The relationship between tone- and speech-audiometry based assessments of hearing loss

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Introduction

In Germany there is a standardised way to assess the reduction in earning capacity (Minderung der Erwerbsfähigkeit, MdE) due to a hearing loss. The guidelines are summarised in the Königsteiner Merkblatt (1996). In these guidelines recommendations are given concerning the entire procedure (which tests should be used at all), and there are also detailed recommendations concerning choice, application and interpretation of the speech audiometric tests.

Usually the main measure for the final assessment is the percentage hearing loss based on the speech audiogram in silence. But in some cases results based on the pure-tone audiogram become relevant, too. One case is, when results from speech audiometry are not available, because the assessment is just based on medical records or because the data could not be collected in a reliable way (e.g. non-native listeners). The pure-tone audiogram also becomes relevant, when speech intelligibility is comparatively high and leads to a percentage hearing loss for speech of less than 20%. In this case it is recommended to use the pure-tone audiogram as an additional basis for the assessment.

It is known that a higher percentage hearing loss will be found on the basis of tone audiometry instead of speech audiometry in most cases. However, a single number to quantify these differences is not available. Still, the results due to the assessment might have far-reaching consequences for the persons concerned. So it is important to deal with the following questions: (1) To what extent are the results based on tone- and speech-audiometry comparable? (2) Is it fair to use the tone audiogram instead of the speech audiogram for an assessment?

To answer these questions existing data from two studies were analysed. The original aim of these studies was a comparison between different speech audiometric test procedures (Brand et al., 2006). We compared both parts of the Freiburg speech test (Hahlbrock, 1953), which is used in general, with more modern test procedures. The results presented in this paper are based on an additional analysis of these datasets.

Methods

Participants. The participants in study I were 31 adults (16 female, 15 male) with mild or moderate hearing loss, and in study II 145 adults (67 female, 78 male) with mild, moderate or severe hearing loss. The participants were not chosen according to a typical pattern of noise induced hearing loss. Since in the experimental design not all participants were assigned for all tests, analyses covering all procedures were just available for 58 listeners in study II.

Experimental design and test procedures. For all participants pure-tone audiometry and a subset of the speech audiometric tests were carried out. In the Königsteiner Merkblatt (1996) it is recommended to use both parts of the Freiburg speech test in quiet (number test and monosyllabic test) to assess a noise induced hearing loss. The number test is used to determine the speech reception threshold (SRT), that is the presentation level at which the listener understands 50% of the presented words. To measure effective intelligibility in percent the monosyllables should be used at presentation levels of at least 60, 80 and 100 dB SPL. The intelligibilities are then combined to a so-called “overall intelligibility” or “weighted overall intelligibility”.

With respect to the speech reception threshold we compared the Freiburg number test (FBNu) with the Göttingen sentence test (GöST, Kollmeier and Wesselkamp, 1997), and with respect to intelligibilities for monosyllables at various levels we compared the Freiburg monosyllabic test (FBMo) with the monosyllabic rhyme test (MoRT, v. Wallenberg and Kollmeier, 1989).

Similar to FBNu and FBMo, the Göttingen sentence test is applied in an “open paradigm”, i.e., the participants have to repeat what they understood. The speech material is a collection of everyday sentences with three to seven words. In contrast to the other tests the monosyllabic rhyme test is conducted in a “closed paradigm”. In this test the participants see five similarly sounding words on a computer screen. One of these words is presented. The participants have to decide which of the five words was presented and mark this on the screen. All tests were presented monaurally via free-field equalized headphones (Sennheiser HDA 200) in silence in a sound-proofed booth.

Concerning the monosyllabic tests there were some differences between study I and study II.

Study I. For all participants the intelligibilities were measured at presentation levels of 60 and 80 dB SPL and in a few cases also at 100 dB SPL (as long as 100 dB SPL does not exceed the individual uncomfortable level). If a result at 100 dB SPL was not available to calculate the overall intelligibility, either the maximum intelligibility was used or the intelligibility at 80 dB SPL was taken into account twice.

Study II. Intelligibilities were also measured at three presentation levels. They were now individually selected with respect to the SRT determined with the GöST. The three levels used for the FBMo were chosen from 35, 50, 65, 80, 95 dB SPL and for the MoRT from 20, 35, 50, 65, 80 dB SPL. Within each set of presentation levels the levels for the MoRT were chosen 15 dB lower than for the FBMo. Since in this study intelligibilities at the recommended levels (60, 80, 100 dB SPL) were not actually measured in most listeners, these intelligibilities were estimated by interpolation or extrapolation from the results at the levels employed.

Results

Calculations for percentage hearing losses (PHL)

Pure-tone audiometry. Percentage hearing losses on the basis of the pure-tone audiogram were calculated using the three-frequency table (1000, 2000, 3000 Hz) and the four-frequency table (500, 1000, 2000, 4000 Hz) by Röser (1980, 1973). In the following sections these results are called “PHL-Tone-3Freq” and “PHL-Tone-4Freq”, respectively.

Speech audiometry. As suggested in the guidelines we used the SRT and the “(weighted) overall intelligibility” from the monosyllabic tests (Boenninghaus and Röser, 1973). These results will be called “PHL-Speech” throughout this paper. The PHL-Speech was determined for the four combinations: FBNu - FBMo, FBNu - MoRT, GöST - FBMo, GöST - MoRT.

Study I

As the next step we calculated the following differences between tone- and speech audiometry based results: PHL-Tone-3Freq resp. PHL-Tone-4Freq minus PHL-Speech based on Freiburg numbers and *monosyllables*; PHL-Tone-3Freq resp. PHL-Tone-4Freq minus PHL-Speech based on Freiburg numbers and the *monosyllabic rhyme test.*

Figure 1 shows the distributions of these differences presented as box plots. Each box gives the interquartile range of the distribution. The fat black horizontal line is the median and the circles mark the outliers. The distributions give positive values for most participants, that means the pure-tone audiogram led to a higher amount of PHL than the speech audiogram. Figure 1 also shows that there were similar distributions for both speech test combinations FBNu with FBMo and FBNu with MoRT. With the two different tables used (3- or 4-frequency table) different medians were found: using the 3-Freq. table the median of the differences was around 5-10%; using the 4-Freq. table the median was around 20%. All distributions reflect a large interindividual variability. In all calculations we found the same two participants with extreme results (outliers).

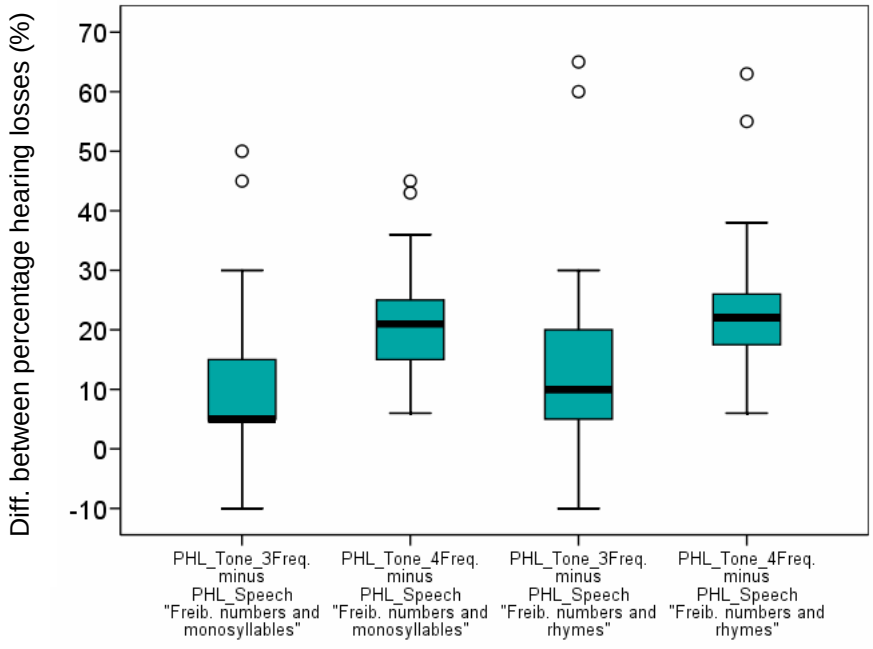

Figure 1: Distribution of differences between tone and speech audiometric based PHLs (details see text).

Further analysis revealed some common aspects in these two participants: Both listeners belonged to the subset of younger people (< 63 years), they had a similar pure-tone audiogram and relatively low thresholds (SRT) in the Freiburg number test in comparison to the tone-audiometric results. For one person also SRT-results from the Göttingen sentence test were available. The threshold with the Göttingen sentence test was much higher and more in line with the other participants than the threshold determined with the Freiburg numbers. The difference between both thresholds was the largest in the entire group.

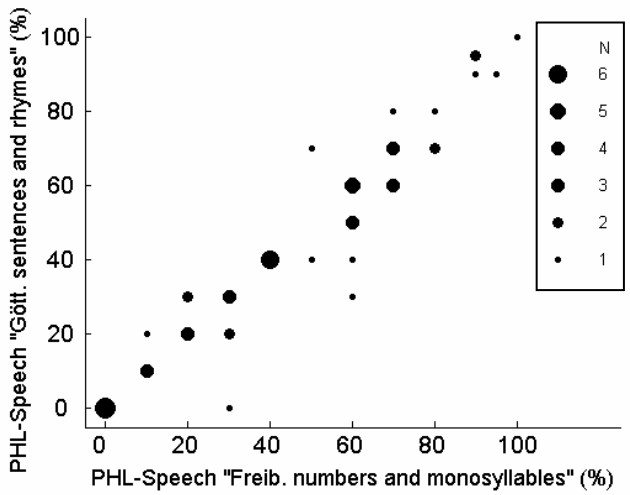

Figure 2: Correlation for PHL-Speech based on the Freiburg speech test and PHL-Speech based on the Göttingen sentence test and the monosyllabic rhyme test (n = 58).

Study II

The distributions for the differences in study I were very similar for both monosyllabic tests. This result suggests that a replacement of the Freiburg monosyllabic test by the monosyllabic rhyme test would be feasible. The results from study II are now used to evaluate the effect of also replacing the Freiburg number test by the Göttingen sentence test.

Figure 2 shows that the correlation of PHL-Speech based on FBNu and FBMo (according to current guidelines) and the PHL-Speech based on the results from GöST and MoRT (modern procedures) was very high (r=0,96). There are only very few cases where the two different estimates of PHL-speech deviate by more than 10%.

Summary and Discussion

In study I we found large differences between tone- and speech audiometric based results (mainly for the four-frequency table), higher percentage hearing losses based on tone- than on speech audiometry and large interindividual variations. All observations were independent from the particular pair of speech tests used. In study II we observed a high correlation between results based on old and modern test procedures. So in principle it would be possible to use the modern test procedures instead of the Freiburg speech test in the assessment of percentage hearing loss.

With respect to the question, whether it is fair to use the tone audiogram instead of the speech audiogram for the assessment in special cases, at the first glance the conclusion seems to be: It is unfair to do so because the estimation of the reduction in earning capacity would possibly be much higher in these cases. But on the other side it also appears to be unfair to pronounce the speech audiogram in general. The results showed that sometimes mainly unusual low thresholds for numbers might be responsible for low percentage hearing losses and would lead to a comparatively low assessment.

Thus for a complete characterization both tests appear to be necessary. However, to avoid misinterpretations of the hearing impairment, it should also be discussed to collect more data for each person. On one hand it seems appropriate to measure speech intelligibility in noise, too, because hearing in noise gives a better representation of listening situations in everyday life than hearing in silence and it better represents the problematic situation for hearing-impaired listeners. On the other hand we also have to take into account the social-emotional handicap due to the hearing loss which is perceived by the subject. In further studies these two measures should be added to the recommended tests by using appropriate audiometric procedures and questionnaires. Since other than hearing-related aspects like general speech competence, aging, or cognitive abilities also might contribute to the final results - mainly concerning speech audiometry - these aspects should also be considered in further studies in order to explain (unusual) results in more detail.

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