The Younger the Better? Variability in Language Development of Young German-speaking Children with Cochlear Implants

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Abstract
The influence of age at implantation and experiential factors on language development in young children with cochlear implants was examined. There were two samples, one cross-sectional with 41 children, and one longitudinal with 26 children. Age at implantation in both samples ranged from 6 to 47 months, with children evenly distributed in the age groups: 6-12, 13-24, 25-42 months at implantation. Linguistic progress was assessed by parental questionnaire, and for the longitudinal sample additionally, by one-hourly spontaneous speech samples. Data were collected 12, 18, 24 and 30 months after implantation. Measures of vocabulary and grammar were taken, including number of word types, MLU, inflectional morphology and sentence complexity. In both samples there was extensive variability in linguistic progress. Children's linguistic progress was significantly related to social class, measured by parental education, but not age at implantation. Maternal dialogue variables were analyzed in the longitudinal sample and found to be related to children's linguistic progress. Thus, experiential factors account for the extensive variability in children's linguistic growth rather than age at implantation. The data support an epigenetic rather than a maturational concept of 'sensitive phase'.

1 Introduction

A cochlear implant (= CI) is an electronic microprosthesis replacing the function of the cochlea in the inner ear. Cochlear implantation provides access to audition for profoundly deaf individuals. It has become increasingly popular with young profoundly deaf children and enables them to acquire spoken language.

Studies in different languages have observed extensive variability in the linguistic progress of children with cochlear implants (Fryauf-Bertschy et al., 1997; Szagun, 2001, 2004a, Schauwers et al., 2002). Such variability far exceeds the variability found in typically developing children, even if the children receive their cochlear implant before the age of four years (Szagun, 2001). In the study by Szagun (2001) with 22 children the average age of implantation was 27 months, with a range of 14 to 46 months. A control group of 22 normally hearing children was included. Children in both groups were matched for initial language level and had an initial MLU of < 1.25. The first three years of language development were studied. Results showed that 45 % of the children with CI acquired language within the range of variability of normally hearing children, whereas 55 % remained far below this range.
How can such variability be accounted for? Medical approaches tend to favour an explanation in terms of age at implantation suggesting, in particular, that children implanted below 24 months of age display faster language learning due to 'sensitive phases' for neural organization of auditory systems and for language learning (Svirsky et al., 2004; Tomblin et al. 2005; Nicholas & Geers, 2007). However, it is far from clear in what way sensitive phases for learning contribute to the differential progress in children with CI. What research on 'sensitive phases' has shown is that deaf children who receive a cochlear implant before the age of 42 months display auditory evoked response latencies equivalent to that of normally hearing children, but children implanted after the age of 84 months do not (Sharma et al., 2002). With respect to neural systems processing language Neville & Bavelier (2002) showed that the biological bias for left hemispheric neural systems to process grammar is only fully expressed, if language learning starts during the first years of life. This being the case, left hemispheric neural systems will get established to process grammar, regardless of modality, spoken or signed.

There is a tendency at present – often evoking 'sensitive phases' – to assume that the quality of CI children's language development is linearly inversely related to chronological age at implantation during the early years of life. Thus, Nicholas & Geers (2007) who found that children implanted by 24 months catch up with their normally hearing peers by 4 ½ years of age, suggest that research should focus on finding out if children implanted by 12 months achieve age-appropriate language even earlier. In a preliminary analysis Lesinsky-Schiedat et al. (2004) suggest that children implanted in the first year of life outperform children implanted in the second year of life.

In my view, the evidence for a strong effect of age at implantation in children implanted before the age of 48 months is not as convincing as it might look. The cited studies consider only the influence of age or time-related factors, and no experiential factors. Consequently, they cannot find their effect. However, as Tomblin et al. (2005) point out, in their study age accounted for 14.6 % of the variance in children's linguistic progress. So, there must be other factors which influence children's linguistic growth.

Developmental psycholinguistic approaches have taken into account cognitive and experiential factors as possible sources of variation in addition to age at implantation (Szagun, 2001; Willstedt-Svensson et al., 2004). When the joint influence of age at implantation and pre-operative hearing with hearing-aids is analyzed, quality of pre-operative hearing accounts for a larger proportion of the variance in grammatical and lexical development than age at implantation (Szagun, 2001). When the combined influence of age at implantation, quality of pre-operative hearing and adult dialogue characteristics is analyzed, age of implantation loses its significance altogether, and maternal speech characteristics gain in importance over time (Szagun, 2004a). Similarly, Willstedt-Svensson et al. (2004) found that time variables, such as age of implantation and time with implant predict grammatical development only when they are considered in isolation. When the influence of working memory is analyzed jointly with time variables, however, age of implantation loses its significance and working memory is a strong predictor of grammatical development (Willstedt-Svensson et al., 2004).

Thus, when a conceptual approach is taken which integrates age, cognitive, and experiential factors in the analysis, it is evident that variability in the linguistic development of children with cochlear implants is explained to a larger extent by cognitive and experiential factors than by age at implantation.

In the present study the influence of age at implantation and experiential factors on the linguistic progress of children with CI is investigated in children implanted between the age of 6 and 47 months. The aim is to find out if age at implantation gains in importance as a predictor of children's linguistic progress when the sample of
children contains a substantial proportion of children who were implanted before the ages of 12 and 24 months. This would confirm the claim that, the younger children are when they receive their implant the better their language development will be (Svirsky et al., 2004; Tomblin et al., 2005; Nicholas & Geers, 2007). It is hypothesized here that, even when children are implanted in their first year of life, age at implantation as well as environmental factors influence children’s language development. As environmental factors, social class and the type of language input children receive from their parents are chosen. Both factors have been shown to influence typical and non-typical language development (Gallaway & Richards, 1994; Clark, 2003; Szagun, 2004a).

2 Method

2.1 Participants

There were two samples of children. One was a longitudinal sample with 26 children, 12 girls and 14 boys. The children’s mean implantation age was 20 months, (SD=11 months, range 6 to 42 months). At the time of implantation 8 children were between 6 and 12 months, 10 children between 13 and 24 months, and 8 children between 25 and 42 months. The other sample was a cross-sectional sample. Data collection for this sample is still ongoing. A sample of 150 children is aimed at. For present purposes, the data from 41 children at 30 months after implantation will be analyzed, because only in this group is the data base sufficiently large at this point in time. The average age at implantation in this sample was 24 months, (SD = 12 months, range 6 to 47 months). At the time of implantation 11 children were between 6 and 12 months, 14 children between 13 and 24 months, and 16 children between 25 and 47 months.

Children in both samples were pre-lingually deafened and had no other diagnosed impairments. They are growing up in a monolingual environment with spoken German. Most of the children attend Cochlear Implant Center Hannover for rehabilitation. A smaller number attend Cochlear Implant Rehabilitation Centers in Essen, Halberstadt, Berlin and Tübingen, respectively.

2.2 Design, Language Measures and Procedure

For both samples measures of language were taken at four data points: 12, 18, 24 and 30 months after implantation. Language was assessed by parental questionnaire (Szagun et al., 2006) in both samples, and in the longitudinal sample, additionally, by one-hourly spontaneous speech samples at the same four data points.

For the questionnaire data language measures were: Vocabulary, inflectional morphology, sentence complexity. The parental questionnaire used (Szagun et al., 2006) is modelled on the CDI (Fenson et al., 1994) but contains a scale on inflectional morphology which captures inflectional knowledge in the paradigms: Noun plurals, gender marking on articles, case marking on articles, verb markings and auxiliaries. The questionnaire also contains a section on demographic data.

Language measures based on the spontaneous speech data were MLU and number of word types. Parental speech was also assessed. Measures of parental language were MLU and dialogue characteristics.

The questionnaires were posted to parents via the Cochlear Implant Centers and were returned by post. Sixty-seven percent of the questionnaires were returned. Spontaneous speech samples were collected in a free play situation in a playroom at Cochlear Implant Center Hannover. Digital auditory recordings were made.
2.3 Data Transcription and Analysis

Spontaneous speech samples were transcribed and analyzed using CHILDES CHAT and CLAN programmes (MacWhinney, 2000). MLU was calculated using rules for calculating MLU in German (Szagun, 2004a). A coding scheme for pragmatic content of utterances in parental speech was developed. The most important categories are:

- **Statements and commentaries about ongoing events**: A comment is made about objects, persons, events in the immediate, perceivable context.
- **Questions asking for maximum information**, mostly w-questions.
- **Devices for calling attention**, such as the child’s name.
- **Expansions**: expanding a child’s incomplete or formally incorrect utterance providing the correct form.
- **Repetition of content**: expressing the same semantic content differently.
- **Routines**: Expressions like good bye, thank you.

Four hundred parental utterances were coded for pragmatic content per data point. Inter-rater reliability was calculated on the basis of 25% of the utterances at different data points. It ranged from 82% to 89%.

3 Results

3.1 Lexical and Grammatical Development

The different scales of the parental questionnaire and their maximum scores were: Vocabulary = 600, inflectional morphology = 42, sentences complexity = 32.

Figures 1, 2 and 3 show means and standard deviations for vocabulary, inflectional morphology and sentence complexity scores, for the total sample 30 months after implantation, whose implantation age ranged between 6-47 months, and for children grouped according to age at implantation, i.e. 6-12 months, 13-25 months, 25-47 months. The figures show that there is extensive variability on all scales, but especially on the grammar scales.

In order to determine whether there are differences in language scores depending on age at implantation one-way ANOVAs were calculated for each scale. In no case was the main effect of age group significant. Thus, there is no difference in lexical and grammatical knowledge depending on whether children were implanted in their first, second or third and fourth year of life.
Figure 1. Mean number of words (SD) according to questionnaire 30 months after implantation for the total sample (6-47mths), and children grouped according to age at implantation

Vocabulary

![Vocabulary Graph](image)

Figure 2. Mean inflectional morpheme score (SD) 30 months after implantation for the total sample (6-47 mths), and children grouped according to age at implantation

Inflectional morphology

![Inflectional Morphology Graph](image)
Figure 3. Mean sentence complexity score (SD) 30 months after implantation for the total sample (6-47 mths), and children grouped according to age at implantation

Sentence complexity

For the longitudinal sample language measures were based on MLU and number of types. Figure 4 shows means and standard deviations for MLU and number of types for the total sample at the 4 different data points, 12, 18, 24 and 30 months after implantation. Standard deviations are large, especially for vocabulary.

Figure 4: Mean MLU (SD) and mean number of types (SD) for the total longitudinal sample over the data points 12, 18, 24, 30 months after implantation

Figures 5 and 6 show mean MLU and mean number of word types per age group according to age at implantation for the longitudinal sample. Two-way ANOVAs with repeated measures on data point (4) and the between-subjects factor age group at implantation (3) were calculated, respectively. For MLU there was a significant effect of data point, $F(3,69) = 52.99$, $p < .001$, a significant data point x age group interaction, $F(4,43) = 2.93$, $p < .03$ (Greenhouse-Geisser), but no significant effect of group. Pair-wise comparisons between age groups (Scheffe) at each data point were non-significant. For number of word types, there was a significant effect of data point,
F(3,69) = 63.48, p < .001. No other effect or interaction was significant. In the longitudinal sample, too, children implanted in the first, second, or third and fourth year of life do not differ significantly in terms of linguistic progress.

Figure 5. Mean MLUs over time per age group at implantation (longitudinal sample)

![Figure 5: Mean MLUs over time per age group at implantation (longitudinal sample)](image)

Figure 6. Mean number of word types over time per age group at implantation (longitudinal sample)

![Figure 6: Mean number of word types over time per age group at implantation (longitudinal sample)](image)

3.2 Relation of Age at Implantation and Social Class to Linguistic Progress

A correlational analysis was used to examine the relation between age at implantation, social class and linguistic progress. Table 1 presents bivariate and partial correlation coefficients (Pearson) between age at implantation, social class and language measures at data point 30 months after implantation for both samples. Questionnaire and spontaneous speech measures are used. Social class, as measured by mother’s educational level, relates significantly to every measure of children’s subsequent linguistic progress, either considered on its own (bivariate coefficients) or when age of implantation is partialled out. Age of implantation relates significantly to linguistic progress only for questionnaire measures of grammar in the
cross-sectional sample, and only if it is considered as the only variable (bivariate coefficients). When social class is partialled out, age of implantation does not explain a significant amount of the variability any more although there is a non-significant tendency in the predicted direction (see Table 1).

### Table 1. Bivariate and partial correlation coefficients between social class, age at implantation and language measures in both samples at data point 30 months after implantation

<table>
<thead>
<tr>
<th></th>
<th>Cross-sectional sample (n=41)</th>
<th>Longitudinal sample (n=26)</th>
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<tbody>
<tr>
<td></td>
<td>Social class</td>
<td>Age at implantation</td>
</tr>
<tr>
<td></td>
<td>bivariate</td>
<td>partial</td>
</tr>
<tr>
<td><strong>Questionnaire measures</strong></td>
<td></td>
<td></td>
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<tr>
<td>Vocabulary</td>
<td>.46**</td>
<td>.42**</td>
</tr>
<tr>
<td>Inflections</td>
<td>.52**</td>
<td>.46**</td>
</tr>
<tr>
<td>Sentences</td>
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<td>.57***</td>
</tr>
<tr>
<td><strong>Spontaneous speech measures</strong></td>
<td></td>
<td></td>
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<tr>
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<td>.52**</td>
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<tr>
<td>Word types</td>
<td>.41*</td>
<td>.43*</td>
</tr>
</tbody>
</table>

*p < .05, ** p <.01, *** p <.001

### 3.3 Relation of Adult Input to Linguistic Progress

For the longitudinal sample time-lagged correlations (Pearson) were calculated between mothers’ dialogue characteristics at 12 months after implantation, and child language measures at 24 and 30 months after implantation. There were positive correlations ranging from .51 to .80 (p < .01) between maternal MLU, expansions, comments about ongoing events and the child variables MLU and type frequency. There were negative correlations ranging from -.42 to -.75 (p < .05) between maternal exact repetitions, routines, attention calling devices and the same child variables. Thus, adult language input relates to subsequent linguistic progress by children.

In a regression analysis the combined contribution of those variables which correlated with child linguistic progress was analyzed, using stepwise forward regression. As all dialogue variables correlate with maternal MLU – either positively or negatively - this measure was chosen to represent maternal speech characteristics. As age at implantation did not correlate significantly with linguistic progress in the longitudinal sample, it was not entered as a variable into the regression equation. The results of the regression are presented in Table 2.

When the combined factors are analyzed social class loses its significance, maternal MLU emerges as the only significant predictor of child linguistic progress.
Table 2. Characteristics of maternal speech as predictors of child linguistic progress

<table>
<thead>
<tr>
<th>Child language measure</th>
<th>Predictors of linguistic progress</th>
<th>( R^2 )</th>
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</thead>
<tbody>
<tr>
<td>MLU</td>
<td>24 months after implantation</td>
<td>maternal MLU</td>
</tr>
<tr>
<td></td>
<td>30 months after implantation</td>
<td>maternal MLU</td>
</tr>
<tr>
<td>Type frequency</td>
<td>24 months after implantation</td>
<td>maternal MLU</td>
</tr>
</tbody>
</table>

*maternal speech measured 12 months after child's implantation

4 Discussion

The present results show that there is extensive variability in grammatical and lexical development of children with cochlear implants, even when these children receive their implants as young as between 6 and 47 months of age. This finding corroborates previous findings of extensive variability in the language development of young children with cochlear implants in samples of children with only slightly higher implantation ages (Szagun, 2001, 2004a; Svirsky et al., 2004; Tomblin et al., 2005; Nicholas & Geers, 2007).

In the present study, the observed variability was not sufficiently accounted for by age at implantation. In the two different samples there were no significant differences in grammatical and lexical development in dependence on whether children received their cochlear implant in the first, second, or third and fourth year of life. Unfortunately, we were unable to distinguish between children implanted in their third or fourth year, because of insufficient numbers of children implanted in their fourth year of life.

Correlational analyses of the relation between age at implantation and linguistic progress showed no more than a mild tendency in the direction of a significant inverse relation between age at implantation and linguistic progress, and only when age was considered in isolation. In this case, measures of grammar were significantly inversely related to age at implantation in one of the two samples. However, when the joint influence of age at implantation and social class was analyzed, age of implantation lost its significance in both samples, whereas social class was strongly related to linguistic progress.

Looking at the effect of age more closely, Figures 1, 2, 3, 5 and 6 show a non-significant trend in the direction of the two younger age groups, i.e. children implanted before 24 months, performing at higher levels than the older children. There is no evidence, however, that children implanted in the first year of life outperform children implanted thereafter, as suggested by Lesinsky-Schiedat et al. (2004). On the contrary, there is a slight tendency in the results of the longitudinal study for children implanted in the second year to do better than children implanted in the first year.

The differences with regard to the impact of age between the present and some other studies may result from the use of different language measures and/or different methods of data analysis. Thus, Svirsky et al. (2004) and Lesinsky-Schiedat et al. (2004) used very general tests of language comprehension, focusing mainly on vocabulary. Even when partly similar language measures were used, procedures for data analyses were different. Thus, Tomblin et al. (2005) and Nicholas & Geers (2007) based their analyses on combined language measures and/or average and
linear growth curves. Svirsky et al. (2004) used estimated average growth curves. Working with average growth curves would seem counter-productive when analysing individual differences. Equally, assuming linearity of growth may be problematic, as developmental growth curve modelling has shown that linearity may not represent growth adequately (van Geert, 1994). In fact, individual growth curve modelling of the present longitudinal data confirmed a significant linear trend in less than half the children. For this reason, actual scores and not growth rates were used in the present analyses.

Where the present study differs most is that it considers the joint influence of implantation age and environmental factors. As environmental variables parents’ social class, as measured by mothers’ education, and parental dialogue characteristics were used. The results show convincingly that environmental factors rather than age at implantation account for much of the variability observed in the linguistic progress of children with CI, even when children implanted in their first year of life are included in the sample. Parents’ social class and language input explain a substantial amount of variability in children’s language development. In the samples studied here, the effect of age is even weaker than in our previous study which rendered a significant, though weaker effect of age than of quality of pre-operative hearing (Szagun, 2001, 2004a). As most of the children in the present samples had even lower implantation ages than those in the previous study, this challenges the hypothesis of faster linguistic progress with ever-decreasing implantation age.

In the regression analysis social and maternal MLU were entered as separate variables. This choice of variables may be criticized because social class and MLU are not completely independent. Characteristics of language use may be viewed as an aspect of social class. Yet, both variables were entered as separate variables into the regression analysis because social class is viewed as the more comprehensive factor encompassing more than characteristics of language use. As the results show, however, when the combined influence of social class and parental dialogue characteristics is analyzed, social class loses its significance and parental MLU remains the only factor predicting children’s language development. This shows that the more specific linguistic aspects rather than the global factor of social class are the ones that influence children’s language most strongly.

What does maternal MLU imply? In the present study longer maternal MLU predicted more rapid language development in children. Long MLU in speech to young children implies the use of moderately long sentences averaging about five words per sentence. In our study longer MLU correlated with more comments about ongoing events, questions to the child and expansions of the child’s utterances. In all, such language implies a rich language input. Thus, rich parental language input explains most of the observed variability in the language development of young children with cochlear implants.

The present results are relevant for conceptions of a ‘sensitive phase’ of language learning. The effect of environmental variables on the linguistic growth of children with cochlear implants and the relative lack of an effect of age at implantation argue against a maturational concept of ‘sensitive phase’. Whatever a ‘sensitive phase’ for language learning implies, it does not seem to imply ‘the earlier the better’ for children who receive cochlear implants – at least not, as long as implantation takes place by the time children are four years old. This does not argue against a special sensitivity of the nervous system for language learning in young humans. What it does argue against is the sole dependence of this sensitivity on maturation, i.e. age, and a very early termination of such sensitivity. It seems rather that children who are implanted in the first four years of life are within the time span of sensitivity for language learning, but their experience with language interacts with this biological readiness for learning language. In this sense, the current data are compatible with an epigenetic view of ‘sensitive phase’.
5 Conclusion

Overall, the present results do not confirm the claim that the younger children receive their cochlear implants the better their linguistic progress (Svirsky et al., 2004; Lesinsky-Schiedat et al., 2004; Tomblin et al., 2005; Nicholas & Geers, 2007). Experiential factors rather than age at implantation account for much of the variability in the language development of even very young children with cochlear implants. Much research focuses on age at implantation as the sole explanatory factor for variability in the language of these children. The present research suggests that this approach may be too narrow. Research should focus on the many factors that may influence language development in children with CI, such as quality of post-operative hearing, working memory, and environmental variables of language input. It seems necessary to study the interaction of these multiple influences, if we want to explain the variability observed in the language development of children with CI.

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