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# Cochlear Implantation Outcome in Prelingually Deafened Young Adults

## A Speech Perception Study

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**Key Words**
Prelingual deafness · Cochlear implant · Speech perception · Cognitive abilities · Residual hearing · Oral communication

**Abstract**
The outcome of cochlear implantation in patients with deafness of prelingual onset is largely unpredictable due to high individual variability. This study evaluated speech perception performances in a group of 18 prelingually deafened subjects (aged 13–30 years) which was homogeneous with respect to duration of deafness, hearing aid use before cochlear implantation, mode of communication and administration of auditory-oral speech therapy. Word discrimination length, word and sentence identification, phoneme identification and word and sentence recognition were tested before cochlear implantation and at 6 months, 1, 2 and 3 years of cochlear implant use. Scores on all tests significantly improved after cochlear implantation, although mean values were lower compared to those achieved by postlingually deafened patients. Speech performances on both word and sentence recognition continued to increase over time also beyond 1 year after cochlear implantation. Moreover, scores on sentence recognition tests were significantly higher compared to disyllabic words at 3 years of cochlear implant use. The presence of an auditory input delivered by hearing aids before cochlear implantation associated with auditory-oral therapy and a good level of education may positively influence the cochlear implant outcome in prelingually deafened adults.



### Introduction

Cochlear implantation is the treatment of choice for patients affected by severe to profound hearing loss. Whereas subjects with postlingual deafness almost invariably benefit from cochlear implantation, there are a number of variables influencing the outcome of patients with deafness of prelingual onset. Prelingually deafened children using cochlear implant show delayed language skills compared to their typically developing peers as they experienced a period of auditory deprivation before cochlear implantation [Svirsky et al., 2004]. Restoration of an adequate auditory signal through cochlear implant by the age of 2 years is associated with an almost normal language development [Svirsky et al., 2004], while cochlear implantation in older children is deemed to produce delayed speech acquisition due to the increased length of auditory deprivation [Fryauf-Bertschy et al., 1997; Manrique et al., 1999; Snik et al., 1997; Svirsky et al., 2004]. These findings support the existence of a sensitive period

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for language development declining with age and related to central plasticity [Johnson and Newport, 1991]. The development of normal language skills seems to require the presence of a robust auditory input guiding the organization of the secondary auditory cortex and association areas during the sensitive period [Kral et al., 2000; Naito et al., 1997; Teoh et al., 2004b; Truy et al., 1995].

The improvement in speech perception abilities deriving from cochlear implantation performed beyond the estimated sensitive period of central plasticity is expected to be lower compared to early cochlear implant use. Indeed studies published so far agree about the poorer performances of prelingually deafened adolescents or adults compared to postlingually deafened or early implanted subjects [Bassim et al., 2005; Manrique et al., 1999; Schramm et al., 2002; Snik et al., 1997; Teoh et al., 2004a; Waltzman et al., 2002]. Nevertheless, different degrees of improvement in speech perception scores on closed-set tests have been reported by various studies, while open-set speech recognition performances vary from null to a moderate increase after cochlear implantation. These differences are deemed to ensue from individual variability in patient performance. Therefore, no definite evidence currently exists concerning the true benefit of cochlear implantation in adolescents or adults with prelingual deafness.

The principal source of variability seems to be underlain by the fact that prelingually deafened adolescents or adults constitute a heterogeneous group of subjects who may differ from one another not only for duration of deafness, but also as regards variables which have been recognized as influencing cochlear implantation outcome such as etiology, residual hearing, mode of communication, speech therapy, education, device and strategy [Osberger et al., 1998; Schramm et al., 2002; Teoh et al., 2004a; Waltzman et al., 2002]. However, since the type of device has finally been recognized as not really influencing postimplant outcome [Teoh et al., 2004a] and obsolete strategies have not been used in recent studies, the observed variability in postimplant performances should mainly be attributed to the characteristics of patients 'per se'. According to Teoh et al. [2004a], studies including large numbers of subjects are needed in order to decrease individual variability and obtain valid measures of cochlear implant effectiveness. However, this constitutes a true challenge since cochlear implantation in this category of patient requires a difficult decision-making process for both clinicians and patients due to the uncertainty of the outcome or the risk of obtaining no improvement in speech perception at all [Schramm et al., 2002].

Another point concerns the time needed to achieve the maximal benefit. The majority of recently published studies report that speech perception scores reach asymptotic levels within 1 year of implantation [Bassim et al., 2005; Fryauf-Bertschy et al., 1997; Manrique et al., 1999; Snik et al., 1997; Teoh et al., 2004a; Waltzman et al., 2002]. This was explained by the limited possibility of neural circuitry to reorganize once the sensitive period of cortical plasticity is finished. Nevertheless, some studies have reported improvement of speech perception scores later than 1 year after cochlear implant use [Fryauf-Bertschy et al., 1997; Manrique et al., 1999; Snik et al., 1997; Waltzman et al., 2002], although no definite conclusion could be drawn due to lack of statistical analysis, small number of subjects included or limited duration of deafness.

In this paper, we will present the results of speech perception measures from 18 prelingually deafened adolescents or young adults who underwent cochlear implantation at our institution and were followed up for 3 years. In order to keep heterogeneity of the group under study to a minimum we included only those patients satisfying the following criteria: hearing aid use since childhood, substantial functional gain as indicated by aided thresholds, oral communication and auditory-oral training throughout school years.

## Materials and Methods

*Subjects*

Eighteen adult implanted subjects (6 females, 12 males; mean age at implantation 19.9 years, range 13–30 years) with deafness of prelingual onset were included in this study. They underwent cochlear implantation at the University of Padua Service of Audiology and Phoniatrics. They were selected from a larger group of prelingually deafened adults of the same age at the time of implantation (n = 35). Inclusion criteria were profound hearing loss [pure tone average (PTA) at 500, 1000, 2000 and 4000 Hz in the better ear higher than 90 dB HL], onset of deafness at an age lower than 3 years, age at implantation higher than 12 years, hearing aid fitting since early childhood, no evidence of mental retardation, oral communication, auditory-oral therapy performed throughout school years and for no less than 1 year after cochlear implantation. Of the 17 subjects not included in the study, 8 had mental retardation or psychotic disturbances, 7 missed several appointments during the follow-up, 1 had worn hearing aids only for a brief period before surgery and 1 decided not to utilize cochlear implant.

Details of etiology, age at deafness onset, age at hearing aid fitting, aided PTA thresholds (0.5, 1, 2 and 4 kHz) in the better hearing ear, age at implantation, ear implanted, device and strategy are reported in table 1. The etiologies of deafness were hereditary (6 subjects), rubella infection (1 subject), birth asphyxia (1 sub-

**Table 1.** Patient demographics

| Subject No. | Sex | Etiology | Age at deafness onset, years | Age at hearing aid fitting, years | Aided PTA, dB | Age at implant years | Ear implanted | Device | Strategy |
|---|---|---|---|---|---|---|---|---|---|
| 1 | F | genetic (Cx26) | congenital | 1 | 75 | 13 | R | Nucleus C124R | ACE |
| 2 | M | unknown | congenital | 3 | 75 | 28 | L | Clarion HiRes 90K | HiRes |
| 3 | F | unknown | 1 | 2 | 60 | 23 | L | Clarion HiFocus CII | HiRes |
| 4 | F | genetic (Cx26) | congenital | 1 | 53 | 23 | L | Clarion HiFocus 1.2 | SAS |
| 5 | F | rubella infection | congenital | 2 | 80 | 26 | L | Clarion HiRes 90K | HiRes |
| 6 | M | familiarity | 2 | 3 | 63 | 14 | L | Clarion HiFocus CII | CIS |
| 7 | M | unknown | 2 | 3 | 73 | 21 | R | Clarion HiFocus 1.2 | CIS |
| 8 | M | unknown | 6 months | 1 | 60 | 16 | R | MED-EL Tempo+ | CIS |
| 9 | M | unknown | 1 | 2 | 79 | 17 | R | Clarion HiRes 90K | HiRes |
| 10 | M | genetic (Usher) | 9 months | 1 | 80 | 27 | L | MED-EL Tempo+ | CIS |
| 11 | F | unknown | 2 | 2 | 70 | 16 | R | MED-EL C40+ | CIS |
| 12 | M | birth asphyxia | 1 | 2 | 59 | 16 | R | Clarion HiFocus 1.2 | SAS |
| 13 | M | genetic (Cx26) | congenital | 1 | 55 | 21 | R | Clarion HiRes 90K | HiRes |
| 14 | M | unknown | 1 | 1 | 69 | 16 | R | Clarion HiFocus 1.2 | CIS |
| 15 | M | unknown | 1 | 2 | 55 | 30 | R | Nucleus 24 C124M | SPEAK |
| 16 | M | streptococcal meningitis | 6 months | 1 | 50 | 14 | L | Clarion HiRes 90K | HiRes |
| 17 | F | ototoxic (streptomycin) | 6 months | 1 | 60 | 24 | R | Clarion HiRes 90K | HiRes |
| 18 | M | genetic (Cx26) | congenital | 2 | 56 | 13 | R | Clarion HiFocus 1.2 | SAS |

R = Right ear; L = left ear; aided PTA = PTA thresholds at 500, 1000, 2000 and 4000 Hz in the better ear; Cx26 = Connexin 26; ACE = advanced combination encoding; HiRes = high resolution; SAS = simultaneous analog stimulation; CIS = continuous interleaved sampling; SPEAK = spectral peak.

ject), streptococcal meningitis (1 subject), ototoxic (1 subject), and unknown (8 subjects). Four out of 6 subjects with hereditary hearing loss exhibited a mutation in the GJB2 gene, while another one had Usher syndrome. Age at deafness onset refers to the first concern regarding child's hearing except for subjects with a Connexin 26 mutation for whom the hearing loss was assumed to be congenital.

Cochlear implantation was performed in the ear showing the better hearing thresholds except for 3 patients who requested implantation in their worse ear. Thirteen patients received a Clarion implant, 3 subjects were implanted with MED-EL and 2 were fitted with the Cochlear device. The majority of patients used the HiRes (high resolution; 7 subjects) or CIS strategy (continuous interleaved sampling; 6 subjects), 3 were fitted with SAS (simultaneous analog stimulation), while the remaining 2 subjects used ACE (advanced combination encoding) and SPEAK (spectral peak), respectively.

With regard to education, 4 patients were at primary school, 6 had finished primary school, 3 were at University, and the last 2 patients had graduated from University.

*Audiological Studies*

Pure Tone Audiometry

We tested air conduction thresholds at octave frequencies from 125 to 8000 Hz and bone conduction thresholds at octave frequencies from 250 to 4000 Hz (Grason-Stadler GSI 61 audiometer) in a sound-attenuated room. Aided thresholds were obtained in free field from 250 to 4000 Hz (Interacoustic AC30 Audiometer connected to a Pioneer A 103 amplifier, JBL TLX130 loudspeakers). Stimulus was calibrated by means of a Brüel and Kjaer 4165 microphone mounted on an 800 B Larson-Davis sound level meter.

Speech Audiometry

Articulation-gain curves were obtained from all patients by utilizing disyllabic, phonetically balanced words reported in an Italian word list for adults [Bocca and Pellegrini, 1950]. Ten words were presented for each stimulus intensity.

*Speech Perception Studies*

All tests were performed in the auditory-only listening condition using live voice presentation and were administered by a speech therapist experienced in controlling the intensity of her voice [70–75 dB(A) as monitored in free field by means of a Brüel and Kjaer 4165 microphone mounted on a 800 B Larson-Davis sound level meter].

The test battery consisted of both closed-set (discrimination of word length, identification of disyllabic words, trisyllabic words, sentences, vowels and consonants) and open-set tests (recognition of disyllabic words, trisyllabic words and sentences). The speech material was obtained from the protocol of patient candidacy for cochlear implantation adapted for the Italian language [Quaranta et al., 1996].

Evaluations were performed before cochlear implantation with subjects wearing their hearing aids, and were repeated at several times after cochlear implantation (6 months, 1, 2 and 3 years). Participants were tested at each interval; however, 4 patients missed the 6-month evaluation, 1 the 2-year follow-up, 1 the 6-month and 2-year evaluations, while 1 subject did not present for the 3-year follow-up.

Identification Tests

Identification tests were performed by presenting the subjects with printed texts. Participants were requested to mark the chosen alternative with a pen.

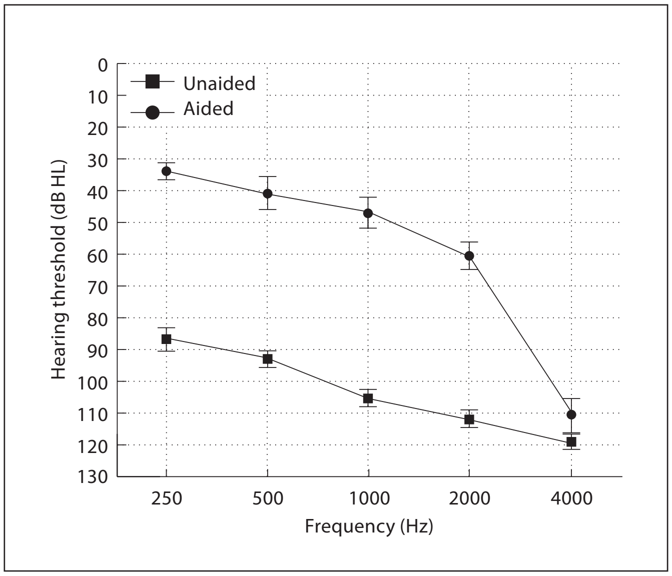



**Fig. 1.** Means and standard errors of both the unaided (■) and aided (●) thresholds from the better ear are reported for all subjects. In this and in the subsequent figures one bar indicates one standard error.

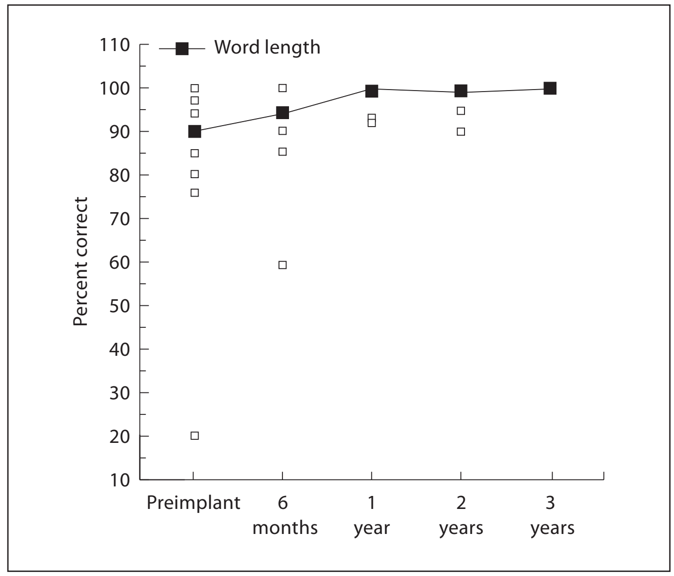



**Fig. 2.** Individual (□) and mean (■) preimplant and postoperative scores obtained on the discrimination of word length test. Saturation was attained within 1 year of cochlear implantation.

In the evaluation of discrimination of word length, patients were presented with a list of 30 items each including 3 different words made up of 2, 3 or 4 syllables. The task was to identify the word, recognizing it by its length.

The identification of disyllabic words was performed by presenting the subjects with 1 of 3 randomly chosen lists each including 20 items made up of 4 disyllabic words (chance 25%). Similar lists were used for trisyllabic word identification. Sentence identification was performed by using 1 of 3 randomly chosen lists with 20 items each including 5 sentences of equal length as regards number of syllables (chance 20%). For all tests, the lists of words were phonetically balanced so that their frequency was similar to that in normal conversation.

For vowel identification, vowels were administered randomly (chance 20%). Consonant identification was performed by presenting consonant confusion matrices compiled from two presentations of each of the 16 consonants /b d f g k l m n p r s t v z j tʃ/ presented in an '/a/-consonant-/a/' context (chance 6%).

Recognition Tests

In recognition tests, patients were requested to repeat words or sentences. Sentences were scored by an exact repetition of the presented items except for articles. If articulatory errors prevented the examiner from understanding words or sentences, the item was not scored.

The recognition of both disyllabic and trisyllabic words was evaluated by means of 1 of 10 randomly chosen lists each including 20 items. The lists of words were phonetically balanced so that their frequency was similar to that in normal conversation. In sentence recognition, subjects were randomly presented with 1 of 3 lists of 20 items each. Sentences contained words with a frequency similar to that in normal conversation.

*Data Analysis*

Each test was scored as a percent of correct responses. Values are contained in the text and tables as mean ± standard error. Analysis of variance procedures for repeated measures were used to analyze the speech perception scores. Single-group or two-factor analyses of variance with factors of time (before implant, 6 months and 1, 2 and 3 years postoperatively) and group (disyllabic and trisyllabic words, sentences) were used to evaluate identification and recognition scores. A p value of $<0.05$ was considered significant.

## Results

### *Audiological Measures*

Hearing thresholds were obtained from both ears of all patients during the 6 months preceding cochlear implantation. Mean unaided and aided threshold levels at 0.5, 1, 2 and 4 kHz as measured in the better ear are reported in figure 1. Mean PTA threshold at 0.5, 1, 2 and 4 kHz was 108.1 ± 2.4 dB HL. All patients had been wearing power hearing aids since childhood and the mean aided PTA (0.5, 1, 2 and 4 kHz) as measured before surgery was 67.8 ± 4.3 dB HL, thus indicating substantial functional gain. Looking at the individual aided PTA thresholds (table 1), it can be seen that all patients showed some amount of functional gain through their hearing aids.

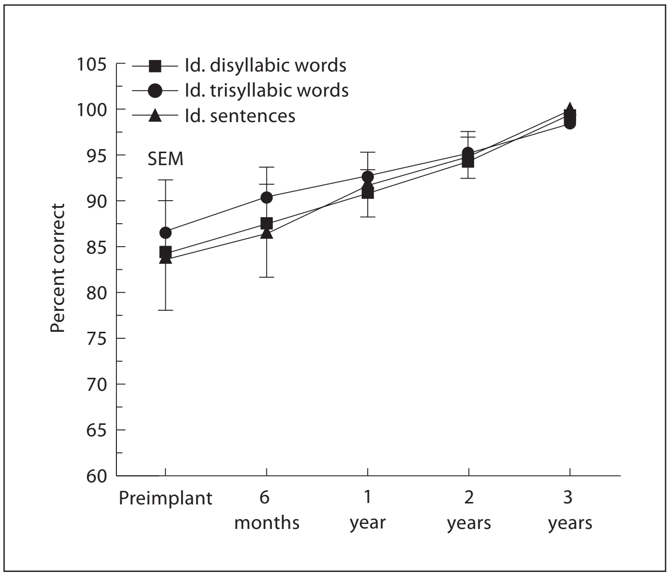
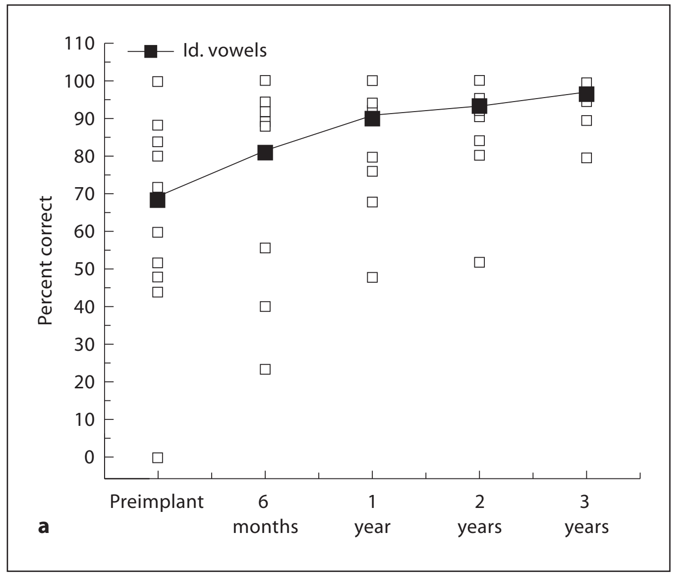



**Fig. 3.** Mean percentage of correct scores for identification (Id.) of disyllabic (■) and trisyllabic (●) words and sentences (▲) obtained before cochlear implantation and at several times postoperatively.



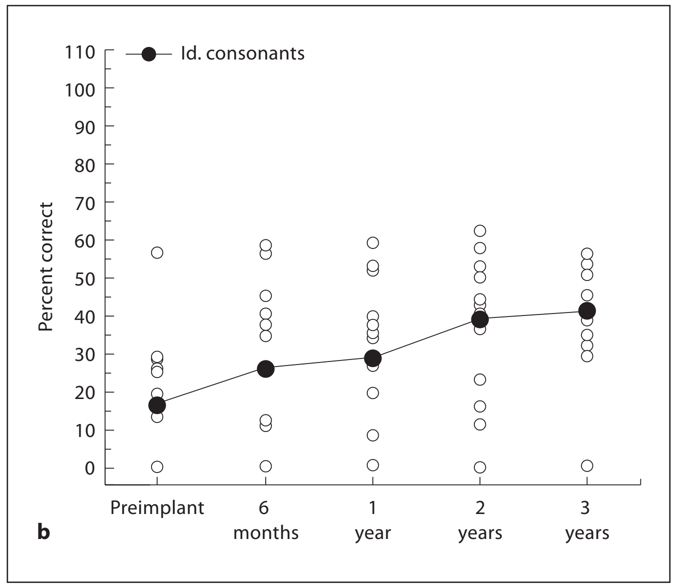




**Fig. 4.** Individual (open symbols) and mean (closed symbols) identification (Id.) scores for vowels (**a**) and consonants (**b**) obtained before cochlear implantation and at the 6-month, 1-, 2- and 3-year follow-up.

The maximum recognition score for disyllabic words as evaluated with patients wearing hearing aids was 8.2 ± 2.7% in the better ear.

*Speech Perception*

Identification Tests

Mean score on discrimination of word length (fig. 2) was 89.9 ± 4.6 before surgery and increased after cochlear implantation with saturation being attained within 1 year. The difference between pre- and postimplant measures as evaluated at 1 year after surgery was significant (paired t test, $p < 0.05$).

Means and standard errors of identification scores for disyllabic and trisyllabic words and sentences are shown in figure 3. Percentage of correct responses increased after surgery compared to preimplantation values. There was a significant increase over time for disyllabic words ($p < 0.05$, $F = 2.94$) and sentences ($p < 0.05$, $F = 2.55$). Posttest indicated that values obtained 3 years after implantation were higher compared to preimplant measures for each item.

Mean vowel identification scores increased from 68.7 ± 5.5% on preimplant evaluation to 96.6 ± 1.5% at 3 years after surgery (fig. 4a). Despite substantial intersubject variability there was a significant increase over time ($p < 0.001$, $F = 10.50$). Posttest indicated that mean identification scores as calculated after surgery were significantly higher than preimplant values at the 1-, 2- and 3-year follow-up.

Subject performance in the consonant identification test (fig. 4b) was remarkably poor before cochlear implantation (16.1 ± 3.5%). It showed a significant improvement after surgery ($p < 0.001$, $F = 6.83$) reaching 40.7.0 ± 3.8% of correct responses after 3 years of cochlear im-

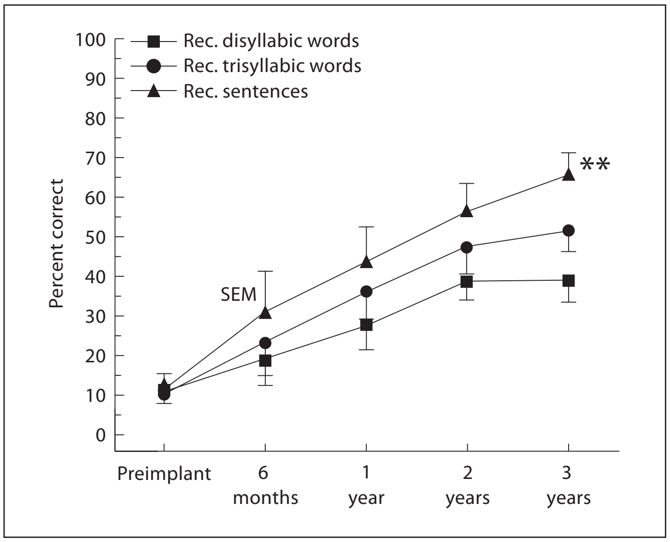



**Fig. 5.** Means and standard errors of recognition (Rec.) scores for disyllabic (■) and trisyllabic (●) words and sentences (▲) obtained before cochlear implantation and at the 6-month, 1-, 2- and 3-year follow-up postoperatively. Recognition scores for the three items were very similar before surgery while tending to be progressively higher for sentences postoperatively. ** $p < 0.01$, sentences > disyllabic words.

plant use. Scores were significantly higher compared to preimplant values at the 1-, 2- and 3-year follow-up.

Both discrimination and identification scores showed substantial intersubject variability as evaluated before surgery. The variability decreased throughout the postimplant follow-up as values approached saturation (100% of correct responses). Of note is also the remarkable decrease of variability in consonant identification scores which was lower at 3 years after implantation compared to previous evaluations.

Recognition Tests

The recognition scores for disyllabic and trisyllabic words and sentences (fig. 5) showed a significant increase after cochlear implantation (disyllabic words, $p < 0.001$, $F = 13.05$; trisyllabic words, $p < 0.001$, $F = 21.90$; sentences, $p < 0.001$, $F = 23.39$). Mean values were close to 10% before surgery and reached 38.7, 51.9 and 65.6% of recognition 3 years after cochlear implantation for disyllabic words, trisyllabic words and sentences, respectively. Posttest indicated that the postimplant values calculated for each variable were significantly higher than those obtained before surgery at 1, 2 and 3 years after cochlear implantation. In addition, the mean recognition score for sentences obtained at the 3-year follow-up was significantly higher compared to 1-year evaluation.

When considering disyllabic words and sentences a significant main effect for group (sentences > words; $p < 0.05$, $F = 4.24$) was found with a significant group by time interaction ($p < 0.05$, $F = 3.48$). Posttests indicated that scores were significantly higher for sentences compared to disyllabic words 3 years after cochlear implantation.

As regards individual values, 3 subjects showed no improvement in word and sentence recognition scores at any time after surgery.

Of the 3 patients receiving cochlear implant in their worse ear, 1 achieved scores of 40, 55 and 95% on disyllabic and trisyllabic words and sentence recognition, respectively, at the 3-year follow-up (compared to 5, 10 and 15% on preimplant evaluation), 1 showed some open-set recognition, while the remaining one had no improvement in open-set speech understanding.

## Discussion

The results of this study found speech perception performances in prelingually deafened adults to improve after cochlear implantation. Although remarkably lower compared to postlingually deafened patients, scores on identification and recognition tests showed a progressive increase from the 6-month to the 3-year follow-up.

Previous studies addressing the issue of how adults with prelingual deafness perform after cochlear implantation [Bassim et al., 2005; Manrique et al., 1999; Snik et al., 1997; Schramm et al., 2002; Teoh et al., 2004a; Waltzman et al., 2002] found that postimplant performances are poorer compared to the postlingually deafened or early implanted subjects. The results of our study agree with these observations. Mean recognition scores at the 3-year follow-up were 38.7 ± 5.1, 51.9 ± 5.2, and 65.6 ± 5.7% for disyllabic words, trisyllabic words and sentences, respectively. These values are remarkably lower compared to those reported for postlingually deafened patients with cochlear implant [Bassim et al., 2005; Manrique et al., 1999; Teoh et al., 2004a]. This was explained by the existence of a sensitive period declining with age for the development of speech perception abilities, which is strictly related to the cortical plasticity processes and requires an auditory input to be accomplished [Kral et al., 2000; Naito et al., 1997; Teoh et al., 2004b; Truy et al., 1995].

The scores on both open-set and closed-set tests were higher after cochlear implantation compared to preimplant values. Nevertheless, it should be pointed out that no improvement on speech recognition was found in 3 subjects. Of these however, 1 patient showed a substantial increase in scores on word and sentence identification, while another performed remarkably better in consonant identification after 3 years of cochlear implant use (56%) compared to preimplant evaluation (12%).

Mean recognition scores for disyllabic words and sentences as evaluated at 1 year after cochlear implantation were similar to the values reported in other studies [Bassim et al., 2005; Schramm et al., 2002; Teoh et al., 2004a; Waltzman et al., 2002]. However, compared to other reports [for a review, see Teoh et al., 2004a] we found a substantially lower degree of individual variability. We believe that this could be ascribed to the fact that the group of subjects included in this study appears to be relatively homogeneous for some individual characteristics such as duration of deafness, residual hearing, aided threshold before cochlear implantation, mode of communication and administration of speech therapy. Moreover, it should also be taken into account that individual variability remarkably decreased over time attaining lower values at the 3-year follow-up compared to previous evaluations.

Patients' performances on both identification and recognition tests continued to improve beyond 1 year after cochlear implantation. After 3 years of cochlear implant use, mean scores on the consonant identification test were higher (40.7%) compared to the 1-year evaluation (28.3%), while sentence recognition appeared to be significantly increased at the 3-year compared to 1-year follow-up (from 42.9 to 65.6%). In contrast, the majority of studies published so far have reported that performances of prelingually deafened adults reach asymptotic levels within 1 year of cochlear implantation [Bassim et al., 2005; Fryauf-Bertschy et al., 1997; Manrique et al., 1999; Snik et al., 1997; Teoh et al., 2004a; Waltzman et al., 2002]. This has been explained by admitting that the restoration of the auditory input through cochlear implant may induce only limited amounts of reorganization of secondary cortical areas involved in speech perception [Naito et al., 1997; Teoh et al., 2004b; Truy et al., 1995]. Moreover, the colonization of these cortical areas by other sensory modalities, namely the visual input, prevents their reorganization through the restored auditory signal coming from cochlear implant [Nishimura et al., 1999; Lee et al., 2001]. We have no definite explanation for differences in speech perception scores between our study and previously published data. One factor possibly involved could be related to differences in the processing strategy. The majority of patients reported in the present study were fitted with HiRes or CIS. However, CIS was also used in some reports again showing a ceiling effect in speech perception abilities within 1 year of cochlear implant use [Bassim et al., 2005; Waltzman et al., 2002]. There are no studies about long-term follow-up in prelingually deafened adults fitted with HiRes; however, we failed to find any significant difference in open-set speech perception scores as evaluated at the 3-year follow-up between subjects using CIS or HiRes (t test for unrelated samples). Other factors possibly related to the characteristics of patients 'per se' may underlie differences between our study and previously published reports. Although the existence of a sensitive period declining with age for language development is widely acknowledged, there is no clear evidence of the upper boundary of this period, while a number of observations indicate that auditory areas retain some form of plasticity in adult life [Irvine et al., 2006] also interacting with other sensory modalities [Doucet et al., 2006]. This may conceivably influence the outcome of cochlear implantation in long-term deafened patients [Doucet et al., 2006]. Recently, Lambertz et al. [2005] have reported that the pattern of cortical activation by sign language in prelingually deafened subjects is critically dependent on the amount of hearing loss as a significant cortical activation was only found in totally deaf subjects. All patients included in the present study had been wearing hearing aids before cochlear implantation with substantial functional gain as indicated by their aided thresholds. Moreover, all used oral communication and none of them have learned sign language. On the basis of these findings, we believe that the presence of an auditory input through hearing aids possibly associated with the absence of training in sign language may have prevented the visual input from extensively colonizing the secondary auditory cortical areas which retained some sensitivity to the auditory input for plastic reorganization in adult life. Nevertheless, when pooling out the subjects showing no improvement on open-set tests after cochlear implantation, the scores on both consonant identification and word and sentence recognition tended to plateau from 6 months to 1 year of cochlear implant use and resumed thereafter (fig. 6). This could indicate that several mechanisms come into play centrally in this category of patients once the auditory input has been restored.

Another point to be considered here concerns the better performances observed in the sentence recognition task as compared to disyllabic and trisyllabic words. Scores for the three categories of items were close to each other before cochlear implantation and progressively di-

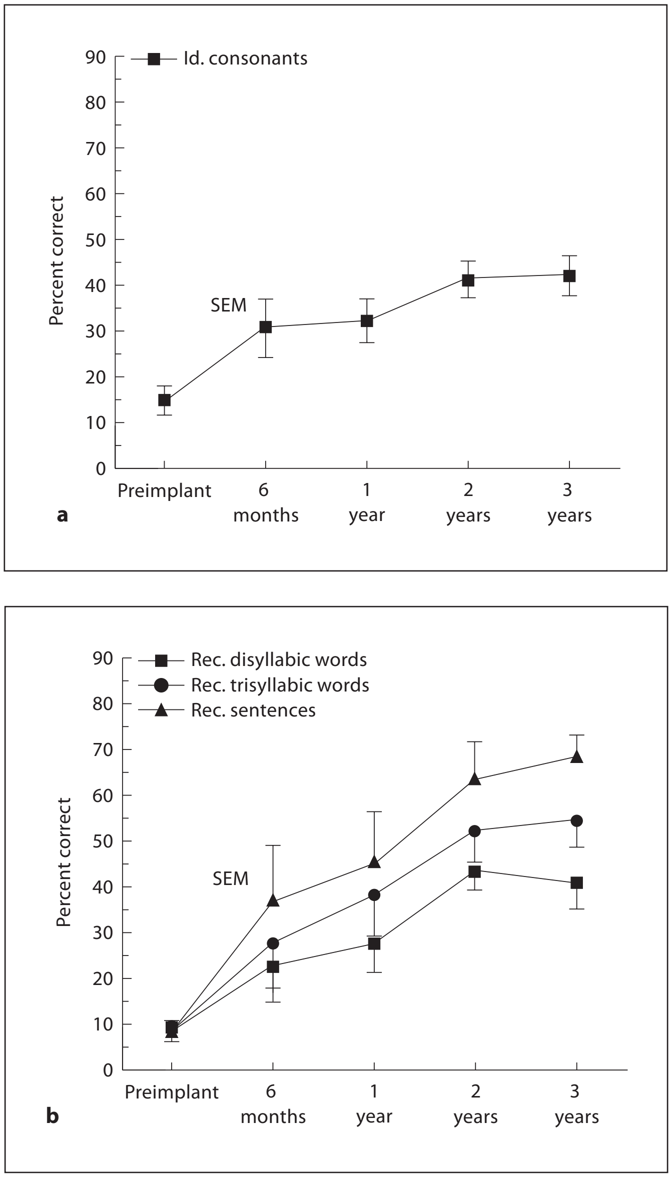



**Fig. 6.** The same as in figures 4b and 5 when pooling out the 3 subjects showing no improvement after cochlear implantation.

verged on postimplant follow-up. Moreover, scores for trisyllabic words tended to be higher compared to disyllabic ones although no significant differences were found between the two groups. A tentative explanation for differences between disyllabic and trisyllabic word scores regards the use of linguistic redundancy cues in the recognition of words of different length [Kirk et al., 2000]; this would improve after cochlear implantation because phonetic distinctions are made clearer and clearer. This hypothesis does not easily apply to sentence recognition. One factor possibly underlying the better improvement in sentence compared to word recognition may be related to the presence of an auditory input through hearing aids since even minimal amounts of residual hearing under aided conditions have been found to positively influence the outcome of cochlear implantation in children [Zwolan et al., 1997]. However, while residual hearing could be involved in speech perception improvement, it is difficult to explain how this could selectively enhance the open-set sentence understanding. Preimplant language skills are also a crucial factor influencing the performances of implanted patients in sentence recognition. For instance, in this regard both lexical and semantic knowledge are of paramount importance. Nevertheless, language skills result from a number of closely intermingled variables (preimplant residual hearing, mode of communication, speech therapy, education, cognitive factors, family background) each possibly influencing the cochlear implant outcome directly or through previously achieved language abilities.

It is well known that cognitive processing abilities exert a strong influence on cochlear implant outcome [Pisoni and Cleary, 2003]. For instance, it has been demonstrated that recognition of spoken words is critically dependent on verbal working memory in both normally hearing and implanted children [Cleary et al., 2001]. Moreover, mode of communication also seems to influence patient performances after cochlear implantation through effects on cognitive processing abilities [Pisoni and Cleary, 2003; Waltzman et al., 2002]. In this view it is tempting to hypothesize that oral communication associated with auditory-oral speech therapy and a good level of education could have enhanced cognitive abilities and memory activities. It seems interesting that of the 5 subjects achieving 90–100% of sentence recognition with cochlear implant use, 2 had graduated from University and 1 is attending University courses. Higher cognitive abilities may have caused sentence recognition scores to increase at a higher rate compared to word recognition abilities, which are more related to the phonological features of spoken words.

In conclusion, speech perception improved after cochlear implantation in adolescents or young adults with deafness of prelingual onset. Speech recognition of both words and sentences increased over time also beyond 1 year after cochlear implantation with the highest scores being achieved in sentence recognition. The presence of an auditory input delivered by hearing aids prior to cochlear implant use together with auditory-oral therapy and a good level of education may positively influence the cochlear implant outcome in this category of patients.

The results of the present study could assist in cochlear implant candidacy and postimplant aural rehabilitation. However, they cannot be generalized to the whole population of prelingually deafened adults as they are obtained from a selected sample of prelingually deafened patients.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