CHAPTER 7

General conclusion

1. Introduction

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

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

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

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

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

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

Measures for verbal morphological development

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

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

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

2. The acquisition of agreement

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

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

CI children in comparison to TD children

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

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

CI children in comparison to HA children

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

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

CI children in comparison to SLI children

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

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

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

3. The acquisition of past tense

TD children

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

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

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

CI children in comparison to TD children

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

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

SLI children in comparison to TD children

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

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

CI children in comparison to SLI children

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

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

4. Age at implantation and hearing age

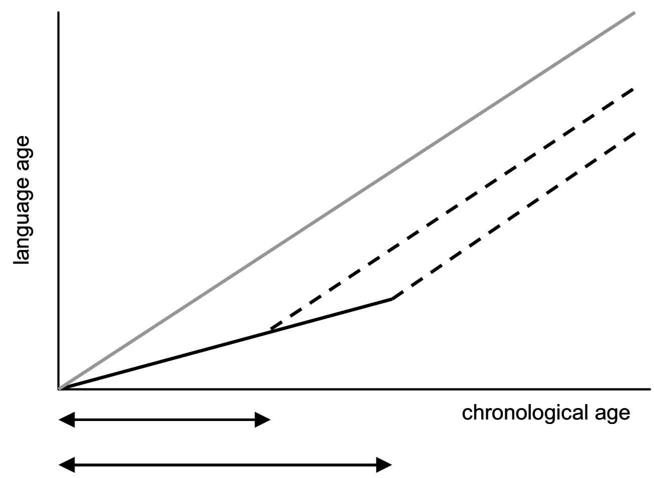
One of the core findings of the present dissertation is the clear effect of hearing age on the children's finite verb production with age at implantation as an indirect factor. The variation in outcomes on MLU and the percentage of subject-verb agreement errors is not explained by age at implantation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

Age at implantation and effects on language learning

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

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

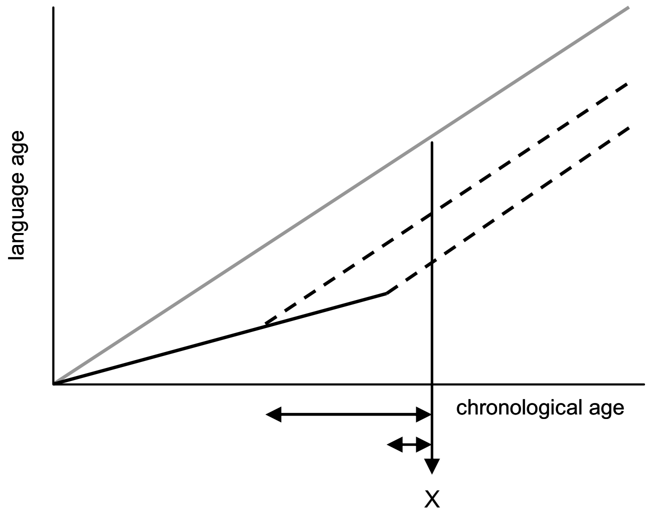
Figure 1. Language growth as a function of chronological age. The grey diagonal presents the language growth for the TD children. The two other language growth curves in this graph present two hypothetical language growth curves for CI children. The transition point from a solid line to a dashed line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



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

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

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

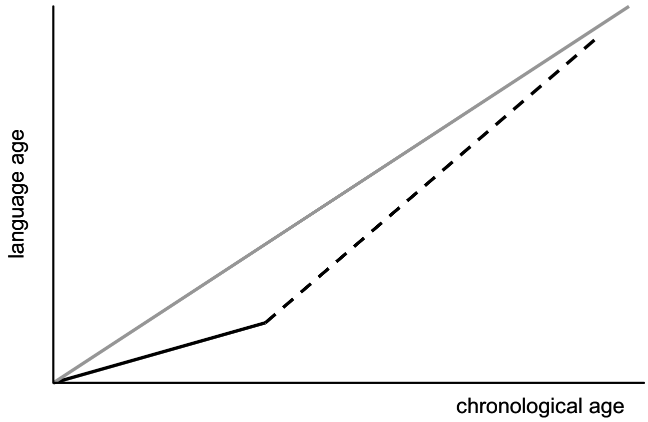


A third account that has been proposed in the literature is that children who received their implant early in life have faster than normal language learning rates (Svirsky et al., 2004, Tomblin et al., 2005, Nicholas & Geers, 2007). Such a language growth curve is presented in Figure 3.

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

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

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

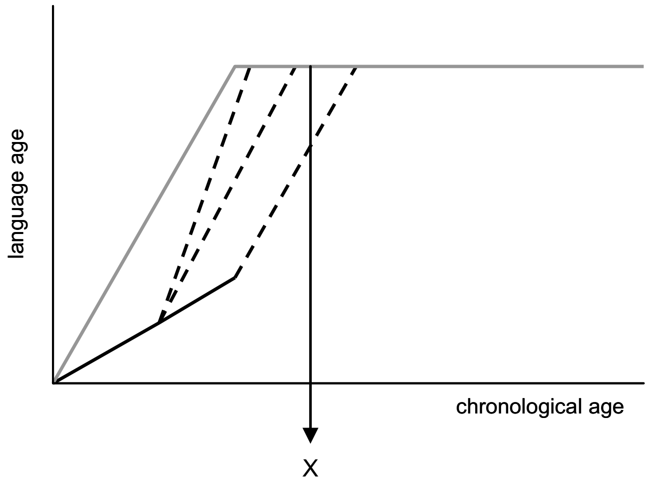


Reaching the ceiling

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

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

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



5. Perceptual salience

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

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

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

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

Morpheme-in-Noise Perception Deficit Hypothesis (MIND)

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

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

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

Reduced auditory speech input versus reduced input

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

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

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

6. Future research

The MIND hypothesis

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

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

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

Delayed language and cognitive maturation

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

7. Clinical implications

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

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

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

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