Influence of the mixing ratio of a FM-system on speech understanding in noise for CI users

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Introduction

Hearing in noise is one of the most important challenges in everyday life for cochlear implant users. In a simple model we have two signal sources in a classroom: Teacher in front of a listener and pupils around him. During interactive lessons we may find two major acoustical situations: first the teacher is talking being disturbed by the pupils making noise and second another pupil is talking being disturbed by the other pupils.

Understanding of a speaker in noise can be improved by using a FM system. A FM system consists of a FM transmitter, worn by the teacher, and the patient's FM receiver device of the speech processor. The FM system shall minimize spatial distance and improve thereby signal to noise ratio. Aim of this study is to test the optimal speech understanding in noise depending on the mixing ratio between FM signal input and microphone signal input to the CI-processor for different listening conditions.

Methods

The acoustical situation and listening conditions in a classroom were simplified by an audiological setup in a sound insulated booth. Using two loudspeakers we simulated the acoustical situation of a pupil equipped with a FM system, sitting in front of a teacher producing the "signal" and among other pupils making "noise" (S0N90, see Fig. 1). Two situations were investigated: (cond 1) Teacher is using the FM system and the surrounding pupils making noise and (cond 2) one pupil in the classroom is speaking disturbed by the others around him. The FM mixing ratio was varied in both conditions from 1:1 up to 5:1 (FM: microphone). Speech understanding without FM system was also tested as individual standardization.

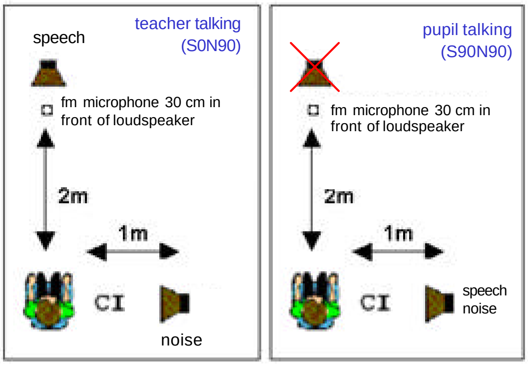

Fig. 1: Audiological setup for the condition „teacher talking" (left) and „pupil talking"(right).

Speech understanding was evaluated using the adaptive Oldenburger sentence test (OLSA) in noise (Wagener et al. 1999; Brand et al. 2004). All patients had to reach a minimal score in OLSA to participate the study: first, v = 80% correct in Oldenburger sentence test in quiet (S0, 1 m, 70 dB SPL) and second, L50 < 5 dB in noise (S0N0 1 m, noise 65 dB, adaptive procedure).

13 adult postlingually deafened CI patients with a good training in speech tests were tested, using unilateral a Freedom cochlear implant system (Cochlear Ltd). The FM system „Microlink for Freedom" together with Campus transmitter (Phonak AG) were used. CI-patients had an experience time of more than 1 month. A group of 7 normally hearing adults was examined in the same setup as controls to get the relation for other pupils in a classroom.

Results

Fig. 2 (left panel) shows the individual data of the CI-patients without FM-system. The mean value of L50 = 0,2 dB for CI patients compared to L50 = -14 dB for normally hearing subjects. In the middle of Fig. 2 shows the L50 in condition S0N90 (teacher talking).

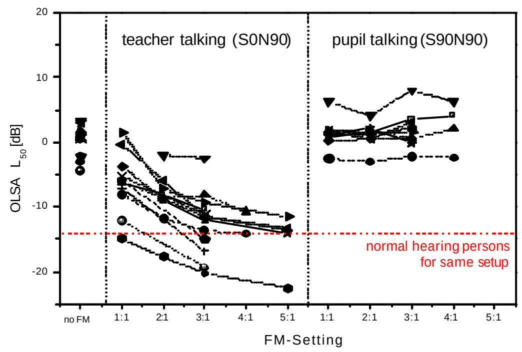

Fig. 2: Individual data of speech understanding in noise (L_{50} of OLSA, 65 dB noise, signal adaptive) without (left) and with FM system (middle and right) depending on the mixing ratio.

The results of L50 in noise decreased with increasing mixing ratio, showing increased understanding. Regarding mean values, the benefits using the FM system is high significant for all tested mixing ratios (Fig. 3, middle panel).

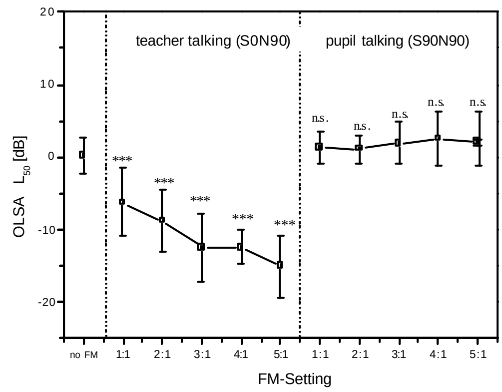

*Fig. 3: Means and standard deviations of speech understanding in noise (L_{50} of OLSA, 65 dB noise, signal adaptive) without (left panal) and with FM system (middle and right panal) depending on the mixing ratio; comparison of results with FM-system and different mixing ratios with the result for "no FM" using the paired t-test (*** $p<0,001$, n.s. $p>0,1$).*

The difference between the situation without and with FM-system is 12 dB for mixing ratio 3:1. If we take into account a steepness of 15 % per dB of the OLSA sentence test in CI patients (Hey et al. 2004) the result of 12 dB would mean a calculated advantage of 180 %.

In contrast speech understanding during the second condition ("pupil talking") remained nearly stable in all used mixing ratios (Fig. 2, right panel). The calculations showed no statistical differences between the situation without and with FM system.

Discussion

There are different studies on speech understanding in noise using a FM-system (Flynn et al. 2000; Mora Espino et al. 2007; Schafer und Thibodeau 2006). They all showed a benefit in patients by introducing a FM-system. This is in general accordance with the actual findings. It should be mentioned that we tested in this study a distance of only 2 m to the teacher. In practice we find greater distances yielding to a greater benefit for CI-patients.

In this study it was also investigated the reverse situation when a pupil is answering the teacher. The non-significant loss of speech understanding to neighbouring speakers was independent on the mixing ratio, an unexpected result when planning the study. This finding also encourages the use of FM-systems in a classroom.

We find a great interindividual variation in results with FM system. The most apparent interpretation is that there is no prediction for the actual benefit for the situation with FM system from the "no FM" result possible. But all Patients in the study show an increased speech understanding in noise.

The understanding of speakers for the two investigated listening conditions showed different directions. Understanding for "teacher talking" increased with increasing mixing ratio and for "pupil talking" remains on the same level. We could not find an optimal combination of both listening conditions. This may lead to different suggestions for different listening conditions. A choice for a classroom may be a mixing ratio of 1:1 up to 3:1 depending on the individual requirements and the acoustics. Whereas in the situation of a lecture without discussion a ratio of 5:1 should be better.

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