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SPEECH INTELLIGIBILITY IN NOISE OF SINGLE-SIDED DEAF COCHLEAR IMPLANT USERS FOR NEAR AND DISTANT TALKERS

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ABSTRACT

People with single-sided deafness (SSD) encounter hearing problems particularly related to speech perception in noise. Among the different treatment options, only the cochlear implant (CI) allows for a (re)habilitation of binaural hearing. Various studies with SSD CI users have shown binaural benefits of CI in speech intelligibility in noise (SIN) for near target talkers including the summation effect, and benefits of the application of remote microphone technology in SIN for distant talkers both on group level.
The aim of this paper is to evaluate the relations between the speech intelligibility in quiet (SIQ) with the CI only and the benefit of a CI in SIN for near talkers on the one hand, and the benefit of remote microphone technology in SIN for distant talkers on the other hand, in adult SSD CI users. The analysis revealed that the SIQ with the CI only was positively correlated with the benefit of remote microphone technology in SIN for distant talkers, while it was not correlated with the benefit of a CI in SIN for near talkers.

Keywords: *cochlear implant, remote microphone, speech intelligibility, summation effect*

1. INTRODUCTION

People with single-sided deafness (SSD) have difficulty understanding speech in challenging listening situations, particularly in noisy environments [1,2]. According to [3], SSD is defined as having a four-frequency (0.5, 1.0, 2.0, and 4.0 kHz) pure-tone threshold average (4PTA) of at least 70 dB HL, i.e. a severe to profound hearing loss in the poorer ear, a 4PTA of at most 30 dB HL, i.e. normal or nearly-normal hearing (NH) in the better ear, and an interaural threshold gap of at least 40 dB HL. Treatment options for SSD include conventional contralateral routing of signal hearing aid, bone conduction device, and cochlear implant (CI). However, (re)habilitation of hearing in the poorer ear and restoration of binaural hearing can only be achieved with a CI.
Several studies have shown CI treatment of people with SSD to enable significant improvements of speech intelligibility in noise (SIN) when binaurally listening with the NH ear and the CI compared to monaural listening with the NH ear only. These studies investigated SIN for near target talkers, i.e. talker-to-listener distances of at most 1.5 meters, and revealed various binaural effects with CI, particularly head shadow and summation [4-7]. For bilateral CI users, the summation effect, which is assessed for frontal presentation of target speech in quiet or collocated noise, has been shown to relate negatively to the interaural asymmetry in SIN, i.e. the difference in monaural SIN between the better and poorer CI [8,9]. In SSD CI users, the summation effect may also be negatively related to the interaural asymmetry in monaural speech intelligibility (SI), i.e. the difference in SI between the NH ear and the CI, and positively related to the SI with the CI only. The first aim of this paper is to evaluate the relation between the binaural summation effect for speech in noise and the monaural speech performance in quiet with the CI in SSD CI users.
SI for distant talkers in multi-source noise environments with medium and higher noise levels such as frontal teaching in a noisy classroom is poor in unilateral, bimodal and bilateral CI users, and is significantly improved by the application of remote microphones (RMs) [10,11]. RMs pick-up the target speech with a high signal to noise ratio (SNR) and transmit it wirelessly to a receiver connected to or built in a hearing device, e.g. CI sound processor or hearing aid (HA). RMs have also been shown to improve

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SIN for distant talkers in multi-source classroom noise in SSD CI users, when used with the CI, NH ear or bilaterally [12]. In SSD CI users, the benefit of RMs, when used with the CI, in SIN may be positively related to the SIQ or SIN with the CI only, respectively. The second aim of this paper is to investigate this relation with regard to the monaural speech performance in quiet with the CI.

2. BENEFIT OF A COCHLEAR IMPLANT

2.1 Methods

To assess the relation between the summation effect with a CI for speech in noise and the monaural speech performance in quiet with the CI, the SIN data of the twelve adult subjects with SSD who participated in a prospective hearing device comparison study at our department and received a cochlear implant during this study [7] were analyzed. In this study, the summation effect was calculated as the difference in speech reception threshold (SRT) between listening in unaided condition preoperatively and binaural listening with the NH ear and CI at six months post activation, and this summation effect is referred to in the present paper. The SRTs were measured for presentation of sentences of the Oldenburg sentence test (OLSA, German matrix test) in collocated speech-shaped noise at 65 dB SPL from a frontal speaker one meter apart from the participants. The Freiburg monosyllabic word recognition score (WRS) in quiet obtained with the CI only at six months post activation within clinical routine was used to describe the monaural SIQ with the CI. To analyze the relation between the summation effect and the monaural SIQ with the CI, the Spearman's rank correlation coefficient is calculated.

2.2 Results

The twelve SSD CI participants showed median SRTs in speech-shaped noise of -4.7 dB SNR (-6.2 dB SNR – 3.1 dB SNR) preoperatively unaided and -5.8 dB SNR (-8.2 dB SNR – -4.7 dB SNR) binaural at six months post activation resulting in a significant median summation effect of 1.4 dB (0.2 dB – 2.8 dB; p = 0.013) [7]. At six months with CI, their median monaural WRSs were 100% (90% – 100%) with the NH ear and 25% (0% – 40%) with the CI resulting in a median interaural difference in monaural WRS of 72.5% (60% – 90%). Figure 1 presents a scatterplot of the individual summation effects versus the individual monaural WRSs with the CI. Between these measures, there was no significant correlation (p = 0.615).

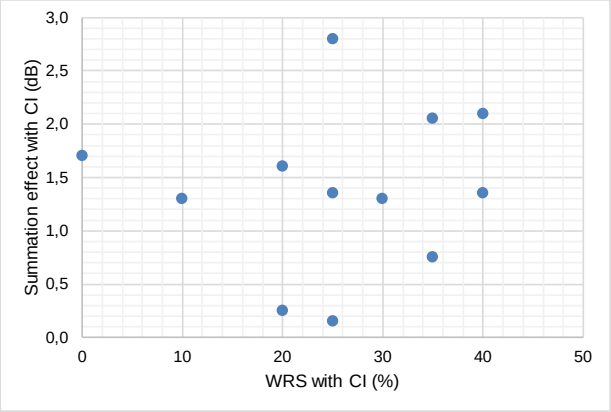

Figure 1. Scatterplot of summation effect versus monaural word recognition score (WRS) with CI.

2.3 Discussion

Contrary to our expectation, there was no significant correlation between the binaural summation effect with the CI for speech in noise and the monaural SIQ with the CI in the twelve SSD CI participants. The missing correlation might be due to the application of a speech in quiet instead of a speech in noise measure to assess the monaural speech performance with the CI, and/or the small sample size and thus low statistical analysis power. Therefore, future studies should include more SSD CI users and use speech in noise measures for both the summation effect and the monaural speech performance to investigate the relation between these measures.

3. BENEFIT OF A REMOTE MICROPHONE

3.1 Methods

The relation between the benefit of a RM in speech performance in noise and speech performance in quiet with the CI is assessed using the SIQ and SIN data of the eleven adult SSD CI users who participated in a prospective remote microphone technology study at our department [12]. In this study, the participants had a CI experience of ten to 122 months at the time of testing. For monaural listening with the NH ear as well as binaural listening with the NH ear and the CI (condition NH+CI), and, amongst other RM conditions, for binaural listening with the NH ear and the CI with a RM (transmitter Roger Pen, receiver Roger X; Phonak AG, Stäfa, Switzerland) connected with the CI (NH+CI/RM), the speech recognition score (SRS) for presentation of OLSA sentences from a loudspeaker 5.5 meters in front of the participants in a multi-source

classroom noise established by Schafer and Thibodeau [13] was measured. At the position of the participants, the speech level was 60.3 dB(A) and the noise level was 65 dB(A) yielding an SNR of -4.7 dB.
For each participant, the benefit of the RM used with the CI, is calculated as the difference in speech recognition score (SRS) between the NH+CI/RM and NH+CI listening conditions. The present paper refers to this RM benefit and to the Freiburg monosyllabic WRS with the CI only obtained at the time of testing in this study, and the Spearman's rank correlation coefficient is calculated to analyze the relation between these measures.

3.2 Results

In multi-source classroom noise, the eleven SSD CI participants yielded median SRSs of 16.0% (0.7% – 39.3%) with the NH ear, 18.0% (4.0% – 36.7%) in the NH+CI condition, and 87.3% (27.3% – 95.3%) in the NH+CI/RM condition. Compared to binaural listening with the NH ear and CI, binaural listening and using a RM with the CI enabled a significant median improvement in SRS, i.e. a significant median benefit of the RM of 57.3% (16.0% – 91.3%). At the time of testing, the participants' median monaural WRS with the CI was 55% (50% – 95%). A scatterplot of the individual benefits of the RM used with the CI versus the individual monaural WRSs with the CI is illustrated in Figure 2. The rank correlation analysis revealed a significant positive correlation between these measures (*rho* = 0.5456, *p* = 0.082).

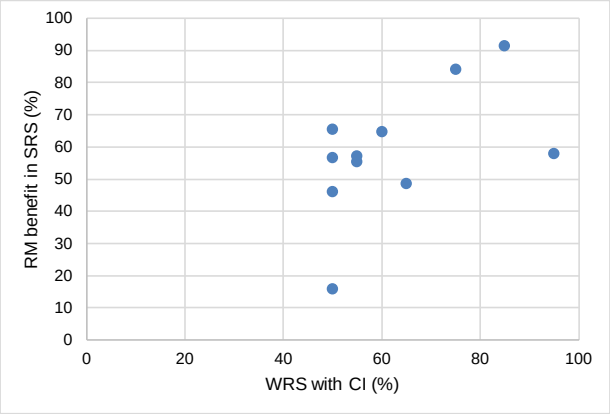

Figure 2. Scatterplot of benefit of a remote microphone (RM) used with CI in speech recognition score (SRS) versus monaural word recognition score (WRS) with CI.

3.3 Discussion

According to our expectation, there was a significant positive correlation between the benefit of the remote microphone (transmitter Roger Pen, receiver Roger X) used with the CI in SIN for a frontal talker in a multi-source noise classroom environment and the SIQ with the CI only in the eleven SSD CI participants. This result suggests that SSD CI users showing a good monaural SIQ with the CI should use RMs with the receiver attached to their CI, while SSD CI users with poor SIQ with the CI only should use RMs with the receiver Roger Focus attached to their NH ear, to obtain a considerable improvement in speech performance for distant talkers in multisource-noise environments. The benefit of the RM in SIN assessed in the eleven SSD CI users in the remote microphone technology study [12] is due to the improvement of the SNR of the target speech at the listener's position, which is based on both overcoming the spatial decay of target speech-level over the distance between the talker and the listener and the application of an adaptive beamformer in the RM transmitter. However, the contributions of both effects were not investigated separately in this study, and thus cannot be disentangled.

4. REFERENCES

[1] T. G. Giolas, D. J. Wark: "Communication problems associated with unilateral hearing loss", *Journal of Speech and Hearing Disorders*, 32(4), pp. 336-343, 1967.

[2] O. B. Wie, A. H. Pripp, O. Tvete: "Unilateral deafness in adults: effects on communication and social interaction", *Annals of Otology, Rhinology and Laryngology*, 119(11), pp. 772-781, 2010.

[3] P. Van de Heyning, D. Távora-Vieira, G. Mertens, V. Van Rompaey, G. P. Rajan, J. Müller, et al.: "Towards a Unified Testing Framework for Single-Sided Deafness Studies: A Consensus Paper", *Audiology and Neurotology*, 21(6), pp. 391-398, 2016.

[4] S. Arndt, R. Laszig, A. Aschendorff, F. Hassepass, R. Beck, T. Wesarg: "Cochlear implant treatment of patients with single-sided deafness or asymmetric hearing loss", *HNO*, 65(Suppl 2), pp. 98-108, 2017.

[5] G. Mertens, M. De Bodt, P. Van de Heyning: "Evaluation of long-term cochlear implant use in subjects with acquired unilateral profound hearing

loss: focus on binaural auditory outcomes", *Ear and Hearing*, 38(1), pp. 117-125, 2017.

[6] J. P. M. Peters, J. A. A. van Heteren, A. W. Wendrich, G. A. van Zanten, W. Grolman, R. J. Stokroos, et al.: "Short-term outcomes of cochlear implantation for single-sided deafness compared to bone conduction devices and contralateral routing of sound hearing aids-Results of a Randomised controlled trial (CINGLE-trial)", *PLoS One*, 16(10), e0257447, 2021.

[7] T. Wesarg, I. Kuntz, L. Jung, K. Wiebe, R. Schatzer, S. Brill, et al.: "Masked Speech Perception with Bone Conduction Device, Contralateral Routing of Signals Hearing Aid, and Cochlear Implant Use in Adults with Single-Sided Deafness: A Prospective Hearing Device Comparison using a Unified Testing Framework", *Audiology and Neurotology*, 29(4), pp. 271-289, 2024.

[8] R. Litovsky, A. Parkinson, J. Arcaroli, C. Sammeth: "Simultaneous bilateral cochlear implantation in adults: a multicenter clinical study", *Ear and Hearing*, 27(6), pp. 714-731, 2006.

[9] Y. S. Yoon, Y. Li, H. Y. Kang, Q. J. Fu: "The relationship between binaural benefit and difference in unilateral speech recognition performance for bilateral cochlear implant users", *International Journal of Audiology*, 50(8), pp. 554-565, 2011.

[10] J. Wolfe, E. Schafer, A. Parkinson, A. John, M. Hudson, J. Wheeler, et al.: "Effects of input processing and type of personal frequency modulation system on speech-recognition performance of adults with cochlear implants", *Journal of the American Academy of Audiol*ogy, 26(6), pp. 532-539, 2015.

[11] G. De Ceulaer, D. Pascoal, F. Vanpoucke, P. J. Govaerts: "The use of cochlear's SCAN and wireless microphones to improve speech understanding in noise with the Nucleus6® CP900 processor", *International Journal of Audiology*, 56(11), pp.837-843, 2017.

[12] T. Wesarg, Y. Stelzig, D. Hilgert-Becker, B. Kathage, K. Wiebe, A. Aschendorff, et al.: "Application of Digital Remote Wireless Microphone Technology in Single-Sided Deaf Cochlear Implant Recipients", *Journal of the American Academy of Audiology*, 31(4), pp. 246-256, 2020.

[13] E. C. Schafer, L. M. Thibodeau: "Speech recognition in noise in children with cochlear implants while listening in bilateral, bimodal, and FM system arrangements", *American Journal of Audiology*, 15(02), pp. 114-126, 2006.