Acquisition of focus by normal hearing and Cochlear Implanted children: The role of musical experience

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Abstract

Two experiments investigated the perception of compound vs. phrasal stress and narrow focus in normally hearing children and children with Cochlear Implants (CI). Additionally, we investigated whether musical experience would predict children's performance in these tasks. The results showed no difference between CI and normal-hearing (NH) children in either experiment. However, whereas we found no clear effect of age in the children's stress detection, there was a clear age related trajectory in the ability to recognise (narrow) focus. Moreover, this trend was similar to what has been found previously for English children. Importantly, prior music experience was significantly linked to CI children's perception of focus.

1. Introduction

Cochlear implants (CI), auditory prosthetic devices implanted in the inner ear, help to induce a sensation of sound in individuals with a severe hearing loss by electrical stimulation of the primary auditory nerve fibers. Even though CIs are successful in facilitating the development of spoken language in children with pre-lingual hearing loss, current devices are limited in the coding of some aspects of speech, for example, fundamental frequency (f0). Subtle changes in voice f0 and the detailed structure of spectral cues can be fully exploited by the normally hearing (NH), but are much less accessible for the children with a CI [1,2,3,4]. Moreover, whereas people with normal hearing are able to take advantage of the duration and intensity-based characteristics of the speech signal that usually accompany fundamental frequency changes, such information maybe only partly available for children with cochlear implants. Even though intensity and duration-based features of speech can be fairly well transmitted by current devices, the ability to discriminate fundamental frequency-based differences, and consequently, the acquisition of pitch and intonation-based linguistic contrasts, is likely hindered in these individuals. It is important to determine the impact of these factors on the development of language skills in children with cochlear implants, especially in relation to information allocation at sentence and discourse levels such as focus.

The acquisition of compound word vs. phrasal stress (*blackbird* vs. *black bird*) has been reported to be very slow at least in children speaking English language. This skill does not develop to adult-like levels before the age of 12 [5]. The ability to identify prosodic focus in English-speaking children may be acquired as late as 10. The late development of the perception of focus is in contrast with the early development of both the auditory ability to discriminate between different rhythmic and prosodic patterns [6,7] and the ability to produce these differences [5]. Production of (non-contrastive) narrow focus has been found to be quite well-developed at the stage of two-word combination utterances [9]. It is evident that, in children, the contrastive use of stress, especially the ability to interpret the meaning of focus in picture pointing tasks, is connected to the development of the ability to attend to both segmental and prosodic qualities of speech, and to the development of receptive and expressive language, as well as grammatical comprehension and production. Children's performance for these skills also varies considerably [5,8].

In addition to these linguistic factors, there is a growing body of evidence that musical background is connected to the perception of prosody in the normally hearing population. For example, children with musical training have been shown to be able to detect pitch violations in speech, and distinguish between interrogative and declarative sentences better than non-musician children. These results suggest that there is a common pitch processing mechanism in language and music perception [10,11,12]. However, there are no studies of the effects of musical background on the perception of contrastive stress or focus.

Many studies have consistently shown that pre-lingually deafened children with a CI have difficulty in perceiving lexical tone contrasts. However, Peng et al. [13] have reported that several children with a CI can achieve high levels of performance in lexical tone perception. In a further study Peng et al. [14,15] reported that, whereas NH children as young as 6 years of age were able to consistently identify speech intonation contrasts in a framework of question vs. statement, pre-lingually deafened individuals with CI-devices had difficulty identifying such contrasts. Their performance correlated positively with both chronological age and the length of device experience, but no correlation was observed with age at implantation. Unexplainable inter-subject variability was found in pediatric CI recipients' production and perception.

Carter et al. [16] found that the imitation of stress in non-words is well preserved in children with a CI. This ability to imitate stress correlated significantly with measures of speech perception, intelligibility, perceived accuracy, and working memory. These findings suggested that children with a CI can encode prosodic patterns of non-words, despite the loss of detailed segmental properties, and this phonological knowledge is also reflected in other language and memory skills. Thus, the ability to perceive stress seems to be of crucial importance for children with a CI [16].

Research on English speaking CI children [17] suggests that they do not perform as well as NH children in the identification of focus and contrastive stress in phrases vs. compound words, and that performance develops with age.

In this study we were interested in how the abilities to identify contrastive focus and stress are interconnected in Finnish speaking CI and NH children. Furthermore, because it is known that musical background is connected to the ability to detect other prosodic features, we also studied the influence of musical background on the ability to perceive prosodic features.

2. Experiments

We conducted two experiments where the participants were asked to determine the target picture of a compound word as opposed to a phrase (e.g., *bluebell – blue bell*) based on a spoken utterance (experiment 1), or choose between three alternative pictures according to a contrastively focused utterance (e.g., *The boy paints the BOAT vs. The BOY paints the boat)*.

2.1. Participants

A total of 17 Finnish-speaking children with CI devices implanted before age of 3 (aged 4-12 during the experiment) participated. This group was implanted at a younger age than children in previous studies, which may be expected to lead to a better outcome in CI use. Moreover, all except one child were in ordinary school, where signing or sign language was not used. This suggested well-developed spoken language skills and the ability to perceive many aspects of speech in general in the participants of this study. CI children were recruited from four different Central Hospitals in Finland. As a control group, 17 age-matched normal hearing Finnish-speaking children without linguistic problems were tested. Some of the children in both groups had been attending musically-oriented kindergartens, so called music kindergartens. Some were also continuing their musical activities by private lessons or started their musical activities in music groups for CI children and their siblings.

2.2. Background Questionnaire

Links to musical background were addressed from a questionnaire to parents developed for this study. Questions about other background factors of the CI children (usage of hearing aid or signs, linguistic development etc.) were also included in the questionnaire.

2.3 Materials and Procedure

Two computer-based tests using the Presentation software were developed in co-operation with UCL, London (Andrew Faulkner and Rosemary O´Halpin). Both tests consisted of a series of simple pictures presented on the computer screen and set accompanying audio files spoken by Finnish speakers. The stimulus utterances (see below) were recorded in a sound treated studio at the Department of Speech Sciences of the University of Helsinki using a high-quality condenser microphone and a high-quality analogue to digital converter. The materials were recorded from four speakers: an adult male, an adult female, a female child of 7 years, and a female child of 10 years. The stimuli were presented to participants with a laptop computer using a separate high-quality sound card and two loudspeakers in 45˚ angle in front of the subject at 60 dB SPL for normal hearing and 70 dB SPL for CI subjects. The children were familiarized with the pictures beforehand.

2.3.1. Experiment 1. Identification of contrastive stress: Phrase vs. Compound words

The picture prompts comprised 2 pictures, representing compound word and phrase (*bluebell – blue bell*). The task of the child was to point to the target picture matching what they heard. The examiner used a wireless keyboard to register the answers.

2.3.2. Experiment 2. Identification of contrastive focus in three word sentences

The speakers and recording of the stimulus, computer settings and intensity levels were the same procedure as in Experiment 1. The picture prompts on a screen contained always 3 pictures, representing the three content words in the sentences. The task of the child was to point to the picture representing the word which was said differently, or which was the most important, in the sentence (e.g., "*The boy paints the BOAT" vs. "The BOY paints the boat" for narrow focus in the spoken stimulus for "boat" and "boy", respectively*).

2.4. Results

Figures 1 and 2 depict the results from both experiments. The figures show the percentage correct identification of the given stress or focus conditions. Statistical analyses with binomial independent variables (i.e., CI vs. NH groups, and whether or not the child had attended a music kindergarten) were conducted with age controlled multiple analyses of covariance (MANCOVA). Links between the experimental results and the background questionnaire were examined using Pearson and partial correlations, age partialled out.

There were no statistically significant differences between CI and NH groups in the identification of contrastive stress or focus. The performance in these tests was very variable across subjects in both groups.

Both of these skills, the ability to discriminate between compound words and phrases or to identify contrastive focus, were interconnected in both groups; however, identification of compound word vs. phrasal stress was improved less rapidly with age than identification of focus in both groups. Musical background was connected to both test results in the CI group. Moreover, the correlations were always positive: the more the children had been involved with music, the better their performance. In the CI group, the correlation between focus perception and the amount parents had sung to the child in the previous year was very strong ($p<0.001$). When age was partialled out, the connection to the child's experience in playing a musical instrument at home was statistically significant. Participation in music kindergarten was also connected to the identification of focus (statistically significant MANCOVA, age controlled). Surprisingly, the best performers in this task were subjects with a CI, scoring 100% correct. These subjects had extensive exposure to parental singing and had attended a music kindergarten.

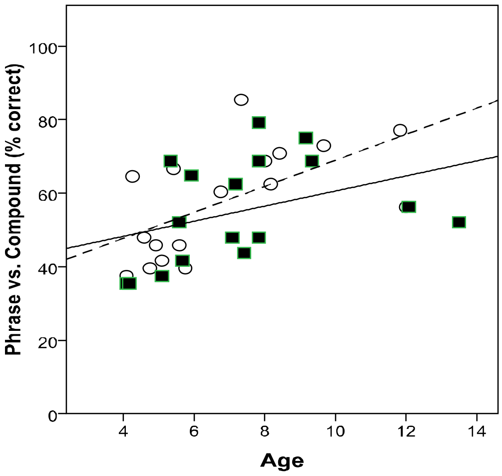

Figure 1. Results from experiment 1. The squares depict CI children and the circles the controls. The solid regression line represents the CI children data and the dashed line the control group.

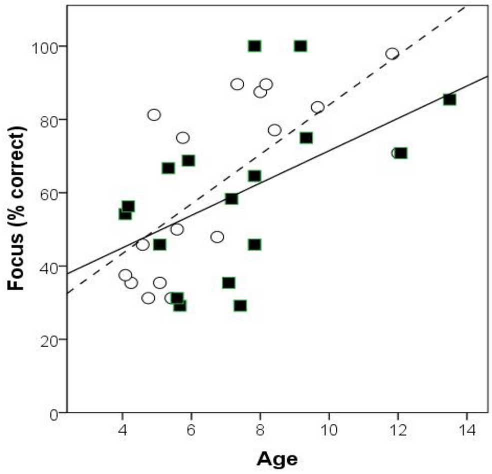

Figure 2. Results from experiment 2. The squares depict CI children and the circles the controls. The solid regression line represents the CI children data and the dashed line the control group.

The connection between phrase vs. compound word discrimination and parental singing was also statistically significant (p<0.010), although attendance in music kindergarten narrowly failed to show a significant link to this test (MANCOVA, age controlled). No statistically significant link between listening to music from television or CDs was found for either task, suggesting that only interactive music tasks were connected to better performance in both experiments. There was also a significant correlation between phrase vs. compound discrimination and the extent of parents playing music.

In the control group, the connections between focus perception and parental singing in the previous year, singing by siblings with the child, and the amount parents had played musical instruments were all weaker than in the CI group, and significant only when age was partialled out. No connection was found in the controls for the phrase vs. compound test (first experiment).

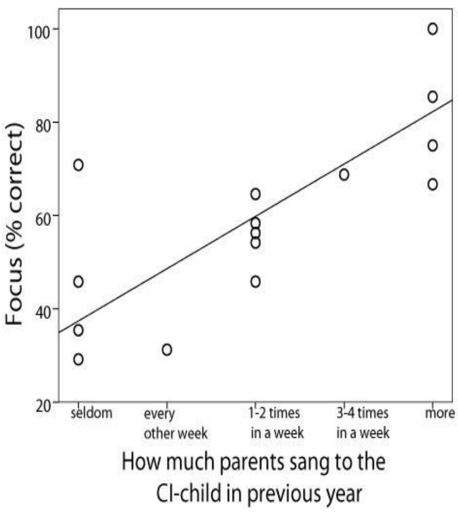

Figure 3. The relationship between the relative success in perception of focus and musical experience in the CI children in experiment 2.

4. Discussion and Conclusions

In this study we investigated both NH and CI children's ability to perceive mainly speech melody-related prosodic and linguistic structures. First, we tested how well children can discriminate between prosodic patterns related to compound words as opposed to segmentally similar phrases (experiment 1). Second, we investigated their ability to perceive contrastive focus in simple three word utterances.

The results for the NH children were generally in line with previous studies in English speaking children. That is, the development of the ability to perceive contrastive focus and stress seems to follow a similar trajectory in both Finnish and English children. However, the present findings are in contrast with previous results concerning children with CI in that their abilities did not differ significantly from the NH controls.

This may be the result of the present group being implanted at an early age (before 3 years of age). In previous studies the age of implantation has been more variable. It is also possible that the CI children in this study have been involved more with music and singing than in previous studies, where the musical background has not been controlled and has likely been less intensive.

The connection of these speech perceptual tasks to music experience in the CI-group is intriguing. It is possible, that the repeatability, slower rate and more stable pitch of stimuli in children's songs and music enhance access to segmental phonetic information for CI children. It may also be that the rhythmic cues to segmenting speech are processed more efficiently in CI children involved with music. Furthermore, larger differences in pitch, intensity and duration in musical stimuli by comparison to speech possibly help these children to direct their attention at these qualities of sounds. The effect of music exposure in CI children may well be more important for CI children than for children with normal hearing, who do not face basic perceptual difficulties in the processing of pitch information.

Because the NH children have no perceptual problems, the perception of stress and focus in behavioral tests like the present study may be easier to such extent that the effect of their musical background may appear less strong, and thus may appear less important in predicting the variability of the results in normal hearing population. For example in the study by Magne et al. [11], musically experienced children were better than others especially in "hard tasks", where the difference in pitch was small. Thus the variability in NH children in the results from experiments 1 and 2 may arise from other factors like development of segmenting the speech, receptive and expressive language and grammatical comprehension and production.

Further, the present results may indicate that the effect of music in both perception of focus and contrastive stress is different in CI than NH children. Why would parental singing be connected to the perception of stress and focus in children with a CI? One reason for this may be that the sound patterns of the familiar voice of the parent are more easily perceived than the pitch patterns of an unfamiliar voice. This may enhance the perception of pitch or other cues for prosody in general. It is also possible that the interactive situation, which is usually face-to-face and involves repetitive listening and singing, facilitates the ability to segment speech, which in turn helps the child with a CI to identify contrastive stress. It is also known, that children learn more efficiently in interactive, face-to-face tasks than in passive settings [18]. Thus these findings may explain the strong effect of parental singing in contrast to passive listening of television or radio.

The results from previous studies indicate that good ability in the perception of stress is of crucial importance for children with cochlear implants, because they help CI children segment the continuous speech stream into words and enhance the ability to learn spoken language in the same way as infant-directed speech does in the normal-hearing population [18, 19]. Also the enhanced ability to detect information allocation due to focus is of crucial importance for these children in everyday communication. In order to further investigate this relation, we are currently conducting follow-up measurements. We will discuss the first results and their relation to music involvement, as well as the possible differences between CI and NH children on detection of non-initial and final focus [20, 21] further in the presentation.

In conclusion, our results showed no clear difference between CI and NH children in either the ability to detect compound vs. phrase stress or the perception of focus. Interestingly, however, whereas there was no overall effect of age in the former case, there was a clear age related trajectory in the children's ability to detect (narrow) focus. Moreover, this trend was similar to what has been found for English children in earlier literature. Importantly, however, especially in the children with a CI, prior musical background significantly predicted their success in the perception of focus. Therefore, our results highlight the cross-modal nature of the abilities underlying perception of prosodic features of speech and their development. Moreover, they suggest that the fairly late acquisition of certain information structure devices, especially the acquisition of prosodic focus, may be partially explainable from the fairly late mastery of the ability to detect changes in pitch that underlie the more linguistically motivated functions of prosody.

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