Spoken Language and Literacy Skills in French-Speaking Children with Cochlear Implants: A 5-Year Follow-Up Study

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Abstract: This paper addresses the question of whether Mean Length of Utterance (MLU), an index of early productive grammar, predicts long-term outcomes of spoken language and literacy skills in French-speaking children with cochlear implants, and how this influence differs according to individual and environmental factors. Twenty-five school-aged children (12 boys and 13 girls), implanted between the ages of 25 and 78 months, were first followed at 3 and 5 years for MLU and then at 8 years after implantation for receptive language, reading and spelling. Univariate analyses of variance indicated that environmental factors (communication mode and SES) were significantly associated to receptive language and to a certain extent to literacy skills. Multivariate and regression analyses revealed that gender and MLU interacted with receptive language and literacy skills at 8 years after implantation. Such findings suggest that MLU at 3 years after implantation is a good predictor of receptive language and literacy skills 5 years later.

Keywords: MLU, language, literacy, longitudinal follow-up, predictive factors.

INTRODUCTION

1.1. Relations between Spoken Language and Literacy in Children with Cochlear Implants

Previous studies examining the relations between spoken language and literacy skills in children with cochlear implants (CIs) have focused mainly on general measures of receptive and expressive language. These studies suggest that many children with CIs, during the school years, perform at a level similar to hearing children at the same age on measures of language, reading and spelling. The large-scale study by Geers for example, provided evidence that language is associated with enhanced reading abilities [1]. She reported on word reading and language comprehension in 181 children aged 8 to 9 years, noting that over half of the children with CIs scored within the average range for their age relative to normative data for typically developing hearing children (TD). A number of other studies also found that the relations between language and reading were similar in children with CIs to the TD group suggesting that developmental process of spoken language and literacy of children with CIs are typical [2-4].

1.2. Relations between Mean Length of Utterances (MLU) and receptive Language in Children with CIs

Mean Length of Utterances (MLU) has been used since Brown [5] among child language researchers to measure syntactic maturity of productive grammar in TD children. MLU is generally considered as a good indicator of grammatical development according to age. Its reliability has been often questioned due to its variability within age groups [6]. It has been shown that MLU is highly correlated with age up to 4 years and with the development of morphological and syntactic skills [7]. MLU has been particularly applied in cross-linguistic studies in children with CIs -for a review with French speaking children [8, 9]; with Spanish children [10]; with German children [11]; with English children [12-17]. Findings, which compared the syntactic maturity of TD children to those of children with CIs, are still controversial: the profiles of grammatical development in children with CIs has been found delayed but similar to that of TD children matched on listening age [18-22]. Other studies found atypical profiles: Szagun [11], for example, compared the morphological development of children with CIs to that of TD children with normal hearing and found differences in noun or pronoun gender assignment.

No studies investigated longitudinally the relations between early productive grammar measured by MLU and subsequent receptive and literacy skills among

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children with CIs. It is important to undertake such longitudinal investigation in order to know how speech perception exerts an influence on MLU. The grammatical words that are best perceived through audition should be the first to be effectively produced.

1.3. Individual and Environmental Factors Associated to Language and Literacy Outcomes in Children with CIs

Individual factors such as age at implantation and gender, and environmental factors such as SES and mode of communication, may contribute to explain the variability in language and literacy outcomes.

Age at implantation is one of the most critical factors in children with CIs. Neurobiological studies suggest that age at implantation is the best predictor of language development because of the greater plasticity of the brain during the first years of life [23, 24]. The ‘critical period’ view precludes language learning progress at pace with typical development, claiming that even if children are implanted around 2 years of age, they are unlikely to acquire a sufficiently large vocabulary within the critical time span of 24-36 months to get grammatical development started, since the critical time span has been missed [25]. The 'sensitive period' view predicts that children with CIs will have a slower language learning than TD children but does not preclude acquisition within the range of normal variation if children with CIs are implanted young, because a longer extension of the sensitive time period is assumed. Therefore, the child’s age at implantation may contribute to having a significant effect on the language and literacy outcomes.

Gender is considered to be a critical variable in explaining the variation in language development in the child literature. Girls are expected to be more talkative and prosocial with their peers, whereas boys are less related to prosocial behavior [26-28]. Although, there is considerable variability between boys and girls among children with CIs [29], gender differences, not yet well determined in the field of pediatric cochlear implantation, may be confounded with maturation, genetic and environmental factors.

The social level of the family may outweigh all the other variables in explaining language and literacy skills. Parents serve as the primary socializing agents for their deaf children, as evidenced, for example, by the positive effects of having parents with a high socio-cultural level. This suggests that among hearing mothers who experience the cochlear implant process with their deaf children, sometimes a particularly strong feeling of being “tuned-in” develops between a mother and a child, which may help the child to develop language more rapidly. The results of many studies suggest that children with implants may experience language difficulties due to two factors: a greater difficulty in attending to multiple conversations conducted simultaneously compared to one-on-one interactions (the acoustic effect), and a greater difficulty in developing social stimulations arising from the sociocultural level. Children with CIs may therefore experience additional levels of difficulty by facing the combined effects of social and acoustic challenges. Note that SES level is often confounded with “implication of the family in the rehabilitation”, which may be the critical factor.

In fact, there is plenty of evidence that the use of augmentative communication systems, and the emphasis on oral language communication, may facilitate language and literacy skills [30]. One of these communication modes, Cued Speech, is a system for delivering phonetically augmented speech reading through the visual modality, and allowing orally educated deaf people to perceive a complete oral message. With this system, talkers can clarify what they say by using hand cues (hand shapes and hand placements near the face) to complement their spoken utterances. Similar lip shapes are disambiguated by the addition of a manual cue. Cued Speech represents a unique system that closely links hand movements and speech since it is based on spoken language. Educational programs emphasizing oral communication are also expected to influence language and literacy skills in children with CIs. For instance, if children are not taught to use their cochlear implant to listen to unstressed grammatical markers, they may not use these markers in their speech. The fact that the children use grammatical structures in spontaneous speech appears to be a result of learning language through listening to language.

In sum, it remains unclear how each of these factors may influence the spoken language and literacy outcomes among children with cochlear implants.

1.4. The Present Study

The present study aimed to examine the relations between early productive spoken language and subsequent receptive and literacy skills five years later in 25 children with CIs exposed to French language.

We address the following research questions: To what extent early productive grammar measured by MLU at three and five years after implantation is related to receptive grammar and literacy skills at eight years after implantation? To what extent do individual and/or environmental factors influence spoken language and literacy skills in children with CIs?

A number of factors might be associated to language and literacy in children with CIs. Individual factors such as gender or age at implantation should be considered very critical in processing lexicon and grammar at the receptive level, making children with CIs ready for performing more sophisticated skills such as reading and spelling. Environmental factors also should contribute to build neural pathways for language learning: children with a high SES level or who benefit from a phonological rehabilitation like Cued Speech should make more rapid progress than children who benefit from total communication. If it is assumed that all of these factors will have a strong effect on language and literacy skills, it is important to determine which factors best predict the long term outcomes.

2. METHODS

2.1. Participants

Twenty-five prelingual deaf children with congenitally profound bilateral hearing loss (13 girls and 12 boys) participated in this study. They were all born from hearing parents. They were diagnosed between 2 and 51 months of life (mean age=14mo, SD=11). Their profound sensory neural hearing loss was examined by the Pure Tone Audiometry (PTA) test. The average threshold was >101+ DB-HL. They were surgically implanted in their preschool years between 25 and 78 months of age. Mean age at implantation was 44 months (SD=14.6, range 25 to 78mo). Thus, age at three years after implantation was 6.7 yr; mo (SD=1.2, range 5 to 9.5yr; mo) and at eight years, 11.7yr;mo (SD=1.2, range 10 to14.5yr;mo). During the first eight years after implantation the children had regularly scheduled appointments for language assessment. For the present study, the same examiner tested them. All children followed the same rehabilitation procedure before and after surgery and were exposed to European French as their first language. Twelve children with CIs have been exclusively exposed in Cued Speech (CS) and thirteen children have been both exposed in Sign French (SF) and in Cued Speech (CS) as a mean of total communication with his/her family. None of the children with CIs had any associated deficits. The educational level of the parents was high (13 years of education (equivalent to the French *Baccalauréat*) for 11 children, and low/middle for 14 children. Parental written informed consent was obtained from all participants from the French National Scientific Board of the *Centre Technique National pour la Recherche sur les Handicaps et les Inadaptations*, (CTNERHI), which approved the protocols. All the demographic characteristics of the participants are given in the Appendix.

2.2. Tasks

The children were administered a 24-picture-sequence storytelling task (“Frog where are you”) [31]. Each child was asked to look at the pictures carefully and tell a story about them. When the child’s description was effortful or if there was no production, the observer provided neutral prompts such as “and then...” The verbal descriptions were recorded on videotape and transcribed by two trained assistants, following the transcription and segmentation conventions for spoken French [32]. All spoken words were transcribed orthographically and phonetically allowing for the computation of linguistic production as described in the Child Language Analysis (CLAN) software [33]. Inter-rater agreement of transcriptions was excellent (98%). Mean length of utterance (MLU) was computed from the complete and intelligible utterances within the entire language sample. MLU is an index of syntactic complexity of productive grammar. This index was calculated in words because nearly all the syntactic categories produced by children were transcribed in standard written French, as separate words. As many word endings are silent in French, there is only a small number of grammatical markers that are both included in the written form of a word and pronounced, even in the adult language (e.g. past-participle and infinitive form of verbs, feminine forms of animated beings, first and second plural person of the verb). These forms are not common in French children’s language, with the exception of the past participle and infinitive forms of verbs. More details of the procedure used to compute MLU in French can be found in [34, 35].

Children were also administered three standardized language tests at eight years after implantation:

The French version of the Peabody Picture Vocabulary Test PPVT3 [36]-Third Edition- is a standardized receptive vocabulary test commonly used for children over the age of 2 years and six months. During testing, the administrator reads a stimulus word while showing the participant a choice of four illustrations. The participant is required to point to the illustration that matches the stimulus word. The test takes approximately 15 to 20 minutes to administer. Age-based standard scores as well as percentile ranks are provided for the PPVT3 which was used in the present study. The test manual reports internal consistency coefficients as corrected split-half reliabilities that range from .89 to .97 (median = .94). The test-retest reliability corrected coefficients for ages 2.6- 5.11 is reported as .92 (Time 1: mean = 106.1, SD = 12.4, Time 2: mean = 107.9, SD = 14.0).

The French version of the Test for Reception Of Grammar (TROG) [37], l'ECOSSE [38], is a standardized test designed to assess the understanding of different grammatical contrasts in European French. This test provides standardized scores for children between the ages of 4 and 12 years of age. Its has been used with younger children and atypical populations and demonstrated variability in these samples suggesting that it is appropriate for younger children. In this test, the administrator reads a word or phrase and the participant chooses the correct picture illustrating the word or phrase. The participant is given four pictures to choose from including lexical and grammatical foils. These foils are included in an attempt to reveal the participant's error pattern and determine whether the errors are due to difficulty with grammatical structures or to a more generalized problem such as inattention. The task begins with the administrator providing vocabulary words for the child to identify and continues to phrases that increase in grammatical complexity with each trial. This test includes a series of 97 sentences with 23 different syntactic structures and four pictures for each sentence. Scores are given in percentiles based on normative data for children. The TROG takes approximately 15 minutes to administer. Internal consistency correlations, reported as split half reliabilities are .76 for ages 6.0 - 6.11 and .65 for ages 8.0 - 8.11. Alpha is reported as .77.

"La Batterie d'Evaluation du Langage Ecrit", **BELEC** battery [39] was designed to explore the cognitive processes involved in reading and spelling skills of French-speaking children. For reading tasks, the children are asked to read aloud 24 regular words (e.g. *ami* –friend), in which the grapheme–phoneme correspondences are consistent) and 24 irregular words (e.g. *femme* – woman in which they are more inconsistencies. The regular and irregular words are presented separately in two lists of 24 words. The expected correct responses for each list are scored (max: 24). For spelling tasks, the children are required to write a series of 40 consistent words (e.g. *cochon*-pig), 36 inconsistent words (e.g. *singe*- monkey) and 24 morphological words (e.g. *épais*-thick). In the present study, all raw scores were transformed into z-scores based on normative data in these two tasks.

2.3. Statistics

Descriptive analysis and Spearman correlations were first used with an alpha level set at .05. Second, effects of gender, age at implantation, SES and communication mode on MLU, as well as on receptive and literacy were explored by analysis of variance (ANOVA) using SPSS software. Lastly, a multivariate regression analysis was performed to explore the amount of variance that could be explained in spoken language and literacy in order to determine the best predictors.

3. RESULTS

3.1. Individual Scores in Language and Literacy

Table **1** shows all the individual scores of the 25 children with CIs in MLU3, MLU5, receptive language (vocabulary in standard scores, receptive grammar in percentiles) and literacy (reading and spelling in z-scores).

3.2. Descriptive Statistics of MLU and Outcome Scores

The Means and Standard Deviation in MLU at 3 years after implantation, in MLU at 5 years after implantation and in language and literacy outcomes at 8 years after implantation are reported in Table **2**. MLU5 was predictably higher than MLU3 for all children (mean difference=1.51, SD=0.77, range 0.60-3.70).

3.3. Factors Associated to MLU3, MLU5 and Outcome Measures

To explore the relations between MLU and all the language and literacy outcome measures, spearman correlations were used. Table **3** shows that MLU3 and MLU5 were significantly related to all outcome measures at 8 years after implantation. Partial correlations show that the contribution of MLU5

Table 1: Individual Scores in MLU and 8-Year Language and Literacy Outcomes

ID	MLU3	MLU5	PPVT [a]	TROG [b]	Reading [c]	Spelling [c]
1	4.3	5.4	101	82.5	0.99	0.11
2	3.7	4.8	111	62.5	0.99	-0.47
3	2.7	3.9	77	62.5	1.44	1.14
4	3	4.3	70	17.5	0.99	-0.29
5	4	5.7	109	95	0.99	-0.03
6	1.7	2.3	79	5	0.40	-2.34
7	2.94	4.2	66	5	-2.53	-4.05
8	4.5	5.8	103	95	0.99	1.30
9	1	2.9	70	5	0.99	-1.88
10	2.8	3.8	66	5	-4.87	-1.35
11	3.4	5.2	86	17.5	0.94	0.70
12	2.2	3.4	96	37.5	0.99	-0.46
13	1	2.8	71	5	-5.5	0.46
14	3.2	3.9	131	95	0.99	1.13
15	4.2	4.9	70	82.5	0.99	-0.26
16	1.94	2.8	71	5	-3.70	-4.02
17	2.04	3.8	63	5	-3.70	-1.88
18	5	6.6	101	95	0.40	0.18
19	3	6.5	87	95	0.75	1.99
20	2.3	6.0	83	37.5	0.99	-3.32
21	1.7	4.0	71	5	-0.18	-2.72
22	3.8	5.4	103	95	0.99	-0.69
23	2.17	2.9	40	5	-1.03	0.29
24	1.51	2.6	40	5	-5.5	-4.5
25	3.70	5.7	74	95	0.40	-0.06

[a]standard scores [b] percentile scores [c]z- scores MLU3: mean length of utterance at 3 years after implantation; MLU5: mean length of utterance at 5 years after implantation; PPVT: Peabody PPVT: Picture Vocabulary Test; TROG: Test for Reception of Grammar.
Note the poor outcomes: 13 participants (52%) in MLU3 (Mean Length of Utterance).
14 participants (56%) in MLU5, 5 participants (20%) inPPVT8 (Peabody Picture Vocabulary Test), 10 participants (40%) in TROG8 (Test of Reception of Grammar), 6 participants (24%) in Reading and Spelling.

Table 2: Descriptive Statistics of MLU and Outcome Scores

Variables	Mean	Stand Dev	Minimum	Maximum
MLU3	2.87	1.10	1	5
MLU5	4.39	1.29	2.3	6.6
PPVT [a]	81.56	21.50	40	131
TROG [b]	44.6	40.07	5	95
Reading [c]	-0.47	2.31	-5.50	1.43
Spelling [c]	-0.84	1.80	-4.50	1.99

Table 3: Relations between MLU and all 8-Year Language and Literacy Outcomes

Outcomes	MLU3	MLU5	MLU5 after Partialing Out MLU3
PPVT [a]	0,60**	0,54**	0,13 ns
TROG [b]	0,83***	0,79***	0,36 ns
Reading [c]	0,48**	0,54**	0,09 ns
Spelling [c]	0.48**	0,42**	0,07 ns

[a]standard scores [b]percentile scores [c]z- scores.
ns = non significant, *p <.05;** p<.01; ***p<.001.

associated to all 8-year outcome scores was no longer significant when MLU3 was taken into account. Therefore, all further correlations were computed with MLU3 as predictor.

3.4. Spearman Correlations among Factors

Figure **1** shows all significant correlations among individual, environmental factors, MLU3 and all 8-year outcomes. The results show that (i) gender was related to MLU3 and to all 8-year outcomes, (ii) SES were related to MLU3 and TROG8 and (iii) communication were related to TROG8. Furthermore, (iv) MLU3 was related to all8-year outcomes and (v) all 8-year outcomes were intercorrelated, except reading with spelling.

3.5. MLU3 and Receptive Language Outcomes (TROG8 and PPVT8)

The scatter plots, in Figure **2a**, indicate the strong correlations between MLU3 and TROG receptive grammar at eight years after implantation (r= .81, p<.001). The distribution of the TROG8 scores tend to have a floor and a ceiling effect with 10 children performing at 5th percentile or lower, and 7 children performing at 95th percentile or higher.

The scatter plots displaying in Figure **2b** indicate the high correlations between MLU3 and PPVT receptive vocabulary at 8 years after implantation (r= .60, p<.001). Five children (20%) get PPVT standard scores<70, and 19 children (80%) get PPVT standard scores >70 or even higher

3.5. Individual and Environmental Factors Associated to MLU3, Language and Literacy Outcomes

In order to confirm how individual and environmental factors influence MLU3 and all language and literacy outcomes (PPVT8, TROG8, Reading and Spelling), a series of one-way analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) was conducted. We confirm the main effect of gender on MLU3 and on all 8-year outcomes as well the effect of SES on TROG8. In contrast to correlational analysis, ANOVA shows that SES

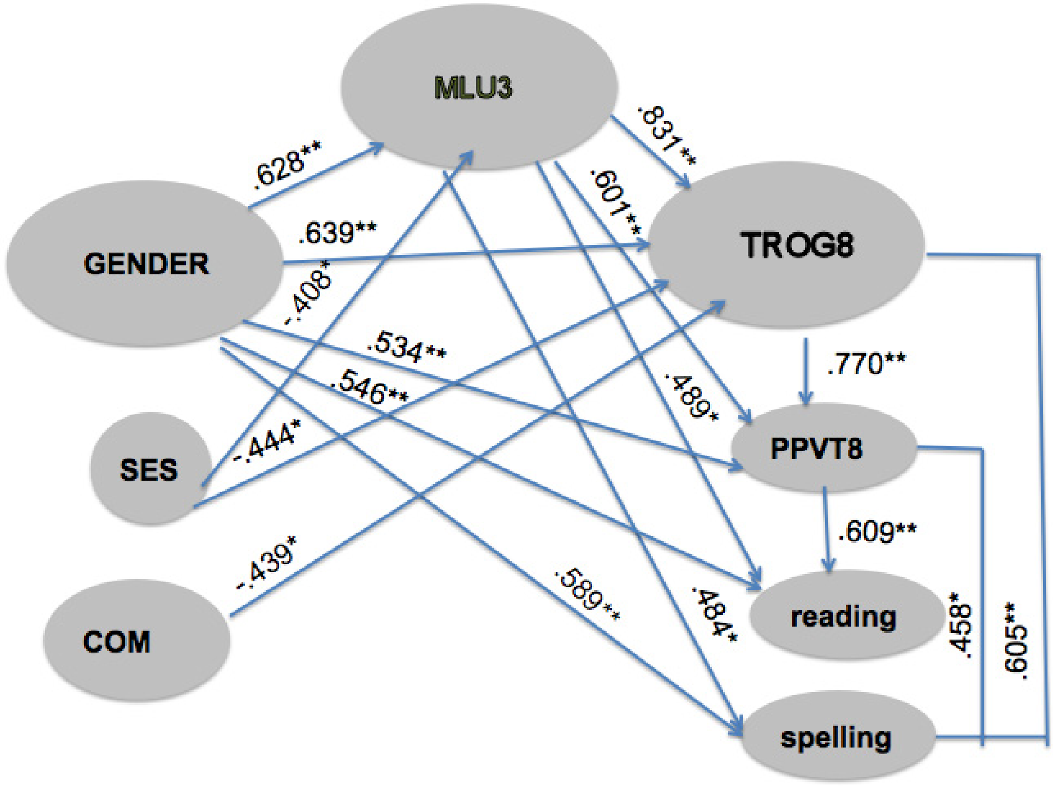

Figure 1: Correlational Model among factors.

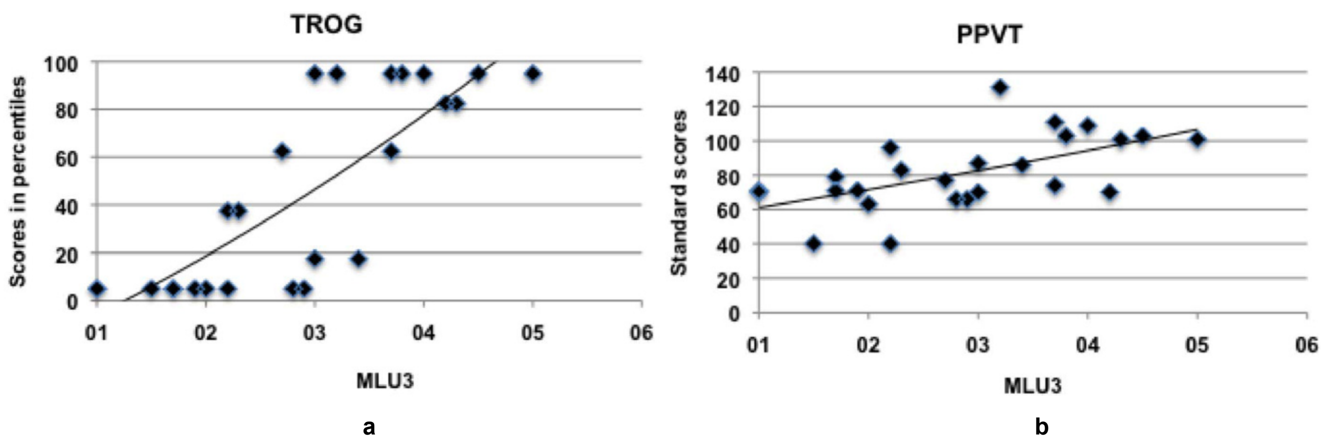

Figure 2: a. Scatter plot between MLU3 and receptive grammar (TROG) at 8 years after implantation.
b. Scatter plot between MLU3 and receptive vocabulary (PPVT) at 8 years after implantation.

influence Spelling, and communication influence MLU3,PPVT8 and Reading. All these results are given in Table **4**.

3.6. Regression Analysis Predicting Receptive Grammar (TROG8) from MLU3, PPVT8 and Literacy Outcomes

Linear regressions were lastly conducted to estimate the degree to which predictors explain independent variance and to examine the concurrent contributions of the outcomes in predicting receptive grammar (TROG8). Table **5** shows the different amounts of variance (R^2) of three possible predictors (PPVT8, Reading and Spelling). When adding MLU3 to PPVT8 and Spelling to the regression analysis, the percentage of explained variance increased to 77%, providing evidence that MLU3 remains the best predictor of TROG8.

4. DISCUSSION

This study was designed to see whether MLU which is an index of early productive grammar, measured at

Table 4: Individual and Environmental Factors Related to MLU3, Language and Literacy Outcomes

Individual	Mean, SD	Mean, SD	F1,24	F3,24
Gender	**Boys n=13**	**Girlsn=12**		
MLU3	2.23 (0.87)	3.57 (0.91)	14.03***	9.73***
PPVT8	70.92(19.18)	93.08(18.15)	8.77**	5.01**
TROG8	21.35(28.93)	69.79(35.49)	14.09***	8.98**
Reading	-1.74(2.64)	0.91(0.28)	11.89***	7.61**
Spelling	-1.84(1.75)	0.25(1.13)	12.31***	8.02**
Age at CI	>45 n=12	<45 n=13		
MLU3	2.74 (1.21)	2.99 (1.03)	.32ns	.82ns
PPVT8	82.25(15.37)	80.92(26.60)	.02ns	5.03ns
TROG8	43.54(41.66)	45.58(40.24)	.02ns	.05ns
Reading	-0.37(2.26)	-0.57(2.44)	.04ns	.01ns
Spelling	-0.84(1.90)	-0.84(1.90)	.00ns	.002ns
Environment SES	High n=11	Low n=14		
MLU3	3.35 (1.10)	2.50(.99)	4.05ns	1.67ns
PPVT8	90.09(19.94)	74.86(20.03)	3.40ns	1.40ns
TROG8	64.09(39.14)	29.29(34.83)	5.52*	2.74ns
Reading	.32(1.74)	-1.10(2.57)	2.47ns	.68ns
Spelling	.01(1.07)	-1.51(2.01)	5.07*	2.51ns
Communication	CS n=12	TC n=13		
MLU3	3.35(1.13)	2.43(.92)	5.11*	3.91ns
PPVT8	90.58(20.69)	73.23(19.40)	4.69*	3.05ns
TROG8	55.83(41.69)	34.23(37.10)	1.88ns	.74ns
Reading	.50(1.02)	-1.37(2.82)	4.66*	3.06ns
Spelling	-.56(1.59)	-1.10(2.01)	.54ns	.01ns

ns = non significant.
*p<.05, **p<.01, ***p<.001.

Table 5: Summary of Regression Analyses Predicting MLU3, PPVT8 and Literacy Scores (Reading And Spelling) from Receptive Grammar (TROG8)

Dependent Variables	Predictors	R^2	Beta	t value	p
TROG8		.51			
	PPVT8		.38	24.1	<.001***
TROG8		.37			
	Reading		.03	13.3	<.001***
TROG8		.39			
	Spelling		.03	14.8	<. 001***
TROG8		.77			
	MLU3		18.1	14.9	<.001***
	PPVT8		.51	5.3	.03 *
	Spelling		4.4	3.1	.09 ns

ns = non significant.
*p<.05; ***p<.001.
TROG8 = Test for Reception of Grammar after 8 years of implantation, PPVT8 = Peabody Picture Vocabulary Test after 8 years of implantation, MLU3 = Mean Length of Utterances after 3 years of implantation.

three years after implantation, predicted long-term outcomes of spoken language and literacy skills in French-speaking children with cochlear implants. In addition, we wanted to examine how this influence was modulated by individual and environmental factors. Support was found for the hypothesis that MLU3 predicted all the 8-year language and literacy outcomes. Strong support was also found for the hypothesis that boys were more variable in language skills than girls.

4.1. MLU at 3 Years after Implantation Predicts all 8-Year Language and Literacy Outcomes

MLU measured at three years after implantation was found to be the best predictor of 8-year language and literacy outcomes, while MLU at five years after implantation did not add any predictive value. Furthermore, the correlational analyses with MLU3 indicated a stronger relation between receptive language (PPVT8 and TROG8) than between reading and spelling. Such findings are compatible with studies suggesting that spoken language is associated with literacy in children with CIs as in any typically developing children [1-4].

4.2. Relations between MLU3, Receptive Grammar and Literacy Skills at 8 Years after Implantation in Children with CIs

A particularly strong relation was found between receptive grammar (TROG8) and MLU3 providing evidence that early productive grammar could be considered as a good predictor of receptive grammar five years later. Ten children (40%) scored very low (5th percentile or lower), 8 children (32%) scored average and 7 children (28%) scored very high (95th percentiles or higher) in receptive grammar. Despite a considerable variability among children the data from the present study show evidence that children with CIs are able to achieve and even to exceed performances to that of TD children at the same chronological age.

Clear evidence of the link between receptive grammar and literacy at 8 years after implantation in children with CIs was also found in this study. Nineteen children (76%) at 8 years after implantation performed almost as well as TD children for reading and spelling. Such findings suggest that cochlear implants may provide enough phonological information for deaf children so that they can rely less on visual memorization strategies than their deaf counterparts without implants. It should be noted, however, that a wide range of individual variability on reading and spelling was also found. This is an important concern because a large number of children with CIs at school age still exhibit language-literacy related problems. It is possible that due to maturational factors and poor perception, some children with CIs are not able to benefit from electronic hearing, which might explain why some of them still struggled to develop reading and spelling. It should be noted that a critical aspect of French reading and spelling systems is that the phoneme-grapheme correspondence (PGC) rules used in spelling are far less consistent than those involved in reading words [40]. It follows that using PGC rules makes it possible to read approximately 90% of French words correctly but to spell only half of all French words only [41]. Different mechanisms might be implicated in perceiving words in order to read and to spell. In the first stage, visual analysis of the face (lips, tongue, teeth and muscle movements) must be performed in order to extract phonemic and lexical information. Readers with CIs may become phonologically sensitive through experience with producing speech and with lip-reading, relying on memorized patterns of speech code. It is important to note that the children with CIs in our study were very accurate in spelling, particularly for consistent (e.g. *camion* - truck), for inconsistent (e.g. *guignol* - puppet) and for morphological (e.g. *exquis* - exquisite) words. These results indicate that children who have good access to the phonological lexicon also have good access to the orthographic lexicon [42]. Spelling for children with CIs was also accurate when the words included sounds with multiple orthographic forms[1]. By contrast the profile of poor outcomes of reading and spelling in our study include only boys from Low SES using Total Communication (TC) i.e. Cued Speech and Sign Language.

4.3. Relations between Individual/Environmental Factors and Spoken Language/Literacy Skills in Children with CIs

In the present study, gender proved to be the factor explaining the best productive grammar (MLU3) and all 8-year language and literacy outcomes. This finding is consistent with studies pointing out gender differences in the child language literature: spontaneous language

[1]For example, in French, /o/ can be written as *eau*, *ot*, *aud* as in *beau-nice, mot, chaud-hot, respectively and /in/ can be written as in, ain, eint as in lapin-rabbit, bain-bath, teint-complexion*, respectively.

use is found generally better among girls than among boys: girls begin talking earlier, acquire vocabulary faster, and show more different words than boys [43-45]. Despite extensive debate on this topic which is predominant in TD children, it could be argued in children with CIs that gender differences may depend not only on maturational but also on socio-cultural factors. In the present study, environmental factors, particularly SES of the family and communication mode were found to be significantly associated to MLU3 and 8-year language and literacy outcomes.

The socio-cultural level of the family, involving parental education and the degree of engagement in communication, was significantly associated with grammatical development (MLU3). These findings are consistent with epidemiological and clinical studies showing the persistent problem of lower language growth experienced by children of low SES families [46, 47]. The notion that children reared in disadvantaged environments may have fewer early language experiences that are associated with optimal language development may be also applied to children with CIs. Language is influenced by parent-child interactions in bidirectional spoken communication. Language exposure and caregivers' mentoring provide the context for language learning. Neuro developmental mechanisms, which rely on interactional cues available almost exclusively in families motivated to create an enhanced educational and social setting for their children, might support grammatical learning. If environmental cues and interactions are not provided in a timely manner, developmental potential is hampered.

Another factor often claimed to influence rapid learning among children with CIs is the type of rehabilitation program provided to the children. Except for some children considered as poor performers in the result section, 13 children (52%) in this study remained in programs that were described as employing simultaneous or total communication systems and 12 children (48%) were exposed to cued speech. Thus, the sample of children studied did not provide a range of programming alternatives that could be used to account for these differences. However, the implementation of their educational and rehabilitation programs was determined and conducted by parents. As a result, there was likely to have been considerable variation in the amount and specific Sign French language, and aural rehabilitation approaches used within these programs. The fact that the educational and rehabilitation programming was not well controlled in this sample limits our ability to identify specific intervention programs that may have influenced the language and literacy outcomes of these children. This limitation, however, also points out that the gains in language and literacy achievement in these children were obtained in mainstream schooling rather than in specialized programs.

In contrast, age at implantation was not found to be a factor influencing MLU and all 8-year language and literacy outcomes. Scores in 13 children implanted before 45 months and 12 children after 45 months were similar. Given the considerable evidence that age at implantation is a critical factor in explaining spoken language, the present results might indicate that because these children were implanted relatively late other factors may have a stronger influence.

Thus, we must conclude that cochlear implantation contributes to spoken language and literacy skills at 8 years after implantation. Children with CIs are not atypical, at least as regards the interaction between spoken and literacy. It is important to note that all these interactions were observable over a five-year period despite the fact that the children had been implanted relatively late. Thus, the results of the present study support the view that language development is a gradual process reflecting interactions between maturation, general cognitive skills and social experience.

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APPENDIX

Demographic and Pure Tone Audiometric Data before Implantation

ID	Gender	Age CI	SES	COM	PTA (DB-HL)
1	G	48	High	CS	III
2	B	45	Low	CS	III
3	G	28	Low	TC	III
4	G	58	Low	CS	III
5	G	28	High	TC	III
6	G	48	Low	TC	III
7	B	39	Low	CS	III
8	G	60	Low	CS	III
9	B	39	High	CS	III
10	B	45	High	TC	III
11	G	39	High	CS	III
12	B	48	High	TC	III
13	B	38	Low	TC	III
14	G	78	High	CS	II
15	G	69	High	TC	III
16	B	49	Low	TC	III
17	B	40	Low	TC	III
18	G	25	High	CS	III
19	G	27	High	TC	II
20	B	28	Low	TC	III
21	B	31	Low	CS	III
22	G	33	Low	CS	III
23	B	56	Low	TC	II
24	B	72	Low	TC	III
25	B	50	High	CS	II

Note. Id#= identification number; age at CI = age at initial stimulation of CI, COM = Communication mode, CS = Cued Speech, TC= Sign French and Cued Speech, PTA-HL = Pure Tone Audiometry-Hearing Loss before Implantation; type II (101-110 DB-HL); and type III (111-119 DB-HL).

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