

## APPLICATION OF SENTENCE TESTS IN THE INVESTIGATION OF SPEECH INTELLIGIBILITY IN QUIET AND NOISE IN ADULT CI RECIPIENTS SUPPORTED WITH A HEARING AID

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The investigations of speech intelligibility were carried out for 9 patients with a cochlear implant (CI), 1 male and 8 females, aged 18–69 (mean 41). In all cases deafness was recognized as postlingual. All patients were using the hearing aid (HA) on the ear opposite to the CI. The novelty of this work consisted in the application of new Polish sentence tests in the evaluation of the effect of supporting electrical hearing with a HA in noise conditions. The sentence tests (developed at the Institute of Acoustics, Adam Mickiewicz University in Poznań – European Union Project HEARCOM) were presented to patients in quiet and in noise conditions (speech bubble noise). The speech intelligibility was determined in two cases: when transmission was only via the CI and when the HA was also used. The presentation of tests was conducted for three angles ( $0^\circ$ ,  $-90^\circ$  and  $+90^\circ$ ) in relation to the patient's head. The value of SRT (Speech Reception Threshold) was determined for the tests carried out in noise conditions. The improvement of the speech intelligibility was affirmed when the process of hearing via the CI was supported with a HA. The particularly essential difference was observed for the angle of  $+90^\circ$  (HA-side). The results obtained in the investigations show that acoustic compensation in the range of the remaining audibility field to a great degree supports electrical hearing. This conclusion can be an important contribution to the application of the HA on the side opposite to the CI, especially in the noisy environment.

**Keywords:** hearing detection, discrimination test, hearing aid, cochlear implant, postlingual deafness, speech intelligibility.

## 1. Introduction

With the development of physical and medical knowledge it is possible to restore auditory and verbal communication in patients who are profoundly hard of hearing by using a cochlear implant. A cochlear implant requires a surgical procedure and is used with patients, in whom considerable damage of hair cells in the cochlea was diagnosed. Hair cells transmit signals to the hearing nerve. This dysfunction prevents patients to use traditional hearing aids – an acoustic compensation of the defect does not stimulate the higher levels of the hearing path. This is caused by the lack of residual communication between the peripheral hearing system and the hearing nerve. As early as 1790 Alessandro Volta described the perception of hearing sensations when the region around the ear was stimulated with an electric current. In 1930 Wever and Bay accidentally discovered that the speech of the scientists who studied an anaesthetized cat can be heard from the loudspeaker in an adjacent room thanks to an electrode surgically placed on the animal's hearing nerve [1]. This was the discovery of the appearance of an electrical potential of the hearing nerve with acoustic stimulation. In 1957 DJURNO and EYRIES published first results of their experiments involving electrical stimulation of the hearing nerve in deaf patients [2]. During the follow-up operation of the face paralysis in an elderly man, an extensive mastoidectomy was performed to remove the cholesteatoma, which destroyed the structures of the cochlea. Electrodes were placed in the remaining nerve, combined with a primitive speech processor. The patient described the sounds he heard as those resembling the rustle of a cricket or the roulette wheel. In 1961 a group of scientists headed by William House implanted electrodes near the hearing nerve in two patients. Unfortunately, because of the discharge and the materials used in the inner part of the implant inflammation developed and the implant was removed after a few weeks. The results of this pioneer work showed that deaf patients can have the reception of the rhythm of speech and music restored and they can start to perceive sounds of the environment. In 1964 Doyle *et al.* implanted an electrode into the cochlea structures for the first time. The results, based on social conditions, i.e. speech intelligibility, were not satisfactory. In 1971 Michelson published data on many patients with a single-channel implant. A multi-channel implant was developed following tests on animals. At the beginning of the 1970s House started to use cochlear implants on a larger scale. A similar programme in Europe was started in 1973 by C.H. Chouard in Paris and in 1975 by K. Burian in Vienna. This work was then followed by G.M. Clark in Melbourne and E. Lenhardt in Hannover. As the results of deafness treatment were very promising, in the mid 1980s doctors started to use cochlear implants in children, initially only in those suffering from post-lingual deafness, and later in those with perilingual and prelingual deafness. Classical implants are based on the compensation of the hearing deficit by acoustic amplification. An acoustic signal in the hearing aid is processed – amplification is improved, signal growth and decay times (transients) are adjusted and advanced algorithms of useful signal recognition against noise are employed. Irrespective of the type of the processes in the hearing aid, at the output of it we get an acoustic signal, properly adjusted de-

pending on the character and severity of the hearing impairment. A modified signal, through an individual insert in the ear, is transmitted to the ear with the hearing aid; stimulation is analogous to physical stimulation. Transformation into electrical stimuli takes place in the receiver. In the case of very considerable hearing impairment in the cochlea, classical hearing aids are not effective – damage of the hair cells in the cochlea results in the breaking of the hearing nerve. The hair cells are afferent – they transform vibrations into electrical pulses and transmit them as such. In this case of pathology deafness is treated surgically – a cochlear implant is put into the inner ear. The implant bypasses the damaged receiver and directly stimulates the ends of the hearing nerve.

Speech intelligibility and speech discrimination (recognition) based on test results are among the most important criteria for the assessment of benefits deriving from the simultaneous use of the cochlear implant and the hearing aid. Investigations carried out by Ching involving a group of children who did not use any hearing aid since the administration of the implant could serve as an example. Tests conducted one month after the implant was put into the ear revealed considerable improvement in understanding sentences and recognizing vowels [3]. Another experiment, conducted on a group of adults, concerned discrimination of words and sentences in quiet and noise conditions. The results revealed a considerable improvement, particularly when signals were presented against noise [4]. In 2006 speech intelligibility tests were conducted at the Department of Otolaryngology, Poznań University of Medical Sciences, which were based on the Polish monosyllabic word tests, developed by a group headed by PRUSZEWICZ [5]. The results confirmed the benefits of supporting “electrical hearing” (via the implant) with “acoustic hearing” (via the hearing aid) [6].

The present work continues earlier investigations. Word tests were replaced with sentence tests, presented in both quiet and noise conditions.

### *1.1. Cochlear implant – operating principle*

Modern cochlear implant systems selectively stimulate a small group of nerve fibres by means of electrical pulses. This is done by a system of 22 platinum electrodes (and ten fixing rings) placed on a silicone carrier. All the electrodes are independently connected to the receiver/stimulator by means of insulated platinum-iridium wires. Electrodes are evenly placed over a distance of ~17 mm. The depth of the entire implant is 20–25 mm. The most basal electrode (closest to the round window) is Electrode 1 and the most apical is Electrode 22 [7].

However, before the acoustic signal from the microphone is passed to the electrodes of the implant, it must be processed and the processing is rather complex. The process is carried out in the speech processor (depending on the design and integration of the elements there are box processors and “behind-the-ear” processors – BTE). The processor changes the acoustic signal from the microphone into an electric code on the basis of the data inputted into it, individual for each user. The most important information of this process comes from the coding strategy used. The input signal is divided into

a defined number of frequency bands (on the logarithmic scale) and then stimulating signals are generated based on the information about the envelopes of the signals in the individual band. Next, the signal is radio sent to the internal part of the implant, where, once decoded in the receiver/stimulator, it is converted into electrical pulses with specific parameters, which, through the electrodes of the implant, stimulate selected groups of nerve fibres, which produces a sound sensation. This principle has been illustrated in Fig. 1.

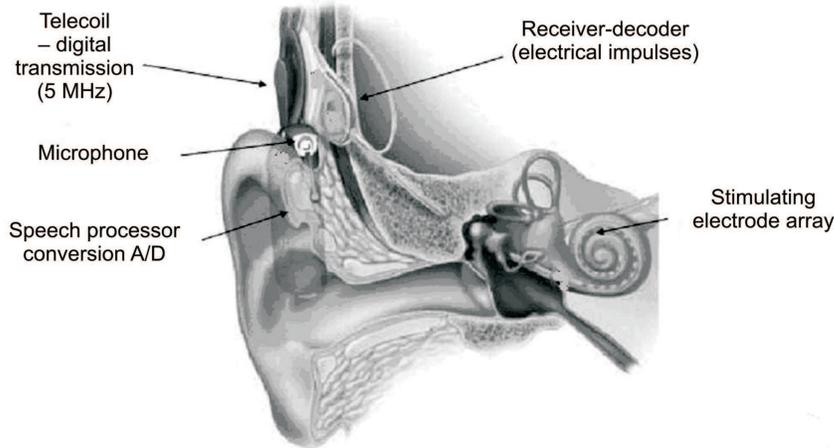


Fig. 1. Cochlear implant system – principle of operation [7].

Actually, one could say that the system described above is a specific type of a hearing aid. Its range of operation begins where compensation of the hearing deficit in the classical way ends, i.e. when the acoustic signal is amplified. A block diagram with a comparison of the operation of a cochlear implant and a hearing aid is presented in Fig. 2.

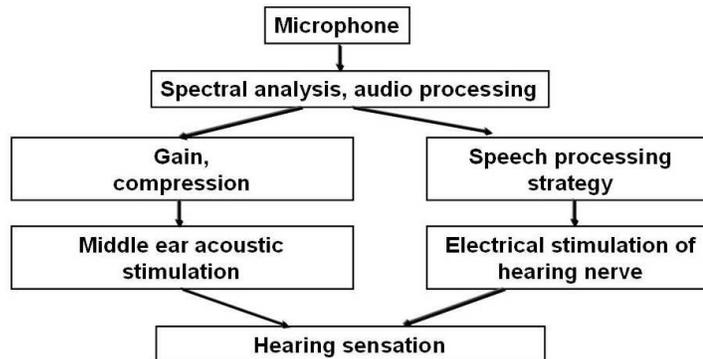


Fig. 2. Operation of a hearing aid and cochlear implant compared.

## 2. Patients

Only a few of the implanted patients of the Department of Otolaryngology, Poznań University of Medical Sciences, use a hearing aid on the opposite ear. This is interesting as the implant is placed in the ear with a greater hearing losses while the other ear retains some hearing capability permitting some (very limited) hearing. An audiogram (losses of the SKI-type) of one of the patients is presented in Fig. 3.

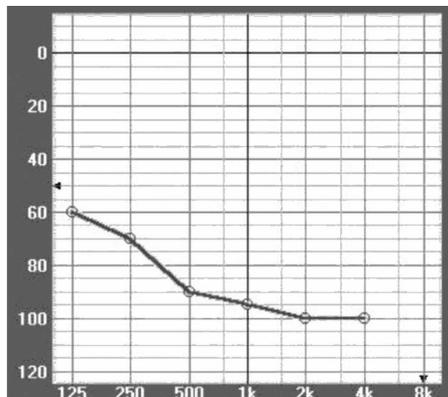


Fig. 3. Hearing threshold level in non-implanted ear in the pure tone audiometry [6].

The investigations of speech intelligibility were carried out for 9 patients with a cochlear implant, 1 male and 8 females, aged 18–69 (mean 41). In all cases deafness was recognized as postlingual. All patients were using the hearing aid on the ear opposite to the implant. The basic criterion used to qualify patients to a relevant group was open-set speech recognition. Most patients could freely talk over the phone and were very active in professional life. Some patients in the group studied took part in earlier investigations of the perception of the sound pitch by the hearing aid and the implant [8] and in the investigations of speech intelligibility based on Polish monosyllabic word tests [6].

## 3. Method

The authors attempted to find out the percentage of speech intelligibility on the basis of correctly repeated words occurring in the sentence. The signal was presented for azimuth  $0^\circ$  (in the head axis) and for the source at the angles of  $-90^\circ$  and  $+90^\circ$  in relation to the subject, for two cases – when the patients used the implant only (CI) and when they additionally used a hearing aid (CI+HA). Sentence tests were used, which were developed at the Institute of Acoustics, Adam Mickiewicz University, as part of the European Union project HEARCOM [9]. The speech signal was presented for the signal level of 65 dB SPL in quiet and noise conditions. In investigations under noise conditions the speech reception threshold value (SRT) was additionally determined. The

investigations were carried out in an isolated room, fulfilling the requirements for listening room (according to ISO 8253). Loudspeaker was located at the height of the subject's head at the distance of 1m. Madsen Midimate 622 clinical audiometer with a free field system and Svantec Svan 945 sonometer (system calibration) were used in the investigations.

#### 4. Results

The results of speech intelligibility for the different observation angles, when the signal was presented in the quiet conditions, are presented in Fig. 4, while Fig. 5 shows the results for the presentation in the noise conditions. SRT values are presented in Fig. 6 (letters in the figures correspond to the subjects' initials).

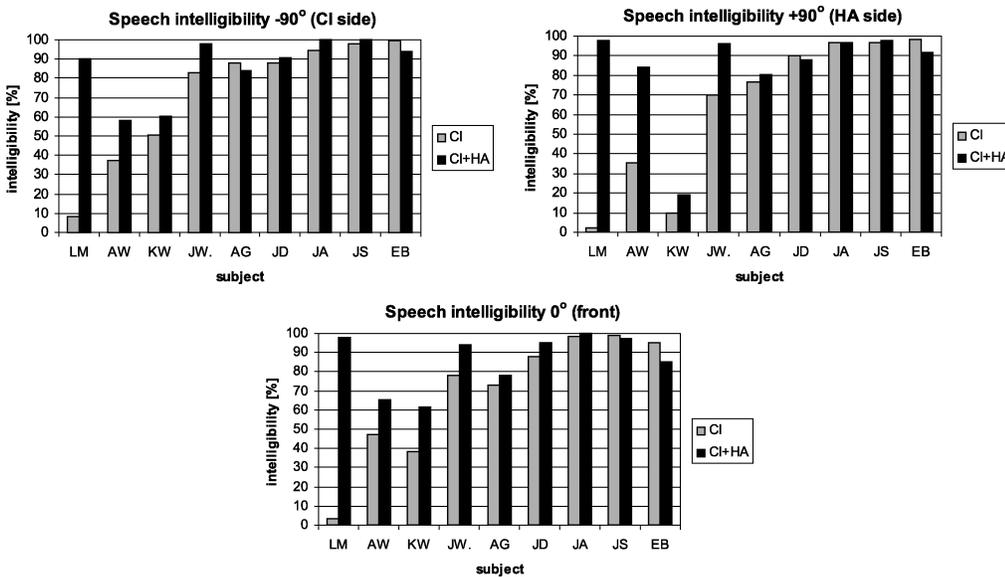


Fig. 4. Percentage of speech intelligibility when the signal is presented in quiet conditions.

The results of speech intelligibility in quiet conditions indicate a significant improvement of intelligibility when a hearing aid is used for the azimuth of 0 and +90 – opposite the subject and on the side of the hearing aid. A particularly high improvement was observed in the case of patients LM, AW, KW, JW – in pre-operative tests profound hearing loss was found in this group (HTL 90–100 dB HL) with the retained threshold in the entire frequency range (1000–4000 Hz). Except for patient LM, who heavily relies of the hearing aid, improvement of speech intelligibility in quiet conditions in this group is equal to 2–38%, the mean being 13%. The advantage of additional use of the hearing aid in noise conditions is particularly significant when the signal is presented opposite the subject. The improvement found was 3–34% (the mean being 17%), while

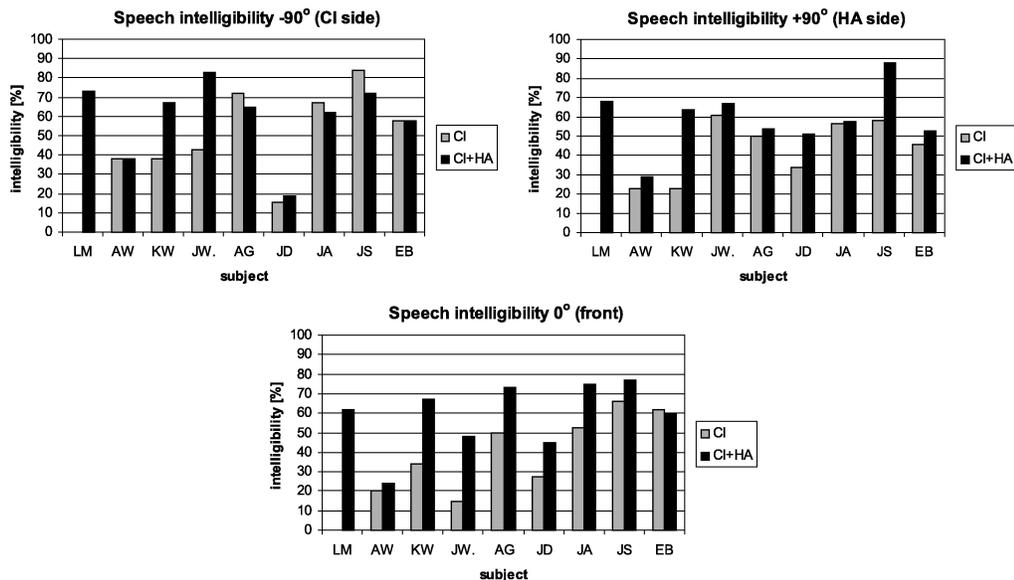


Fig. 5. Percentage of speech intelligibility when the signal is presented in noise conditions.

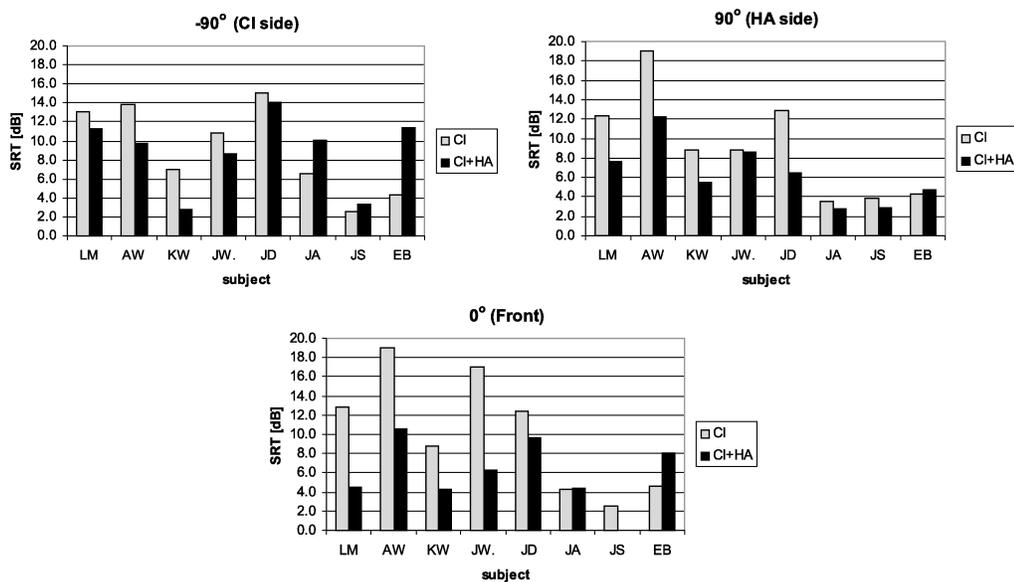


Fig. 6. SRT values.

in the case of patient LM use of the hearing aid permits her to understand speech in noise conditions. Presentation of the speech signal in noise conditions leads to a 19–52% drop in speech intelligibility, the highest when the signal is presented opposite the subject and on the hearing aid side – for these azimuths the greatest advantage from the use of the hearing aid was observed.

## 5. Conclusions

Acoustic compensation for the hearing remnants supports the process of electric hearing: it reduces the effect of the head shadow and improves the speech intelligibility ratio. The results of the speech perception in noise reveal a similar trend. It follows from the interviews conducted with the patients that the hearing aid also improves the perception of the prosodic features (melody) of speech and the possibilities of spatial localization. The results indicate significant problems, which are due to the co-existing masking signals (background noise, cocktail-party noise) in hearing impaired patients. The signal-noise ratio must be significantly higher in persons with normal hearing – SNR = –6 dB, SRT = 50%. When the hearing aid effectively supports the remaining hearing in implanted patients, their comfort of life and communication with other people are greatly improved.

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