Comparing Speech intelligibility in quiet and in noise using different CI-speech-processors and signal pre-processing

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The effect of the speech processor "Freedom" on speech perception is analyzed in this study at two Cochlear Implant centres in Kiel and Erlangen by upgrading speech processors for CI24-users. Speech audiometric tests are carried out to compare the performance using the Freedom processor with the previously used SPRINT, ESPRIT24 and ESPRIT3G.

Comparing the formerly used speech processors with the new Freedom processor and focusing on features which might influence speech intelligibility there are only in the Freedom the speech coding strategies SPEAK, CIS, ACE available together with all signal pre-processing algorithms WHISPER, ADRO and BEAM.

In our study 30 cochlear implant patients from Kiel and 10 from Erlangen took part, aged from 5 to 79 years with a median of 44 years. Two patients were bilaterally implanted. They were all experienced CI-users with an average using time of 6 ± 2.6 years (from 21 months up to 10 years). 24 subjects were provided with a SPRINT and 18 of them used the signal pre-processing ADRO, 16 used the behind the ear wearable speech processor ESPRIT3G, two of these used WHISPER. And only one patient used the rather old processor ESPRIT24 with SPEAK. The vast majority of 35 systems run at the stimulation rate of 1200 Hz (250 Hz, 720 Hz and 900 Hz: two patients, 1800 Hz : one patient).

We carried our study out as follows: At first speech audiometric tests were done using the old system with the patients preferred settings. Then, this map is upgraded by the fitting software including changes of gain and the frequency allocation table. After a 2 to 3 weeks period of home usage we repeat the same speech audiometric tests with the new Freedom processor, without pre-processing and with the signal pre-processing algorithms ADRO and BEAM applying the patient's preferred settings.

We applied the Fribourg speech intelligibility test in quiet and the Oldenburg sentence (OLSA) test in noise. Every sentence of this test with fixed syntax consists of 5 words which are randomly selected. To overcome the known learning effect the patients were trained on this test before this investigation started and before every test session they hear at least one test list in quiet.

The effect of the selected input sensitivity and the input dynamic range of the speech processor is determined measuring the threshold (L_{50}) with the Fribourg number test. The Fribourg monosyllable test is performed twice for each presentation level of 50 dB and 70 dB in quiet [Fig. 1].

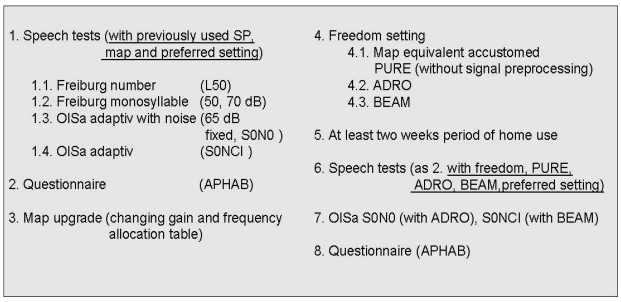


Fig. 1: study protocol

The speech reception threshold in noise is determined using an adaptive procedure with the OLSA. The noise level is fixed at 65 dB and the signal level is varied. Two different set ups were used for signal presentation. Either signal and noise are delivered from the front (S_0N_0) or the signal comes from the front and the noise perpendicular from the CI side (S_0N_{CI}).

Additionally, the subjective benefit using the different speech processors is determined applying the APHAB (Abbreviated Profile of Hearing Aid Benefit) questionnaire at test time. This is a 24-item self-assessment inventory in which patients report the amount of trouble they are having with communication or noises in various everyday situations. It produces scores for 4 subscales: Ease of communication, reverberation, background noise, and aversiveness.

The patient gets equivalent to his accustomed map three upgraded maps within the Freedom speech processor: One without pre-processing, marked as "PURE", one with the ADRO and one with the BEAM pre-processing. We compare the speech reception threshold for the PURE-map with ADRO for the SoNo-placement and with BEAM for the SoNci-placement.

The subjective benefit using the CI systems is compared applying the APHAB (Abbreviated Profile of Hearing Aid Benefit) questionnaire. Although nearly all patients found the new system substantially better, this questionnaire does not seem to be a suitable tool to analyze this. In all 4 subscales were no differences detectable.

When we compare speech reception thresholds, we find a significant decline of threshold using the upgraded Freedom speech processor of 5.7 ± 5.0 dB, measured without any pre-processing, probably according to the extended input dynamic range.

Applying the Fribourg monosyllable word test we tested the PURE map and the ADRO map against the

formerly used map discounting whether the patient used signal pre-processing or not [Fig.2].

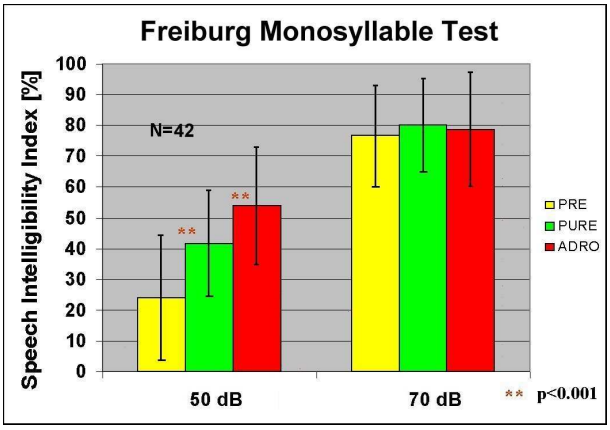


Fig. 2: Speech test in quiet

The upgraded pure map shows a highly significant increase of the mean speech intelligibility from 24 ± 20 % to 42 ±17 % with the Freedom in soft speak and is furthermore increased with ADRO to 54 ± 19 % (Wilcoxon pair test, p<0.001). These differences are higher than the test-retest difference of 9 ± 9 %. At the loud speech level the old and the upgraded systems are not distinguishable. Significant differences could not be expected because of ceiling effects.

But if we consider only those patients who were accustomed to maps without pre-processing in the old speech processors, we can find an improvement of nearly 25 ± 18% in speech intelligibility at 50 dB and an improvement of 6 ±18% at 70 dB too (Wilcoxon pair test, p<0.001).

Comparing the differences of speech intelligibility indexes with the differences of speech reception thresholds in pre and post speech processor upgrade measurements, only a weak correlation (R^2=0.55) was found.

One of the patients, who showed an impairment of speech intelligibility index, rejected the new system after the home use. But nevertheless he had an improvement in noise.

In noise with the SoNo setting there was a highly significant SRT improvement of -3.0 ± 6.1 dB with the Freedom speech processor. Using ADRO the improvement was even slightly higher (-4.0 ± 3.0 dB). This differences are significant (Wilcoxon pair test, p<0.001).

The most considerable improvement of SRT we found when using BEAM pre-processing in the SoNci placement in our test booth. The SRT gains -6.3 ± 6.5 dB and this is very highly significant (Wilcoxon pair test, p<0.001) [Fig. 3].

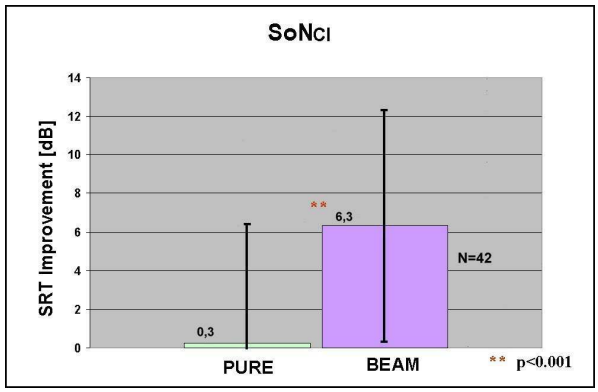


Fig. 3: Oldenburg sentence test in noise. Measurements with PURE maps in SoNCI placement were done only with 34 patients

Summary

All but one of the patients preferred the Freedom system and wanted to keep it.

The APHAB questionnaire is inadequate to analyze their subjective benefit.

Speech intelligibility in soft speak is highly significantly improved, probably by the increased input dynamic range and is furthermore enhanced by the use of ADRO pre-processing.

Speech intelligibility is highly significantly improved even without pre-processing when speech and noise come from the same direction.

Pre-processing algorithm BEAM gives a very remarkable improvement in a rectangular placement of signal and noise sources.

1. Speech tests (with previously used SP, map and preferred setting)
   - 1.1. Freiburg number (L50)
   - 1.2. Freiburg monosyllable (50, 70 dB)
   - 1.3. OlSa adaptiv with noise (65 dB fixed, S0N0)
   - 1.4. OlSa adaptiv (S0NCI)
2. Questionnaire (APHAB)
3. Map upgrade (changing gain and frequency allocation table)
4. Freedom setting
   - 4.1. Map equivalent accustomed PURE (without signal preprocessing)
   - 4.2. ADRO
   - 4.3. BEAM
5. At least two weeks period of home use
6. Speech tests (as 2. with freedom, PURE, ADRO, BEAM, preferred setting)
7. OlSa S0N0 (with ADRO), S0NCI (with BEAM)
8. Questionnaire (APHAB)

Fig. 1: study protocol

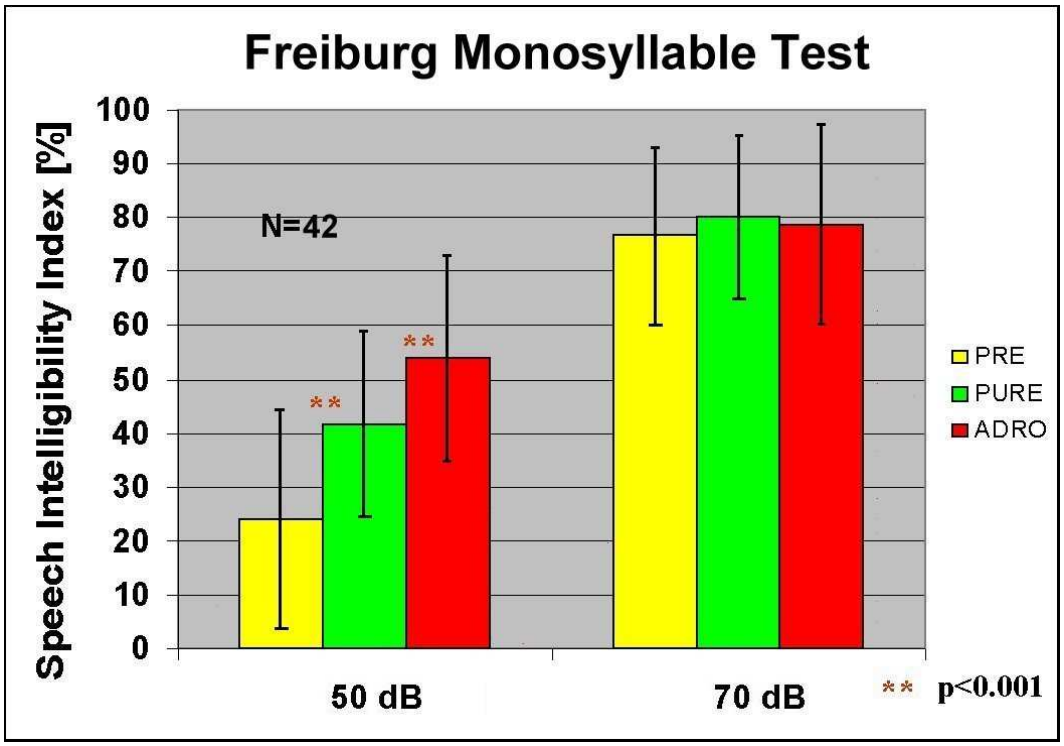
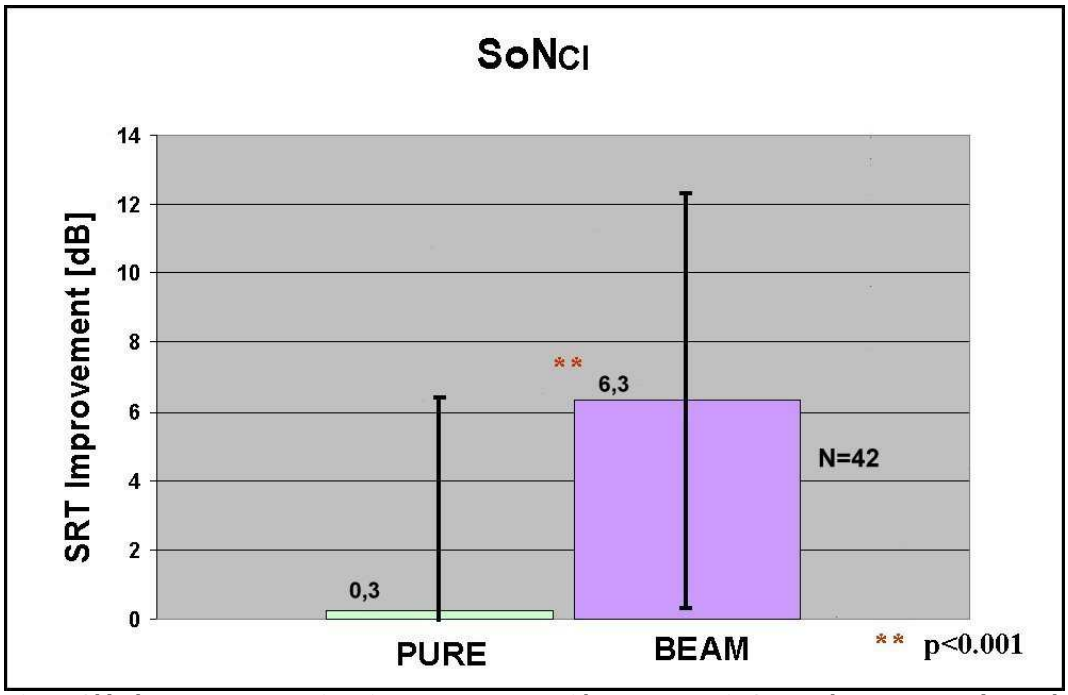


Fig. 2: Speech test in quiet



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