Performance of Prelingually and Postlingually Deaf Patients Using Single-Channel or Multichannel Cochlear Implants

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The auditory and aided lipreading performance of 8 prelingually and 11 postlingually deaf patients who had received a single-channel or multichannel cochlear implant was evaluated during 2 years of follow-up. Although all the patients improved on both closed-set pattern recognition and speech discrimination tests and on a Continuous Discourse Tracking task, the most significant improvement was observed in the postlingually deaf patients who were using a multichannel implant. These patients were the only ones to achieve open-set speech recognition in the auditory-only condition. Only small differences were found between prelingually deaf patients who were using a single-channel system and those who were using a multichannel system. The users' evaluations, obtained by means of a questionnaire, were generally positive in all patients. Based on the study results, the authors concluded that it is feasible to use cochlear implants in highly motivated prelingually deaf patients who have learned to use oral-aural communication.

INTRODUCTION

The efficacy and safety of cochlear implantation in postlingually deaf adults have been well-established by numerous studies,[1–3] including one large, prospective, randomized trial.[4] In this group of patients, the performance with multichannel devices is superior to that with single-channel devices, especially for the understanding of speech. To date, only a few studies have specifically focused on the results of cochlear implantation in prelingually deaf adults, and no direct comparisons have been made between the results achieved with different cochlear implant systems in this group of adults. Studies[5–11] have shown, however, that prelingually deaf adults can benefit subjectively and objectively, as measured by speech perception tests, from various types of cochlear implants.[5–11]

In the present study, the speech discrimination performance of two groups of postlingually deaf adults, using either a single-channel or a multichannel cochlear implant, was compared with the performance of two groups of prelingually deaf adults who were using the same types of implants. Speech discrimination tests were performed at various intervals during a 2-year follow-up period. In addition, a questionnaire was used to evaluate the subjective experience of all patients.

PATIENTS AND METHODS

Patients

Table I presents patient data on the 19 deaf adults who received cochlear implants in the Nijmegen/St. Michielsgestel implant program between 1988 and 1991. The subjects were assigned an identification code that began with an O (postlingually deaf) or an E (prelingually deaf) and was followed by an S (single-channel cochlear implant) or an M (multichannel cochlear implant) and the implant program patient identification number. One of the prelingually deaf subjects (ES4) was reimplanted with a multichannel system (EM22) after 2 years of using a single-channel implant and was monitored for the following two years.

The mean ages of the prelingually deaf patients (n = 8) and the postlingually deaf patients (n = 11) at the time of implantation were 24 years and 47 years, respectively. The mean duration of deafness was 24 years for the prelingually deaf subjects and 28 years for the postlingually deaf subjects. The prelingually deaf subjects all had been pupils at the Institute for the Deaf in St. Michielsgestel and had completed oral-aural communication programs. All patients came from middle-class backgrounds and had normal intelligence. They all had profound bilateral deafness and had experienced no benefit from a hearing aid. However, as shown in Table I, some of the prelingually deaf patients had used a hearing aid during childhood. The selection procedure for cochlear implantation has been described previously.[12,13]

Selected tests were performed at 3, 6, 12, and 24 months after cochlear implantation in all patients except patient ES7, who stopped using his implant during the first

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TABLE I.
Patient Data for 19 Deaf Adults Who Received Cochlear Implants.

Patient No.*	Sex	Etiology	Age at Onset of Deafness (Years)	Duration of Deafness (Years)	Age at Implantation (Years)	Implant System†	Active Electrodes	Ages at Which Hearing Aid Was Used (Years)
ES4/EM22‡	F	Usher's syndrome	0	20.1/23.2	20.1/23.2	S/M	20	3–12
ES5	M	Meningitis	0.3	20.5	20.8	S	1	3–20
ES7	M	Meningitis	1.6	22.3	23.8	S	1	2–3
ES10	M	Meningitis	2.3	17.3	19.5	S	1	4–20
ES12	M	Usher's syndrome	0	28.9	28.9	S	1	3–4
ES29	F	Mondini	0	24.3	24.3	S	1	2–24
EM23	F	Usher's syndrome	0	21.0	21.0	M	20	3–21
EM30	M	Hereditary	0	33.5	33.5	M	20	3–27
OS1	M	Trauma	8.3	20.5	28.8	S	1	8–10
OS2	M	Progressive	31.6	5.0	36.6	S	1	32–35
OS3	M	Meningitis	10.8	47.8	58.6	S	1	None
OS8	F	Meningitis	10.7	45.5	56.2	S	1	12–45
OM6	F	Meningitis	10.8	43.7	54.4	M	15	11–54
OM13	M	Meningitis	6.2	20.2	26.3	M	20	8–26
OM14	M	Meningitis	37.3	5.9	43.2	M	20	29–43
OM15	F	Unknown	26.3	36.0	62.3	M	20	None
OM16	F	Meningitis	14.3	23.1	37.3	M	18	20–27
OM19	F	Otosclerosis	44	16.3	60.3	M	16	30–57
OM21	M	Meningitis	7.4	43.9	51.3	M	18	15–50

*The letters in the patient identification code have the following meanings: O = postlingually deaf; E = prelingually deaf; S = single-channel cochlear implant system; M = multichannel cochlear implant system. The number is the implant program patient identification number.

†Single-channel (S) cochlear implant or multichannel (M) cochlear implant.

‡This prelingually deaf patient used a single-channel system for two years and then was reimplanted with a multichannel system.

year. For the presentation of results, four subgroups were distinguished: prelingually deaf patients with a single-channel cochlear system (n = 6), prelingually deaf patients with a multichannel system (n = 3), postlingually deaf patients with a single-channel system (n = 4), and postlingually deaf patients with a multichannel system (n = 7).

Implantation, Rehabilitation, and Test Materials

Details on implantation, rehabilitation, and test materials are given elsewhere.[14] The type of implant used—the single-channel systems (Med-E1\E1 or 3M/Vienna) or the multichannel system (Nucleus Mini System 22)—and the number of active electrodes are given in Table I.

The auditory perception of segmental and suprasegmental aspects of speech was assessed in the free field by means of a Dutch version of the Monosyllable-Trochee-Spondee (MTS) test[15] and by means of the Antwerpen-Nijmegen (AN) test battery.[16] The AN test battery, which contains a number of prerecorded closed-set tests for speech and pattern discrimination, is described elsewhere.[14] Lipreading skills were tested using Continuous Discourse Tracking (CDT).[17] The users' evaluations were recorded by means of the "Gestel-Nijmegen implant questionnaire" at 1-year follow-up.

Data Analysis

Analysis of variance (general linear model procedure; SAS Institute) was used to evaluate the different test scores on the closed-set tests and on the CDT task. Independent factors included the following: onset (prelingually deaf or postlingually deaf), implant system (single channel or multichannel), test type (MTS and/or individual AN tests), and follow-up interval (3, 6, 12, and 24 months after the processor was fitted). The patients formed random variables (nested in the onset and implant system factors). Post-hoc Student Newman Keuls' multiple range tests (alpha = 5%) were performed on the adjusted scores for each follow-up interval, and the adjusted scores averaged across all the patients.

For analysis, the scores on the closed-set pattern and speech discrimination tests were adjusted for the number of test items and the number of alternatives, using the formula described by Osberger, *et al.*[18]: $S_{ad} = \{(C\text{-}I/[N\text{-}1])/n\} \times 100$. In this formula, S_{ad} is the adjusted score, C is the number of correct items, I is the number of incorrect items, N is the number of alternatives, and n is the total number of items. The pooled adjusted scores over different tests are referred to as "composite scores."

RESULTS

Figure 1 shows the composite scores of the pattern recognition tests averaged over the independent factor test type for the four groups of patients at the different follow-up intervals. The average performance improved significantly over time ($F[3,45] = 6.93$, with F signifying degrees of freedom; $P = .0006$). Post-hoc Student Newman Keuls' grouping revealed that the average performance improved significantly between 3 months and 6 months, but not after the 6-month follow-up. The postlingually deaf users performed better than the prelingually deaf users ($F[1,16] = 19.49$, $P = .0004$). The improvement over time differed between the prelingually and postlingually deaf subjects ($F[3,45] = 3.16$, $P = .03$) with greater and more prolonged improvement occurring in the postlingually

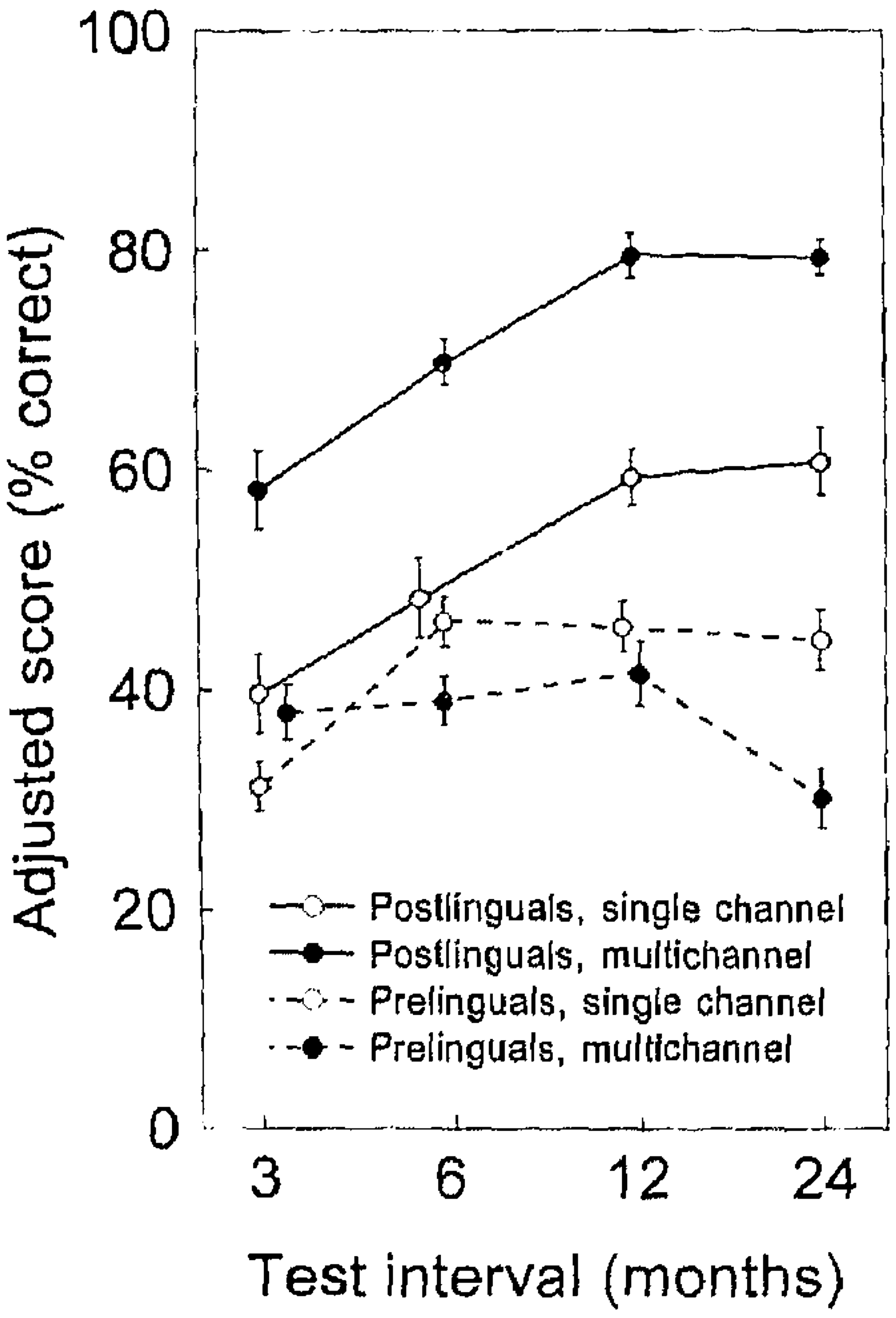

Fig. 1. Composite scores on the pattern recognition tests for the four groups of patients at 3, 6, 12, and 24 months after cochlear implantation. Vertical bars represent 1 standard error.

deaf subjects. No other significant effects were found.

The independent factor test type interacted significantly with the factors onset ($F[4,64] = 4.21$, $P = .004$) and implant system ($F[4,64] = 5.29$, $P = .001$). Figure 2 shows the scores of the individual speech discrimination tests for each patient group. From Figure 2 it is evident that these interactions can be ascribed to the performance of the postlingually deaf subjects with a multichannel cochlear implant.

The composite scores of the speech discrimination tests also improved significantly over time ($F[3,45] = 7.20$, $P = .0005$). Student Newman Keuls' grouping of the mean scores of all patients showed that the performance improved significantly between the 3-month and 6-month follow-up evaluations and between the 6-month and 12-month evaluations. The improvement between the 12-month and 24-month follow-up evaluations was not significant. The improvement over time was observed mainly in the two groups of postlingually deaf patients and was substantiated by the finding of an interaction between the independent factors onset and follow-up interval ($F[3,45] = 3.84$, $P = .02$). A multichannel implant was of significantly greater benefit than a single-channel implant for speech discrimination only in the postlingually deaf subjects ($F[1,16] = 15.00$, $P = .001$).

The auditory-plus-visual (AV) enhancement over the visual-only (V) performance in the CDT task was determined as follows: $([AV-V]/V) \times 100$. The postlingually deaf users showed greater AV enhancement than the prelingually deaf users ($F[1,16] = 5.63$, $P = .03$). Figure 3 shows that the enhancement in the postlingually deaf subjects mainly occurred in those who were fitted with a multichannel implant ($F[1,16] = 4.89$, $P = .04$). Post-hoc analysis of variance on the AV and V scores of the postlingually and prelingually deaf subjects revealed that the two groups of patients with a single-channel implant experienced significant benefit in the AV condition over the V condition: $F(1,3) = 11.89$, $P = .04$ and $F(1,5) = 6.97$, $P = .05$, respectively. No significant enhancement was found in the group of prelingually deaf subjects with the multichannel system. No significant increase of the enhancement occurred over time in any of the groups.

Speech recognition in the auditory-only (A) condition was achieved by all of the postlingually deaf subjects who had received a multichannel cochlear implant but not in the other groups (Fig. 3, thick grey line). This performance improved significantly over time ($F[4,33] = 7.84$, $P = .0004$). The Student Newman

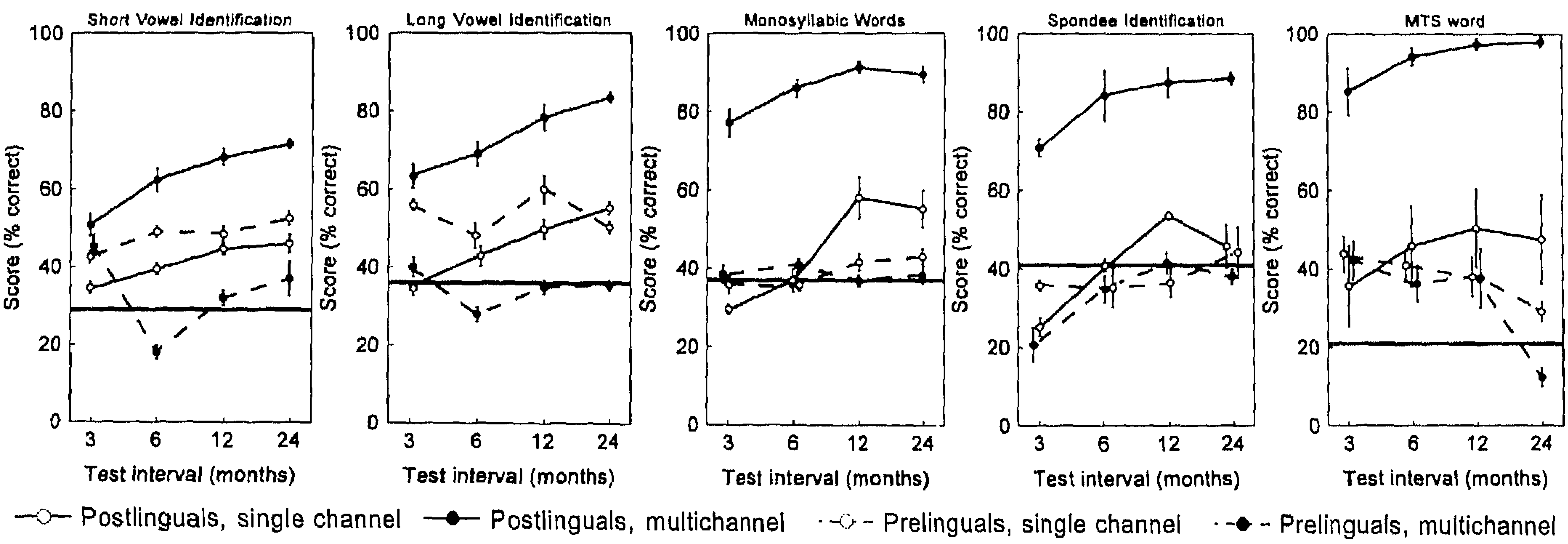

Fig. 2. Test scores on the individual speech perception tests for the four groups of patients. The full lines indicate the upper limit of the 95% confidence intervals. Vertical bars represent 1 standard error. Note that the raw unadjusted scores are presented in this figure (MTS = Monosyllable-Trochee-Spondee test).

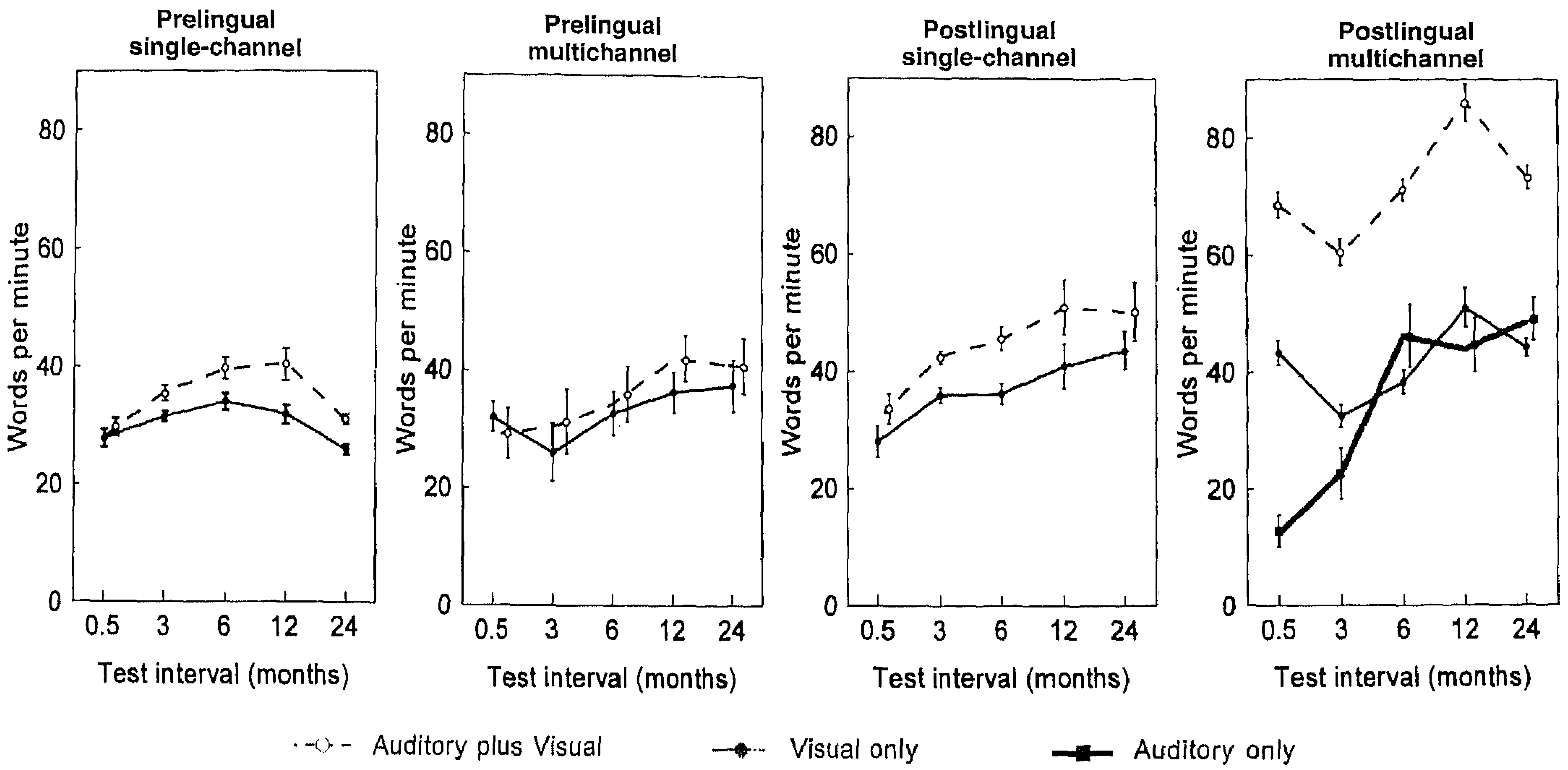

Fig. 3. Continuous Discourse Tracking scores for the four groups of patients. The broken lines represent the auditory-plus-visual scores, the solid lines represent the visual-only scores, and the thick grey line represents the auditory-only scores. Vertical bars represent 1 standard error.

Keuls' grouping showed significant improvement between the 3-month and 6-month follow-up evaluations, but the performance after 6 months did not improve significantly at the 5% level.

The users' responses to the questionnaire can be summarized as follows:

1. Seventeen of the 19 patients were using their implant in all situations. One patient (OS1) only used the implant in some situations, and 1 patient (ES7) stopped using the implant after 1 year, partly because of unsatisfactory sound detection and subjective annoying and sometimes painful sounds and partly because he became increasingly involved in the deaf community.

2. Seventeen of the 19 patients reported that the implant had made it easier to communicate with one other person. Two patients (ES5 and ES7) reported no change. While 10 of the 19 patients reported that they felt more at ease when communicating with other deaf people, 16 patients indicated that they now felt more relaxed when communicating with normal-hearing people. Patients ES5 and ES7 reported that they felt more tense while using their implant.

3. Nine of the 11 postlingually deaf patients and 7 of the 8 prelingually deaf patients, including all the patients with Usher's syndrome, reported feeling safer in traffic while using the implant. Only 1 patient (ES29) felt less secure because of annoying traffic sounds.

4. Sixteen of the 19 patients were content with the implant. Two patients (OS3 and ES12) were somewhat disappointed. Only 1 patient (ES7) expressed great disappointment and had stopped using the implant.

DISCUSSION

Although this study involved a limited number of patients, some preliminary conclusions can be drawn from the results. The performance of the postlingually deaf subjects on the closed-set pattern and speech perception tests was found to be superior to the performance of the prelingually deaf subjects, which is in accordance with previous studies.[6–8] Nevertheless, the average performance of the prelingually deaf subjects was significantly above chance on both the pattern recognition and speech discrimination levels. The type of implant used had no significant effect on the results of the pattern recognition tests. On the closed-set speech discrimination tests, the performance of the postlingually deaf subjects with a multichannel system was clearly superior to the performance of those in other groups, while in the prelingually deaf subjects no significant differences were found with regard to the type of implant used. This latter finding agrees with the performance of patient ES4/EM22, who was reimplanted with a multichannel system after failure of the single-channel system. This patient performed equally well with the single-channel implant and the multichannel implant on various speech perception tests. More details on the performance of this patient can be found elsewhere.[14]

Although comparison of the CDT scores from different patients has limited value because of the semistandardized presentation of the test materials and possible differences in the presentations of the test,[19] the AV enhancement was found to be largest in the postlingually deaf subjects who had a multichannel implant; this finding agreed with the results of the prerecorded closed-set speech discrimination tests. Furthermore, the postlingually deaf subjects with a multichannel implant were the only patients who achieved open-set speech recognition in the auditory-only condition. However, a small but statistically significant visual enhancement was found for all patients except the small group of prelingually deaf patients (n = 3) with a multichannel system.

Despite only moderate results, almost all prelingually deaf subjects reported that they were satisfied with their implant and claimed that it had added quality to their life. Only one prelingually deaf patient stopped using the implant, partly because of the persistence of annoying, sometimes painful sounds, despite several readjustments. It is interesting to note that he was the only prelingually deaf patient in the study who found a deaf partner after he had been implanted. Subsequently, this patient started to lean more and more toward the deaf community. In contrast, the other prelingually deaf patients were highly motivated to continue using oral-aural communication and become increasingly involved in the "hearing" world.

It is important to note that the benefit of implantation should not be expressed only by enhanced performance on speech perception tests. Personal factors, such as ease of communication with other people, reduction of stress when in traffic, and the psychological benefit of actually being able to hear sounds, are difficult to assess objectively. The results of the questionnaire in this study indicate that personal factors play an important role in the amount of benefit provided by a cochlear implant.

Whether the present results can justify the large-scale implantation of prelingually deaf adults is open to discussion. In this study, all but one of the prelingually deaf patients showed a persistent high motivation to learn to function in the hearing world by means of oral-aural communication. The results of this study indicate that it is feasible to implant highly motivated, oral-aural–oriented prelingually deaf patients, but it is doubtful whether any additional benefit can be gained from implanting highly sophisticated, expensive multichannel systems in these patients.

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