# Impaired auditory functions and degraded speech perception in noise

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## Introduction

Hearing-impaired people often experience great difficulty with speech communication when background noise is present. In most cases, the problem persists even if reduced audibility has been compensated for by hearing aids. Other impairment factors besides reduced audibility must be involved. Relations between frequency selectivity and speech perception, particularly in noise, have been reported previously [1]. Recently, also the processing of temporal fine-structure (TFS) has been considered to contribute significantly to comprehension of speech [2]. Therefore, in this study we assessed speech perception in the presence of different interferers, as well as the individual's frequency selectivity and the integrity of temporal fine-structure processing in normal-hearing and hearing-impaired listeners. The TFS processing was addressed binaurally via measurements of lateralization thresholds, and monaurally via measurements of detection thresholds of low-rate frequency modulation. In addition, these measurements were undertaken in a stationary noise background in order to assess the persistence of the fine-structure processing to interfering noise.

## Methods

A total of 18 listeners participated in this study. 6 were normal-hearing (NH) and 10 had a sensorineural hearing impairment (HI). 2 had an obscure dysfunction (OD), complaining about difficulties with speech comprehension in noisy backgrounds despite normal audiograms. In order to minimize confounding effects, the HI listeners were selected to constitute a homogeneous group in terms of their hearing thresholds. The audiograms were normal up to 1 kHz (thresholds $\leq$ 20 dB HL) and from there on sloping to moderate levels of up to 70 dB HL at the highest frequencies. *Speech reception thresholds* (SRTs) were measured with Dantale II, a Danish closed-set sentence test, in the presence of different background interferers: a stationary speech-shaped noise (SSN), a dichotic, lateralized noise (LATSSN) and a two-talker background (TALKER). In addition to full-spectrum speech, SRTs for 1-kHz low-pass filtered speech (FILT) in SSN were measured. *Frequency selectivity* at 750 Hz was determined via the notched-noise paradigm in simultaneous masking and with the signal level fixed at 50 dB SPL. *Lateralization thresholds* were measured for 750-Hz tones with ongoing interaural phase delays (IPDs), at levels of 70 and 35 dB SPL. This was done in quiet and in dichotic noise, the level of which was chosen relative to the individual's masking level. Monaural detection thresholds for 2-Hz sinusoidal *frequency modulation* (FM) were obtained for 750-Hz and 1.5-kHz tones at a level of 30 dB SL. However, the effect of noise was only assessed at 750 Hz.

## Results and Discussion

### Speech perception

For all interferer conditions, the HI listeners showed larger SRTs than the NH listeners (average increase relative to NH: 3.8 dB for SSN, 4.0 dB for LATSSN, 6.2 dB for TALKER, and 1.9 dB for FILT). The OD listeners showed only slightly increased SRTs relative to NH. Their deficit was most significant for the filtered speech condition, suggesting a potential problem in the processing of low-frequency sounds.

### Frequency selectivity

The HI listeners showed significantly elevated bandwidths compared to NH [one-way ANOVA: $F(1, 28) = 10.2$; $p < 0.005$], on average by a factor of 1.2. However, the results varied considerably across the HI listeners. For one of the OD listeners ($OD_2$), the bandwidths were significantly increased (compared to NH), while for the other ($OD_1$), only one ear showed an elevated bandwidth. Furthermore, both OD listeners showed larger bandwidth asymmetries between the ears than the NH listeners.

### Lateralization

The results of the lateralization experiment are shown in Fig. 1. The HI listeners (left panel) performed significantly poorer than the NH listeners on lateralization [two-way ANOVA: $F(1, 47) = 38.8$; $p < 10^{-6}$]. On average their IPD thresholds were larger by a factor of 1.6. For the higher tone level (green sybmols), the HI listeners performed worst in quiet (relative to NH). Instead of showing a further degradation of performance at the lower tone level (blue symbols), their performance in quiet actually improved (blue cross). This is in line with the following interpretation: at 70 dB SPL, excitation is spread over a certain range of the basilar membrane. For the NH listeners, portions of the membrane corresponding to higher frequencies are likely to contribute to the lateralization judgement. However, the HI listeners might not be able to benefit from this information at higher frequencies since it falls into the region of elevated thresholds. On the contrary, if actually included into the decision process, information from defective units might have a detrimental effect on lateralization acuity. The background noise would then confine the excitation to the relevant region around 750 Hz and thus mask the deleterious spread at higher frequencies. At the lower tone level, the excitation would spread less and thus the

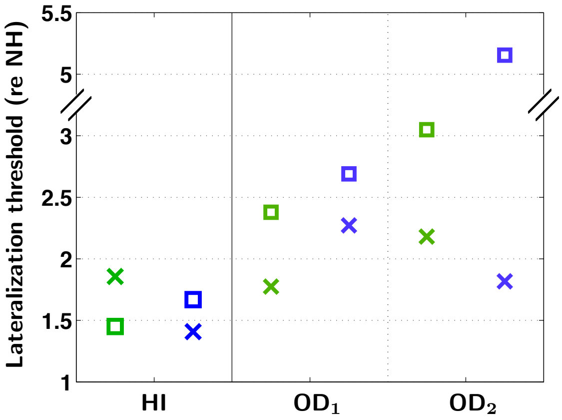


**Figure 1:** Results of the lateralization threshold measurements (green: 70 dB SPL, blue: 35 dB SPL; cross: in quiet, square: in noise). Left: average threshold IPD for the HI listeners divided by the average threshold for the NH listeners. Middle and right: individual results for the two OD listeners.

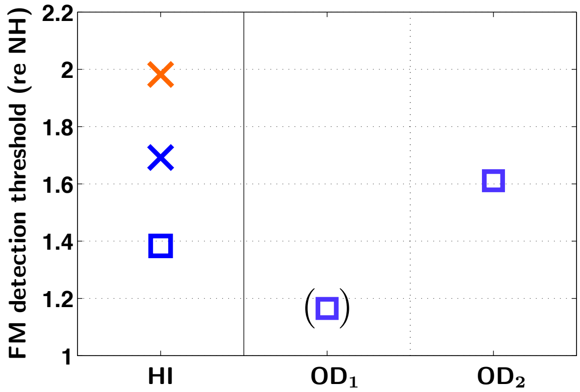


**Figure 2:** Results of the frequency modulation measurements (blue: 750 Hz, orange: 1.5 kHz; cross: in quiet, square: in noise). Left: average FM detection thresholds for the HI listeners divided by the average threshold for the NH listeners. Middle and right: individual results for the two OD listeners; the result in brackets is not significantly different from NH.

lateralization performance would be expected to be less affected than at the higher level. In absolute terms, for all listeners, the low-level condition in noise was most challenging. At the low level, less units are activated and due to the noise interferer only a portion of them will be actually phase-locked to the tone. However, note that the HI listeners were not particularly susceptible to the noise interference (the difference between the quiet and the noise condition at 35 dB SPL is not significant). The two OD listeners showed markedly increased IPD thresholds compared to the NH listeners. Both performed best in quiet but showed pronounced problems with lateralization in the presence of noise interference.

### Frequency modulation

Fig. 2 displays the results of the FM measurements. The HI listeners (left panel) performed significantly poorer than the NH listeners on FM detection at 750 Hz (blue symbols) [two-way ANOVA: $F(1, 27) = 12.3$; $p < 0.005$]. Here, on average, their FM detection thresholds were larger by a factor of 1.5. However, as observed in the binaural task, they did not show an increased susceptibility to noise interference (blue square) in this monaural task either. A larger deficit is seen at 1.5 kHz (orange cross), where the HI listeners had elevated audiometric thresholds (however, the individual results were not correlated with the audiometric thresholds at that frequency). The OD listeners did not show as pronounced problems on this monaural task as on the binaural task. A significant degradation, compared to the NH listeners, was found only for subject $OD_2$ in noise.

### Comparison of results across tests

Correlations between frequency selectivity, lateralization and FM performance, and speech perception were examined within the group of HI listeners. No significant correlations were found between frequency selectivity and the other measures mentioned above. Thus, it seems that the deficits observed in TFS processing do not simply reflect deficits in frequency selectivity but rather constitute a problem on their own. Various significant correlations were found between the performances on (monaural) FM detection and (binaural) lateralization. This is not particularly surprising, as both are supposed to assess the integrity of TFS processing. Regarding speech perception, the SRT for the dichotic noise condition (LATSSN) was found to correlate with the lateralization performance in noise. Furthermore, the SRT for the two-talker interferer (TALKER) was correlated with the performance on FM detection, particularly at 1.5 kHz. The correlations given above remained significant ($p < 0.05$) when controlling for hearing loss in terms of the average pure-tone threshold.

## Summary and conclusions

Despite normal audiometric thresholds (at low frequencies), significantly degraded performance on frequency selectivity, lateralization and FM detection was found in both subject groups, HI and OD listeners. However, while the binaural and monaural TFS processing in the HI listeners did not seem to be particularly vulnerable to noise, the OD listeners showed pronounced problems with the binaural task in noise. Finally, the deficits in TFS processing found here were not related to degraded frequency selectivity.

## References

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[2] Lorenzi, C., Gilbert, G., Carn, H., Garnier, S., and Moore, B. C. J.: Speech perception problems of the hearing impaired reflect inability to use temporal fine structure. Proc. Natl. Acad. Sci. USA, 103(49) (2006), 18866-18869