Speech perception and localization in seniors

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Introduction

In common with other countries, there is a dramatic shift in the population pyramid in Germany. Firstly, the overall population decreases. Secondly, the number of younger people decreases whereas the population of older people increases. Furthermore, life span (today's mean: 80 yrs) constantly increases. Estimation for life span for the year of birth of 2030 is 83.5 yrs. This shift toward an older population has major implications for the economy and society in general.

Proper hearing abilities are important for the elderly to ensure adequate participation in social activities. A hearing impairment due to presbycusis oftentimes begins in the 5th or 6th decade of life. Speech perception in quiet is usually not as much degraded as speech perception in noisy environments. It has to be considered that with growing age also the degree of the hearing loss is increased due to the progressiveness of age related hearing loss. With higher age the other senses also slow-down. A lack of directional hearing combined with declined balance proficiency leads to impaired stance and gait of the elderly. In conclusion, quality of life for an increasing population of seniors is severely deteriorated due to impairment of the auditory and vestibular system.

In the past decades, the provision of hearing aids (HA) was the first choice to overcome presbycusis to a certain extent. However, recent studies reveal only inadequate provision and benefit of hearing aids for the elderly. The aim of the present study is to obtain an overview and a comparison of the provision with HAs and cochlear implants (CIs) in the elderly in Germany.

Material and Methods

Subjects

Forty subjects which considered themselves as hearing normal between 60.1 and 89.7 years (mean age: 69.3±7.1 years) took part in the study. Twelve were male and 28 subjects were female. Additionally, 40 subjects between 66.4 and 88.1 years (22 male, 18 female) wearing hearing aids (mean age: 76.3±4.7 years) were test. The third group were 57 CI patients aged between 61.2 and 88.5 years (mean age: 72.1±6.5 years, 38 male, 19 female). 38 were bimodal CI users, 15 bilateral, 4 unilateral.

Screening for dementia

Indication of a potential dementia was assessed by the DemTect test [1]. Five tasks were included in the DemTect: a word list, a number transcoding task, a word fluency task, digit span reverse, and delayed recall of the word list. The DemTect is short (8-10 minutes), easy to administer, and its transformed total score (maximum 18) is independent of age and education. The DemTect helps in deciding whether cognitive performance is adequate for age (13-18 points), or whether mild cognitive impairment (9-12 points) or dementia (8 points or below) should be suspected.

Speech perception in quiet

The Freiburg numbers and monosyllables tests were conducted in a soundproof room at our department. Unaided speech scores were measured in all subject groups with calibrated headphones and monosyllable presentation levels of 60 dB, 65 dB, 80 dB and 100 dB. In addition, the speech score in the aided groups were tested in free field condition with either hearing aids or cochlear implant at 65 dB presentation level.

Speech perception in noise

To assess speech perception in a more realistic scenario, additional speech tests with different types of noise were conducted with a multichannel setup (128 loudspeakers) in an anechoic chamber [2]. The loudspeaker array was of rectangular shape in the horizontal plane and was installed at the height of the listener's ears (see Figure 1). This system is capable to produce stimuli at discrete loudspeaker positions and at arbitrary positions inside the listening room by means of wave field synthesis (WFS, [3]).

The speech reception threshold (SRT) in background noise was assessed in a customized version of the 'Oldenburg Sentence Test' (OLSA, [4]). The noise level was fixed to 65 dB SPL and the speech level was set adaptively according to the number of words perceived correctly.

Two different loudspeaker configurations and two different noise characteristics (continuous and amplitude modulated) were applied. The different configurations were necessary to investigate the benefit of either binaural interaction or the potential improvement obtained from listening into short temporal masker gaps. To become familiar with the task, an initial training was conducted with all subjects. Afterwards, the SRT was measured for every participant and each of the following two conditions (Figure 1):

1. S0N0: speech S and N were presented from front (0°)
2. Virtual Multi-Source Noise Field (V-MSNF):
   - Speech was presented from front 0°
   - 4 spatially and temporally decorrelated noise sources as proposed by Rader et al. [5]. Noise sources were focused sources rendered via wave field synthesis.

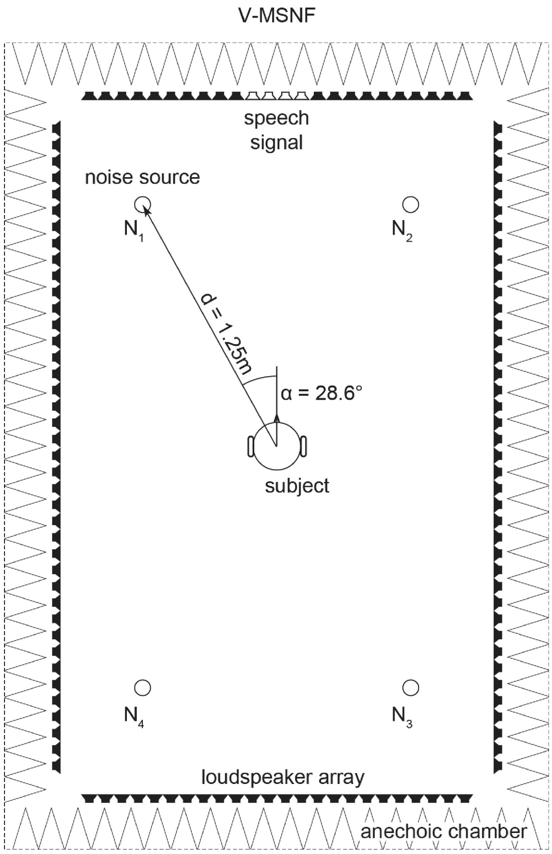

Figure 1: Measurement conditions of speech perception in Noise. S_0N_0: speech and noise were presented from front; V-MSNF: speech presented from front, 4 spatially and temporally decorrelated noise sources $N_{1\text{-}4}$ created with WFS.

Localization

Individual auditory localization ability was assessed in the horizontal plane for 7 different angles between 300° and 60° (front) and 7 different angles between 120° and 240° (back). 5 noise bursts of white noise (according to [6]) were presented from one loudspeaker and the patient's task was to indicate the perceived direction of the sound with a LED pointer method. All test angles were presented 5 times to assess localization accuracy and also localization uncertainty. The presentation order of the playback angles was randomized. The localization task was conducted in best-aided condition in complete darkness.

Results and Discussion

Screening for dementia

The DemTect scores of the three different subject groups are shown in Figure 2. Results were analysed by a one-way ANOVA. No significant difference between subject groups was found. Only one subject of the HA group and one subject of the CI group scored below 9 points. However, 35% of the control group, 31% in HA and 34% in CI group showed signs of a mild cognitive impairment.

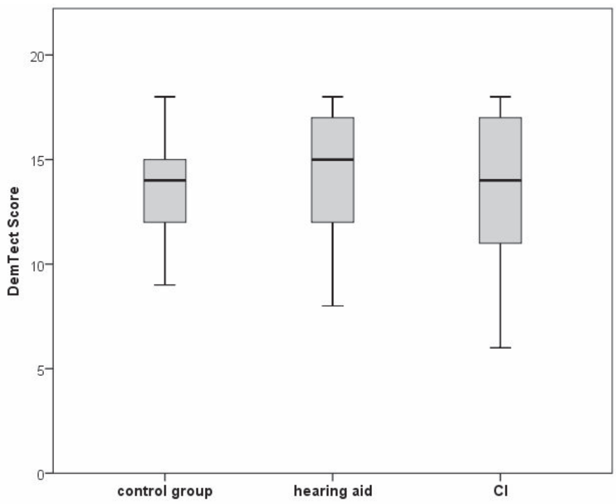

Figure 2: Comparison of DemTect score in control group, hearing aid, and CI group.

Speech perception in quiet

Mean monosyllable scores in the control group averaged across all ears depending on presentation level (headphone measurements) were in the control group: 60 dB: 79.9% ± 21.3%, 65 dB: 89.6% ± 19.4%, 80 dB: 97.1% ± 8.3%, 100 dB: 98.8% ± 4.6%.

At 60 dB presentation level, a comparably poor average performance was observed as well as a large SD (21.3%). A closer look at the frequency of certain speech score levels revealed that at the poorer performing ear only 50% of all subjects did gain a score of at least 80%. At 65 dB speech level, this number decreased down to 17% of all subjects. This indicated that some control group subjects suffered presumably without their own notice from an asymmetric hearing loss. Nearly one fifth of the subjects of the control group were candidates for the provision of a hearing aid at least in one ear.

Speech perception in noise

Results of speech perception in noise are shown in Figure 3.

S_0N_0 condition

A Tukey post-hoc test showed significant difference between control group and both hearing impaired groups in continuous noise (HA group: 2.8 dB difference, $p<0.001$; CI group: 3.6 dB difference, $p<0.001$). No significant difference between HA and CI group was found.

In modulated noise, average SRT in the aided groups showed a massive deterioration compared to the control group (HA group: 7.7 dB difference to control group, $p<0.001$; CI group: 12.7 dB difference to control group, $p<0.001$). Although speech perception in quiet was found nearly at the same level in the aided groups, the average SRT measured in the CI group was found 5 dB poorer (higher) compared to the HA group ($p<0.001$).

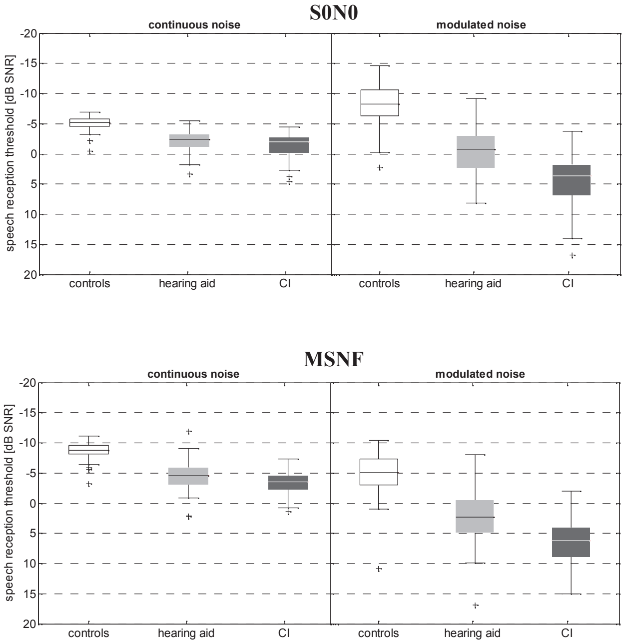

Figure 3: Mean speech reception threshold (SRT) for two test conditions S_0N_0 (upper) and MSNF (lower) in continuous and modulated noise. Noise level was fixed to 65 dB SPL. Hearing aid and CI groups were tested with everyday fitting (moderate fixed directionality to the front in CI group).

MSNF condition

In continuous noise, a significant decrease of performance was found in both aided groups compared to the control group data (HA group: 4.2 dB difference to control, $p<0.001$; CI group: 5.4 dB difference to control, $p<0.001$). Both hearing impaired groups performed at the same poorer level ($p=0.058$).

In modulated noise, a large decrease of performance (increase in terms of SRT) was found in both aided groups compared to control group data (HA group: 7.2 dB difference to control, $p<0.001$; CI group: 11.4 dB difference to control, $p<0.001$). A more pronounced shift of the average speech reception threshold was found in the CI group data compared to the HA group (difference between CI and HA group 4.2 dB, $p<0.001$).

Localization

Mean amount of front/back confusion is shown in Figure 4. There was a significant difference between subject groups ($p<0.001$). A post-hoc Tukey test revealed significant differences between control group and both hearing impaired groups ($p<0.001$). The amount of front/back confusions in the hearing impaired groups was about 50% and, thus, reached chance level.

Mean relative localization error was 7.1° in the control group, 15.5° in the HA group, and 18.0° in the CI group. There was a significant difference between subject groups ($p<0.001$). A post-hoc Tukey test revealed significant difference between control group and both hearing impaired groups ($p<0.001$). However, due to the high variation, no significant difference between HA and CI group was found. Mean localization error in the bimodal group (19.9°, N=23) was 6° worse than the bilateral group (13.3°, N=12).

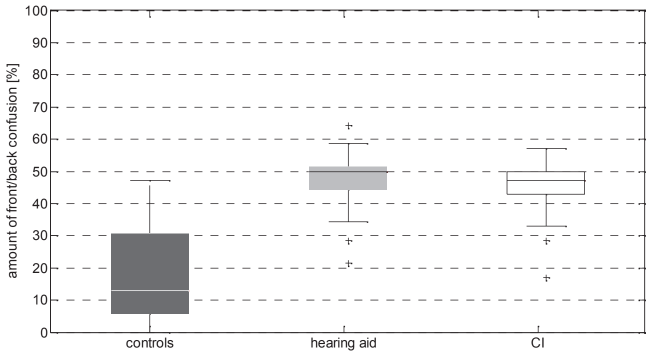

Figure 4: Mean amount of front/back confusion [%] in control (N=40), HA (N=40), and CI (N=35) group. Subjects of the HA and CI groups were tested in best aided condition.

Summary and Conclusion

Interestingly, a high amount of considerable hearing disability was discovered in control subjects, which regarded their hearing as normal. About 20% of the control group had the indication for the provision of a hearing aid at least in one ear. The here investigated aged control group showed degraded SRTs in all conditions compared with a younger control group. Especially SRTs in modulated speech were increased. Localization accuracy was also decreased compared with a young control group.

In terms of cognitive skills (screening for dementia, short-term memory span) the range of performance in the CI senior group was equal to the control and HA groups.

Accuracy of auditory localization in terms of mean error was also comparable between HA and CI groups. Likewise, both aided groups showed nearly equal mean SRTs in continuous noise. However, in more realistic noise conditions as reflected by temporal modulations of the masker the CI group still shows more degradation.

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