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SPEECH PERCEPTION AND SOUND LOCALIZATION IN CI SUBJECTS WITH ELECTRIC-ACOUSTIC STIMULATION AND CONTRALATERAL NORMAL HEARING

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ABSTRACT

In unilateral deafness or unilateral partial deafness with contralateral normal hearing, the lack of ability to localize sound, decreased speech perception in noise, and increased hearing effort lead to the desire for cochlear implantation. The aim of the present study was to assess hearing abilities in subjects using electric-acoustic stimulation (EAS) with contralateral normal hearing.

16 subjects with EAS in the ipsilateral ear and normal hearing in the contralateral ear were implanted at our department. Speech reception thresholds (SRTs) in noise were assessed in different spatial noise conditions and for different noise characteristics with and without reverberation. Mean error in sound localization was measured with an LED pointer method.

Improved SRTs with EAS stimulation in simultaneous and spatially separated masker conditions were observed. In more diffuse noise conditions and in the presence of reverberation, no benefit on SRTs was found. Mean localization error using EAS was in the range of normal hearing listeners.

Even for patients with contralateral normal hearing, EAS can improve speech perception in noise and restore sound localization in everyday life. While sound localization abilities in the horizontal plane were comparable to normal hearing, SRTs were still worse than in normal hearing participants.

Keywords: *cochlear implant, electric-acoustic stimulation (EAS), unilateral normal hearing, speech perception in noise, sound localization.*

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1. INTRODUCTION

Cochlear implant (CI) users often perform well in speech perception under quiet conditions, but their ability to understand speech is notably diminished in the presence of background noise and/or reverberation. In addition, CI users oftentimes have difficulties with sound localization. Individuals with severe to profound high-frequency hearing loss and significant residual low-frequency hearing benefit from soft CI surgery with preserving the residual hearing and using combined electric-acoustic stimulation (EAS).

In the population of EAS subjects, a very rare subpopulation has normal or close to normal hearing in the contralateral ear (EAS-NH) and could, unlike bimodal or bilateral CI recipients, potentially benefit by binaural cues from interaural time differences. Only few studies were published on auditory performance of this population so far [1-3]. In particular, there is a lack of data on speech perception in everyday listening environments, which typically cannot be captured in clinical routine. Furthermore, sound localization performance was not compared with results of other groups of CI users so far.

The aim of this study was to investigate speech perception in noise in different listening conditions and to compare

sound localization abilities with normal hearing subjects and different groups of cochlear implantees.

2. MATERIAL AND METHODS

Experiments were conducted in an anechoic chamber (size: 4.1m x 2.6m x 2.1 m) equipped with a horizontal sound reproduction system with 128 loudspeakers (see [4] for further details on the sound reproduction system).

2.1 Participants

Six EAS-NH subjects (mean age 60±8.5 years) performed study tests. The pure-tone audiograms of the implanted ear measured at study visit are shown in Figure 1.

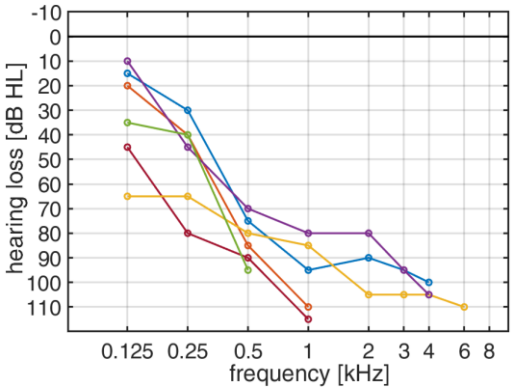

Figure 1. Pure-tone audiograms of the implanted ear measured at study visit (n=6).

2.2 Speech perception test in noise

Speech reception thresholds (SRTs) in noise were measured using the German Matrix Test (Oldenburg Sentence Test) for five different test conditions, which varied in (1) position of speech and noise and (2) in modulation characteristics of the noise:

- S0N30 continuous: speech from 0°, continuous noise at 30° towards the NH ear,
- S0N30 modulated: speech from 0°, modulated noise at 30° towards the NH ear,
- MSNF modulated: speech from 0°, modulated noise presented from 4 virtual noise sources (Multi-Source Noise Field, MSNF according to [5]),
- S-30N30 reverb continuous: speech from 30° towards the EAS ear, continuous noise at 30° towards the NH ear,
- S-30N30 reverb modulated: speech from 30° towards the EAS ear, modulated noise at 30° towards the NH ear.

Details on the technical realization of the room simulation for the conditions "reverb" are described in [6].
For the study, the individual clinical mapping of the EAS sound processors was used. Tests were conducted with EAS fitting ("EAS on" condition) and with deactivated acoustic component while occluding the ear (electric only, "EAS off" condition).
Results were compared to a group consisting of seven normal hearing (NH) subjects (mean age: 26.7±8.0 years)

2.3 Sound Localization

The sound localization test was carried out in the same anechoic chamber using the same sound reproduction system. Sound localization was assessed for seven frontal loudspeaker positions in the horizontal plane between ±60°. The stimuli consisted of five white noise bursts (according to [7]) presented at a level of 65 dB SPL. Test participants used a rotary encoder to indicate the perceived angle of the sound on a LED chain. The mean localization error was determined as the median error over all sound directions.

3. RESULTS

3.1 Speech perception in noise

SRT results for the EAS users with either EAS "on" or "off" compared with NH subjects were shown in Figure 2. SRTs in the EAS-NH group were significantly worse than in the NH group for all five test conditions ($p<0.001$).
SRTs in the EAS-NH group were improved by 0.7 dB (condition S0N30 in modulated noise) to 2.9 dB (condition S0N30 in continuous noise) when the acoustic component of the EAS processor was active.

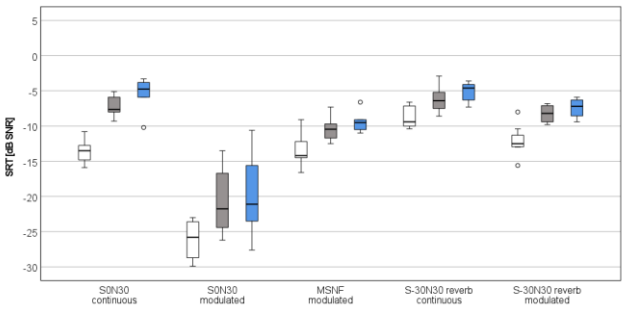

Figure 2. Speech reception thresholds (SRT) in five test conditions with different spatial conditions and

noise modulation characteristics for normal hearing (white boxes), EAS users with EAS on (grey boxes) and EAS off (electric only, blue boxes).

3.2 Sound localization

Mean localization error (MLE) in the EAS-NH group was 8.4°. MLE in the EAS-NH group was 6.1° worse than for subjects with normal hearing (MLE: 2.3°). However, localization performance of the EAS-NH group was 3.5° better than in bilateral CI users and even 10.1° better than in bimodal CI users with a hearing aid in the contralateral ear.

4. DISCUSSION AND CONCLUSION

A beneficial effect of acoustic hearing compared to the electric only condition on speech perception in different complex listening conditions and on sound localization was observed in EAS users with contralateral normal hearing. Sound localization results in the group of EAS-NH were superior compared to all other CI groups.

The results are in line with the results from a study in which greater subjective hearing benefits by using the EAS system compared to other CI groups were reported using a questionnaire [17]. Another study found significant improvements in speech perception in noise and in subjective hearing abilities in EAS-NH users within the first few months of EAS use compared to their preoperative performance [19].

Consequently, it is recommended that CI candidates with residual hearing undergo hearing preservation surgery to enable the use of EAS.

5. REFERENCES

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