Changes in synthetic and natural vowel perception after specific training for congenitally deafened patients using a multichannel cochlear implant

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SUMMARY

The study investigated whether congenitally deafened patients using the 22-electrode cochlear implant who show limited speech perception ability, could improve their ability to use place-coded vowel formant information after specific training. The relationship between electrode difference limens and synthetic vowel recognition was also investigated. A heterogeneity of findings characterized the patients. Significant improvements on several assessments of synthetic vowel perception occurred after 10 training sessions for 2 of the patients and gains were consistent with their electrode discrimination ability. There were minimal gains for the remaining patients. A poorer apical electrode difference limen could partly explain the relatively low scores pre- and post-training for one of these patients.
INTRODUCTION

Although many children and adolescents implanted with the 22-electrode cochlear implant achieve significant open-set speech perception there are many early-deafened users who show limited progress. These poorer performers may not be able to utilize the spectral information provided by the implant which is place-coded by stimulating different electrodes. This study focused on the ability of poorer performers to utilize formant information in synthetic vowel perception and investigated the benefits of specific training which emphasized spectral differences in vowels. Vowel perception will be poorer if stimulation of different electrodes does not result in discriminable sounds. The study therefore considered the relationship between vowel perception performance and electrode discrimination. Few studies have considered this relationship, especially with children. This study is unique in that it uses synthetic vowels, speech stimuli which more closely approximate the psychophysical stimuli. There are also very few studies which directly assess the benefits of auditory habilitation for children and adolescents using multichannel cochlear implants. In a specific training study, Busby et al (1991) reported no significant gains in vowel perception after three hours of habilitation. Specific questions investigated in the present study were: (1) would a significant improvement occur in vowel perception after training, compared to a non-significant change in performance during a pre-training period? (2) would improvements in vowel perception generalize to a closed-set word recognition task? (3) would gains be retained after removal of the training? and (4) what is the relationship between vowel perception and electrode position discrimination?

MATERIALS AND METHODS

The group of congenitally deafened patients included 3 children, 1 adolescent and 1 young adult whose ages at the time of testing ranged from 6y4m to 21 y 10m. Duration of deafness ranged from 4y7m to 14y 11m and implant use from 1y 8m to 6y 11m. Patients used the MSP processor with a multiplex strategy encoding F0, F1 and F2, as well three high frequency bands: 2.0-2.5 kHz (Band 3), 2.5-4 kHz (Band 4) and frequencies above 4 kHz (Band 5) onto three basal electrode positions. A single-subject design was employed, in which each patient served as his/her own control. The change in performance during at least one pre-training period was compared to the change in performance after a 10 week training period. An additional post-training assessment was conducted 3 weeks after the training had ceased, to investigate whether skills acquired after training were retained. Initially the stimulus levels of the electrodes were adjusted for equal loudness at the maximum comfortable listening level. Then immediately prior to the pre-training period difference limens for electrode discrimination were obtained, using an odd-man out, adaptive procedure (Busby and Clark, in press). Two regions of the cochlea were assessed, using reference electrodes 18 and 11. Loudness was varied across comparison and reference electrodes to prevent the patients from relying on any amplitude differences between the electrodes. Assessments of synthetic vowel perception included minimal pairs of synthetic vowels incorporating easy to difficult contrasts and a 6-alternative forced-choice test using the 6 short synthetic vowels in an h-d frame. Natural speech stimuli assessments included a 6-alternative short vowel test and a 12-alternative, monosyllabic word task. Speech materials were presented via direct audio-input, with a cable sending the tape-recorded stimuli directly into the implant processor. The training program was tailored to suit each patient's age and cognitive ability. There were ten 50 minute sessions, incorporating mainly analytical exercises.

RESULTS AND CONCLUSIONS

Of the five patients, four showed significant improvement using a chi-square analysis of change, on at least one of the assessments following training. Only two of the patients (#3 & 4) however, showed gains across a number of tests. Figure 1 reveals the mean performance on the 6-short synthetic vowel test before and after pre-training periods and before and after training. Except for patient 5, patients' performance on this test was significantly greater than chance across the assessment periods. Patients #3, 4 & 5 revealed a significant gain 1 week and 3 weeks post-

![Figure 1](https://example.com/figure1.png)

Training was hierarchical, moving from easier tasks (gross contrasts) to harder tasks according to the patient's success. Games were used to ensure patient motivation. The concept of rhyme was the basis of several games since it focused the patient on the vowel sounds. One of the activities for the adolescent and young adult was to generate poetry. The children played games such as "Lotto" in which the child and trainer each had a board with for example 6 words and pictures to represent the words. The words differed predominantly in terms of the vowel sound. When it was the trainer's turn, the trainer picked up a card from a pile without allowing the child to see it and said "Who has the word "cat" for example and the child was encouraged to listen and find the matching word on the board.

![Figure 1](https://example.com/figure1.png)
training, indicating some retention of skills acquired after the removal of training. For one of the patients (patient 3) improvements in vowel perception generalized to a monosyllabic word task in which vowels and consonants varied. It is possible that this gain reflects an improvement in the place-pitch ability of this child for consonants and vowels that were not trained as well as for the vowels that were trained. Some generalization of training occurred for all patients showing any improvement, because the vowels in the test items were presented in untrained contexts. Patient 2 also revealed a significant gain on the monosyllabic word test after training but the post-training performance did not significantly exceed the average pre-training performance.

Mean electrode position difference limens for the basal and apical cochlea regions were obtained by averaging difference limens obtained across several degrees of loudness variation between the reference and comparison electrodes. Overall mean difference limens are plotted in Figure 2 as a function of mean pre- and post-training performance on the 6-short synthetic vowel test. Mean difference limens did not exceed 3 electrodes for patients 1-4, whilst the apical difference limen for patient 5 was almost 6 electrodes. Patient 5's speech recognition performance was consistently poorer than that of the other patients across tasks and this can be partly explained by the poorer electrode discrimination ability. Nevertheless although this patient's scores were generally low, there was a significant gain after training for the 6-alternative synthetic vowel task. Prior to training, vowel and speech recognition was poorer than expected on the basis of measured electrode difference limens for patients 1-4 (see Figure 2). For example patient 3 could not differentiate the minimal vowel pair /had/ had/ whose 2nd formant electrode separation was 7 electrodes. It should not be assumed however, that a patient with small difference limens will have good vowel perception even as a minimal pair level of assessment. The psychophysical task still differs from the minimal pair speech task. For example, in the former task the patient only listens to one electrode at a time. One would however, still predict potential for improvement with training for patients 1-4 on the basis of the electrode discrimination measurements. Specific training did help patients 3 & 4 to utilize formant information in vowel recognition, but had little to no impact on the performance of patients 1 & 2.

Other factors must be contributing to the poorer vowel performance of patients 1 & 2. It is possible at least for patient 2 that some areas of the electrode array have poorer channel independence and pitch reversals. The long duration of deafness prior to implantation may be contributing to the lack of improvement with training for patient 1. There is likely to be a "critical period" for plasticity and learning in the auditory system. Substantial gains in vowel perception occurred for the two children whose duration of profound deafness was 6-7 years.

REFERENCES


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