A NEW APPROACH FOR THE EVALUATION OF TONAL NOISE
(TONALITY)

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1 Introduction:

Tonal noise (DIN 45681 [1]) is an important parameter affecting sound quality and is substantial for the assessment of the annoyance of tonal components in environmental noises.

For the measurement of time varying weak tonal components of complex technical and natural sounds none of the existing methods correspond to subjective ratings [2].

This is due to the fact that conventional methods neglect the time and frequency resolution as well as masking properties of the human hearing [2]. Furthermore a possible frequency dependence of tonal noise components is disregarded.

The aim of this study is to investigate the aspects of frequency for tonal noise.

2 Method:

In the following experiments 36 sounds are generated by adding 6 sinusoidal tones with different frequencies \( f \) (equally shifted on a bark-scale) to 6 uniform masking noises with decreasing steps of sound level. The highest level \( L_{N,1} \) for each individual tone is chosen as the noise-level \( L_G \) which is the masked threshold of the tone (with sound level \( L_T \)) in the critical band around the tone-frequency plus the masking index \( a_V \) (\( a_V = L_T - L_G \)). The following 4 levels \( L_N \) of the uniform masking noise are successively decreased in 4 steps of 12 dB. The sixth level \( L_{N,6} \) is chosen as infinity. All 36 modifications of the sounds are displayed in figure 1, showing the different frequencies in horizontal and the different levels \( L_N \) in vertical direction. All of the sounds are scaled to the same loudness (12 sone GF).

3 Experiments:

1. Subjective scaling of the 18 sounds with \( f = 100, 920 \) and 2700 Hz from figure 1 is done by forced choice paired comparison in random order.
2. Subjective scaling of the 18 sounds with different levels of $L_N = 12, 36$ and infinity (pure tone) dB from figure 1 is done by forced choice paired comparison in random order.

![Figure 1](image.png)

Figure 1. The 36 sounds used for experiments: horizontal axis: frequency of test tone [Hz], vertical axis: noise-level $L_N = L_T - L_G - a_v$ [dB].

4 Results:

Both experiments show very good (individual) consistency of the subjects. The results are reliable and reproducible. The overall consistency among all subjects (‘Akkordanz’ [3]) is relatively high and very significant. The results are shown in tables 1 and 2: The numbers $n$ in the tables account for the quantity how often (how many times) the signal is rated more tonal as $n$ other signals in the same experiment. Because there are 18 different sounds the maximal number is $n = 17$. All figures show averaged data of the corresponding groups.

4.1 Experiment 1:

- 11 Subjects: 2 female, 9 male, age 22 to 30, normal-hearing
- individual consistency [3] of subjects: between 0.73 and 0.99, average 0.89
- cyclic-triads [3] of paired comparison: between 66 and 3, average 27 (204 possible)
- significance-level [3] (SL): >0.9995 for all subjects
- overall consistency (‘Akkordanz’ [3]): over all subjects: 0.51, SL >0.999
- the subjects show in general 2 different behaviours: group1: a pure tone is the maximum possible tonal noise, group2: a pure tone is not the max. tonal noise
- group1: 8 subjects, overall consistency (‘Akkordanz’ [3]): 0.70 SL >0.999
- group2: 3 subjects, overall consistency (‘Akkordanz’ [3]): 0.55 SL >0.999
For this experiment the subjects split up into 2 groups: 8 of 11 subjects perceive a pure tone as the most possible tonal noise, the remaining 3 stated the pure tones to be a different perception “something else but a tonal noise”. The first group rates pure tones with a frequency about 900 Hz as most tonal (table 1, lower left panel). For every constant $L_N$ the 900 Hz-tone is most, the 50 Hz-tone rated least tonal (group 1). All subjects are experienced in psychoacoustic experiments, but it is remarkable, that group 1 consists only of natural scientists, whereas the subjects of group 2 are non-natural scientists.

4.2 Experiment 2:
- 9 Subjects: 1 female, 8 male, age 22 to 30, normal-hearing
- individual consistency [3] of subjects: between 0.67 and 0.94, average 0.85
- cyclic-triads [3] of paired comparison: between 14 and 80, average 35 (204 possible)
- significance-level [3] (SL): >0.9995 for all subjects
- overall consistency (‘Akkordanz’ [3]): over all subjects: 0.46, SL >0.999

Table 1. Results for experiment 1: the upper left table contains data averaged over all 11 subjects, the lower left shows the averaged data for group 1, the lower right table data is averaged over the subjects of group 2.

The numbers in the tables account for the quantity how often the signal is rated more tonal as all other signals.

A frequency dependency with a maximum tonality in the range of 920 to 1450 Hz is obvious.

Table 2. Results for experiment 2: averaged data over all 9 subjects.

The numbers in the tables account for the quantity how often the signal is rated more tonal as all other signals.

A frequency dependency with a maximum tonality in the range of 920 to 1450 Hz is obvious.
In this experiment a similar frequency-dependence for tonality is obtained as in experiment 1: the maximum tonality for the test-tone is perceived in the frequency region between 920 and 1450 Hz. The pure tone with a frequency of 50 Hz is more tonal as any sound with a tonal component and $L_N = 12$ dB. This is remarkable due to the fact, that frequencies lower than about 100 Hz are generally suggested not to evoke the sensation of tonality [1].

5 Discussion

- The experiments show that frequency has a distinct effect on tonal-noise perception, which is contradictory to the DIN45681 [1].
- The fact that sounds with a tone of 50 Hz and high $L_N$ values are rated more tonal than tones with higher frequencies but smaller $L_N$ values is contradictory to the DIN45681 [1], too.
  \[ \Rightarrow \] both points requires the DIN45681 to be modified
- It seems that different subjects have different perceptions of tonal noise, especially the sense of pure tones is still not clear.

6 Future Research:

Additional experiments with many more subjects for both experiments have to be done to verify these results and to be able to use different statistic methods such as analysis of variance. Especially the difference between natural scientists and ‘other’ subjects has be further investigated.

The aim of this is to modify and improve the DIN45681 [1]. In the following step the DIN45681 will be implemented on a computer to receive data which is in line with subjective ratings.

Therefore the influence of the selection of subjects must be explored and taken into consideration adequately.

References