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An acoustic study of speech production by French children wearing cochlear implants

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Abstract

Background. The aim of this paper is to present an acoustic analysis of the speech produced by deaf children wearing cochlear implants (CI). Most studies describing speech production by CI children show that progression after implantation is rapid and that intelligibility and fluency reach typical norms after few months (Sanchez et al. 2006, Ertmer, 2003, Warner-Czyz, 2010), yet some studies show residual difficulties in speech production affecting some consonant and vowel contrasts, though often with conflicting results.

In two studies on vowel production, Löfqvist et al. (2010), and Horga & Liker (2006), who compared CI children and normal-hearing (NH) children, found that CI children more than 5 years after implantation have a less expanded vowel space than NH children. However, other studies have found that CI children have a higher second formant (F2) than NH children (e.g. Liker et al., 2007; Baudonck et al., 2011).

As concerns voicing production, Baudonck et al. (2010) showed that CI children produce voiced consonants for targeted unvoiced items. Dillon et al. (2004) found that CI children have voicing or devoicing difficulties, even if they have a better production of voiced than voiceless targets. Horga & Liker (2007) found that CI children, like other deaf children, have a poorer voice onset time (VOT) contrast than NH children.

CI children also seem to have difficulties producing fricatives. Baudonck et al. (2010) showed that CI children replace fricatives with other consonants. In Uchanski et al. (2003)'s study, CI children showed a better production of plosives than of fricatives. Peng et al. (2004) rank accuracy of consonant production in CI children as follows: plosives, nasals, affricates, fricatives, and last, laterals. Liker et al. (2007) showed that affricates are generally longer and that /s/ noise frequency is lower in CI children than in NH children.

To sum up, these studies suggest that CI children have difficulties producing VOT, fricatives, laterals and formants in vowels. However the results lack uniformity, mostly because of methodological issues. First, many studies calculate averages over children of different ages and/or different implantation ages and they do not always include comparisons with normal-hearing children. Second, only a few studies are based on objective acoustic measurements, others often only rely on subjective perceptual evaluation of phonological contrasts. There are also no consistent acoustic measurements across studies (formant space, formant distances, spectral slopes, etc.). And finally, there aren't many studies on French (but see Le Normand and Lacheret, 2010) although French is particularly interesting because it has many vowels, including nasal vowels.

Objective and method of the present study. The goal of the present study is to carry out an acoustic analysis of the production of a number of segmental and suprasegmental features by 5 French prelingually deaf CI children aged 5 to 10 years (mean age of implantation: 3;3 years), who are compared to a group of 7 NH children aged 6 to 8 years. We recorded two speech productions tasks: word repetition and narration and an Oral Language Assessment test for all children (ELO, Khomsi, 2002). Only the word repetition task is analysed here. The corpus included all the French vowels in word-initial position, plus voiced and voiceless stops and sibilant and non-sibilant fricatives, in word-initial position, before [i] and before [u].

Analyses. An accuracy score was assigned to each production, at the segmental, syllabic and word levels, perceptually. Acoustic measurements for vowels consisted in F1 and F2 values, F1 and F2 means and ranges, and vowel space size, evaluated as in Löfqvist et al. (2010). Voice Onset Times were measured for stops and spectral moments were measured for fricatives.

Results. Accuracy scores are systematically lower in CI children than in NH children, for vowels, fricatives and stops. As concerns fricatives, only the first spectral moment (centre of gravity) is significantly lower for CI children than for NH children. VOT values for voiced stops are significantly shorter in CI children's productions than in NH children's productions. For unvoiced stops, CI children's VOT values are higher than those of NH children. CI children seem to be producing an exaggerated contrast between the voiced and the unvoiced mode. Vowel spaces and F1 values are not significantly different in each group. However, F2 mean values are lower for CI children than for NH children. Moreover, CI children's F2 ranges are smaller than those of NH children.

Our future studies will aim at relating these results with the duration of auditory experience, and with the speech perception abilities of the CI children.

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