story-grammar scores. The same two participants also had the lowest scores on measures of general working memory.

The three children with prelingual SPHI with CI performed poorer than the four children with postlingual SPHI with CI on the test tapping phonological decoding strategies and the nonword repetition test. They also had the lowest scores on tests assessing speech recognition in noise.

To sum up, in spite of the poor nonword repetition skills in all participants (all far below 2 SD), the performance on the majority of reading and writing tasks for the teenagers with CI was at the level of hearing teenagers.

Conclusion and implications
We interpret our result as support for the claim that children with CI might, to a higher extent than hearing children, use orthographic decoding strategies than phonological decoding strategies. Overall, the results yield a far better performance on decoding and spelling than suggested by the tests assessing phonological processing. Poor phonological working memory, or phonological processing, seems to influence phonological decoding skills but does not seem to have as pervasive effects on literacy

development as in hearing typically developing children and in individuals with language impairment.

DISCUSSION

Methodological considerations

There are several reasons for being cautious when generalising results from the studies in this thesis based on a total of 26 children/adolescents with CI. One factor, already emphasized, is that the children/adolescents with CI constitute a very heterogeneous group. They vary with regard to medical, audiological, cognitive, linguistic and environmental conditions. Further, children with CI represent a small population in Sweden and they are spread out nationwide, which makes the recruitment process time-consuming. The children/adolescents are also subject to extensive assessments on repetitive occasions and in different contexts. As a consequence some of the children that were asked to participate turned down the invitation.

To date, little research has been conducted on children with CI in Sweden. Therefore, generalisation of the present results requires additional support from theory and the results also need to be related to results from other studies. We mostly refer to international studies based on individuals with CI growing up in different cultural settings (linguistic, educational, social and maybe economical), well aware of the fact that this restricts the basis for comparisons.

A related question is the choice of comparison and reference groups, which has been dealt with in different ways depending on the research questions in each paper. When considering different comparison groups a number of factors need to be taken into account. For example, using children with SPHI without CI is problematic since they are often placed in schools were sign language is used as the main communication mode, and they constitute a very different group, in particular if they have parents who also are native signers. In this thesis, hearing children, as well as children with mild to moderate HI and children with SLI have been used as comparison groups. The inclusion of hearing children of the same age as comparison and/or reference group might also be problematic, since they have different prerequisites for the development of cognition and oral language than children with SPHI. It is also important to acknowledge that many hearing children of the same age as the children/adolescents with CI reach ceiling effects on some of the assessments used in this thesis.

Given this complex picture of high heterogeneity, small population size and a low level of knowledge, a research strategy based on designs where more or less sharp theoretical hypotheses are tested may become less suitable. Alternative approaches based on descriptive research questions may be the most relevant way to proceed as we are in an early stage of extending our knowledge. This also has consequences for the level of analysis. The empirical material in this thesis has been analyzed at three levels: at group and subgroup level and at case-level. At a group level, we only expected to capture empirical trends and directions in cognitive, linguistic and communicative development in children and adolescents with CI.

Subgrouping children/adolescents (as in paper I and III), according to age and to pre- or postlingual SPHI or contrasting cases with good and poor performances (as in paper IV) may increase the internal validity. It is then possible to isolate one or more background factor(s) that may act as confounding variables and thereby provide alternative explanations of the findings. In some cases visual analysis in combination with comparisons with reference data was more applicable than statistical tests.

The fact that the population of children and adolescents with CI in Sweden is small makes participants relatively easy to identify. This has implications for how data has been presented so that individual information on different background factors (demography and aetiology) has not always been possible to present.

General discussion

The purpose of this thesis was to explore the interaction between working memory capacity, phonological processing and more complex skills, such as the ability to interact with hearing peers, and literacy in children/adolescents with CI. Given that the majority of children with CI are placed in mainstream preschools today and that most of them will be mainstreamed in the future, it is important to study how they cope with real life conversations with hearing peers. They will spend their days in noisy surroundings, where the requirements for them to learn as well as to interact socially with peers will tax their speech recognition, as well as their working memory capacity.

As Figure 1 shows, when a child receives sensory hearing with a CI, skills related to both cognition and language are affected by the auditory input and these skills are in turn prerequisites for the development of complex skills, e.g. conversation and literacy. On the other hand, the relationship is reciprocal: some of these complex skills like speech recognition in noise, reading and writing have impacts on basic skills such as phonological processing.

We need to increase our knowledge base and theoretically based assessment tools that can be used to find out more about the development in areas related to cognition, language and communication in children with CI. All professionals working in this field would benefit from an interdisciplinary theoretical framework to interpret results in more multidimensional ways.

A development of different procedures for the assessment and analysis of skills related to cognition and communication has been started in this thesis. Hopefully, these tools will inspire other researchers in their efforts to deepen the understanding of how cognition and communication develop as a function of cochlear implants. Clinicians and teachers working with children/adolescents with CI may also gain some useful insights in how to more thoroughly explore the strengths and weaknesses in the individual child with CI, which is necessary for individually based intervention strategies and rehabilitation.

The theoretical framework that has emerged from research on children with SLI might be fruitful to adopt when studying children with CI. By comparing children with SLI with children with CI, a better understanding of why some children with CI do not develop as expected cognitively and linguistically could be achieved. One main theory about the underlying deficit in SLI is that of limitations in information processing (Leonard, 1998). Researchers taking this theoretical stance often use assessment procedures grounded in models of working memory (Briscoe *et al.*, 2001; Gathercole, 2006). Given the strong relationship that is generally found between nonword repetition skills and different language skills, Baddeley, Gathercole and Papagano (1998) consider phonological processing, assessed with nonword repetition as a language learning device. Nonword repetition has also been considered as one of the best predictors of language impairment in children, and thus a clinical marker of SLI (Bishop, North and Donlan, 1996; Simkin and Conti-Ramsden, 2001).

By studying nonword repetition skills in children/adolescents with CI, we believe that it is possible to identify children at risk for not developing language typically. However, the choice of analysis is a delicate matter. In this study an analysis where both segmental and suprasegmental accuracy were taken into account was developed and adopted. Further, by using an analysis where percent segmental and suprasegmental accuracy was calculated instead of using a binary analysis, the floor effects found in other studies on children with CI (Spencer and Tomblin, 2009) were avoided.

According to Goswami (2003) phonological representations do not develop automatically only because a child can perceive speech in terms of segmental features. Instead, syllable-based encoding takes place, including early sensitivity to suprasegmental features, as duration, pitch and stress. This is supported and further discussed by Carter et al. (2002) who argue that children with CI might, to an even higher extent than hearing children, depend upon suprasegmental features since their phonological representations are more instable and not as robust as in hearing children. Further, studies on children with SLI have identified the suprasegmental area as particularly vulnerable in children with SLI (Nettelbladt, 1983; Samuelsson, 2004).

We also suggest that nonword repetition in children with CI should be assessed longitudinally. This is based on the finding that age seems to have less impact on the ability to imitate suprasegmental features for the children with SLI than for the other two groups in paper I. The older children with SLI did not perform better than the younger children. If the problem imitating nonwords persists, this might be a risk marker for language problems.

The ability to repeat both segmental and suprasegmental features in a nonword involves a series of operations that must take place within a few seconds, as described by Baddeley and Hitch (1974). One of these operations needed is the ability to perceive the spoken input. Therefore, there is always a risk involved in testing a child with HI using auditory-based stimuli, as was done in the nonword repetition task in this thesis.

Spencer and Tomblin (2008) addressed the lack of valid assessment procedures for phonological processing skills in children with CI, since the existing tools were developed for hearing children. They investigated phonological processing skills in 29 children with prelingual SPHI with CI and compared them with hearing children. The children with CI and the hearing comparison group were presented with tests assessing different phonological processing skills (such as phonological awareness, nonword repetition and rapid naming) in two different conditions: auditory-only and auditory-visual. Spencer and Tomblin (2008) argue that if poor hearing is the cause of poor performance on tests assessing phonological processing, the auditory-visual condition would be more advantageous than the auditory-only condition. More importantly, the difference between the two conditions would be larger in the children with CI than in the hearing children. Both groups performed slightly better in the auditory-only condition. On some of the tests assessing phonological awareness and rapid naming, however, the children with CI did not to a higher extent than hearing children perform better in conditions where auditory-visual stimuli were used compared to auditory-only. The authors conclude that tests assessing phonological awareness and rapid naming can be considered as valid for children with CI as for hearing children. On the nonword repetition test, the children with CI had much poorer performance in the auditory-only condition compared to the auditory-visual condition, and compared to the hearing children. The children with CI performed at floor while the hearing children achieved ceiling effects. This may partly be due to the analysis that was used. Nonword repetition skills were analyzed using a binary analysis, i.e. judging the performance on each item as either correct or incorrect. A binary scoring, according to Carter et al. (2002), involves a substantial risk for floor effects in children with CI.

In accordance with studies on both hearing children with typical language development and children with language impairment (Nyman, 1999; Reuterskiöld Wagner *et al.*, 2005) nonword repetition correlated significantly with nonword discrimination for the children/adolescents with CI in both study I and study III. This can be taken as an indication that these two tasks measure some common factor in the population of children with SPHI and that nonword repetition cannot be entirely dependent on articulation.

It also seems as if the ability to repeat a nonword can not alone be explained by auditory lower-level processing. Barry, Hardiman and Bishop (2009) used an ERP paradigm based on passive elicitation of mismatch responses very early after auditory input (MMN responses) to compare poor and good nonword repeaters. The prediction was that if nonword repetition is due to deficits in auditory lower-level processing, poor nonword repeaters would have reduced MMN responses, which are thought to index auditory discrimination. Barry et al. (2009) found that the MMN responses did not differ between good and poor nonword repeaters. They therefore conclude that deficits in auditory lower-level processing alone cannot explain the performance by the poor nonword repeaters and that poor nonword repetition is not attributable to deficits in lower-level auditory processing, at least in hearing individuals.

Many of the tests used in clinical audiological settings require a complex interaction between bottom-up and top-down processing. It is interesting to note that an almost identical test is used in speech pathology to assess expressive language as in audiology to assess speech recognition (Blamey, Sarant and Paatsch, 2006). Both could be justified if the following conditions are satisfied: if the person with suspected language impairment assessed with the expressive language test has perfect hearing and if the person being tested in an audiological evaluation has perfect language (Blamey *et al.*, 2006). However, there is reason to believe that for some children with HI none of these conditions are satisfied, i.e. they have neither perfect hearing nor perfect language. Taking this into consideration it is once again important to point to the necessity of developing a more comprehensive theoretical framework for clinicians to rely on for their interpretation of poor performance. Further, for both children with HI and for children with SLI, the addition of noise, in a speech recognition task makes the task more cognitively demanding. It could be that a child performing poorly on a speech recognition in noise task does so not only/or because s/he has poorer "hearing", but also because s/he has poorer language comprehension. We know from studies on children with SLI that the inclusion of noise severely impacts children with language impairments (Robertson, Joanisse, Desroches and Ng, 2009).

In this thesis, a standardized Swedish speech recognition in noise test, the Hagerman Sentences is used. The performance, measured as SNR, was associated with nonword repetition skills (study III), conversational skills (study III), and with reading and writing (study IV). It seems as if speech recognition skills, measured as SNR, influence several areas related to phonological processing and complex language skills. However, we found no association between SNR and general working memory capacity.

From a linguistic point of view we want to point to the predictability in this test, which is considered as non-redundant (Hagerman and Kinnerfors, 1995). However, linguistic factors are in fact likely to influence the performance. For example, the sentences that are used all have the same structure: a proper name as subject, a verb (always the same) and a direct object consisting of a numeral (1-10), an adjective and a noun (always referring to a concrete object). Thus, the predictability is not negligible, and allows the subject to rely on both lexical and grammatical representations in long-term memory as support. Further, it is a repetition task requiring output processing, both motor-planning and articulation.

A situation that can be viewed as the ultimate challenge for some children/adolescents with CI is to take part in every-day conversations with hearing peers. The participants in this study took part in a referential communication task that can be regarded as analogous to problem-solving tasks. These are common in educational settings. By using a referential communication task, it is possible to assess both speaker and listener skills, which children need to make themselves understood and to understand a message. If children have good speaker and listener skills, they are more likely to use strategies that enable them to take part in conversations.

Lloyd et al. (2005) consider referential communication tasks as useful in order to examine listener skills in individuals with HI and the strategies they use for managing communication breakdowns, i.e. their use of requests for clarification. According to Erber (1996), these are indicators of the success an individual with HI accomplishes in conversations with others.

We let the participants choose a friend as a partner. Lloyd et al. (2005) suggest that it is important to assess children with HI in referential communication with peers of the same age. Negotiation with peers is essential for learning and for social interaction at school. Studies of conversational skills in children with SLI have shown that interaction in a conversation between a child and an adult is different from interaction in a conversation between a child and a peer. Conversations between a child and an adult are more coherent. The adult supports, but also tends to take control over the conversation, for example by asking questions. Conversations between a child with SLI and a peer, in particular a younger peer, are less coherent, but also more equal in the sense that children with SLI tend to be more active as conversational partners (Hansson, Nettelbladt and Nilholm, 2000).

The children/adolescents with CI in the present study used more requests for clarification than their hearing peers, which indicate that they asked a clarifying question whenever they were not certain. This means that they showed a different pattern in the use of requests for clarification compared to both their hearing peers and to other clinical populations of children, such as children with SLI (Brinton and Fujiki, 1982; Leinonen and Letts, 1997), and children with HI without CI wearing hearing aids (Arnold *et al.*, 1999; Lloyd *et al.*, 2005). They also had a different pattern as to the different types of requests for clarification that were used, i.e. they hardly used any non-specific requests for clarification, which has been reported to be the most commonly used request by individuals with HI, wearing hearing aids (Caissie and Rockwell, 1994; Caissie and Wilson, 1995). Instead, the predominating type was requests for confirmation of new information. It thus seems as if the children/adolescents with CI used a strategy that kept them ‘on the safe side’. By using a higher number of requests for clarification and a request formulated as a yes/no question, they gained more control of the conversations. This could be interpreted as an adaptation to their impairment which leads to an avoidance of situations that would require more listening (as compared to when requesting for elaborations) and thus would be more demanding given their HI.

Given the high proportion of requests for clarification used by the children/adolescents with CI, as well as the reduced use of nonspecific requests for clarification, and the fact that they solved the task as well and used as many words and turns as their hearing peers, the conclusion from these results is that the children/adolescents are competent and active communicators.

One question is why these children seem to be better communicators than children from other clinical populations. Arnold et al. (1999) propose that one explanation for the low proportion of requests for clarification found in their study on five to nine year old children with HI, might be what they call a sense of learned helplessness. They suggest that children with HI, given their prior experience of misunderstandings in conversations with others, become more passive, waiting for others to take initiatives. Clinicians in Sweden often report that children with CI seem self-confident. This might make them more comfortable asking for clarifying information if something is not heard or understood. One reason for this might be that children with CI have received a lot of attention by parents and teachers, which has boosted their self-confidence. Being a relatively exclusive group in Sweden it is likely that they have received relatively more support and attention from society than children with HI, using hearing aids. Another contributing factor to the success might be the type of task. The results in this thesis might have turned out differently in a less structured task, like a free conversation. Other success factors might be that the participants were asked to choose their own conversational partner and maybe that there was no time limits for the task.

When focusing on the conversations as wholes, (in order to study how the hearing impairment influences the conversation), we found that conversations between the pairs where one of the participants had a CI and the pairs composed of two hearing children/adolescents were constructed in much the same way as when taking the individual perspective. That is, the pairs where one participant was a child/adolescent with CI tend to contain both more requests for clarification and a type of requests that contributes new content.

When relating conversational skills in the children/adolescents with CI to working memory capacity and speech recognition in noise these two factors seemed to contribute to different aspects of conversational skills. Participants with poorer speech recognition in noise used more requests for clarification and they needed more time to solve the task together with their hearing partner. Participants with poorer general working memory capacity used more requests for confirmation of already given information. One explanation might be that they used this strategy to secure the progress of the conversation and to avoid requests for elaboration in which there is less control of the answer. Participants with better general working memory capacity used more requests for confirmation of new information, formulated as yes/no questions, which might indicate that they wanted and needed control of the conversation.

Mainly listener skills in referential communication have been focused in this study. Future studies will focus on speaker skills as well. Preliminary analysis of the responses to the requests for clarification in the data (Sandgren, Hansson, Ibertsson and Sahlén, manuscript) indicate that both the length of responses and trends regarding the types of responses (i.e., a tendency to give more information than explicitly requested) are similar in the children/adolescents with CI and their hearing peers. Another issue in studying speaker skills will be to explore the structure and content in the descriptions of the pictures.

According to Tye-Murray (2003), it is important to instruct children with CI how to manage communication in order for them to be able to take part in every-day conversations, e.g. using specific rather than non-specific requests for clarification. Lloyd et al. (2005) suggest that referential communication tasks might be useful not only for assessment but also for intervention to make children with HI aware of the strategies they use as both speaker and listener. By looking at videotaped sessions including referential communication tasks together with the child with CI, the clinician may support the child to increase his/her awareness about the requests he/she uses, how they are responded to (verbally as well as nonverbally) by the speaker, and whether they are efficient for the progress of the problem-solving or not.

In this thesis, the findings that phonological processing skills were much poorer in children with CI than what has been reported from hearing children have often been repeated. Spencer and Tomblin (2008) claim that this is not definite but more a question of the learning phase being more prolonged in children with CI. This is important to keep in mind and also challenges clinical endeavors helping children with CI early enough to build up more precise and stable phonological representations. One good candidate for this might be sound-based reading instruction.

The suggestion by Lyxell et al. (2008) that children with CI might use other routes than phonological processing in reading is given some support by our study. The teenagers with CI seemed to be better at using orthographic decoding strategies than phonological decoding strategies. It is sometimes argued that teachers of children with SPHI use “whole word reading” approaches more often than sound-based approaches (Webster, 2000; Spencer and Tomblin, 2009). A whole word reading strategy may make children with SPHI resilient readers in that they rely too much on orthographic decoding strategies. A skilled reader must be able to smoothly shift strategies when needed, especially in texts with novel, long, and unknown words. On the other hand, the development of phonological representations can be helped by sound-based training. For example, a child with CI who does not hear all the sounds in a word properly can realize that there are some sounds after having seen the word in written form. Spencer and Tomblin (2008) argue, as we do, that the reciprocal relationship between phonological decoding strategies fostered by sound-based training and phonological processing skills might be even more obvious in children with HI than in hearing children. Finally, it is important to point out that reading is so much more than reaching high levels of decoding skills. Reading in children and adolescents in the age groups of the participants of this thesis require a lot more in order for them to really comprehend and learn from texts they read.

Writing is an unexplored area in children with CI. We have emphasized the reciprocal relationship not only between basic and complex skills in Figure 1 but also between different complex skills, such as reading and writing. To increase children’s awareness of their writing process by making them read and reflect over their written products can be helpful in clinical/pedagogical settings. This can be done in a similar way as we recommended for referential communication tasks. The written narrative task we used in paper IV was recorded by the use of a key-stoke logging program ScriptLog (Strömqvist and Karlsson, 2002). The whole activity is recorded by the computer and can thus be replayed. By looking at a record of the key-board activities, saved by the program, the child might become aware of how the text was planned and created, his/her patterns of editing, pausing, reformulations etc. This could be done together with the clinician in much the same way as we recommended for referential communication tasks.

CONCLUSIONS

Since nonword repetition is considered a language learning device and a clinical marker of SLI the importance of finding ways to assess nonword repetition in children with CI was addressed in study I. A procedure to assess both segmental and suprasegmental accuracy was developed and is recommended to help professionals working with children with CI to identify children at risk for language problems, in particular if used longitudinally.

The lack of knowledge regarding how children with CI cope in real life conversations with hearing peers was underlined in study II. A procedure to assess conversational skills, measured as the use of requests for clarification in a referential communication task, was developed. Children and adolescents with CI were compared with age and gender matched hearing peers, taking both a dialogic and individual perspective. The children/adolescents with CI displayed a different pattern compared to hearing comparisons and other clinical populations, and they used requests for clarification in ways that permitted them to manage the conversation and lead it forward.

The relationship between measures of speech recognition, working memory and conversational skill, measured as the use of requests for clarification in a referential communication task was explored in study III. Both speech recognition in noise and general working memory capacity seem to contribute to conversational skills but in different ways. Speech recognition in noise influences more general aspects of conversation skills whereas general working memory capacity seems to contribute to the type of requests for clarification used in the role as listener. Results indicate that children with better general working memory capacity used types of requests for clarification that helped them lead the conversation forward whereas children with poorer working memory used types of requests for clarification that secured the progress of the conversation and helped to avoid misunderstandings.

The complex relationship between different aspects of reading, writing and working memory was highlighted in study IV by taking an intra-individual perspective. Results indicate that teenagers with CI might use strategies tapping orthographic decoding to a greater extent than hearing children and can develop fairly good reading and writing skills, despite poor phonological processing. There was a relationship between phonological processing and reading, so that the two teenagers with the lowest scores on the nonword repetition test also had the lowest scores on the test tapping phonological decoding strategies. They also achieved the lowest story-grammar scores and the lowest scores on measures of general working memory capacity.

Altogether, this thesis highlights the importance of building a theoretical framework in order to get a clearer picture of the strengths and weaknesses of children with hearing impairment and to be better able to decipher results in a more multidimensional way.

SWEDISH SUMMARY

Ett cochleaimplant (CI) är ett hörseltekniskt hjälpmedel som genom elektrisk stimulering av hörselnerven ger gravt hörselskadade individer möjligheten att utveckla talspråk. Det första barnet i Sverige som fick ett CI implanterades 1991 och sedan dess har ca 600 barn fått ett implantat. Det finns ett behov av ökad kunskap om hur dessa barn utvecklar förmågor relaterade till kognition och kommunikation, likaså finns ett stort behov av utvecklig av teoretiskt förankrade metoder som kan användas för bedömning men också för att lägga upp individanpassad intervention samt för att få en uppfattning av prognos.

Huvudsyftet med denna avhandling var att studera kognition, och språk, närmare bestämt arbetsminne och fonologisk förmåga och hur dessa är kopplade till mer komplexa förmågor såsom förmågan att samtala med hörande kamrater och läs- och skrivförmåga. Inom ramarna för detta arbete har olika metoder utvecklats som kan användas dels för att fördjupa vår förståelse av hur olika förmågor är kopplade till varandra, dels bidra till ökad kunskap om vilka styrkor och svagheter barn och ungdomar med CI besitter.

Avhandlingen består av fyra studier. Sammanlagt har 26 barn/ungdomar med CI deltagit. I studie I deltog 13 fem- till nio-åriga barn och 13 nio- till nitton-åriga barn och ungdomar deltog i studie II, III och IV.

I studie I utvecklades en metod för att bedöma segmentell och suprasegmentell korrekthet i repetition av s.k. nonord (påhittade ord), dvs. förmågan att upprepa de enskilda ingående ljuden (segmentell korrekthet) samt förmågan att upprepa rätt antal stavelser och att återge rätt betoningsmöster (suprasegmentell korrekthet) i orden. Testet består av 24 nonord av olika längd (2-5 stavelser långa). Tre olika grupper av barn deltog. De 13 fem till nio-åriga barnen med CI jämfördes med barn med mild till måttlig hörselnedsättning samt med hörande barn med specifik språkstörning (SLI). Resultaten visade att samtliga barn hade sämre segmentell korrekthet än suprasegmentell. Barnen med mild till måttlig hörselnedsättning presterade bättre på både segmentell och suprasegmentell korrekthet än barnen med SLI, som i sin tur presterade bättre än barnen med CI. När ålder och kön togs med i beräkningen för att studera hur längden på nonorden påverkade segmentell och suprasegmentell korrekthet fann vi att suprasegmentell korrekthet påverkades mest av den ökande längden. För att ytterligare studera åldersinflytandet delade vi upp samtliga grupper i två subgrupper, baserat på ålder. Resultaten visade då att ålder hade betydelse för både barnen med mild till måttlig hörselnedsättning och barnen med CI, så att de äldre barnen presterade bättre än de yngre. Detta var dock inte fallet för barnen med SLI.

Genom att studera förmågan att repetera nonord hos barn med CI så tror vi att det är möjligt att identifiera barn som inte kommer att utveckla språk optimalt. Vi rekommenderar att man bedömer både segmentell och suprasegmentell förmåga, och att man använder mått på relativ korrekthet, eftersom tidigare studier har visat golveffekter hos barn med CI när man använder en sk. binär analys (bara rätt eller fel på hela ordet). Eftersom förmågan att upprepa korrekt på både segmentell och suprasegmentell nivå verkar belastas framförallt i längre nonord är det viktigt att inkludera ord upp till 5 stavelser i testet. Då ålder inte hade stor betydelse för prestationen hos barnen med SLI kan utebliven förbättring vid förnyad testning efter viss tid vara ett observandum. Det kan därför vara viktigt att testa barnen longitudinellt.

Fler och fler barn med CI går integrerat tillsammans med hörande kamrater. Det är därför viktigt att undersöka hur de klarar av att delta i samtal. I studie II utvecklades en metod för att bedöma hur en hörselnedsättning påverkar ett samtal och för att bedöma samtalsförmåga, med fokus på användandet av klargörande frågor hos barn och ungdomar med CI. Deltagarna i denna studie löste tillsammans en s.k. referentiell kommunikationsuppgift där de skulle beskriva ansikten för varandra. Detta kan jämföras med olika problemlösningssituationer, ofta förekommande i skolan. I studien deltog sammanlagt 32 barn och ungdomar. Tillsammans bildade de 16 par, åtta par bestående av barn och ungdomar med CI och deras hörande samtalspartner som de själva valt och åtta par bestående av hörande deltagare, köns- och åldersmatchade till barnen/ungdomarna med CI och hans/hennes hörande samtalspartner.

De variabler som studerades var antal ord, antal turer, den tid paren tog på sig för att lösa uppgiften samt det antal klargörande frågor som ställdes och vilka typer av frågor som användes. Tidigare studier på hörselskadade barn, utan CI, har rapporterat att barn med hörselnedsättning ställer färre frågor om klargörande än hörande kontroller (Lloyd *et al.*, 2005). Man har även funnit att hörselskadade till högre grad än hörande individer använder många s.k. icke-specifika frågor (t.ex.: ”Va?”; Caissie and Rockwell, 1994; Caissie and Wilson, 1995). Barnen och ungdomarna med CI i denna studie visade ett annat mönster. Jämfört med ålders- och könsmatchade hörande kontroller så ställde deltagarna med CI istället signifikant fler klargörande frågor och nästan inga icke-specifika frågor. De använde istället specifika frågor, där det blir tydligt för partnern vilken del av ett yttrande som inte har uppfattats. Jämfört med hörande kontroller använde deltagarna med CI signifikant fler frågor efter bekräftelse av ny information, formulerade som ja/nej-frågor (t.ex.: ”Har han blåa ögon?”). Vår slutsats är att barn och ungdomar med CI ställde klargörande frågor så fort de var osäkra på om de hade hört eller förstått rätt, och detta verkar skilja dem från andra kliniska populationer. Genom att ställa många klargörande frågor, formulerade som ja/nej-frågor, tog de kontroll över samtalet. De undvek att ställa frågor som kräver mer elaborerande svar och därmed ställer högre krav på att lyssna. Sammanfattningsvis tyder resultaten på att barnen/ungdomarna med CI var aktiva kommunikatörer.

I studie III studerades vilka faktorer som påverkar deltagarnas samtalsförmåga. Deltagare var 13 barn och ungdomar med CI mellan nio och nitton år. Vi fokuserade på sambandet mellan arbetsminnesförmåga, dvs. förmågan att samtidigt ta emot och lagra information, taluppfattningsförmåga, mätt i brus, samt användandet av klargörande frågor. Resultaten visar att både arbetsminnesförmåga och taluppfattningsförmåga verkar ha betydelse för hur deltagarna agerar i samtalssituationen, men på olika vis. Taluppfattningsförmåga är relaterat till mer generella aspekter av samtal, såsom antalet klargörande frågor och tiden det tar att lösa uppgiften, medan arbetsminne är relaterat till vilka typer av frågor som ställs. De med sämre arbetsminnesförmåga tenderar att ställa fler frågor efter bekräftelse på att de uppfattat given information korrekt (t.ex.: ”Sa du att han hade blå ögon?”), medan de med bättre arbetsminneförmåga ställer fler frågor där de vill ha bekräftelse på ny information.

Tye-Murray (2003) menar att det är viktigt att träna barn med CI I att agera som samtalspartner, för att förbättra deras förmåga att delta i samtal, både med tanke på att underlätta deras lärande och deras utveckling av sociala kontakter med jämnåriga. Lloyd et al. (2005) föreslår att referentiella kommunikationsuppgifter kan vara användbara inte bara för bedömning, utan också för att träna lyssnar- och talarförmåga. Genom att titta på videoinspelade samtal i denna situation kan barnen göras uppmärksamma på hur han/hon använder t.ex. klargörande frågor, hur de bemöts (både verbal och icke-verbalt) och bedöma hur de påverkar problemlösningen.

I studie IV var syftet att undersöka relationen mellan vissa aspekter av läsförmåga, skrivförmåga, arbetsminnesförmåga samt fonologisk bearbetningsförmåga, mätt med ett nonordsrepetiontest (Sahlén *et al.*, 1999). I denna studie deltog 7 tonåringar med CI. Deras läsförmåga undersöktes med olika test som finns i testbatteriet Duvan (Lundberg and Wolff, 2003). Tre olika avkodningstest användes, ett som testar ortografisk avkodningsförmåga och två som testar fonologisk (dvs. ljudbaserad) avkodningsförmåga samt ett som testar lexikal förmåga. Tonåringarnas intresse för att läsa samt deras egen uppskattning av läsförmåga undersöktes med hjälp av enkätfrågor, också från Duvan. Förmåga att skriva undersöktes i en uppgift där de skulle skriva en berättelse till bilder. Skrivprocessen registrerades med hjälp av ett datoriserat verktyg (ScriptLog, Strömqvist and Karlsson, 2002). Både den skrivna produkten och processen (pauser och ändringar) analyserades.

Resultaten visar att ungdomarna med CI inte avsevärt skiljer sig från hörande barn vad gäller förmåga att läsa och skriva, men att de i högre grad än hörande barn förlitar sig på ortografiska, i stället för fonologiska, avkodningsstrategier. Tre av de sju deltagarna som hade lägst resultat på testet som mäter fonologisk avkodningsförmåga hade också sämst fonologisk bearbetningsförmåga. Samtliga deltagare, även de med sämre läs- och skrivförmåga skattade sin egen läsförmåga som god samt läsintresset som högt.

De som hade bäst resultat på samtliga lästest skriver också mer elaborerande berättelser samt presterar bättre på det arbetsminnestest som testar generell arbetsminnes förmåga, CLPT (Gaulin and Campbell, 1994).

Resultatet att ungdomarna med CI förlitade sig mera på ortografisk avkodningsstrategi antyder att de kan ha fått läsundervisning som betonade sådan strategi (Webster, 2000; Spencer and Tomblin, 2009). Detta har hjälpt dem att komma igång med sin läsning, men det kan också finnas en risk i att de förlitar sig för mycket på denna strategi. En skicklig läsare måste smidigt kunna växla mellan ortografisk och fonologisk strategi, speciellt i texter som innehåller nya okända och långa ord. Lästräning baserad på fonologisk avkodning kan stödja utvecklingen av fonologiska representationer och således få en återverkan på det talade språket. För träning av skrivförmåga skulle man kunna utgå från verktyget ScriptLog, som spelar in hela skrivprocessen. Genom att tillsammans med en logoped/pedagog i efterhand titta på den inspelningen som visar både pauser och ändringar kan barnet blir mera medvetet om sina egna mönster när det gäller pauser, ändringar och omformuleringar och vid behöv justera sina strategier till att bli mera effektiva.

Resultaten från de fyra studierna visar sammantaget på hur viktigt det är att ha teoretiskt förankrade bedömningsmetoder och teoretiska ramverk som hjälper till att tolka och förstå resultaten från bedömningar. Detta kan hjälpa oss att få en tydligare bild av styrkor och svagheter hos den enskilda individen med CI, vilka kan utgöra utgångspunkt vid planering av intervention.

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Paper I

Errata for Paper I

The captions of tables 1-5 in paper I are incorrect in the printed version. The correct legends together with the tables are therefore printed on the following pages.

Table 1. Demographic data for the children with cochlear implant.

ID	Gender	Onset of deafness (months)	Age at cochlear implant (months)	Time as deaf before cochlear implant (months)	Time with cochlear implant (months)	Age at testing (months)	FB * (%)	IQ	Communication mode in preschool/school at testing	Linguistic status of oral language at testing
1	F	0	51	51	54	99	70	130	oral language	functional
2	F	0	33	33	63	90	72	118	sign language + oral language	functional
3	M	0	40	40	63	97	78	118	sign language	functional
4	M	0	24	24	78	98	37	111	oral language	functional
5	F	0	56	56	48	98	60	118	sign language	transitional
6	M	0	66	66	48	107	0	100	sign language	preverbal
7	F	0	31	31	46	68	84	107	oral language	functional
8	F	0	73	73	29	95	0	118	sign language	preverbal
9	F	0	62	62	29	87	72	111	oral language	transitional
10	F	0	40	40	26	64	0	107	sign language + oral language	transitional
11	F	20	28	7	74	96	90	100	oral language	functional
12	F	21	48	26	18	62	0		sign language + oral language	transitional
13	M	0	28	28	67	90	57	100	oral language	functional

* Phonetically Balanced lists of words used to measure maximum speech recognition score (%)

Table 2. Demographic data for the children with a hearing aid.

ID	**Gender**	**Age at diagnosis (months)**	**Age at hearing aid (months)**	**Age at testing (months)**	**Time with hearing aid**	**BEHL $_{0.5\text{-}4\ \text{kHz}}$* (dB)**	**WEHL $_{0.5\text{-}4\ \text{kHz}}$** (dB)**	**Progress of hearing impairment**	**Aetiology**
1	M	55	57	97	40	49	49	No	Not known
2	M	30	34	80	46	30	33	No	Ototoxic medicine
3	F	49	49	78	29	51	51	No	Hereditary
4	F	13	20	80	60	39	43	Not known	Hereditary
5	M	28	29	75	46	43	44	No	Not known
6	F	53	54	67	13	46	49	No	Hereditary
7	M	55	55	64	9	54	58	No	Hereditary
8	M	30	30	67	37	48	48	No	Not known
9	M	29	29	71	42	55	***	Not known	Not known
10	M	52	53	93	40	39	46	No	Not known
11	F	17	18	94	76	48	71	No	Not known
12	F	40	42	107	65	63	65	Not known	Not known
13	F	30	29	106	77	69	70	Not known	Not known

*BEHL $_{0.5\text{-}4\ \text{kHz}}$ = Better ear hearing level, average threshold at 0.5, 1, 2 and 4 kHz
**WEHL $_{0.5\text{-}4\ \text{kHz}}$ = Worse ear hearing level, average threshold at 0.5, 1, 2 ad 4 kHz
***Deaf ear

Table 3. Descriptive data for children with normal language development using the Swedish non-word repetition test.

Authors	**Age**	**No of children**	**Mean percent consonants correct (pcc)**	**SD**
Göransson and van der Pals, 2004	3;2-4;0	20	68	13.7
Göransson and van der Pals, 2004	5;0-5;11	20	75	9.7
Lindström and Malmsten, 2003	7;11-9;8	21	94	3.7
Hagesäter and Thern, 2003	6;5-7;6	15	93	4.4
Hagesäter and Thern, 2003	8;10-9;9	22	96	3.3

Table 4. Number of syllables, number of consonants, number of clusters and the stresspatterns on each syllable level.

Number of syllables	**Consonants**	**Number of clusters**	**Stress pattern**	
			Trochee	Iamb
2-syllables	16	3	2	4
3-syllables	29	5	1	5
4-syllables	27	1	1	5
5-syllables	39	6	0	6
Total:	111	15	4	20

Table 5. Descriptives on each syllable level on segmental (PCC) and suprasegmental accuracy (PSA) in non-word repetition task of the three groups of children studied. Total performance on non-word discrimination (%) also is presented for each group

Tests	**Children with cochlear implant (CI)**					**Children with hearing aids (HI)**					**Children with specific language impairment (SLI)**				
	N	**Min**	**Max**	**Mean**	**SD**	**N**	**Min**	**Max**	**Mean**	**SD**	**N**	**Min**	**Max**	**Mean**	**SD**
Segmental accuracy, 2 syllables	13	13	75	44.2	22.5	13	38	94	72.0	16.8	13	31	94	62.1	17.0
Segmental accuracy, 3 syllables	13	10	76	45.7	20.7	13	45	100	76.4	18.5	13	10	93	59.1	18.5
Segmental accuracy, 4 syllables	11	0	70	30.0	22.3	13	30	93	68.4	16.5	13	19	78	51.9	16.5
Segmental accuracy, 5 syllables	11	0	67	26.9	20.7	13	30	92	63.0	20.1	13	5	69	39.3	18.4
Segmental accuracy, total	13	10	64	34.8	16.3	13	35	89	69.5	16.2	13	14	81	50.7	16.3
Suprasegmental accuracy, 2 syllables	13	50	100	85.2	18.3	13	83	100	98.0	4.9	13	75	100	95.5	8.0
Suprasegmental accuracy, 3 syllables	13	67	100	82.8	12.4	13	67	100	93.0	11.1	13	83	100	97.4	5.2
Suprasegmental accuracy, 4 syllables	11	0	92	57.1	31.3	13	67	100	92.9	10.6	13	50	100	87.7	16.6
Suprasegmental accuracy, 5 syllables	11	0	75	40.3	25.7	13	33	100	87.7	18.3	13	25	100	71.8	24.6
Suprasegmental accuracy, total	13	33	88	66.5	15.7	13	63	100	92.9	9.9	13	63	100	88.1	11.6
Percent nonword discrimination	10	0	75	38.5	27.7	12	56	100	79.5	14.4	13	19	94	61.0	21.0

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ORIGINAL ARTICLE

A methodological contribution to the assessment of nonword repetition—a comparison between children with specific language impairment and hearing-impaired children with hearing aids or cochlear implants

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Abstract

Poor nonword repetition is considered as a clinical marker of specific language impairment (SLI). In children with expressive language problems, the analysis and scoring procedures are often insufficiently described. We argue for a combined analysis of segmental and suprasegmental accuracy in nonword repetition tasks as well as an appreciation of gender differences. The view is taken based on empirical findings in a comparison between children with specific language impairment, children with mild/moderate hearing impairment and hearing aids (HI), and children with severe to profound hearing impairment with cochlear implants (CI). With age and gender taken into consideration, the main effects of both group and syllable level on a combined measure of segmental and suprasegmental accuracy remained. Although not necessarily an index of limited working memory capacity, persistently poor imitation of nonwords might be an indication of language impairment in children with mild/moderate HI and in children with CI.

Key words: *Hearing impairment, phonological short-term memory, segmental accuracy, suprasegmental accuracy*

Introduction

The present paper is above all a methodological contribution to research in the area of nonword repetition in children at risk for language impairment representing different disability groups. Few comparisons have so far been made, and little attention has been paid to analysis and scoring procedures of nonwords, an issue that we specially want to explore. In the present study we compare three groups of children (children with severe/profound hearing impairment with cochlear implants (CI), children with mild to moderate sensorineural hearing impairment aided with conventional hearing aids (HI), and children with specific language impairment (SLI)) on nonword repetition.

According to Gathercole (1) and Baddeley et al. (2), phonological short-term memory, as measured by nonword repetition, plays a significant role in supporting the acquisition of language, knowledge, and skills during childhood. Nonword repetition is often used to index phonological short-term memory in children, since it is difficult during such a task to access lexical knowledge stored in long-term memory (3–5). In a longitudinal study by Gathercole et al. (6) nonword repetition predicted the development of vocabulary and grammar until the age of five in children with normal language development. A large amount of research provides support for a link between nonword repetition skills and language abilities in children with normal language development (in the following referred to as children with NL) (7), in children with SLI (4,8,9), in children with HI (10), and in children with CI (11,12). Some researchers argue that there is a causal link between

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poor phonological short-term memory and language impairment in children with SLI. Bishop et al. (13) even consider poor nonword repetition as a 'genetic marker' of SLI, since children with SLI, well beyond preschool years, often demonstrate specific and persistent problems with nonword repetition.

Children with HI show weaknesses in a range of linguistic skills (14). Our own comparisons between children with HI and children with SLI (5,15) and also studies by Briscoe et al. (10) and Frazier Norbury et al. (16) indicate that children with SLI generally have more severe and persistent language and literacy problems than children with HI, but a subgroup of children with HI demonstrate as severe and as pervasive problems as children with SLI. According to Gilbertson and Kamhi (14) there is a risk that the language problems in children with HI might be 'masked' by their hearing impairment. For clinicians working with children with HI and with children with CI, valid instruments for early identification of children at risk for language impairment is called for.

Is nonword repetition really a reliable index of phonological short-term memory?

A range of factors influences performance on a nonword repetition test. For example, the lexical familiarity of the nonword has an impact on repetition skills, i.e. when nonwords are similar to real words they are more easily repeated by children with normal language development (NL) and by children with SLI (17). When the nonwords resemble real words the task taps into the long-term store, and earlier lexical knowledge supports more accurate and rapid repetition.

Apart from lexical familiarity, segmental complexity seems crucial for repetitions skills; nonwords containing consonant clusters are more difficult than nonwords without clusters. Further, when the phonotactic rules of the ambient language are obeyed, nonword repetition becomes a less sensitive measure (2). The repetition of nonwords is, according to Gathercole et al. (18), strongly influenced by the phonotactic frequency of the memory item. Thus, if phonotactic complexity is low, or if frequency of consonant clusters is high, children with NL tend to repeat nonwords easily.

Some researchers argue that limitations in nonword repetition are related to the phonotactic complexity and stress patterns of the particular language studied. Poor nonword repetition by children with SLI speaking Swedish or English might be due to prosodic properties of the language and not necessarily to poor phonological short-term memory. This might explain why, in Cantonese-speaking children, nonword repetition does not discriminate children with SLI from younger language-matched children with typical language development (19). Almost all studies on nonword repetition have been carried out in English-speaking populations, and very few studies have focused on suprasegmental aspects of nonword repetition. The number of syllables and the stress pattern of the nonword seem to play an important role in accuracy of repetition. For 5-year-old Swedish children with SLI, Sahlén et al. (9) showed that unstressed syllables in prestressed position were omitted six times more often than unstressed syllables in post-stressed position of the nonwords.

In children with CI, suprasegmental aspects of nonword repetition have been taken into consideration in some studies. Carter et al. (20) studied children with CI aged 8–10 years. They found that only 5% of the nonwords were produced correctly without any errors. However, almost 50% of the nonword imitations were reproduced with both the correct syllable number and the correct stress placement, whereas 64% of the responses were reproduced with the correct number of syllables. Their results also showed a significant correlation between correct imitation of syllable number and stress of the nonwords and measures of speech perception, speech intelligibility, and working memory. Willstedt-Svensson et al. (12) found that it was easier for Swedish children with CI, diagnosed as profoundly hearing impaired before 36 months of age, to imitate the correct number of syllables and to correctly place primary stress than to imitate consonants correctly. Nonwords with two syllables were repeated more correctly than those with three syllables regarding both segmental as well as suprasegmental features.

Simkin and Conti-Ramsden (21) found that normally developing English-speaking children perform at ceiling on nonword repetition by the age of 10 on a widely used nonword repetition test, the CNrep, developed by Gathercole et al. (6). Similar results were reported in a study of Swedish normally developing children aged 9:11–11;9 (22) on a Swedish nonword repetition test (9). The same nonword repetition test was used in groups of 3- and 5-year-old Swedish children with NL (23). The twenty 3-year-old children imitated 68% of the consonants in the nonwords correctly and the twenty 5-year old children 75%. In another study (24), 93% of the consonants were correctly repeated by a group of fifteen 6-year-old children. Thus, Swedish children with NL seem to improve rapidly in nonword repetition during their preschool years.

Output phonology has turned out to strongly predict nonword repetition skills in children with SLI (9). Output constraints (phonological and/

or articulatory) have therefore been handled in several different ways in nonword repetition tasks. Sometimes nonwords only consisting of phonemes present in the child's own phoneme inventory have been used (8). At other times, children with phonological problems manifested as context-bound substitutions have been excluded. Gathercole and Baddeley (1990) as well as Bishop et al (1996) gave credit for errors that were due to context-free and consistent substitutions of phonemes in nonwords, if the child made the same substitutions in spontaneous speech (4,13). This means that the child could reach a full score in spite of an incorrect repetition. In the widely used CNrep task (6), an online scoring procedure with items judged only as correct or incorrect is applied. Sahlén et al. (9) used a different approach with a group of Swedish children with SLI ($n = 27$), who had deficits in output phonology. Nonwords produced by the children were recorded and transcribed phonemically. The percentage of correctly repeated consonants (PCC) in each sample was computed. Credit was given for each consonant that was correctly repeated in the right position of the nonword.

The strong influence of output constraints is only one factor that makes nonword repetition a less reliable index of phonological short-term memory in children with language impairment. Sensory or perceptual limitations might also hamper nonword repetition. Nonword discrimination was significantly correlated with nonword repetition in twenty-eight 5-year-old children with SLI studied by Reuterskiold-Wagner et al. (25). The authors argue that the ability to discriminate nonwords should always be related to nonword repetition skills in children with output constraints. In the current study a nonword discrimination test will therefore be used.

To sum up, it might be that nonword repetition is a 'clinical marker' of language impairment only in some languages. Further, nonword repetition must be handled with care in children with output constraints or sensory deficits (hearing impairment). Whether or not nonword repetition serves as an index of working memory in Swedish- or English-speaking children, the task is widely used today and strongly calls for further methodological consideration. The following is an attempt to further add to our knowledge about methodological pitfalls and possibilities using tests of nonword repetition.

Purpose

The main purpose of the present study was to explore the relationship between segmental and suprasegmental imitation accuracy as a function of syllable length in nonwords. Our empirical data are collected from three groups of children on a nonword repetition test: one group of children with CI, one group of children with HI, and one group of normally hearing children with SLI.

We expected a positive relationship between nonword discrimination and nonword repetition in the three groups of children. Further, we expected all the children to be more accurate imitating suprasegmental features than segmental features, and segmental and suprasegmental accuracy to decrease with syllable length of the nonwords. Due to less constraint on output phonology, children with HI as a group were expected to perform better than children with SLI in nonword repetition and this difference is expected to be more evident in longer nonwords. The children with CI will perform worse than the children with HI and the children with SLI. Their severe/profound hearing impairment and lower hearing age (the time they have been aided by the implant) is expected to influence phonological development and thereby nonword repetition skills.

Method

Participants

Three groups of children were included in the study. The first group consisted of 13 children with CI (4 males, 9 females). The children were aged 5;2–8;11 (mean age 7;5 years) and had a mean nonverbal IQ as assessed by Raven's colored matrices (26) of 112, SD = 9. Eleven children had a congenital, two had a prelingual, severe to profound hearing impairment ascertained before 36 months of age. They had all used their implant for at least 1.5 years. Their age at activation of the CI ranged from 24–73 months (mean 45 months). Their hearing ages (HA), i.e. time with CI, ranged from 18 to 78 months (mean 49 months). It is important to keep in mind that all the children with CI were aided with conventional hearing aids before implantation; a definite HA is therefore very hard to define. Their mean maximal speech recognition score measured by phonetically balanced lists of words (FB-lists) was 48%. However, only 9 out of 13 children participated in this task (children nos. 6, 8, 10, and 12 were not able to participate). Output phonology, measured as correctly produced consonants in percent (PCC) in a picture-naming test (27), was 55.

The children had their surgery in Lund at the ENT Clinic, Lund University Hospital, Sweden. Of the 13 children, 6 used oral language as their communication mode in preschool or school, and 3 used a combination of sign language and oral language; 4 children attended a special school for children with HI, 9 children were mainstreamed. All

Table I. Total percentage of correctly imitated consonants (total pcc) for all participants in the study.

ID	Gender	Onset of deafness (months)	Age at cochlear implant (months)	Time as deaf before cochlear implant (months)	Time with cochlear implant (months)	Age at testing (months)	FB* (%)	IQ	Communication mode in preschool/school at testing	Linguistic status of oral language at testing (28)
1	F	0	51	51	54	99	70	130	oral language	functional
2	F	0	33	33	63	90	72	118	sign language + oral language	functional
3	M	0	40	40	63	97	78	118	sign language	functional
4	M	0	24	24	78	98	37	111	oral language	functional
5	F	0	56	56	48	98	60	118	sign language	transitional
6	M	0	66	66	48	107	0	100	sign language	preverbal
7	F	0	31	31	46	68	84	107	oral language	functional
8	F	0	73	73	29	95	0	118	sign language	preverbal
9	F	0	62	62	29	87	72	111	oral language	transitional
10	F	0	40	40	26	64	0	107	sign language + oral language	transitional
11	F	20	28	7	74	96	90	100	oral language	functional
12	F	21	48	26	18	62	0		sign language + oral language	transitional
13	M	0	28	28	67	90	57	100	oral language	functional

*Phonetically Balanced lists of words used to measure maximum speech recognition score (%)

the children in this group had Swedish-speaking and hearing parents. At home all the children used oral language, some of them in combination with key signs. For demographic data see Table I.

The second group, the children with HI, consisted of 13 children with mild/moderate hearing impairment. They all wore a hearing aid in at least one ear and had a symmetrical, bilateral, sensorineural impairment (Better Ear Hearing Level (BEHL) 0.5–4 kHz) with a mean of 48.55 dB, range 30–69 dB. The children were aged 5;4–8;11 (mean age 6;11). Their average time using hearing aids ranged from 9 to 77 months (mean 45 months). These children were recruited from ENT clinics in southern Sweden. Neither BEHL nor speech recognition was tested with amplification at the ENT clinics from which we recruited the children, which is why such data are lacking. All the children had a nonverbal IQ above 80 as assessed with the Raven's colored matrices (26). They had a mean IQ of 105 (SD = 14). All the children were monolingual speakers of Swedish and educated in an oral setting. Three of the children attended a special school for children with HI but all the rest ($n = 10$) attended mainstream schools. The children were not recruited on language criteria, and they turned out to have almost no phonological problems. Output phonology as measured by PCC on a picture naming test (27) was 97 (mean PCC). All children except one reached a mean of >97 PCC. One child only reached 82 PCC. For demographic data see Table II.

The third group consisted of 13 children with a diagnosis of SLI. They were aged between 5;1 and 7;0 (mean age 5;10) and were all recruited through speech and language pathologists in southern Sweden. All children passed a hearing screening (at 0, 0.25, 0.5, 1, 2, 4, and 6 kHz) with a signal level of 20 dB HL. Nonverbal IQ assessed with the Ravens colored matrices (26) in this group revealed that they all had an IQ above 88 (mean 107, SD = 15). Output phonology on the phoneme test was 66 PCC (mean). All children except one reached a mean of more than 60 PCC, one child only reached 15 PCC. The children also were monolingual speakers of Swedish with hearing parents. They all attended a mainstream school, but the majority had individual support from a special teacher.

Several studies at our department have explored nonword repetition skills in children with normal language development and normal hearing; using the same nonword repetition test as in the present study (9), see Table III. In this Table the number of children tested in each study and their mean PCC are shown. The studies presented in Table III will be referred to here for age references (24,23).

No indications of difficulties in the suprasegmental domain were found since no incorrect items regarding stress, syllable omission and syllable length were found in the 5-year-olds with NL. In the 3-year-olds with NL no stress errors were found but some omissions of syllables in the four- and five-syllable nonwords, most of them in the five-syllable nonwords (range 0–12 omitted syllables out of 84 syllables, mean 3.6) (23).

Table II. Total percentage of correctly imitated number of gestalts (total gestalt) for all participants in the study.

ID	Gender	Age at diagnosis (months)	Age at hearing aid (months)	Age at testing (months)	Time with hearing aid	$BEHL_{0.5\text{–}4kHz}$ (dB)[a]	$WEHL_{0.5\text{–}4\ kHz}$ (dB)[b]	Progress of hearing impairment	Aetiology
1	M	55	57	97	40	49	49	no	not known
2	M	30	34	80	46	30	33	no	ototoxic medicine
3	F	49	49	78	29	51	51	no	hereditary
4	F	13	20	80	60	39	43	not known	hereditary
5	M	28	29	75	46	43	44	no	not known
6	F	53	54	67	13	46	49	no	hereditary
7	M	55	55	64	9	54	58	no	hereditary
8	M	30	30	67	37	48	48	no	not known
9	M	29	29	71	42	55	[c]	not known	not known
10	M	52	53	93	40	39	46	no	not known
11	F	17	18	94	76	48	71	no	not known
12	F	40	42	107	65	63	65	not known	not known
13	F	30	29	106	77	69	70	not known	not known

[a] $BEHL_{0.5\text{–}4\ kHz}$ = Better ear hearing level, average threshold at 0.5, 1, 2 and 4 kHz.
[b] $WEHL_{0.5\text{-}4\ kHz}$ = Worse ear hearing level, average threshold at 0.5, 1, 2 and 4 kHz.
[c] Deaf ear.

Procedure

The children with CI were all assessed at the ENT clinic, Lund University Hospital, by the second author. The children with HI and SLI were assessed at the Section of Logopedics, Phoniatrics and Audiology, Lund University, except for three children with HI, who were tested in a special school for children with HI. The children with HI and SLI were tested in a soundproof room by an audiologist (the first author) or a speech-language pathologist. The whole procedure was audio- and videorecorded.

The following tests were used: a nonword repetition test, Sahlén et al. (9); and a nonword discrimination test, Reuterskiöld-Wagner et al. (25).

Nonword repetition task

The nonword repetition test consists of 24 nonwords with 6 two-syllable nonwords, 6 three-syllable nonwords, 6 four-syllable nonwords, and 6 five-syllable nonwords in mixed order of two-, three-, four-, and five-syllable nonwords (in total 84 syllables). The nonwords were constructed according to Swedish phonotactic rules. The stimuli were not balanced in terms of linguistic characteristics such as consonant vowel structure, consonant or vowel features, or stress patterns. In Table IV, number of consonants, number of clusters, and stress patterns for each syllable level are shown.

The children were told that they had never heard the words before and that they should imitate the items to the best of their ability. They were also instructed that they should guess if they were uncertain. The responses were recorded and later transcribed phonemically.

The children's ability to imitate nonwords was scored according to the following. First they were scored for each consonant correctly repeated in the correct position of the nonword. For example, for the target nonword *mangersblä gge* (7 phonemes), the imitation *manerblege* would give a score of 5, but the imitation *malebele* would give a score of 2. A maximum score of 111 was possible, and percent consonants correct (PCC) were computed for the whole nonword repetition test (total PCC). An analysis was also made for suprasegmental accuracy.

Table III. Percentage of correctly imitated number of gestalts (percent gestalt) for nonwords of varying length in the three subject groups.

Authors	Age	No of children	Mean percent consonants correct (pcc)	SD
Göransson and van der Pals, 2004	3;2–4;0	20	68	13.7
Göransson and van der Pals, 2004	5;0–5;11	20	75	9.7
Lindström and Malmsten, 2003	7;11–9;8	21	94	3.7
Hagesäter and Thern, 2003	6;5–7;6	15	93	4.4
Hagesäter and Thern, 2003	8;10–9;9	22	96	3.3

Table IV. Percentage of correctly imitated number of gestalts (percent gestalt) on each syllable level, divided by gender on each of the three subject groups.

			Stress pattern	
Number of syllables	Consonants	Number of clusters	Trochee	Iamb
Two syllables	16	3	2	4
Three syllables	29	5	1	5
Four syllables	27	1	1	5
Five syllables	39	6	0	6
Total	111	15	4	20

The children were given a score of 1 if they repeated the same number of syllables as the target nonword and a score of 1 if they used the correct stress pattern, i.e. a total score of 2 for each word. For example, for the target nonword *lebo'suf* the imitation *bo'suf* would give a score of 1, for the correct stress pattern but the incorrect number of syllables. For each syllable level a score of 12 was possible, and a maximum score of 48 was thus possible for the total. The percentage of the correctly repeated nonwords regarding suprasegmental accuracy was then computed (total PSA). Secondly, PCC and percent correctly imitated number of syllables and stress patterns (PSA) for each syllable-level were computed.

In a study of Swedish children with NL aged 3;2–4;0 years, the children reached a mean of 68 PCC (SD = 14) on the nonword repetition test used in this study, and children aged 5;0–5;11 reached a mean of 75 PCC (SD = 9.7) (23).

Nonword discrimination test

The test consists of 32 pairs of nonwords. Sixteen nonwords were selected from the nonword repetition test by Sahlén et al. (24) and then paired with either an identical item or a different item constructing a minimal pair, altogether 32 pairs. The minimal pair had one consonant phoneme that differed from the nonword (e.g. *sallotan/sallovan*). The children were told to discriminate the nonwords, i.e. to judge if the two nonwords were different from each other or the same.

For a full score both pairs of nonwords, i.e. a correct discrimination of the identical as well as the nonidentical pair, had to be correct. Thus, the maximum score of the test was 16.

In the study by Göransson and van der Pals (23), the 20 children with NL at the age of 3;2–4;0 reached a mean of 36% correct (SD = 4.4) and the 20 children with NL aged 5;0–5;11 a mean of 70% correct (SD = 3.3) on the nonword discrimination test.

Results

The scores on the tests were subjected to two-tailed *t*-tests and to a series of analyses of variance with the significance level set of 5% throughout. Parametric methods were used due to their greater versatility and power. In general terms, both the *t*-test and *F*-test are usually considered to be robust against violations of the assumptions of normality and homogeneity of variance. As we were interested in the possibility of interactions between the dependent variables, e.g. difficulty (number of syllables), and the three groups of children, ANOVAs were the choice. Also, as the mean age of the groups were not equal, this had to be dealt with using ANCOVAs.

Descriptives

Descriptive data for children with CI, HI, and SLI are shown in Table V. Two of the children with CI (children number 6 and 10) did not repeat the four- and five-syllable nonwords. A score of 0 was given for these nonwords. Three of the children with CI (children number 5, 10, and 12) could not cooperate in the nonword discrimination task and also received a score of 0. One child with HI (child number 5) was not given the nonword discrimination test. This is regarded as missing data.

As can bee seen in Table V, when simply comparing the means, the children with HI seem to outperform the children with SLI on all measures except one, and the children with SLI generally perform better than the children with CI. It should, however, be noted that the children with HI were almost one year older (mean age 6;11) than the children with SLI (mean age 5;10). Further, the children with CI were older (mean age 7;5) than the children with HI and the children with SLI. Compared to the younger hearing children with NL, 3;0–3;11 years old (23), who reached a mean of 68 PCC, the children with CI and the children with SLI performed worse. Compared to the children 5;0–5;10 years old with NL who scored 75 PCC, the

Table V. Percentage of correctly imitated number of gestalts (percent gestalt) as a function of number of syllables for children with CI below and above the median hearing age (42 months).

	Children with cochlear implant (CI)					Children with hearing aids (HI)					Children with specific language impairment (SLI)				
Tests	*n*	Min	Max	Mean	SD	*n*	Min	Max	Mean	SD	*n*	Min	Max	Mean	SD
Percent consonants correct, 2 syllables	13	13	75	44.2	22.5	13	38	94	72.0	16.8	13	31	94	62.1	17.0
Percent consonants correct, 3 syllables	13	10	76	45.7	20.7	13	45	100	76.4	18.5	13	10	93	59.1	18.5
Percent consonants correct, 4 syllables	11	0	70	30.0	22.3	13	30	93	68.4	16.5	13	19	78	51.9	16.5
Percent consonants correct, 5 syllables	11	0	67	26.9	20.7	13	30	92	63.0	20.1	13	5	69	39.3	18.4
Percent consonants correct, total	13	10	64	34.8	16.3	13	35	89	69.5	16.2	13	14	81	50.7	16.3
Percent gestalt correct, 2 syllables	13	50	100	85.2	18.3	13	83	100	98.0	4.9	13	75	100	95.5	8.0
Percent gestalt correct, 3 syllables	13	67	100	82.8	12.4	13	67	100	93.0	11.1	13	83	100	97.4	5.2
Percent gestalt correct, 4 syllables	11	0	92	57.1	31.3	13	67	100	92.9	10.6	13	50	100	87.7	16.6
Percent gestalt correct, 5 syllables	11	0	75	40.3	25.7	13	33	100	87.7	18.3	13	25	100	71.8	24.6
Percent gestalt correct, total	13	33	88	66.5	15.7	13	63	100	92.9	9.9	13	63	100	88.1	11.6
Percent nonword discrimination	10	0	75	38.5	27.7	12	56	100	79.5	14.4	13	19	94	61.0	21.0

children in all three subject groups performed worse. Direct comparisons regarding suprasegmental accuracy between the subject groups and the reference groups cannot be made, since scoring procedures were different. It is, however, interesting to note that there were no problems in the reference group of 5-year-olds at all. There were no stress errors and only few omissions of syllables in longer nonwords in the group of 3-year-old children (23).

When comparing the means for the performance on nonword discrimination in the three subject groups, the children with CI reached a mean of 38.5%, the children with HI 79.5%, and the children with SLI 61%. Compared to the mean performance (70%) for children in the reference group of 5–5;11 years (23), the means for the children with SLI and CI were lower. The children with CI performed almost at the level of the 3-year-old children with NL (36%).

Segmental accuracy (PCC)

Intragroup comparisons. We studied the effect of number of syllables (two, three, four, and five syllables) on PCC in each subject group by using three separate one-way ANOVAs (repeated measures with number of syllables as the independent variable). The analysis revealed that in each subject group the effect of number of syllables was significant (CI: F(3,36) = 5.82, $p<0.1$; HI: F(3,36) = 5.21, $p<0.01$; and for SLI: F(3,36) = 19.77, $p<0.001$). Thus, the longer the nonwords the more difficult it was to imitate the consonants correctly for the participants in the three subject groups.

Intergroup comparisons. When comparing the groups, we had to take into consideration that children in the three groups were not equally distributed regarding gender and age (see Tables I–III).

A mixed ANCOVA was carried out, comparing PCC as the dependent variable with group and gender as between-group factors, age as covariate, and number of syllables as within-group factor. Neither revealed significant effects of group (F(2,27) = 12.33, $p<0.12$) nor number of syllables (F(3,81) = 0.88, ns). The main effect of neither gender (F(1.27) = 0.16, ns) nor age (F(1.27) = 0.001, ns) approached significance. However, the interactions group × age (F(2.27) = 3.38, $p<0.05$) and group × gender (F(2.27) = 3.93, $p<0.05$) showed that the boys performed better than the girls in the HI and SLI groups, but not in the group with CI. The three-way interaction group × age × gender (F(2.27) = 4.40, $p<0.05$) was also significant.

Suprasegmental accuracy (PSA)

Intragroup comparisons. When studying the effect of number of syllables on suprasegmental accuracy or percent correctly imitated number of syllables and stress patterns (PSA) by using three separate one-way ANOVAs (repeated measures with number of syllables as independent variable) it was revealed that in the three subject groups, the effect of number of syllables was significant (CI: $F(3,36) = 17.41$, $p < 0.001$; HI: $F(3,36) = 3.37$, $p < 0.05$; and for SLI: $F(3,36) = 12.21$, $p < 0.001$). Thus, the longer the nonwords were, the more difficult it was to imitate their suprasegmental features correctly.

Intergroup comparisons. If suprasegmental accuracy (PSA) is used as the dependent variable in a mixed ANCOVA, with group and gender as between-group factors, age as covariate, and number of syllables as within-group factor, the main effects of both group ($F(2,27) = 7.31$, $p < 0.01$) and number of syllables ($F(3,81) = 2.79$, $p < 0.05$) are significant. Gender was also significant ($F(1,27) = 6.41$, $p < 0.05$) but the effect of age (covariate) only approached significance ($F(1,27) = 3.91$, $p = 0.06$). All interactions except one also were significant, namely number of syllables × age ($F(3,81) = 2.69$, $p = 0.052$), which approached significance. The boys generally performed better than the girls (except for boys with SLI and boys with CI regarding the shorter two- and three-syllable nonwords). The girls in all groups had particular difficulties with the four- and five-syllable level nonwords.

For all 39 children (the children in the three subject groups taken together), there was a significant correlation between the total PCC and the total PSA ($r = 0.72$, $p < 0.01$), indicating that the two measures are tapping some common factor. We therefore combined the variables PCC and PSA as dependent variable in a mixed ANOVA, with group and gender (age as covariate) as between-group factors, and number of syllables as within-group factor. A significant main effect of group ($F(2,27) = 4.86$, $p < 0.05$) as well as of number of syllables ($F(3,81) = 3.03$, $p < 0.05$) was found.

In order to illustrate the age effect, the children in each group were also divided into two age categories: younger children (below the median age for the group) and older children (above the median age for the group). A mixed ANOVA with the sum of PCC and PSA as the dependent variable, and group and age category as between-group factors, revealed a significant main effect for group ($F(2,29) = 12.38$, $p < 0.001$). The interaction between group and age category shows that older children in the group of children with HI and in the group of children with CI perform better than younger children. In the children with SLI, however, the seven older children were not performing better than the six younger children, instead the pattern was reversed.

Children with CI—the influence of time with implant on segmental and suprasegmental accuracy

Considering the PCC, using a mixed ANOVA with time with implant as covariate and number of syllables as a within factor, neither the effect of number of syllables ($F(3,33) = 0.93$, $p = 0.438$, ns), nor the interaction between number of syllables and time with implant were significant ($F(3,33) = 0.25$, $p = 0.86$, ns). The effect of time with implant, however, approached significance ($F(1,11) = 4.57$, $p = 0.056$).

When taking time with implant (covariate) into consideration regarding PSA, using a mixed ANOVA with number of syllables as a within factor, time with implant was significant ($F(1,11) = 5.52$, $p < 0.05$) as well as syllables ($F(3,33) = 17.31$, $p < 0.001$) and the interaction between number of syllables and time with implant ($F(3,33) = 6.34$, $p < 0.01$). A similar analysis with the combined score of PCC and PSA gives almost the same result, although the interaction is not significant, i.e. time with implant ($F(1,11) = 5.45$, $p < 0.05$), syllables ($F(3,33) = 8.90$, $p < 0.001$), and the interaction ($F(3,33) = 2.10$, $p = 0.12$).

Nonword discrimination and nonword repetition

For all 35 children where data were complete, a significant correlation between total PCC and nonword discrimination ($r = 0.55$, $p < 0.01$) and between total PSA and nonword discrimination ($r = 0.57$, $p < 0.01$) was found. A combined measure of PCC and PSA significantly correlated with nonword discrimination ($r = 0.60$, $p < 0.05$) for all 35 children. When looking at the groups separately, for the 11 children with CI the correlation was also significant ($r = 0.84$, $p < 0.001$), but for the 13 children with SLI and for the 12 children with HI the correlation between the combined measure of PCC and PSA and nonword discrimination was not significant ($r = 0.70$ and $r = 0.70$, respectively, $p > 0.05$).

Discussion

The present study is a methodological contribution to a paradigm often used to assess phonological short-term memory: nonword repetition. Nonword repetition was studied in three groups of children: one group of children with CI, one group of children with HI, and one group of children with SLI. Our expectation was that the children would generally make fewer errors on suprasegmental features than on segmental features and that segmental and suprasegmental accuracy would decrease with increasing syllable length. This expectation was supported by our data.

As expected, the children in all three groups generally performed worse than normally hearing and typically developing 5-year-old children regarding the ability to imitate segmental and suprasegmental features in nonwords. The children in the SLI and CI groups also seemed to perform worse than the 3-year-old children with NL in a reference group (23), although the data are not completely comparable.

The significant difference found for suprasegmental accuracy and for the combined measure of segmental and suprasegmental accuracy between the children with CI and the children with HI and SLI does not necessarily mirror phonological working memory deficits or linguistic deficits in children with CI. Current speech recognition tests used clinically are gross and do not give information on prosodic features, and we know nothing about if or how prosodic information is transmitted by a cochlear implant. However, cochlear implants seem to give significant benefits developmentally to children with profound hearing impairments in terms of prosody as compared to similar children without cochlear implants, according to Lenden and Flipsen (29). In their longitudinal study of spontaneous speech in six children with CI implanted before 3 years of age, a range of prosodic problems was noted initially, but the children clearly improved over time. The authors also found that phrasing and pitch were less problematic than stress.

Segmental versus suprasegmental accuracy

When each subject group was considered separately, we found higher imitation accuracy for the suprasegmental features than for the segmental features. Regarding the comparison between the groups, one very intriguing question is why children with HI do not differ significantly from the children with SLI on segmental accuracy when syllable length increases. The children with HI in our study had, compared to the children with SLI, almost no phonological output problems and they had, compared to the normally hearing reference group of 5-year olds, a relatively good ability to discriminate the nonwords. We therefore expected their performance to be better than that of the children with SLI. However, segmental features seem to be as difficult to imitate for children with HI as for children with SLI in longer nonwords. Instead, our results indicate that it is the suprasegmental area that is particularly vulnerable in children with SLI compared to children with HI. As mentioned in the introduction, Swedish preschool children with language impairment have difficulties in the acquisition of suprasegmental features at the word level as described by Nettelbladt (30). In a study on preschoolers with SLI, Sahlén et al. (9) found that unstressed syllables in prestressed position were six times more vulnerable than unstressed syllables in poststressed position in nonwords.

As expected, the children with CI performed significantly worse on both segmental and suprasegmental accuracy than the children in the other two subject groups. They had considerably greater difficulties on the longer nonwords (four- and five-syllable level) than children with HI and SLI. The fact that there was a lower percentage of errors on the suprasegmental features than on the segmental features is supported by studies on children with CI by Carter et al. (20) and by Willstedt-Svensson et al. (12). Carter et al. (20) argue that CI users often can code the overall pattern despite the loss of detailed segmental properties. Segmental accuracy decreased with syllable length in our study as well as in other studies on children with CI (20,31).

A relevant question is also whether our findings have to do with the construction of the nonwords. The three-syllable nonwords used in this study had similar stress patterns as the four-syllable nonwords, but they comprised more consonants and more clusters than the four syllable nonwords. Thus, they can be considered as segmentally more complex. One could therefore expect that the segmental complexity of the three-syllable nonwords would make them more challenging than the longer but less complex four syllable nonwords. This was not the case. The four-syllable nonwords were harder to imitate than the three-syllable nonwords for all three groups of children.

Gender

An unexpected finding was that the boys ($n = 23$) were better at imitating the suprasegmental features than the girls ($n = 16$) in the four- and five-syllable nonwords. Traditionally, typically developing boys have been found to be less proficient in linguistic tasks than girls. Also, the frequency of language impairments has always been higher in male populations. Our interpretation is that this finding has to do more with the differences in attitudes towards the task between boys and girls and less with the linguistic proficiency. Boys might be more willing to take the risk of repeating the nonwords incorrectly and thereby score higher. They might take a more holistic approach to nonword repetition. A similar discrepancy between boys and girls is reported by Hagesäter and Thern (24). They studied speech recognition in noise and working memory in children with normal hearing. The authors of the present study initially requested the children to make a guess even if they were uncertain about what nonwords they had heard. The boys seemed more inclined to make a guess, and thereby they reached higher scores than the girls.

Children with CI—the influence of hearing age on nonword repetition

In line with our hypothesis, the children with CI had more difficulties than the children in the other two groups in repeating the nonwords. We argue that this might be due to a combination of insufficient CI technology, sensory-perceptual limitations, output phonological constraints, and also to the fact that their hearing impairment was severe to profound and had emerged before 36 months of age (their hearing age varied between 18 and 78 months). The majority of the children with CI had worn their implants for less than 4 years. Their hearing ages were thus much lower than for the children in the other two groups. When taking hearing age into consideration for PCC the significant effect of number of syllables disappeared. The effect of number of syllables on PSA, however, remained significant when hearing age was considered. It thus seems as if hearing age influences the imitation of suprasegmental features in longer nonwords.

As pointed out in the introduction, nonword discrimination has been found to correlate significantly with nonword repetition in children with normal hearing and typical language development (25). In this study, nonword discrimination correlated with nonword repetition in the children with CI but not in the children with HI or SLI. The lack of significant correlation in these groups might of course be due to the small sample size and the large variation in the group. Comparing simple means, the ability to discriminate nonwords in the children with CI was just slightly better (38.5%) than that in the 3-year-olds with NL (36%), and the children with HI were slightly better (79.5%) than the 5-year-olds with NL (70%), whereas the children with SLI performed in-between (61%) compared to the children in the reference groups (23). It thus seems as if poor nonword repetition, at least in our group of children with HI, cannot be explained by poor discrimination.

Some of the shortcomings of the present study should be pointed out. Due to difficulties with recruiting, the children with HI are older than the children with SLI, and the children with CI are older than the children in the other two groups. Recruiting a sufficient number of age- and gender-matched children, fitting inclusionary criteria of different diagnoses for a comparative study, is a difficult task in a small country like Sweden. This is a pitfall in many clinical studies and calls for careful interpretations as to the comparison of groups.

Another complicating factor is that Swedish, severely to profoundly hearing-impaired children with CI generally differ from children with mild/moderate hearing impairment using conventional hearing aids regarding communication mode. In our study, none of the children with HI used sign language or attended schools where the mode of communication in the classroom was sign language. The situation for some of the children with CI was different. Many Swedish children with CI are bilingual (sign language and oral language). There are, for example, four educational settings for children with CI in Sweden. Some children are individually integrated in mainstream school for hearing children; some attend a class for hearing-impaired children integrated in a mainstream school. Children with CI may also attend a special school for children with hearing impairment and receive instruction in oral language. Further, they may attend a special school for deaf children were they are instructed only in sign language. To get information on the amount of verbal auditory input is thus almost impossible. Two of the children with CI in the present study were not congenitally hearing-impaired. The onsets of hearing impairment for children number 11 and 12 was 20 and 21 months, respectively. Thus, they have had the opportunity to benefit from auditory verbal input during a very important period of language development. This might have influenced their results in the nonword repetition task positively compared to the congenitally hearing-impaired children. Their hearing ages, however, differed substantially from each other, which makes the specific influence of early verbal stimulation difficult to rule out. Child number 11 has had his CI for 74 months, and child number 12 for 18 months at the time of testing.

To sum up, suprasegmental accuracy should not be neglected in the analysis and scoring of nonwords. We believe that the combined measure of segmental and suprasegmental accuracy is a sensitive and clinically useful measure in nonword repetition and can help clinicians to identify children at risk for language impairment. Nonword repetition ability should be assessed longitudinally. If poor nonword repetition is a ‘clinical marker’ of language impairment, little developmental change is expected in this area in children with SLI or in children at risk for language impairment. Our study gave some indication in this direction; older children with SLI were no better than younger, but conclusions cannot be drawn from our cross-section study design. Gender differences should also be appreciated: boys may be better performers, although not necessarily linguistically more developed, than girls.

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Paper II

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Deaf teenagers with cochlear implants in conversation with hearing peers

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Abstract

Background: This study investigates the use of requests for clarification in conversations between teenagers with a cochlear implant (CI) and hearing peers. So far very few studies have focused on conversational abilities in children with CI.
Aims: The aim was to explore co-construction of dialogue in a referential communication task and the participation of the teenagers with CI in comparison with individually matched hearing children and teenagers (HC) by studying the use of requests for clarification.
Methods & Procedures: Sixteen conversational pairs participated: eight pairs consisting of a child with CI and his/her hearing conversational partner (CIP); and eight pairs consisting of an HC and a conversational partner (HCP). The conversational pairs were videotaped while carrying out a referential communication task requiring the description of two sets of pictures depicting faces. The dialogues were transcribed and analysed with respect to the number of words and turns, the time it took for each pair to complete the tasks, and the occurrence and different types of requests for clarification that were used in each type of conversational pair and in each type of dialogue.
Outcomes & Results: The main finding was that the teenagers with CI produced significantly more requests for clarification than the HCs. The most frequently used type of request for clarification in all dialogues was request for confirmation of new information. Furthermore, there was a trend for the teenagers with CI to use this type of request more often than the HC. In contrast, the teenagers with CI used significantly fewer requests for confirmation of already given information and fewer requests for elaboration than the HC.
Conclusions & Implications: The deaf teenagers with CI in the study seem to be equally collaborative and responsible conversational partners as the hearing

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teenagers. The interpretation is that certain conditions in this study facilitate their participation in conversation. Such conditions might be a calm environment, a task that is structured and without time limits and that the partner is well known to the teenager with CI.

Keywords: hearing impairment, conversation, request for clarification, referential communication, cochlear implant.

What this paper adds

What is already known on this subject

Language development and language ability in children and teenagers with cochlear implants varies and many different demographic and cognitive factors seem to influence the outcome. Most studies are experimental studies, focusing on cognition or structural aspects of language. Much less research has been done on how they cope in everyday verbal interaction. This study focuses on the use of requests for clarification in a referential communication task where one participant has a cochlear implant.

What this study adds

The results indicate that teenagers with cochlear implants using oral communication as their main communication mode act as competent conversational partners in the context studied, i.e., a referential communication task in a quiet environment with a friend who knows the child with cochlear implants well and thus is used to adapt. However, there was a tendency for dialogues involving a child with cochlear implants to be slightly longer and to contain more requests for additional information, in particular a type of request that gives an opportunity to control the answer.

Introduction

A cochlear implant (CI) stimulates the auditory nerve electrically and thus provides a channel to convey auditory information to the brain. This offers auditory sensations to deaf or severely hearing-impaired individuals. The hearing capacity is not restored to normal level, but the auditory sensations open up the possibility for a different course of development in a wider variety of areas than would otherwise have been the case (Geers *et al.* 2003). This is most pronounced in areas where processing of cognitive and language-related information is central. Children with CI have a different development of basic academic skills such as language and reading skills compared both with hearing children and with children with severe or profound hearing impairment who have not been implanted. Demographic factors such as age at implant, duration of deafness, and time with the CI also have an impact on the course of development. A central feature of the empirical picture is that early implantation is more beneficial for development than implantation at a later age (Geers *et al.* 2003, Wass *et al.* 2007, Pisoni *et al.* 2008).

According to a survey made by the Swedish association for children with CI (A.-C. Gyllenram, personal communication, 2007) approximately 40% of all Swedish children and teenagers wearing a CI who attend compulsory school are placed in mainstream education. However, we do not know much about to what degree they possess the communicative prerequisites for learning or how they interact to form and maintain relationships with their hearing peers. The only Swedish study is Preisler *et al.* (2002), who studied a group of Swedish children with CI in preschool education and found that after one to 3.5 years of implant use these children did not interact with other children or adults by means of speech and hearing. The same authors conducted a longitudinal study of children with five to seven years' experience with CI and report that those in mainstream classes have difficulties understanding what their teachers say and have problems taking part in conversations in the classroom setting (Preisler *et al.* 2005). However, from international studies we know that there is a large variability in outcomes. According to Geers *et al.* (2003), for example, the amount of time children with CI have spent in a mainstream group is a significant predictor of speech production and reading outcome. The more time spent in mainstream class, the better the outcome. Uchanski and Geers (2003) further found that children with CI attending schools where spoken language is used achieve higher speech intelligibility.

In addition to communication mode at school there are several other factors that influence the outcome of implantation, e.g., age at implantation (Kirk *et al.* 2002), duration of deafness (Sarant *et al.* 2001), and working memory (Pisoni and Cleary 2003, Willstedt-Svensson *et al.* 2004).

So far, research on children and teenagers with CI has focused mainly on the influence of different demographic, cognitive or linguistic factors on outcome, and not so much on how these children or teenagers cope in real-life situations or everyday verbal interaction. Oral verbal interaction in a hearing environment is crucial for establishing and maintaining relationships with other people and for the feeling of inclusion in society. Studies of how children or teenagers with CI participate in conversations with hearing peers are therefore an important topic for research.

In the present study we have chosen to shed some light on how conversations between a teenager with CI and a hearing peer are constructed. Mutual adaptation might be different or more difficult to achieve in dialogues between children or teenagers with CI and hearing conversational partners due to the hearing impairment. Conversation is a joint and mutual activity, constructed by both participants together. All contributions are context dependent, being determined by earlier contributions as well as preparing for and determining following contributions (Linell 1998). Therefore, we wish to emphasize the importance of looking not only at each individual in a conversational pair, but to treat the conversation as a whole.

Only one study of conversational abilities in children with CI has, to our knowledge, been reported. Tye-Murray (2003) studied conversational fluency by letting 181 children with CI, aged eight to nine years engage in conversations with a clinician. She defined high conversational fluency as minimal need for clarification, an ample opportunity between the conversational partners to speak and few prolonged silent intervals (i.e., time spent in conversational breakdowns and in silence) and found that children who had had their implants for four to five years still had poor conversational fluency compared with hearing children.

Adults with hearing impairment (HI), according to Erber (1996), have the ability to achieve greater success in conversations if they are aware of how they use requests for clarification. Arnold *et al.* (1999) found that children with HI aged five to nine produced significantly fewer requests for clarification that controls with normal hearing. Their interpretation is that children with HI have a different strategy to cope with the conversational situation than hearing peers. Lloyd *et al.* (2005) found no difference in the use of requests for clarification when comparing children with HI (a mixed group using hearing aids or CIs) aged eight to twelve and children with normal hearing aged six to eight, i.e. the children with HI acted comparably to younger controls in their use of requests for clarification.

Requests for clarification can be categorized into non-specific (neutral or 'what/huh/pardon') requests and specific ones (Gallagher 1981, Tye-Murray *et al.* 1995). By using non-specific requests for clarification, for example, by saying 'what?', the partner will not receive any indication of which part of the message was not understood or not heard, while specific requests (e.g., 'What colour did you say his hair has?') can provide the necessary information to the partner.

Generally, it is believed that it is more effective for persons with HI wearing conventional hearing aids, to use specific requests for clarification than non-specific requests (Gagné *et al.* 1991, Erber 1996). In spite of this, studies on the subject show that the most commonly used type of request for clarification by both children and adults with HI wearing conventional hearing aids is non-specific requests for clarification (i.e. 'What?'; Caissie and Rockwell 1994, Caissie and Wilson 1995, Tye-Murray and Witt 1996, Caissie and Gibson 1997, Jeanes *et al.* 2000). Another type of request for clarification frequently used by adults with HI according to Tye-Murray and Witt (1996) is request for confirmation (e.g., 'Did you say that he had blue eyes?'). Earlier studies have also revealed that the ability to select the appropriate type of request for clarification can to some degree influence how successful the speaker is in conveying her/his message as well as influencing the reaction from hearing listeners (Gagné *et al.* 1991, Caissie and Wilson 1995).

The context selected for the present study was a problem-solving task, which commonly occurs in educational settings. The problem-solving task used here is a referential communication task, which is an elaborated version of a task designed by Glucksberg and Krauss (1967). This is an experimental approach to the analysis of speaker and listener skills in for example classroom interaction (Lloyd *et al.* 2005). The activity in a referential communication task is thus not quite comparable to spontaneous conversation. In the task used in the present study the participants focus on the items (faces), arrange and compare them and make different choices. The interaction and the utterances are therefore related to the manipulation of the items.

The ability to use referential communication according to Lloyd (1994) is a pragmatic skill, where the challenge for the speaker is to describe an item so that the listener can identify that specific item. The speaker's task is thus to make knowledge available to his/her partner. Referential communication tasks are also highly structured (Leinonen and Letts 1997). The task usually involves different kinds of physical items, or pictures depicting different kinds of items, that vary on certain dimensions (for example, size or colour). Referential communication tasks have been widely used in studying different clinical populations (Brinton and Fujiki 1982, Bishop and Adams 1991, Leinonen and Letts 1997, Reuterskiöld Wagner *et al.* 2001, Merrison and Merrison 2005). Brinton and Fujiki (1982) report that children with language impairment used fewer requests for clarification in a referential communication task than children with typically developing communication skills. According to Merrison and Merrison (2005) children with pragmatic language impairment did not initiate repairs as frequently as children with language impairment without pragmatic problems and children with typical language development when participating in a referential communication task. Donahue *et al.* (1980) suggest that children with learning disabilities are less likely to initiate repairs in conversation than normal controls. No study has, to our knowledge, been reported on children with CI and their use of requests for clarification in referential communication tasks. Furthermore, most studies involve conversation between a child with HI and an adult. Lloyd *et al.* (2005) conclude that it is important also to investigate peer interaction in referential communication.

The intention when designing the referential communication task for the present study was to make it resemble a problem-solving task that may occur in the school setting. The participants with CI were therefore allowed to choose a conversational partner that they knew well.

Purpose

The first aim is to study the co-construction of conversation and the use of requests for clarification in two types of conversational pairs in order to be able to find out to what extent a child with CI influences the conversation. The first type of conversational pair consists of a child with CI and a hearing partner and the other type consists of two hearing children or teenagers (HC).

The second aim is to compare the use of requests for clarification in the teenagers with CI with the hearing teenagers, who were individually matched to the teenagers with CI regarding age and gender. This comparison is thus made between individual teenagers in two different conversational pairs, one involving a person with CI and a hearing peer, the other involving two hearing participants.

More specifically the research questions are as follows:

- Do the two types of conversational pairs differ with respect to the number of words and turns produced, the time used to solve the task, the number of requests for clarification that were used and the distribution of different types of requests for clarification?
- Do the teenagers with CI differ from the individually matched HC with respect to the number of words and turns produced, the time used to solve the task, the number of requests for clarification that were used and the distribution of different types of requests for clarification?

Method

Participants

Eighteen children with CI older than seven years were invited to participate in the study. They were all included in a follow-up at the Department of Audiology, Lund University Hospital. They all spoke Swedish as their first language, had non-verbal IQ within normal limits and wore only one implant. They were also judged by a speech–language pathologist to be cooperative in test situations, which was a requirement for participation. Thirteen accepted the invitation and in a second step eight teenagers, four boys and four girls, who were able to participate within the time limits for the study, were selected to match eight hearing teenagers regarding age and gender. The teenagers with CI ranged in age from 11;9 to 19;1 years (mean=15;9) at the time of testing. The duration of deafness before amplification was initiated ranged from 4 to 30 months (mean=11,2 months) and the duration of device usage ranged from 6;2 to 13;9 years (mean=9;3). All subjects wore a Nucleus 22 device. A group of hearing teenagers (HC) selected to match the teenagers with CI consisted of four males and four females aged 11–19.

All the participants with CI have hearing parents and were exposed to sign language before implantation, according to Swedish praxis. However, they all used oral communication as their main communication mode at home and at school at the time of testing.

Due to the small size of the community of children with CI in Sweden, individual information on the diagnostic age, age at amplification or aetiology of the children's deafness cannot be revealed for ethical reasons. According to medical records, the aetiology was unknown in four cases, two had hereditary sensorineural hearing impairment and in two cases deafness was caused by infectious disease. Four of the participating teenagers had had progressive hearing loss.

Each child with CI and HC chose a hearing conversational partner (CIP and HCP, respectively) of the same age that s/he knew well to create a conversational pair. The CIPs ranged in age from 11 to 19 years. Four were females and four were males and most of them were classmates of the teenagers with CI. The HCP group consisted of three males and five females aged 11–19. All the hearing participants were reported to have typical development in all respects.

Speech recognition test

The teenagers with CI were assessed regarding speech recognition, as the signal-to-noise ratio (SNR) in which they recognized 50% of sentences correct, as described by Hagerman (1995). There is a lack of valid speech recognition tests for Swedish children. According to the clinical records, speech recognition in quiet was measured by a range of different tests and administered in different ways. Results were therefore not appropriate to use for scientific purposes. We chose to use the sentence recognition in noise test (Hagerman 1995) in assessing the teenagers with CI because we considered it to be the most ecologically valid existing Swedish speech recognition test.

The results from the assessment showed that the participants' SNR ranged from −2.9 to 8 dB, with a mean of 1.5.

According to Hagerman (1995), normally hearing adults have a mean of −7.8 dB. Normative data for hearing children are sparse. One exception is Hagesäter and Thern (2002), who reported that hearing children aged seven range from −5.3 to −1.3 dB, with a mean of −3.89 dB, and that children aged nine range from −7.3 to −4.0 dB, with a mean of −5.63 dB. This indicates a great variation in the group of children and teenagers with CI and that their speech recognition differs from normative data from hearing children to varying degrees.

Procedure

Before the main study different referential communication tasks and different procedures were tried out on conversational pairs including children with HI as well as deaf children with CI. First a referential communication task with simple faces used in an earlier study on children with language impairment age 5–6 (Reuterskiöld Wagner *et al.* 2001) was used. This task was found to be too easy for teenagers. We therefore constructed a more complex and challenging task, where more variables had to be taken into consideration in the descriptions. For the main study, the referential communication task was administered by the first author in a quiet room at the teenagers' homes or at their school. All participants performed the task orally.

The task was to describe two sets of 16 pictures depicting faces. One set of pictures was placed in a predetermined pattern in front of one child (*the describer*), another in a pile in front of the other child (*the receiver*). The task was for the describer to describe each face (e.g., 'He has green eyes, red hair and a hat') and its position so that the receiver could identify each face and arrange his/her set of pictures in the same way as the set in front of the describer. To make the task more challenging, the describer and the receiver did not have identical sets of cards; each had one card that the other did not have. The participants were not informed about this. The subjects were given the following instructions:

> You will sit on each side of this screen (see below). Your task is to describe each face that you have in front of you as accurately as possible so that your friend can choose the same face from his/her set of pictures. You should also describe the position of each face so that your friend can arrange his/her set in the same way as yours. When you are done we will change roles so that your friend will describe another set of pictures and you will try to arrange them in the same way as his/her set.

Thus two structured dialogues were elicited for each type of conversational pair. The participant with CI and the HC acted as describers in the first dialogue and the CIPs and HCPs were receivers. The roles were reversed in the second dialogue. This means that both participants acted both as describer and as receiver.

The teenagers were seated right opposite each other on each side of a 30-cm-high screen. Due to the rather low screen the dialogues were thought to be more similar to the 'real life' conversations since visual cues (such as the possibility to lip-read, or to use gestures) were not altogether eliminated. In the trials made prior to the main study we found that visual cues were important for the participants to be able to participate in the task. The dialogues were recorded on a digital video camera and the microphone was attached to the teenagers' sweatshirts. While the teenagers performed the task the test leader left the room, which according to Caissie and Rockwell (1993) may take away some of the discomfort that the participants might feel.

Analysis

Each videotaped conversation was transcribed orthographically using CHAT conventions (MacWhinney 2000). Either the first author or a research assistant, a trained speech and language pathologist, made the transcriptions. The second author then checked the transcriptions. In cases of disagreement consensus was reached by discussion, listening to the tapes together. Disagreements were more frequent in the CI-dialogues than in the HC-dialogues, but they were more often related to segmentation and marking of hesitation phenomena than to the interpretation of what the children actually said. The CLAN program (MacWhinney 2000) was used for quantifications of number of words and turns as well as for coding and quantification of requests for clarification (see below).

The duration of each dialogue was measured in minutes. This was considered as the time spent for the teenagers to solve the task, i.e. for the receiver to have arranged the whole set of pictures in the same way as the describer on the other side of the screen.

A classification system for different types of requests for clarification and information made by the describer and the receiver in order to solve the task was developed. The dialogues were coded and checked by the first and the second author. Cases of disagreement were solved by discussion.

The requests for clarification were first classified into the main categories of non-specific and specific requests. Specific requests were then further classified into different subcategories. This yielded a system with the following seven different categories inspired by earlier studies made by Caissie and Rockwell (1993), Tye-Murray *et al.* (1995) and Caissie and Gibson (1997):

- Non-specific requests for clarification (e.g., 'What?' or 'Huh?').
- Requests for repetition, asking the conversational partner to repeat the whole or parts of a message (e.g., 'Could you please say that about the hair again?').
- Requests for confirmation of new information (e.g., 'Has he got blue eyes?').
- Requests for confirmation of already given information (e.g., 'Did you say that he had blue eyes?').
- Requests for elaboration (e.g., 'What colour are his eyes?').
- Forced choice questions, either requesting confirmation or elaboration (e.g., 'Has he got blue or brown eyes?').
- Control questions, to make sure that the conversational partner understands (e.g., 'Do you know what I mean?', 'Have you got him?').

The following measures were computed:

- The number of words used by both types of conversational pairs and by each participant in each dialogue.
- The number of turns produced by both types of conversational pairs and by each participant in each dialogue.
- The time spent to solve the tasks for both types of conversational pairs and for each dialogue.
- The total number of requests for clarification used by both types of conversational pairs and by each participant in each dialogue.
- The types of requests for clarification used: the total number and the distribution (%) in each type of conversational pair and made by each participant in each dialogue.

The dyads performed the task with almost 100% accuracy. Thus accuracy was not useful as a variable.

Statistical analysis

The number of subjects in each group was small. Due to the small sample size and large individual variation non-parametric statistical methods were used. For comparisons between the two types of conversational pairs and between the teenagers with CI and the HCs the Wilcoxon signed-ranks test was used. The level for statistical significance was set to 0.05.

Results

First the two types of conversational pairs as wholes, i.e. including both participants in both dialogues are compared. Secondly, the two different dialogues within each type of conversational pair are compared focusing mainly on the teenagers with CI and the individually matched HC.

Number of words and number of turns

Table 1 presents the range and the mean value of the total number of words and turns used in each type of conversational pair. Table 2 shows the range and mean value of number of words and turns produced in each dialogue. As seen in table 1 the two types of conversational pairs did not differ with respect to the mean number of words and the mean number of turns. The patterns were the same when looking at the mean number of words and mean number of turns for each participant in each type of dialogue (table 2).

Within dialogue comparisons showed, as could be expected, that the describer in all dialogues produced significantly more words ($p=0.012$) than the receiver. Furthermore, a higher number of words were used by both describer and receiver in the first dialogues compared with the second dialogues. In this respect the difference between HC and HCP was significant ($p=0.036$).

Time used to solve the task

The total time used for each type of conversational pair and in each type of dialogue is shown in tables 3 and 4. Differences with respect to time spent by the two types of conversational pairs were non-significant (table 3).

The comparisons between individual participants indicated that the dialogues where the CIP acted as describer tended to be longer (7.9 min) than when the HCP acted as describer (5.9 min). This difference approached significance ($p=0.069$).

Wilcoxon signed-ranks test revealed that for the conversational pairs HC-HCP, the first dialogues were significantly longer than the second (7.6 and 5.9 min,

Table 1. Mean value, standard deviation (SD), and minimum and maximum values for total number of words and turns produced in each type of conversational pair

		CI-CIP ($n=8$ pairs)	HC-HCP ($n=8$ pairs)
Total number of words			
	Mean	1509	1458
	SD	689	513
	Minimum–maximum	616–2484	741–2410
Total number of turns			
	Mean	266	208
	SD	127	82
	Minimum–maximum	119–456	93–329

Table 2. Mean value, standard deviation (SD), and minimum and maximum number of words and turns produced by each participant in both roles. In dialogues 1 the children with CI and the HC act as describers and in dialogues 2 the CIP and the HCP act as describers

		Number of words used	Number of turns used
Dialogue 1 for the CI-CIP pair			
CI describer			
	Mean	528	70
	SD	228	37
	Minimum–maximum	182–806	25–118
CIP receiver			
	Mean	245	67
	SD	181	40
	Minimum–maximum	34–587	11–119
Dialogue 2 for the CI-CIP pair			
CIP describer			
	Mean	491	66
	SD	194	30
	Minimum–maximum	230–765	24–117
CI receiver			
	Mean	245	65
	SD	149	31
	Minimum–maximum	60–434	23–117
Dialogue 1 for the HC-HCP pair			
HC describer			
	Mean	635	56
	SD	250	22
	Minimum–maximum	289–1124	28–90
HCP receiver			
	Mean	215	55
	SD	94	22
	Minimum–maximum	82–363	27–90
Dialogue 2 for the HC-HCP pair			
HCP describer			
	Mean	445	46
	SD	119	21
	Minimum–maximum	290–639	19–78
HC receiver			
	Mean	163	46
	SD	102	21
	Minimum–maximum	30–284	19–78

respectively, $p=0.012$), i.e. the difference in duration between the first and second dialogue was more consistent, and larger, for the HC-HCP pairs than for the CI-CIP pairs.

Number of requests for clarification

Figure 1 shows the mean number of requests for clarification that were made by the two types of conversational pairs. Significantly more requests for clarification were produced in the CI –CIP pairs than in the HC-HCP pairs ($p=0.018$).

Table 3. Time that each type of conversational pair spent to solve both tasks

Conversational pair		Total time (min)
CI-CIP ($n=8$)		
	Mean	16.36
	SD	6.25
	Minimum–maximum	7.52–23.95
HC-HCP ($n=8$)		
	Mean	13.01
	SD	4.37
	Minimum–maximum	8.66–20.26

There were no significant differences when comparing individual participants acting as describers (figure 2).

In the role as receiver, shown in figure 3, the teenagers with CI made significantly more requests for clarification (mean=30.1) than the HCs (mean=15.8, $p=0.035$).

The number of requests for clarification made by the CIPs did not differ significantly from the HCPs.

Distribution of different types of requests for clarification

First, to compare the distribution of the different types of requests for clarification between the two types of conversational pairs, we counted each type of request for clarification that was used by each participant and computed the percentage out of the total number of requests for clarification made by that participant. The distribution for the five most frequently used types of requests is shown in figure 4. Requests for repetition and forced choice questions hardly occurred at all. Therefore we chose not to include them in the presentation of the results.

Table 4. Duration of each dialogue

Dialogue		Time (min)
1. CI describer		
	Mean	8.45
	SD	3.29
	Minimum–maximum	3.65–12.60
2. CIP describer		
	Mean	7.90
	SD	2.24
	Minimum–maximum	3.87–12.17
1. HC describer		
	Mean	7.60
	SD	3.00
	Minimum–maximum	4.93–12.98
2. HCP describer		
	Mean	5.09
	SD	1.52
	Minimum–maximum	3.73–7.48

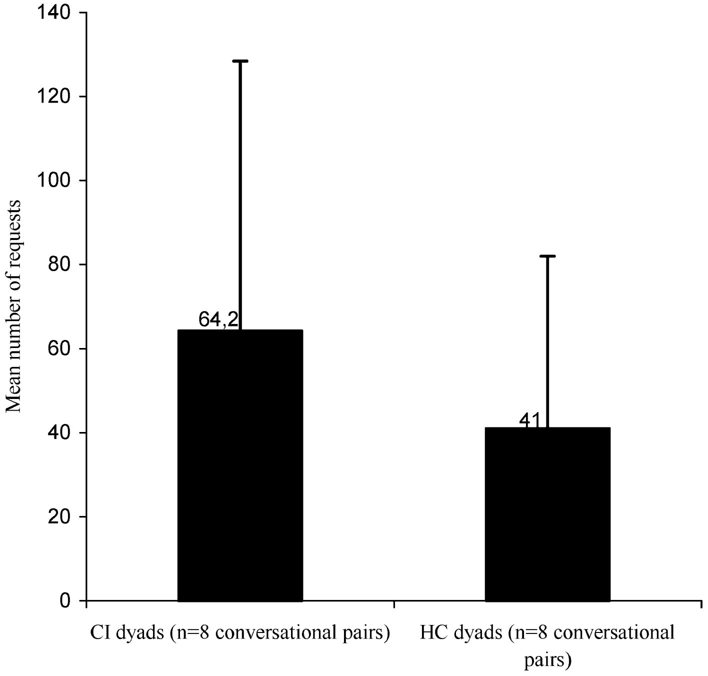

Figure 1. The number of requests for clarification in the two types of conversational pairs.

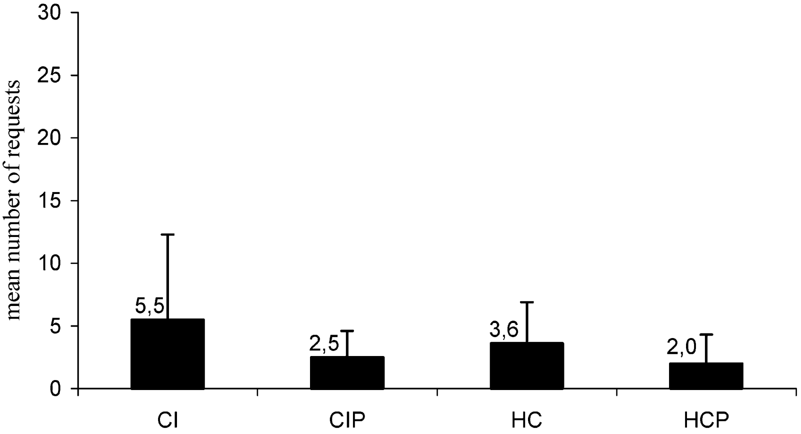

Figure 2. The mean number of requests for clarification made by the describers in each dialogue.

As seen in figure 4 the most frequently used type of request was *requests for confirmation of new information* in both the CI-CIP and the HC-HCP pairs. However, the CI-CIP pairs used it significantly more often than the HC-HCP pairs ($p=0.036$). The HC-HCP pairs used significantly more *requests for confirmation of already given information* than the CI-CIP pairs ($p=0.017$). The HC-HCP pairs also used more *requests for elaboration*, although this difference was not significant. Figure 4 also reveals that there is no significant difference between the two types of

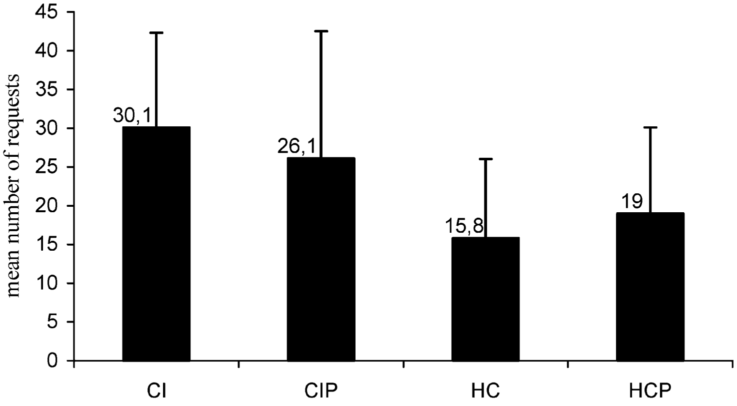

Figure 3. The mean number of requests for clarification made by the receivers in each dialogue.

conversational pairs regarding the use of *non-specific requests for clarification* and *control questions.*

Table 5 shows the proportion of different types of requests for clarification used by each individual participant in each dialogue (CI, CIP, HC and HCP). Once again the single most frequently used type of request was *requests for confirmation of new information.*

It seems as if the three types of requests for clarification that differ among the participant groups are *requests for confirmation of new information*, *requests for confirmation of already given information* and *requests for elaboration.*

Requests for confirmation of new information tended to be more frequent in the teenagers with CI (63.7%) than in the HCs (42.6%), but this difference only approached significance (p=0.093). However, the teenagers with CI use significantly fewer *requests for confirmation of already given information* (11.4%) than the HC (23.0%;

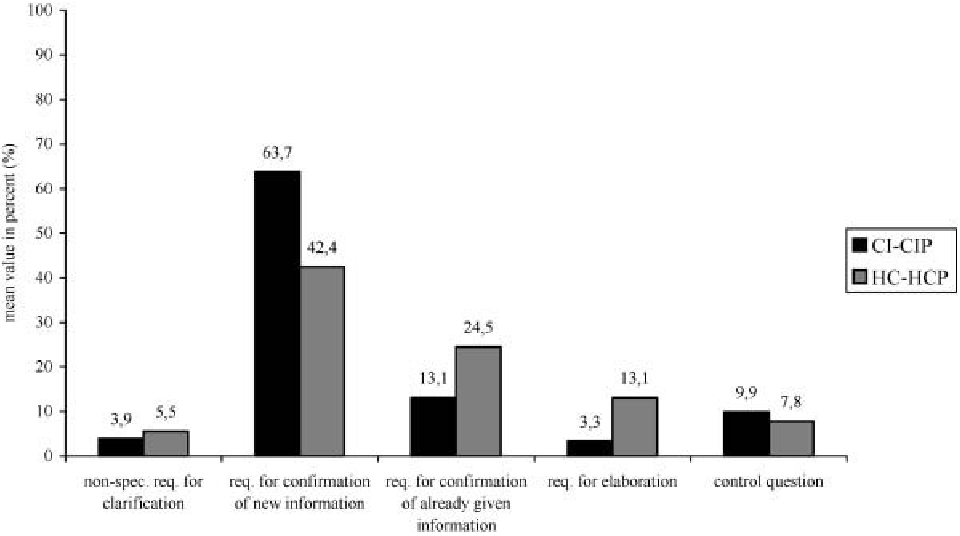

Figure 4. Distribution (%) of the five most frequently used types of requests for clarification in each of the two types of conversational pair.

Table 5. Distribution (%) of the five most frequently used types of requests for clarification made by each participant in the dialogues

Type of request for clarification		CI	CIP	HC	HCP
Non-specific requests for clarification					
	Mean	4.5	6.3	6.7	4.5
	SD	3.4	1.6	7.5	4.4
	Minimum–maximum	0–9.5	0–33.3	0–21.4	0–11.1
Requests for confirmation of new information					
	Mean	63.7	62.4	42.6	43.1
	SD	28.2	22.0	21.7	11.1
	Minimum–maximum	16.7–94.1	16.7–94.4	10.0–68.4	11.1–70.6
Requests for confirmation of already given information					
	Mean	11.4	14.4	23.0	25.6
	SD	11.9	8.1	12.6	12.8
	Minimum–maximum	0–33.3	4–25.6	5.3–40.0	0–44.4
Requests for elaboration					
	Mean	7.0	9.5	10.4	14.8
	SD	12.8	10.8	10.7	9.6
	Minimum–maximum	0–38.0	0–28.9	0–33.3	5–35.8
Control questions					
	Mean	10.6	8.9	5.4	8.9
	SD	13.0	12.6	9.7	11.8
	Minimum–maximum	0–30.4	0–33.3	0–28.6	0–36.4

$p=0.018$). There also seems to be a tendency for the teenagers with CI to use fewer *requests for elaboration* than for the other participants.

Summary of the results

To summarize the results, the dialogues involving a participant with CI differ from the dialogues between two teenagers with normal hearing mainly in containing significantly more requests for clarification. Furthermore, a significantly higher proportion of the requests in the CI-CIP dialogues where requests for confirmation of new information and a significantly lower proportion were requests for confirmation of already given information. The individual teenagers with CI differed from their matched HC in making more requests for clarification and a lower proportion of requests for already given information. Some differences found were not related to whether the participant was hearing or hearing impaired, but to whether it was the first or second dialogue. The first dialogue of the pairs contained a significantly higher number of words and took longer time than the second dialogues. Finally, the participants produced significantly more words in the role as describer than in the role as receiver.

Discussion

The aim of the current study was to explore how conversations between teenagers with cochlear implant (CI) and hearing peers are constructed focusing on requests for clarification. The novelty and challenge of this study resides in focusing not only on studying and comparing the contributions of individual participants, but also on the conversations as wholes. In order to learn about participants' adaptation in conversation, such an approach is necessary since conversation is a truly joint venture, constructed by the participants together. The overall picture is that all teenagers participating in this study took an active part in the interaction. They all acted as equally cooperative and responsible conversational partners, although there were some interesting differences as to the nature of their contributions.

The first research question concerned the number of words, the number of turns, as well as the frequency and distribution of different types of requests for clarification that were used in each of the two types of conversational pairs. It was found that the number of words produced differed depending on whether the speaker was a describer or a receiver and whether it was the first or the second time the task was performed, but not depending on the hearing status of the participants. The main finding was that the CI-CIP pairs made significantly more requests for clarification. This might be due to an awareness in the CI-CIP pairs of the fact that one partner has a hearing impairment. Thus, they might have been more inclined to secure the progression of the conversation by taking their time. In contrast to this study, Arnold *et al.* (1999) found that children with hearing impairment (HI) produced significantly lower number of requests for clarification than children with normal hearing when interacting with an adult in a referential communication task. Given that the participants with CI produced more requests than the other participants (figure 3), the interpretation is that they wanted 'to be on the safe side' producing a request for clarification whenever they were not certain. Thereby they might have avoided communication breakdowns.

The CI-CIP pairs not only used significantly more requests for clarification than the HC-HCP pairs, they also used somewhat different types. The CI-CIP pairs used significantly more *requests for confirmation of new information* than the HC-HCP pairs but significantly less *requests for confirmation of already given information* and also tended to produce a smaller proportion of *requests for elaboration.* An interesting question for future analyses of our data is whether the explanation for a more frequent use of requests for confirmation of new information in the CI-CIP pairs is that comparatively more information is actually provided by the receiver in the CI-CIP pairs than in the HC-HCP pairs.

When comparing the two dialogues for each type of conversational pair, a general and not very surprising pattern is that the describer always used more words than the receiver and more words were always used in the first than in the second dialogue. A shorter dialogue completed the task the second time, indicating that learning is taking place. Interestingly, the time difference between dialogues 1 and 2 is less obvious for the CI-CIP pairs than for the HC-HCP pairs. The question is if the CI-CIP learned less from the first dialogue or if they rely less on what they learned.

For the second research question, i.e., the comparison between the teenager with CI and the matched HC it is important to bear in mind that their respective partners are not identical. Each teenager with CI and the HC is adapting to a different partner, since the inclusion criteria for the partners to the teenagers with CI and the matched HC was that it should be somebody they knew well. Comparing the teenagers with CI to the matched HC in the role as receiver, which, given their hearing impairment, seems the most challenging, we found that the teenagers with CI used significantly more requests for clarification than the matched HC.

Previous studies investigating conversations between hearing-impaired individuals and their conversational partners suggest that there might be an 'unequal amount of participation' (Caissie and Rockwell 1994) between the interactors. Caissie and Rockwell (1994) show that adult hearing-impaired individuals often control the conversations with hearing conversational partners by, for example, taking longer speaking turns. This finding is supported by Tye-Murray and Witt (1996), who studied adults with CI. The authors made the interpretation that this is a strategy the CI users apply in order to control the interaction. To some extent the present results are in line with Tye-Murray (2003) who found that children with CI spent a large part of their conversational time to repair communication breakdowns. Although communication breakdowns were rare in both types of conversational pairs, the CI-CIP pairs produced a higher number of requests for clarification and took slightly longer time and more turns to complete the task. This might indicate that more negotiation was taking place in the CI-CIP dialogues.

Furthermore, the tendency among the teenagers with CI in the present study to use more requests for clarification when taking part in a referential communication task seems to differ from what has been found for other clinical populations with communicative/linguistic handicaps (Brinton and Fujiki 1982). Our interpretation is that the awareness of the consequences of the hearing impairment forces them to interact more (request more) with the partner in a conversation in order to anticipate misunderstandings.

As for the types and distribution of the requests for clarification that were used by the teenagers with CI and HC we found the same pattern as for the two types of conversational pairs, that is to say that similar results are found in a dialogue as in an individual approach to the conversations. The teenagers with CI and their matched hearing peers did not differ substantially with respect to the number of non-specific requests for clarification that were used. The type of specific request for clarification most frequently used in both types of conversational pairs was *request for confirmation of new information*. Of the requests for clarification that were used by the teenagers with CI 69% belonged to this category. Only 44% of the requests for confirmation used by the individually matched hearing peers were *requests for confirmation of new information*. It thus seems as if the teenagers with CI participating in the present study prefer using *requests for confirmation of new information* to a higher degree than their matched hearing peers. In contrast, the use of *requests for elaboration* as well as *requests for confirmation of already given information* occurred more frequently in the HC than in the teenagers with CI. In general, it seems as if all participants prefer using specific requests for clarification rather than non-specific.

According to Tye-Murray (2003) most of the research on children who are deaf or hearing-impaired suggests that these children tend to revise utterances that are not understood by the partner and that they use non-linguistic means to obtain clarification whereas hearing children more often repeat than revise and verbally ask for clarification. The design used in the present study did allow eye contact, but the teenagers could only see each other's faces above the screen, which prevented them from using body language. The impression is that they mainly relied on the verbal mode. A future study focusing on the responses to the requests for clarification and information will reveal whether there are any differences like the ones found by Tye-Murray (2003) in how the two groups of children do this.

To summarize, the teenagers with CI in the present study showed a preference for the types of requests for clarification that are specific rather than non-specific, which may give them more control of the responses or feedback that they could get from their conversational partner. By choosing requests for confirmation of new information (which only require yes/no answers) they were more in control of the interaction compared with using, for example, requests for elaboration, which may result in longer and less predictable responses.

When interpreting the results it is important to keep in mind the limitations of the study. First of all the number of participants is low, which severely restricts the possibilities to make any generalizations. Furthermore, within group variation was large with respect to chronological age, duration of deafness and device usage, speech recognition and speech intelligibility. One contextual factor that may have had an influence on the results is that all teenagers had different conversational partners and that this partner was somebody the child knew well. This was a deliberate choice in order to make the situation resemble a situation that might take place at school. In addition, it would be very difficult to find a peer who was as familiar with the child with CI as with the matched HC. We also consistently let the participant with CI (and the matched HC) act as describer in the first dialogue. The number of participants was too low to allow for variation of the order of who acted as describer in the first and in the second dialogue. It would be interesting to investigate if the patterns would be the same if the order had been reversed, i.e. if the hearing partner acts as describer first.

To conclude, the results indicate that teenagers with CI may spend some more time to get their message through and tend to use more requests for clarification of a type that helps to avoid communication breakdown. On the whole the impression is that they function well as conversational partners in a referential communication task with a well-known same-age peer. The aim was to highlight well-functioning interaction and factors that might support verbal interaction in a conversation where one of the participants is a child with CI. The implications are that teachers, for example, should be aware that these teenagers might need some extra time to carry out a task that involves interaction and collaboration with others. Other prerequisites for success might be a quiet environment. It should also be taken into account that whether a peer who is selected to work with the child with CI knows him/her well or not may influence how the interaction develops. In future studies it would be interesting to explore further the interaction in dialogues where one participant is a person with CI by varying the conditions in different ways, e.g., a less structured conversational task, and an unknown conversational partner. Other aspects of the interaction, e.g., dominance and coherence conditions also call for future exploration. In this study little attention is given to the role that other factors like speech recognition, speech intelligibility and working memory might play in interaction. Such influences are currently being studied by the present authors.

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Paper III

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Speech Recognition, Working Memory and Conversation in Children with Cochlear Implants

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ABSTRACT

This study examined the relationship between speech recognition, working memory and conversational skills in a group of 13 children/adolescents with cochlear implants (CIs) between 11 and 19 years of age. Conversational skills were assessed in a referential communication task where the participants interacted with a hearing peer of the same age and gender. The measures were the number of requests for clarification produced, time used to solve the task and the proportion of the different types of requests for clarification made by the participants with CIs. The results revealed that speech recognition correlated significantly with the general measures of conversational skills (time to solve the task and the total number of requests for clarification used). General working memory was associated with certain types of requests for clarification. The participants with better working memory capacity used more requests for confirmation of new information (i.e. made more suggestions of their own) and fewer requests for confirmation of already given information compared to the participants with poorer working memory. It thus seems as if both speech recognition and working memory contribute to conversational skills but in different ways. Copyright © 2009 John Wiley & Sons, Ltd.

Key words: cochlear implant, hearing impairment, working memory, referential communication, request for clarification

INTRODUCTION

Hearing plays an important role in the development of spoken language. When a deaf child is given the opportunity to receive auditory sensation by a cochlear implant (CI) hearing capacity is not restored to normal levels but the auditory input opens up the possibility to develop skills related to oral communication and language (Geers et al., 2003; Svirsky et al., 2000).

There are large variations in language development among children with CIs and numerous variables could potentially explain this variation. Demographic factors, such as age at implant, duration of deafness and communication mode, have been proven to be of importance for these children's language development (Geers et al., 2003; Richter et al., 2002; Uchanski and Geers, 2003). Apart from time factors, such as age at testing, age at implant and duration of deafness, a range of bottom-up and top-down driven processes also play important roles for communicative development in children with CIs. Some studies have demonstrated that, when cognitive/linguistic factors are taken into account, the association between demographic factors and communicative development may be less robust than the association between communicative development and cognitive/linguistic skills. To quote Dillon and Pisoni (2004) 'Phonological processing skills are significant contributors above and beyond the traditional demographic variables that have been shown to affect outcome and benefit following CI'. This statement is corroborated by results in studies of Swedish children with CIs by Willstedt-Svensson et al. (2004) and Wass et al. (2008).

The ultimate challenge for a child with severe/profound hearing impairment is to take part in everyday conversations. To enhance communicative effectiveness the child needs to develop strategies as both a listener and speaker. We were, in the present study, mainly interested in exploring this further by focusing on the relationship between bottom-up processes (measured by speech recognition in a noise test), top-down processes (as measured by a general working memory test and a phonological short-term memory test) and conversational skills assessed in referential communication tasks which can be regarded as a analogue to problem solving activities common in educational settings.

Archbold et al. (2008) have reported that almost 40 per cent of 101 children with CIs attending Nottingham Cochlear Implant Programme were placed in mainstream schools without special units or specialist resources. A similar percentage is reported for Swedish children with CIs. According to a survey made by the Swedish parents' association for children with CIs, approximately 40 per cent of all Swedish children/teenagers wearing a CI are placed in mainstream education (A. C. Gyllenram, 2007, personal communication). The ability to interact with hearing peers in noisy surroundings is therefore crucial for children and teenagers with CIs. Poor speech recognition may affect both learning and social interaction with peers. A deeper knowledge about the complex interaction between hearing, cognition and communicative strategies in children with CIs could therefore give important clinical and educational implications. In the present study, we wanted to capture children's hearing in noise and therefore chose to use a test called *Hagerman sentences* (Hagerman and Kinnerfors, 1995). This is one of the tests used in Sweden to assess speech recognition in noise.

The test requires repetition of spoken sentences presented in background noise and performance is scored in terms of speech to noise ratio (SNR).

Working memory capacity refers to the memory system responsible for simultaneous storage and processing of information over a brief period of time (Baddeley, 2000). This capacity is fully developed at the end of adolescence (Gathercole, 1999). In the present work, working memory capacity was assessed with three tasks. One measure was used to assess the capacity to store and process information simultaneously, and two were used to examine a subcomponent of working memory, the phonological short-term memory (Gathercole and Baddeley, 1990). There is today evidence that a CI promotes a different course of cognitive development, for example, working memory, for deaf children than would have been possible without CIs. For example, Dillon and Pisoni (2004) conclude that a CI facilitates the development of processes such as inner speech and verbal rehearsal in working memory. The simultaneous processing and storage of information, or general working memory (Just and Carpenter, 1992; Towse et al., 1998), were assessed with the Competing Language Processing Task (CLPT; Gaulin and Campbell, 1994; Swedish version by Pohjanen and Sandberg, 1999). The second test, created to examine phonological short-term memory, is a non-word repetition test (Sahlén et al., 1999). Non-words do not have lexical representations, and repetition skills are therefore relatively independent of lexical knowledge in long-term memory. However, according to Sahlén et al. (1999), in children with verbal output constraints and/or reduced hearing, repetition tests should be used together with a test assessing the ability to discriminate phonemes. A non-word discrimination test (Reuterskiold-Wagner et al., 2005) was therefore used together with the non-word repetition test.

In the present study, conversational skills were measured as the number and types of requests for clarification used in a referential communication task. Referential communication tasks are often used to assess interactional skills. In such tasks both speaking and listening skills can be assessed. In conversations between two partners misunderstandings can occur for a number of reasons. It could be that the speaker may not give enough information or that s/he may not speak intelligibly enough. Further, the listener may not pay enough attention; s/he may lack motivation or may have comprehension or hearing problems (Lloyd, 1999). According to Erber (1996), the use of requests for clarification determines the degree of success that individuals with hearing impairment achieve in conversations. Therefore, we have in the present study chosen to focus on children/teenagers with CIs in the role as listeners (receivers of information) and their use of requests for clarification in a referential communication task.

Referential communication tasks are more structured than spontaneous conversations and can be regarded as analogues to problem solving activities common in educational settings. The task used here is an elaborated version of a referential communication task originally designed by Glucksberg and Kraus (1967). The challenge is for the speaker to describe something or someone (i.e. the referential array), so that the listener can identify what s/he is describing. A 'good' listener must be able to make use of the information received and understand when a message is not clear or good enough and then ask for additional information (i.e. request clarifying information).

No study has, to our knowledge, been reported on children with CIs and the use of requests for clarification in referential communication tasks. However, the use of requests for clarification has been studied in other disability groups such as children with severe to profound hearing impairment without CIs, where a limited use of requests for clarification compared to hearing children is reported (Arnold et al., 1999; Lederberg and Everhart, 2000; Nicholas and Geers, 2003). The same pattern of a smaller amount of requests used is shown in studies of children with language impairment compared to hearing children (Brinton and Fujiki, 1982; Leinonen and Letts, 1997; Reuterskiöld-Wagner et al., 2001).

Arnold et al. (1999) examined 12 seven year old children with profound hearing impairment without CIs and their use of requests for clarification in a referential communication task compared to 12 hearing children. The children acted as listeners to messages of various degrees of ambiguity. The authors report that hearing controls used more requests for clarification and could select the correct referent more often than the children with hearing impairment. There was a significant correlation between chronological age and the number of requests for clarification, suggesting that the older the children, the more requests for clarification were used. The authors suggested that the poorer performance compared to age-matched hearing controls might depend on either a developmental lag in children with hearing impairment or that they approach the situation in a different way than the hearing children. According to the authors, it could also be poor understanding of the experimental situation in the children with hearing impairment. The reason why children with hearing impairment have difficulties understanding the situation, however, remains unanswered by the authors. It might be that that children with severe hearing loss feel insecure and abandon the task, or avoid asking questions for fear of ending up in misunderstandings.

Requests for clarification can be categorised into non-specific and specific requests (Gallagher, 1981; Tye-Murray et al., 1995). A non-specific request for clarification tells the speaker that something has been misunderstood or not heard but does not indicate why or what part of the message that was misunderstood. A specific request gives more information about exactly what part of the message was not understood or heard. Earlier studies on adult individuals with hearing impairment (Caissie and Rockwell, 1994; Caissie and Wilson, 1995; Tye-Murray and Witt, 1996) have shown that the most commonly used request for clarification is the non-specific type (what? uh? pardon?).

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Ibertsson et al. explored the use of requests for clarification by children with CIs in a referential communication task. In this study, the focus was on methodological development and an individual, as well as a dialogic, perspective was taken. Dyads with children with CIs and hearing peers were compared to dyads consisting of two hearing children. Taking an individual perspective (comparing children with CIs with matched hearing children in another dialogue), the authors showed that children/teenagers with CIs produced significantly **more** requests for clarification than hearing peers, matched regarding age and gender. The authors proposed that this could be a strategy used by the children with CIs 'to be on the safe side', asking for clarification whenever they were not certain. The children with CIs also used very few non-specific requests for clarification. Further, they tended more often to ask for confirmation of new information (i.e. requests formed as yes/no questions) than the hearing control group. The authors' interpretation was that children with CIs, by doing so, were managing the conversation and leading it forward. This might be a strategy used by children with CIs to be more in control of the response from their conversational partner. The fact that children with CIs use more requests and also other types of requests for clarification than their hearing peers, and also compared to other clinical populations assessed in referential communication tests, may be due to an awareness of the consequences of their hearing impairment. This awareness may make them more active and more prone to request clarification from the partner in order to anticipate misunderstandings (Ibertsson et al., 2008b).

Ibertsson et al. (2008b) did not relate conversational strategies either to hearing or working memory capacity and therefore the findings do not give any answers regarding the association between, for example, hearing and the number of requests for clarification that was used. The purpose of this study is therefore to examine the influence of speech recognition and working memory capacity on conversational skills, measured as the number and types of requests for clarification used by 13 children/teenagers with CIs in referential communication.

Our hypotheses are that:

1. There is an association between speech recognition and the number of requests for clarification made by the children/teenagers with CIs so that individuals with better speech recognition make fewer requests for clarification in the role as listener.
2. There is an association between working memory capacity and the number and types of requests so that children/teenagers with better working memory: a) make fewer requests for clarification overall, and b) have a lower proportion of requests for confirmation of already given information and a higher proportion of questions requesting confirmation of new information and more requests for elaboration.

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METHOD

Participants

Children/teenagers were recruited from the CI programme at the Department of Audiology, Lund University Hospital. Inclusion criteria were nine to 19 years of age, unilateral implantation, spoken Swedish as first language and non-verbal IQ within normal limits assessed by a psychologist prior to implantation. All children fulfilling the inclusion criteria were invited to participate. Thus, 18 children/teenagers were eligible for invitation to participate in the study. Thirteen children/teenagers accepted the invitation, seven males and six females. The five children who declined participation did so for different reasons. In some cases for geographical reasons and in some cases parents referred to heavy pressure on the family (several other appointments) at the time for the study. The 13 participating children/teenagers ranged in age from 11 : 9–19 : 1 years (median 174 months) at the time of testing. The duration of deafness ranged from four months to 4 : 2 years (median 8 months) and the duration of device usage ranged from 4 : 2 to 13 : 9 years (median 8 : 3 years). According to medical records, deafness was caused by infectious disease in four cases, inner ear anomaly in one, unknown aetiology in six and two had hereditary sensorineural hearing impairment. Seven of the participants had progressive hearing impairment. For one child, only scores from a speech recognition task where per cent words correct are presented are available. The child's speech recognition was, however, considered as good speech recognition (88%). Since the conditions are quite dissimilar in the two hearing tests, this child will not be included in computations where SNR is reported.

All subjects wore a Nucleus 22 device and have hearing parents. According to Swedish praxis, all children born deaf or hard of hearing are exposed to sign language and can therefore to some extent be viewed as bilingual. However, at the time of testing when they had used their implant at a median of 8 : 3 years (4 : 1–13 : 5) they all used oral communication as their main communication mode. Nine subjects attended mainstream education without help from special units, three attended special schools but used oral communication and one child attended mainstream education but had access to sign language in the classroom if needed.

Due to the small size of the community of children with CIs in Sweden, individual information on the aetiology of the children's deafness cannot be revealed for ethical reasons.

Procedure

An audiologist at the Department of Audiology, Lund University Hospital assessed speech recognition in noise in a sound proof room according to the prevailing clinical praxis at a follow-up appointment. All other assessments were administered by the first author in a quiet room in the children's/

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teenagers' homes or in their school. All instructions were given orally and all tasks were performed orally. The tests were video- and audio-recorded.

Tests

Speech recognition

Hagerman's sentences were used to assess speech recognition in noise. *Hagerman's sentences* measure the SNR in which the participants recognise 50 per cent of a number of sentences correctly, as described by Hagerman and Kinnerfors (1995). The test consists of a trial list and ten lists, each containing ten sentences. Each sentence consists of five words that throughout the test occur in the following order: proper name, verb, numeral, adjective and noun. The SNR ranged from −2.9 to +8 dB, with a mean of 1.3 and a median of 0.5. According to Hagerman and Kinnerfors (1995), normally hearing adults have a mean of −7.8 dB. Ibertsson (2002) reports a mean of −3.2 dB for 20 adult CI users. To our knowledge, normative data for hearing children are sparse. One exception is Hagesäter and Thern (2003) who reported that 15 hearing children aged seven had SNR on Hagerman's sentences that ranged from −5.3 to −1.3 dB, with a mean of −3.89 dB.

General working memory

The capacity to simultaneously store and process information was assessed with the CLPT (Gaulin and Campbell, 1994; Swedish version by Pohjanen and Sandberg, 1999). This test consists of 42 sentences constructed as semantically acceptable or semantically unacceptable propositions, divided in two times six sets where each set consists of two to six sentences. The child was first asked to judge whether the proposition was semantically acceptable or semantically unacceptable by saying yes or no, then the child was asked to recall the last word in each sentence in each set. For every word correctly recalled, a score of one was given. A maximum score of 42 was possible. Twenty-seven hearing Swedish children (10:0–11; 10 years old) reached a mean score of 67 per cent (SD 8.5) (Ahlgren and Grenner, 2005) and 20 older children (14:4–15:3) reached a mean of 69 per cent (Gustafsson and Skog, 2007).

Non-word repetition skills

To assess phonological short-term memory a *Non-word repetition test* was used (Sahlén et al., 1999). The child was asked to repeat 24 non-words of increasing syllable length (e.g. sallo'ta:n, purima'gu:l). The children's productions of the non-words were recorded, using both digitally video- and audio-taped recordings, and then transcribed. Per cent consonants correct (PCC) were computed, crediting the production of each consonant produced in the correct position of the non-word, according to Sahlén et al. (1999). Thirty-four hearing Swedish children, aged five to 5 : 10, reached a mean score of 85.5 per cent (SD 7.4) (Andersson and Magnusson, 2005) on PCC and 27 children aged ten to 11 : 10 reached a mean score of 95.1 per cent (Ahlgren and Grenner, 2005).

Non-word discrimination skills

The ability to discriminate phonemes is important for speech understanding (Reuterskiold-Wagner et al., 2005). Usually phoneme discrimination tasks assess the discrimination of minimal word pairs (hat-cat). In order to more purely tap bottom-up processing of speech and reduce redintegration (top-down processing), the discrimination of non-words was assessed. The *non-word discrimination task* (Reuterskiöld-Wagner et al., 2005) consists of eight of the non-words from the non-word repetition test that creates 16 non-word pairs. Each non-word was presented in two conditions, once together with an identical non-word (e.g, i'fu:m-i'fu:m) and once together with a similar non-word differing by only one phoneme (e.g. i'fu:m-i'bu:m). The task was to indicate, by saying 'same' or 'different', whether two auditorily presented non-words were identical. In order to receive the maximum score of eight, the child had to make the correct decisions about all of the non-words, in both conditions. Fifteen Swedish hearing children (aged 6 : 5–7 : 6) reached a mean of 95.8 per cent (Hagesäter and Thern, 2003) on this test.

Conversational skills

Conversational skills were assessed in a referential communication task where a child with a CI and a hearing peer chosen by the child with a CI was seated on each side of a 30-cm tall screen. They were able to see each other's faces but not each other's items placed in front of them. The task was to describe a set of 16 pictures depicting faces so that the partner could identify each face from another pile of 24 pictures and arrange the set of pictures in the same way as the set in front of the speaker (e.g. 'he has green eyes, red hair and a hat'). Both the child with a CI and the hearing partner acted as speaker as well as listener. After arranging the items (i.e. the pictures), the screen was removed and the children could see each other's arrangements. After deciding whether the arrangement was correct or incorrect, the turns shifted and the former listener now had to describe another set of pictures. In this study, we will focus on the children/teenagers with CIs in the role as listener.

As the focus of this study was oral communication no signing was used during the task by the examiner or the children. During the task the examiner left the room but was available outside the door. The children could at any point disrupt and ask questions regarding the task if something was unclear or not understood.

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Each conversation was recorded on a digital video camera as well as audio-recorded. The videotaped conversations were orthographically transcribed using Codes for the Human Analysis of Transcripts (CHAT) conventions (MacWhinney, 2000). The dialogues were then further coded by the first and the second author, according to a classification system for different types of requests for clarification developed by the authors in an earlier study (Ibertsson et al., 2008b). Any case of disagreement was solved by discussion. The duration of each conversation was measured in minutes, as the time spent for the children to solve the task (i.e. for the listener to have arranged the whole set of pictures in the same way as the speaker on the other side of the screen).

The requests for clarification were first classified into the main categories non-specific and specific requests for clarification. Specific requests were then further classified into different sub-categories. This yielded a system with seven different types of requests for clarification. Only four of the seven types were used by the children/teenagers with CIs as listeners and three of them were found to be used by the children with CIs either significantly more often or significantly less often than hearing children. In this study, we therefore chose to focus on the following three types of requests for clarification (note that type 1 and 2 are yes/no questions and type 3 open questions):

1. Requests for confirmation of new information (e.g. 'Has he got blue eyes?').
2. Requests for confirmation of already given information (e.g. 'Did you say that he had blue eyes?').
3. Requests for elaboration (e.g. 'What colour are his eyes?').

The following measures were computed for each conversation:

1. The time it took for each pair to solve the task.
2. The number of requests for clarification used by the children/teenagers with CIs.
3. The proportion of different types of requests for clarification used by the children/teenagers with CIs.

Statistical analysis

Due to the small number of participants, large individual variation and variables not normally distributed correlations were computed using Spearman's rank order correlation test. Statistical significance was accepted at the $p < 0.05$ level.

RESULTS

Descriptive data

Descriptive data from tests assessing speech recognition in noise, general working memory and phonological short-term memory are illustrated in Table 1

Table 1: Tests and descriptive data in the children with a cochlear implant (CI) and hearing children as reference groups.

General area	Specific area	Test	Quantification	Children with a CI N = 13		Hearing children			
				Mean	Min-max	N	Age	Mean (min, max)	Authors, year
Speech recognition	Speech recognition in noise	Hagerman sentences	Signal-noise ratio (SNR)	1.3	8.0–2.9	15	6:5–7:6	–3.9 (–1.3, –5.3)	Hagersäter and Thern (2003)
Working memory	General working memory	The Competing Language Processing Task (CLPT)	Accuracy per cent correct out of 42	72.6	61.9–85.3	20	14:4–15:3	69 (54.7, 80.1)	Gustafsson and Skog (2007)
	Phonological short-term memory	The non-word repetition test	Per cent consonants correct repeated out of 111	59.9	32.5–80.0	34	5–5:10 10–11:20	85.5 (60.8, 95.8) 95.1 (60.8, 100)	Andersson and Magnusson (2005) Ahlgren and Grenner (2005)
	Phoneme discrimination	The non-word discrimination test	Accuracy, per cent correct out of 16	77.9	50.0–100	15	6:5–7:6	95.8 (88, 100)	Hagersäter and Thern (2003)
Conversation	Referential communication task	Number of requests for clarification used	Number of requests for clarification used	26	14–47	8	9–18	19 (3, 44)	Ibertsson et al. (2008b)
		The time it took to solve the task	The time it took to solve the task (min)	7.73	3.65–12.60	8	9–18	6.9 (4.93–18.22)	Ibertsson et al. (2008b)
		Different types of requests for clarification used	The distribution of requests for confirmation of new information (%)	74.1	17.3–94.1	8	9–18	62.3	Ibertsson et al. (2008b)
			The distribution of requests for confirmation of already given information (%)	16.1	0–42.8	8	9–18	20.1	Ibertsson et al. (2008b)
			The distribution of requests for elaboration (%)	3.2	0–39.1	8	9–18	1	Ibertsson et al. (2008b)

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and compared to different reference groups of hearing children from earlier studies. When comparing simple means for speech recognition, measured as SNR, younger hearing children (aged 7) in the study by Hagesäter and Thern (2003) clearly outperform the children with CIs on *Hagerman's sentences*. This was also the case on measures of non-word repetition and non-word discrimination in which the children with CIs were outperformed by hearing children (aged 5, 7 and 10). However, the children/teenagers with CIs do not differ from either younger or older hearing children in performance on the *CLPT*, which measures the capacity to simultaneously store and process verbal information.

Within group correlations

In Table 2, a correlation matrix illustrating a two-tailed Spearman rank order correlation is shown. Significant correlations were found between speech recognition, measured as SNR, and general measures of conversational skills (time used to solve the task (r = 0.58, *p* = 0.048) and number of requests for clarification (r = 0.78, *p* = 0.003), see also Figure 1a where it is also indicated if deafness was pre- or postlingual. These two significant correlations indicate that the better the SNR the less requests for clarification used and the shorter the time to solve the task.

There was no significant correlation between general working memory (*CLPT*) and speech recognition (r = 0.10, *p* = 0.753) and neither between general working memory and the number of requests for clarification that were used (r = 0.24, *p* = 0.413). However, there was a significant negative correlation between two types of requests, requests for confirmation of new information and for confirmation of already given information (r = –0.94, *p* = 0.000). A significant positive correlation between general working memory and requests for new information (r = 0.62, *p* = 0.024) was found and a significant negative correlation for already given information (r = –0.67, *p* = 0.012) see Figure 1b and c. As for elaborations no significant correlations were found.

The influence of different time factors such as age, age at diagnosis, duration of deafness and time with a CI on the measures of speech recognition, working memory and conversational skills was evidenced in only one significant correlation, namely between chronological age and speech recognition (r = –0.75, *p* = 0.005). This indicates that the older the child the better the speech recognition. Further, significant correlations between speech recognition and non-word discrimination (r = –0.79, *p* = 0.003) and between speech recognition and non-word repetition (r = –0.79, *p* = 0.002) were found.

DISCUSSION

The purpose of the present study was to explore the relationship between speech recognition, working memory and conversational skills in 13 children/

Table 2: A two-tailed Spearman rank order correlation between measures of different time factors, speech recognition, working memory and conversational skills.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Age													
2. Age at diagnosis	0.46												
3. Duration of deafness	–0.38	–0.80**											
4. Time with a CI	0.20	–0.47	0.60										
5. Speech recognition in noise (SNR)	–0.75**	–0.47	0.46	–0.10									
6. Non-word discrimination	0.53	–34	0.14	–0.06	–0.78**								
7. General working memory (CLPT)	0.23	0.30	–0.25	–0.17	0.10	–0.27							
8. Phonological short-term memory (non-word repetition)	0.34	0.45	–0.33	–0.10	–0.79**	0.75**	0.07						
9. Number of requests for clarification	–0.50	–0.05	0.33	–0.24	0.78**	–0.54	0.24	–0.43					
10. Time used to solve the task	–0.32	–0.09	0.28	–0.16	0.58*	–0.37	–0.09	–0.54	0.76**				
11. Requests for confirmation of new information	–0.00	0.05	0.02	–0.06	0.16	–0.07	0.62*	–0.01	0.08	–0.06			
12. Requests for confirmation of already given information	–0.16	–0.18	–0.01	0.09	–0.10	0.05	–0.67*	0.02	–0.11	–0.08	–0.94**		
13. Requests for elaboration	–0.02	0.05	–0.01	0.11	0.18	–0.36	–0.20	–0.42	0.20	0.41	–0.20	–0.00	

Abbreviations as given in Table 1.
*/** Significant Values.

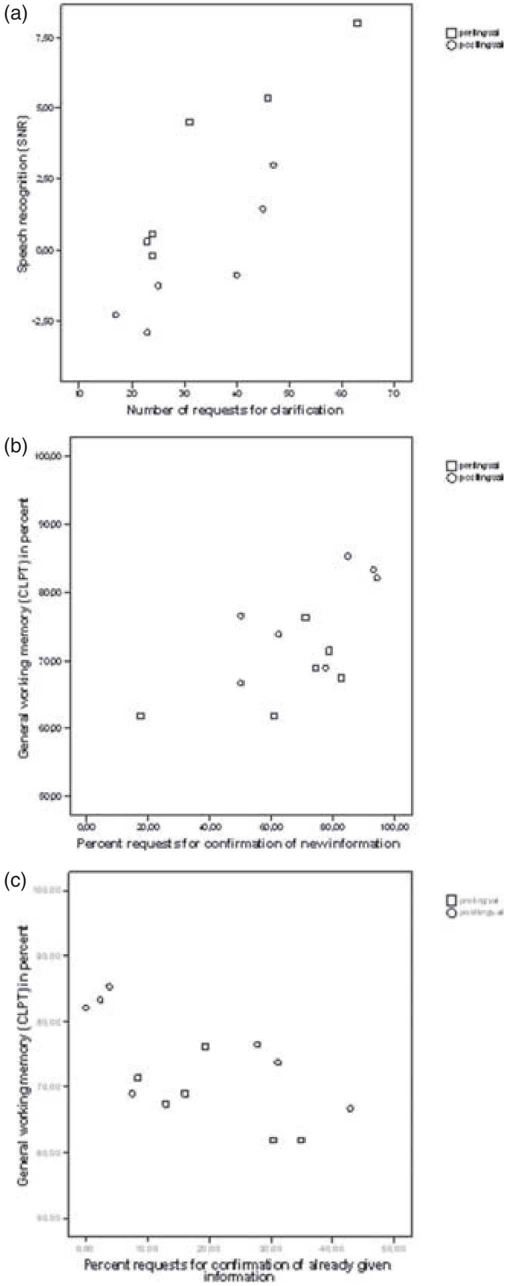

Figure 1: Figure 1a shows Teenagers with pre/-or postlingual deafness and CI and their SNR and the number of requests for clarification they used. In figure 1b teenagers with pre/-or postlingual deafness and CI and their result on the test assessing general working memory and the distribution of the requests for confirmation of new information that they used are shown. Figure 1c shows teenagers with pre/-or postlingual deafness and CI and their result on the test assessing general working memory and the distribution of the requests for confirmation of already information that they used.

adolescents with severe/profound hearing impairment with CIs. We know of no other authors who have reported on children with CIs and their use of requests for clarification in a referential communication task nor has the relationship between conversational skills and top-down and bottom-up processing like hearing and cognition, to our knowledge, been explored. The study has a range of methodological shortcomings, the most important being the limited and heterogeneous population of children with CIs. The results should therefore be interpreted with caution. However, our study contributes methodologically to the field and also generates important hypotheses that await more solid verification in the future.

Eight of the participants in the present study were the same as in Ibertsson et al. (2008b) who compared the children with CIs to eight hearing children, matched regarding age and gender to the children with CIs, and their use of requests for clarification in a referential communication task. Both the task and the set up of the task were the same as in the present study.

The first hypothesis, in this work, was that there would be an association between speech recognition and the number of requests for clarification so that children with better speech recognition need to make fewer requests for clarification in the role as listener. The hypothesis was confirmed by our results, since there was a significant correlation between those two variables. The second hypothesis was that there would be an association between working memory and the number and types of requests so that children with better working memory would make fewer requests overall. This prediction was not confirmed by our data. Further, we hypothesised that the children with CIs with better working memory would use more requests for confirmation of new information and more requests for elaboration than the children with poorer general working memory. This hypothesis was, at least partly, confirmed. The children with better working memory used a significantly higher proportion of requests for confirmation of new information than the children with poorer general working memory. Children with poorer general working memory, on the other hand, more often asked for confirmation of already given information.

By comparing simple correlations no significant association was found between general working memory and number of requests for clarification or between general working memory and number of requests for elaboration. This could be explained by the fact that very few elaborations were requested in the data. Only three per cent of the requests for clarification were requests for elaborations, whereas 70 per cent of the requests for clarification were requests for confirmation of new information and 16 per cent of the requests were requests for already given information.

We also measured the time it took for the conversational pairs to solve the task and found a significant association between the listener's speech recognition and the time it took for him/her to choose the correct picture and place it correctly. The children with CIs with better speech recognition solved the task quicker together with their hearing partner than the children with poorer speech recognition and their respective partners did.

No significant correlation between speech recognition and general working memory was found. Such an association is often reported in studies on adults with hearing impairment (Lunner, 2003). An explanation for the lack of association might be that, as far as we know, no study on children with CIs has used the same test for speech recognition and general working memory as in the present study. Not surprisingly, speech recognition was significantly associated to non-word discrimination. Both tests are tapping auditory verbal input, speech recognition in more a holistic way and non-word discrimination more in a more detail way using phoneme discrimination.

According to Gathercole (1999) and Baddeley et al. (1998), non-word repetition is considered to index phonological short-term memory. Non-word repetition is, however, a complex phonological task sensitive to input (hearing) as well as output (consonants correct) in children. The association between non-word repetition and, both speech recognition and non-word discrimination, is therefore not surprising. The same strong associations between non-word repetition and non-word discrimination have been reported in other studies in prelingually deaf children with CIs (Ibertsson et al., 2008a).

Time factors such as chronological age, age at implant and age at deafness were not significantly associated with any of the measures of conversation or with general working memory. However, the small sample size in this paper must be taken into consideration. Arnold et al. (1999) reported, in their study of children with hearing impairment without CIs, that there was a significant correlation between age at testing and number of requests for clarification used so that older children used more requests for clarification. This finding is not supported in our study. Age was, however, significantly associated with speech recognition. Therefore, when considering the relationship between speech recognition and conversational skills it is important to remember that the older children had better speech recognition scores. Even though the only time factor that is significantly associated with any of the measures of working memory and conversation is age at testing, there is a tendency for association between age at deafness and speech recognition, see also Figure 1a.

So, both speech recognition and general working memory seem to contribute to efficient communication, but in different ways in the adolescents with CIs studied here. The conclusion in both Ibertsson et al. (2008b) and the present study is that the children with CIs act as competent and active conversational partners in the sense that no communication breakdowns occurred. The conversation is also intense, the participants cooperate and negotiate and the participants with CIs produce as many words and utterances as their hearing partners, and as the participants in the hearing dyads. Another factor that supports the claim of these children with CIs being competent conversational partners is that hardly any non-specific requests for clarification occur.

The question is why these children compared to hearing children seem to be better communicators than what has been concluded from results of studies on children in other disability groups compared to hearing and normally developing peers (Arnold et al., 1999; Brinton and Fujiki, 1982; Nicholas and Geers, 2003; Reuterskiöld et al., 2001). Although the methodologies are not always comparable, children with Specific Language Impairment (SLI), for example, seem to be less active and more withdrawn (Brinton and Fujiki, 1982; Reuterskiöld et al., 2001) and conventionally aided children with hearing impairment are reported to use fewer requests for clarification than their hearing peers (Arnold et al., 1999).

We believe that one explanation for the fact that the children with CIs in the present study seem more active and cooperative might be the structure of the task. The results might have been different in a less structured task than a referential communication task, like free conversation, like in the paper on children with SLI by Brinton and Fujiki (1982). Another factor might be that the children participating in this study were asked to choose their own conversational partner and there were no time limits for the task, which means that the children with CIs and their conversational partner could keep on until they had solved the task, without time pressure. A third possible explanation might be that the children with CIs, due to their hearing impairment, are aware of their shortcomings and are therefore more used to and comfortable with asking for clarifying information.

Clinicians in Sweden often report that children with CIs think of themselves in a positive way and are self-confident. A reason might be that children with CIs have received a lot of attention by parents and teachers, which has boosted their self-confidence. As being a relatively new group of children in Sweden it is likely that children/teenagers with CIs have received relatively more support from society than children with hearing impairment using hearing aids and may therefore have a relatively better self-esteem.

The group of children/adolescents with CIs varied considerably regarding a range of demographic factors, for example, age and age at deafness. Although not a focus for our research questions, we have divided the group into pre/post-lingually deaf children, however, as can be seen in Table 2 and Figure 1a age at deafness or whatever the children are pre or post-lingually deaf did not contribute significantly to any of the tests assessing speech recognition, working memory or conversational skills.

Le Mauer-Idrissi et al. (2008) assessed cognitive and social development in pre-lingual children with CIs using Doll's Vineland Social Maturity Scale, pre-implant, one year after implantation and two years after implantation. When development in communication, socialisation and autonomy was compared, the children turned out to have progressed in communication and socialisation but not in autonomy, which is interpreted by the authors in terms of overprotection by parents. The children in their study were, however, much younger than ours and had used their implants for a much shorter time. For parents and educators the balance between giving attention to a child and overprotection may be difficult and might call for consideration.

Other clinical and educational implications from our study are that when working with children with CIs we should be aware of the importance of working memory capacity for conversational strategies and also of the challenge children encounter in different conversational settings. In referential communication, children with poor general working memory might need to use many questions of already given information in order to secure the progress of the conversation and also to avoid requests for elaboration where there is less control of the answer. Yes/no questions might be very useful in such settings but not necessarily in free conversations. In free conversations, yes/no questions do not support the co-creation of dialogue and the partner may interpret requests as poor attention. The awareness of how different conversations require different skills is therefore crucial.

In the present study, we have only focused on listeners' requests for clarification. The next step will be to study other aspects of conversational skills such as speaker skills. Lloyd et al. (2005) found no difference between children with hearing impairment without CIs and hearing children regarding the accuracy of giving instructions in referential communication. In our data, it is possible to further explore the effects of the speaker's contribution in terms of correct choices by the listener and also the speaker's responses to the listener's requests. Speech intelligibility is one of many factors that may seem important for efficient dialogues and needs to be further studied.

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Paper IV

The complex relationship between reading, writing and working memory in seven teenagers with cochlear implant

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ABSTRACT

The overall purpose was to investigate the intra-individual relationship between some aspects of reading, writing and working memory in seven teenagers with CI. Three different decoding tasks, self-estimations of reading skill and interest, a written narration task and two working memory measures were used. Overall the teenagers with CI performed as hearing teenagers on reading tasks tapping orthographic strategies. The decoding task tapping phonological decoding strategies was more challenging; only four of the seven teenagers were on a par with hearing teenagers. The teenagers performing best on reading tasks wrote more elaborate written narratives and achieved better results on working memory measures. All teenagers with CI performed far below -2 SD on nonword repetition. Our results yield a far better performance on decoding and spelling than suggested by the phonological working memory measure.