Pol J Med Phys Eng 2009;15(3):135-141.
PL ISSN 1425-4689
doi: 10.2478/v10013-009-0013-9
website: http://www.pjmpe.waw.pl

Olgierd Stieler[1, 2], Alicja Sekula[3]

Evaluation of phoneme perception based on the digitalized phoneme test in children with cochlear implants

[1]Institute of Acoustics, Adam Mickiewicz University, Poznan, Poland
[2]Department of Otolaryngology, Poznan University of Medical Sciences, Poland
[3]Department of Phoniatrics and Audiology, Poznan University of Medical Sciences, Poland
e-mail: osaku@ump.edu.pl

Early diagnosis of congenital defect of hearing poses new challenges for a multidisciplinary team of pedoaudiologists, ENT (ear-nose-throat) specialists and speech therapists. This study assessed the perception of phonemes in children with a cochlear implant and the possibilities of applying acoustical solutions in the audiologic evaluation. The participants were 17 implanted children, aged 5-9 years, who received a cochlear implant when they were from 18 months to 3 years old. Detection thresholds and discrimination score were assessed. This study also aimed at verifying the possibilities of applying the digital audioprocessing algorithm in clinical practice. The test based on the phonemes aa, uu, ii, ss, sh (Ling 5 sound test) was used. The test was modified in the frequency domain – the main aim of this modification was to improve the precision of the reconstruction of the audible threshold. The results indicated significant correlations between pure tone audiometry results and thresholds of phoneme detection [dB SPL]. The identification score in this group was 95-100% for sound pressure level 65 dB SPL.

Key words: Cochlear implant, deafness, phoneme perception, digitalized phoneme test, speech perception.

Introduction

Evaluation of the rehabilitation of a communicative process in small children with prelingual deafness (prelingual hearing impairment) requires a precise identification of a hearing gain from the cochlear implant. The basic examination helping to detect the hearing threshold involves stimulation of the patient's hearing with a tonal stimulus (like in tonal audiometry). A tonal stimulus is the easiest one to generate. However, knowledge about the hearing threshold of speech sounds, their discrimination and identification [1, 2] threshold is more important for the assessment of the hearing perception in the development of speech. For this purpose Ling 5 sound test was used [4, 5]. Tests sounds were digitalized so as to create the conditions of objective impact on the hearing organ in the entire auditory field for speech.

Material

Seventeen pre-school and school age implanted children (5-9 years old) (Poznan Cochlear Implants Programme) were included in the tests. In all patients in the test group prelingual deafness, i.e. originating during the pre-language period or prior to speech development, was diagnosed. The patients were implanted when at the age of 18 months to 3 years. No other pathology was found in the children of the test group; their psychomotor development after the implantation was typical of that age group. All the patients used the Nucleus cochlear implant manufactured by Cochlear (Australia). Minimum 3 years after the implantation procedure correct progress of the rehabilitation process was found. Evaluation was done by a multidisciplinary team [2, 7] consisting of an audiologist, psychologist, a clinical engineer responsible for the programming of the speech processor, and speech therapists. The patients attended regular schools and kindergartens with their hearing peers.

Method

The classical Ling 5-sound test [3, 4] was used in the experiment, which is based on sounds of phonemes AA, OO, EE, SS, SH (phonetic transcription). In the frequency domain phonemes in the Ling test cover the entire range of the hearing field in their spectral representation, which is significant for speech perception. In earlier studies the authors used the Ling 5-sound test in detection tests (detection of signal presence) and discrimination (differentiation) in implanted children at the pre-school age 4-7 years [8]. In this experiment identification of phonemes by children at the pre-school and school age based on the same sound material was evaluated. The experiment proceeded in two directions – first the sound material was evaluated followed by the evaluation of the results of the patients. SoundForge ver. 9.0, a digital audio editing suite, was used to prepare the sound material. Sound files were converted to .wav files with a sample rate of 44.1 kHz, 16 bit. The sounds were recorded in an anechoic chamber, using EMU 1616, a professional sound card. A computer, which controlled the sound card, was acoustically isolated. The reverberation time in the room was also measured. Noise samples were taken during the 3 seconds of silence between the recordings and the noises were removed from the recording. A technical analysis of the samples (sound files) was made and the dynamics range was defined. A 2-second silence was left at the beginning of each recording to account for the technical drawbacks of older generation CD players. After the spectral analysis of each phoneme, a digital filter was designed so as to leave only the spectral components, which help in correct identification. Low pass filters for low components (AA, OO), medium pass filters (EE) and high pass filters (SS, SH) were used. A cut-off frequency was selected so that the control group of normally hearing subjects reached the identification ratio of 100% for the sound pressure level of the signal equal to 65 dB SPL. This procedure aimed at a more precise reconstruction of the hearing threshold in detection tests used with children younger than 3 years, while it is possible

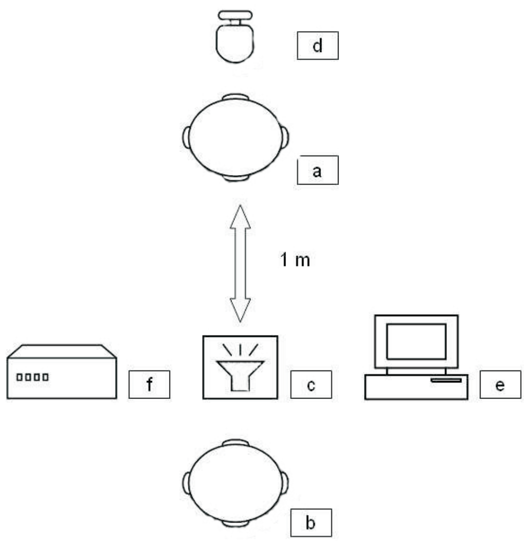

Figure 1. The measurement setup – an anechoic chamber: a) subject, b) experimenter, c) loud speaker, d) sonometer, e) computer, f) audiometer.

to correctly discriminate and identify modified phonemes in the subsequent evaluation of auditory skills. Following the correction in the frequency domain, the signals were standardized based on the RMS value. The same methods of signal digitalization were used as in the preparation of the Polish monosyllabic tests, used in adult speech audiometry [6]. The acoustic signals used in the tests were recorded with a calibration signal – a bubble noise. All the sound files had the same level as the calibration signal. This helped to control the level by means of a 5 dB step audiometer, used in clinical practice. The audiometer was calibrated in a free field by means of Svantek sound level meter [9]. The level of the recorded signals was compared with the master signal. Playback levels were controlled using Madsen Midimate 622 clinical audiometer with a free field system and measurement step of 5 dB SPL. The results were recorded with a sound level meter with audiometer readings. The measurement setup is shown in

The threshold of detection and identification of phonemes was measured in patients in the control group. The Is [%] correct identification coefficient was defined for sound levels of 50, 65 and 80 dB SPL, which correspond to the silent, normal and loud speech levels. The results were statistically analysed.

Results

A detection threshold (hearing threshold) in the cochlear implant by means of tonal audiometry was determined. The averaged hearing threshold in a free field in patients in the control group is illustrated in Figure 2.

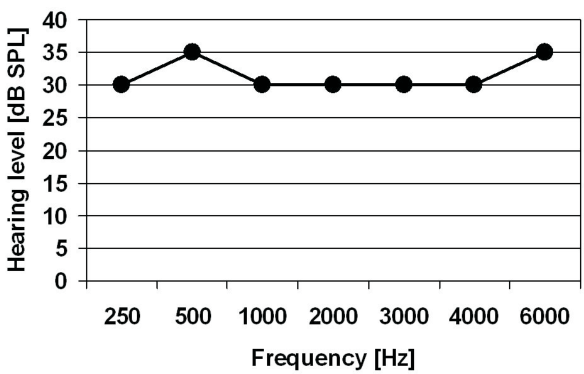

Figure 2. Mean threshold of tonal audiometry in patients in the control group (audiogram with the implant in a free field).

a)

b)

c)

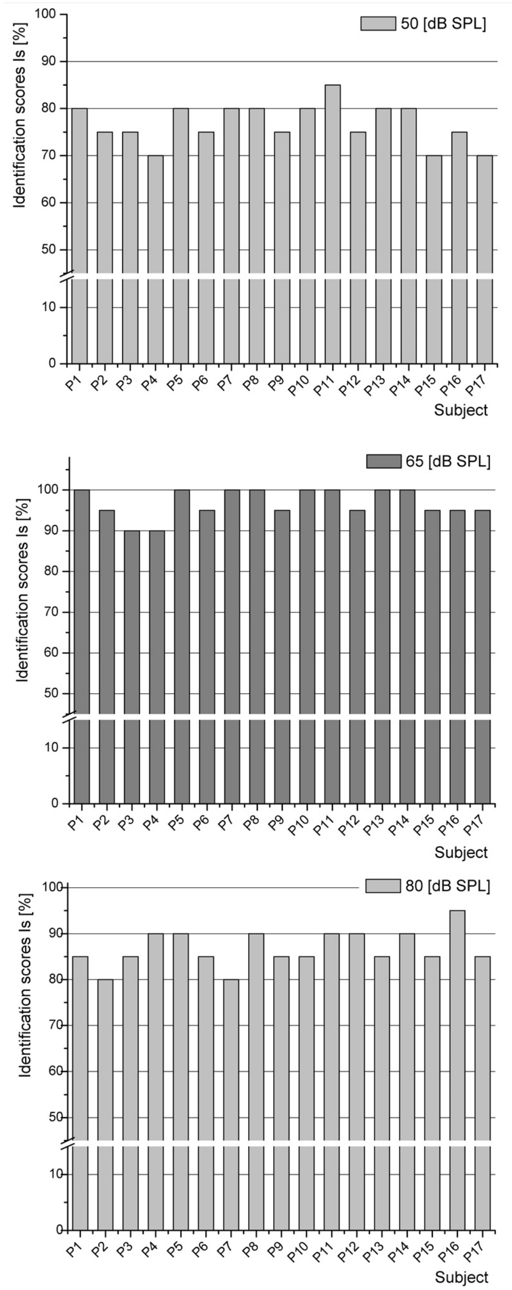

Figure 3. Is [%] correct identification coefficient for different signal levels: a) 50 dB SPL, b) 65 dB SPL, c) 80 dB SPL. X-axis – patient's number, Y-axis – percentage of correct identification.

The results for pure tones were compared with the results of the detection test for the phonemes, which was carried out in the same measurement conditions. The detection threshold of phonemes with known spectral characteristics was compared with thresholds determined for pure tones in the same frequency range. Average values of both tests were similar – standard deviation of 10 measurements for each frequency range was never higher than 1.7 dB (StdDev < 1.7 dB). The result has confirmed that it is useful to use complex sound and speech sounds to reconstruct the hearing field and determine the hearing threshold. The value of Is [%] correct identification coefficient was determined for signal levels of 50, 65, and 80 dB SPL (Figure 3 a, b, c).

A lower value of the Is [%] correct identification coefficient for the 80 dB SPL signal level is interpreted as the effect of compression at the preprocessing stage in the speech processor.

Conclusions

Preliminary results confirmed the usefulness of the tests in clinical applications. The correct identification coefficient, measured in the tests, has confirmed the acoustic signals. It is also an indicator of the level of comfortable hearing (meaning – the best result of the identification test). In the authors' opinion it is useful to use speech sounds in such tests – they help estimate the Most Comfortable Level (MCL) threshold when assessing the quality of hearing aid adjustment. Classical tests of tonal audiometry only permit assessment of the hearing threshold and identify the type of hearing impairment. The use of speech signals permits assessment of the higher levels of auditory perception, such as discrimination and identification. Acoustic signals of speech with a calibration signal recorded on a DVD disk give speech therapists a precise assessment tool, independent of the fluctuation of the natural voice emission. The tool permits a precise control – a speech therapist, while assessing auditory perception in the rehabilitation process can precisely define the acoustic features of the stimulus – the level and frequency characteristics of the signal. The tests will now be used in clinical assessment of children with hearing aids.

Acknowledgements

The authors acknowledge the financial support of the Polish Ministry of Sciences and Education: Grant No. N 504 038 32/3138.

References

[1] Erber N. Auditory training Alexander Graham Bell Association for the Deaf. Washington DC 1982.

[2] Gravel JS. Behavioural Audiologic Assessment. In: Paediatric Otology and Neurology. Lalwani A., Grundfast K. (Eds.). Lippencott-Raven Publishers. Philadelphia 1998, 103-12.

[3] Jerger J, Hayes D. The crosscheck principle in pediatric audiometer. Arch Otolaryngol. 1976; 102: 614-20.

[4] Ling D. Speech and the hearing-impaired child: Theory and practice. Alexander Graham Bell Association for the Deaf, 1976.

[5] Ling D. Foundations of spoken language for the hearing-impaired child. Washington, DC: Alexander Graham Bell Association for the Deaf, 1989.

[6] Pruszewicz A. [An outline of clinical audiology]. Karol Marcinkowski University of Medical Science Press, Poznan, 2002. Polish.

[7] Stieler O. Investigation on relationship between the subjective and objective response of auditory pathway in children with cochlear implant. Polish J Environ Stud. 2006; 15(4A): 103-105.

[8] Stieler O, Sekula A, Komar D. Application of Sound Engineering in Detection Tests for Children below the Age 3 Annual Meeting of American Auditory Society, Scottsdale, Arizona, 2008.

[9] ISO 8253. Acoustics-Audiometric Test Methods. Sound field audiometry with pure tone and narrow-band test signals. Geneva: International Organization for Standardization, 1996.