Evaluation of sound quality affected by tonal components in Germany and Japan

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Introduction

In this study the effect of tonal components on sound quality was investigated by use of a semantic differential. A cross-cultural perspective was taken into account by performing the evaluation of sound quality under practically the same conditions in Japan and Germany.
Majorly, tonality has an annoying influence on the timbre of sounds [1] [2]. As a feature of sounds in daily life, it is common in both countries. To investigate this effect, a set of sounds was used in which tonal components, one or two sine signals, are added to pink noise. The level difference between noise and signal and the frequency of the second sine signal are varied systematically.

Experiment

Stimuli Two groups of stimuli were used:

1. Seven pink noises superimposed by a 500 Hz sine signal are digitally generated. The level of the sine varied from 7 dB to 26 dB above noise level.
2. The second group contains sounds with pink noise superimposed by two sine signals. One sine frequency was constant at 500 Hz and the other was either 530 Hz, 700 Hz or 1000 Hz. All frequency pairs were presented with level differences from 9 to 25 dB. Both sines had equal SPLs.

Procedure Sound quality was examined by using a semantic differential with 7 step scales. The English adjectives scales are listed below. They were translated into Japanese and German by native speakers. The same instruction was given to Japanese and German subjects in their respective mothertongue. In the beginning, the participant had to judge 6 test sounds representing the whole perceptual range in order to get accustomed to the adjective scales. Along with the instruction, the scales and the selection of sounds constituted a frame of reference for the subjects. The sounds and the adjective scales are both randomised in three different orders to minimise order effects. Each subject has to examine one order of sounds and scales.

Apparatus & Subjects To assure an identical presentation of stimuli, the same headphones and amplifier were used in Japan and Germany. The stimuli were reproduced in sound-proof rooms at Osaka University and Oldenburg University.
Comparable samples of subjects were used in both countries: Japanese students (9 female/11 male) aged $22.9a \pm 1.7a$ and German students (8 female/12 male) aged $23.7a \pm 2.6a$ with normal hearing ability.

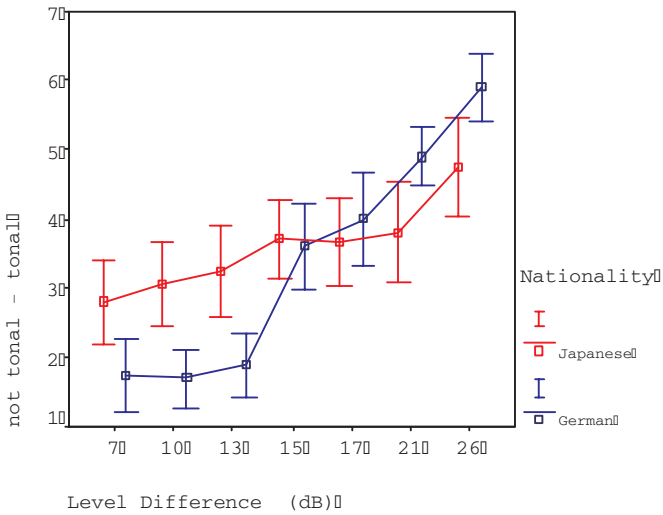

Figure 1: Means for judgements on a 7-step scale "not tonal - tonal" given by Japanese and German subjects. The stimuli are pink noise with an added sine frequency at 500 Hz. The level differences between noise and sine range from 7 to 26dB. Error bars represent the 95 % confidence interval.

Results

The Japanese and German data was combined for subsequent analysis.

Sound Quality Factors A factor analysis of the adjective pairs was conducted to determine the main perceptual dimensions. A typical three factor solution was extracted using the principle component analysis explaining 69.8 % of the variance [2]. The solution was rotated by Varimax rotation. After this, the percentage of variance explained for factor I is: 29.5 %, for factor II 22.2 % and for factor III 18.1 %.
After performing the Varimax rotation the adjective scales "pure-impure", "pleasant-unpleasant", "harmonic-discordant", "annoying-not annoying","pleasing-

unpleasing" and "beautiful-ugly" load highly on factor I. It can be interpreted as the "pleasant" factor.
Factor II may be regarded as the "metallic" factor, because "shrill-calm", "metallic-deep", "hard-soft" and "tonal-not tonal" load highly on it .
The last factor is called the "powerful" factor, because both "powerful-weak" and "loud-soft" load on it.
For specific adjective pairs loadings on different factors vary between Japanese and German subjects. However, this aspect will not be discussed here.

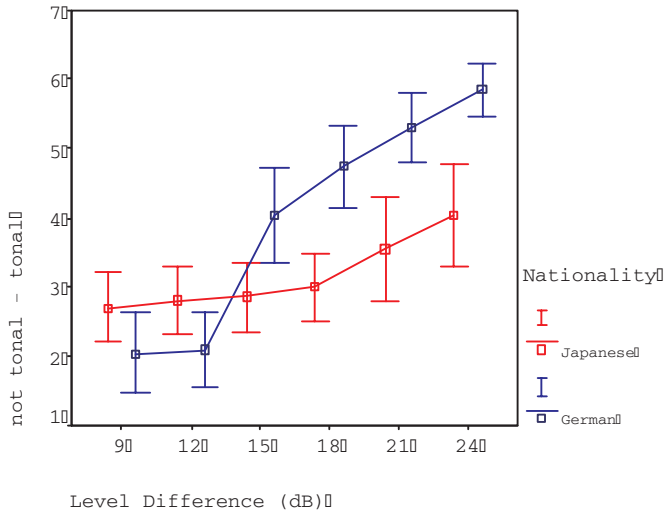

Figure 2: Means for judgements on a 7-step scale "not tonal -tonal" made by Japanese and German subjects. The stimuli are pink noise with two sine frequencies at 500 and 530 Hz added. The level differences between noise and sine range from 9 to 24dB. Error bars represent the 95 % confidence interval.

Effects of level differences, sine frequencies and nationality The first difference seen between Japanese and German subjects is the usage of the provided scale. The German subjects make use of nearly the full scale range, while the Japanese subjects tend to maintain judgements within the scale's middle (Fig. 1 and 2). Results of other semantic differentials with Japanese subjects show comparable results [1][2].
To analyse which stimulus condition has a significant effect on a specific adjective scale, the analysis of variance is employed. In this context the following fixed factors are used: sine frequencies, level differences between sines and noise, and nationality.
Subjects in both countries tend to judge the stimuli more "powerful" and "unpleasant" as soon as the tonal components are clearly audible. The increase of the judgement "unpleasant" is commonly known as the 'annoying' character of tonal components [2].
The largest effect of the increasing second sine frequency is on the "metallic" factor. The increasing second sine frequency increases the judgement of "metallic". Adding higher frequencies to the noise provides an increase in sharpness which correlates with the judgement of "metallic" [2]. The effect on the other factors is rather small. Expressing only the tendency that the adjectives are perceived more "unpleasant" and "powerful" with increasing second sine frequency.
The increasing level difference has a different influence on the subjects in both countries. The reported judgement of "metallic" is more strongly influenced by the level increase for the German group. The same holds for the other factors "powerful" and "pleasant". For examples, the effect of the level difference increase on "not tonal - tonal" is shown for different sine frequencies in Fig. 1 and Fig. 2. In Fig. 1 the frequency is constant at 500 Hz. Between the 13 and 15 dB level differences, as the tonal component becomes prominent, judgements by German subjects change strongly towards "tonal". The reported judgements by Japanese subjects do not change in such a strong manner. For the sine frequencies 500 and 530 Hz the judgements of "not tonal - tonal" are shown in Fig. 2. In this case, judgements by German subjects change drastically between 12 and 15 dB, while Japanese judgements of "tonal" only increase with larger level differences. A possible explanation for this effect could be a different frame of reference.

Conclusion

- The stimuli evaluated with the semantic differential were analysed by factor analysis (PCA). The typical three factor solution yielded the factors "pleasant", "metallic" and "powerful".
- The increasing of the level of sine frequencies above noise yields an influence on all three factors. The stimuli are judged more "metallic", "unpleasant" and "powerful" as the frequency becomes more prominent. With increasing second sine frequency, the stimuli are judged more "metallic".
- The usage of the adjective scales varies according to participant group. The German subjects tend to use the scales in a broader way. The reported judgement change in regard to level difference is stronger for the German group. Japanese subjects show a higher tendency towards mid-range judgements.

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