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Loudness-thermometer: evidence for cognitive effects?

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ABSTRACT

To illustrate for a broad public acoustic magnitudes, level-thermometers can be used which show e.g. on the lower end whispering leaves and on the upper end a jet aircraft. When using instead a loudness-thermometer, the sequence of sounds sometimes can be reversed compared to a level-thermometer. From an engineering point of view, these differences frequently can be traced back to differences in the spectral distribution. However, also some cognitive effects might play a role, e.g. that musical sounds are preferred in comparison to technical sounds.

In order to get a handle on possible cognitive effects, a procedure was used which keeps the loudness-time function the same, but largely obscures the information about the sound source. The loudness of 19 musical, natural, and technical sounds in both original and processed version was scaled by a magnitude estimation procedure. The information about the sound source, i.e. whether or not the sound source could be identified, had little effect on the loudness rating. In line with data from the literature, these results could be interpreted that cognitive effects like the recognition of the sound source might play a minor role in loudness evaluation. However, in some cases, the identification of the sound source may considerably influence the rating of its annoyance.

1 INTRODUCTION

In order to illustrate for a broad public acoustic magnitudes, frequently level-thermometers are used which show e.g. on the lower end the image of whispering leaves and on the upper end the image of a jet aircraft (e.g. [1]). These thermometer-displays can be regarded as a first step to give a broad public some feeling for the magnitude dB. However, since at the same dB-value, sounds with different spectral characteristics can produce quite different loudness perception, it is of advantage to use a loudness-thermometer scaled in sone. In this case, even for sounds of rather different tone colour their perceived loudness is in line with their arrangement on the thermometer-scale.

For the illustration of the loudness-scale, familiar musical, natural, and technical sound sources are displayed [6]. Hence, also cognitive effects may play some role. If a person dislikes

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sounds from a specific sound source, e.g. aircraft noise, this may lead to a particularly negative rating. Therefore, a procedure [4] was applied which keeps the loudness-time function the same, but obscures the information about the sound source. By comparing the loudness rating of sounds where the sound source can be identified and sounds where the information about the sound source is obscured, the magnitude of the influence of cognitive effects can be estimated. In this paper, results of related experiments are presented.

2 LOUDNESS THERMOMETER

Figure 1 shows a loudness-thermometer (left) in comparison to a level-thermometer (right). The data displayed in figure 1 indicate that irrespective of the scale used, a jack hammer is considered to be pretty loud, and a trickling faucet to be rather soft. However, closer inspection reveals that for example the loudness of the violin is lower than the loudness of the electric drill although both have almost the same level.

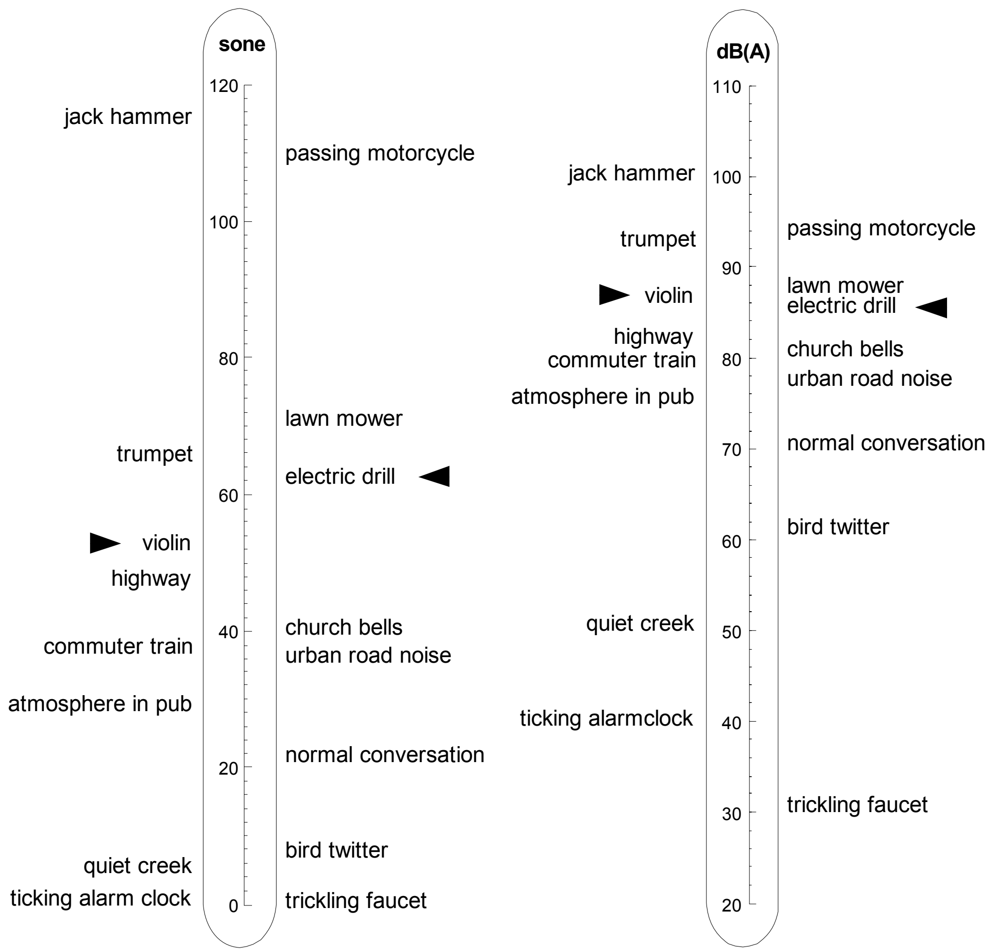

Figure 1: Loudness-thermometer (left) in comparison to level-thermometer (right) (after [5])

From an engineering point of view, these differences could be traced back to different spectral distributions of the sounds considered. However, also cognitive effects might play a role that the musical sound of a violin is liked better than the technical sound of an electric drill.

3 PROCESSING OF SOUNDS

In order to get a handle on the magnitude of possible cognitive effects, a procedure was developed [4], which largely obscures the recognition of the sound source despite keeping the loudness-time-function the same. The principle of this procedure is outlined in figure 2 in form of a block diagram.

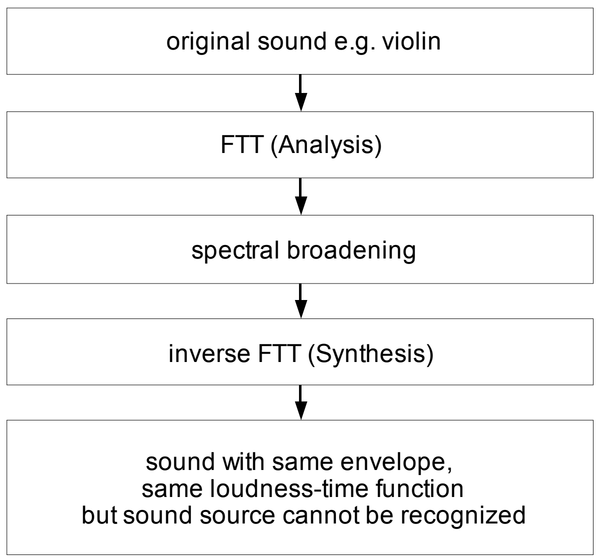

Figure 2: Block diagram illustrating the procedure for obscuring the information about the sound source.

In the procedure the original sound, e.g. from a violin, is first analyzed by a Fourier-Time-Transform FTT [9]. After spectral broadening, a sound is re-synthesized which shows the same spectral envelope and same loudness-time-function as the original sound but the information about the sound source is obscured.

The details of the procedure introduced in figure 2 are illustrated in figure 3. The left part shows the FTT spectrum of the violin-sound used. The harmonic structure of the violin-sound is clearly seen: Directly at the ordinate, the harmonics at 700 Hz, 1400 Hz, 2100 Hz, 2800 Hz, and 3500 Hz show up near 6.5 Bark, 10.7 Bark, 13.3 Bark, 15.2 Bark, and 16.7 Bark. Also it becomes clear that the pitch of the violin first increases and then decreases to a note of long duration.

In the right part of figure 3 this general pattern, i.e. the increase in pitch and then the decrease to a long note, is in principle also visible. Moreover it becomes clear that some harmonic structure is hidden in the sound. However, in comparison to the left part of figure 3, in the right part all the detail is lost and the image is blurred. From a perceptual point of view this leads to a continuous noise with barely audible frequency modulation.

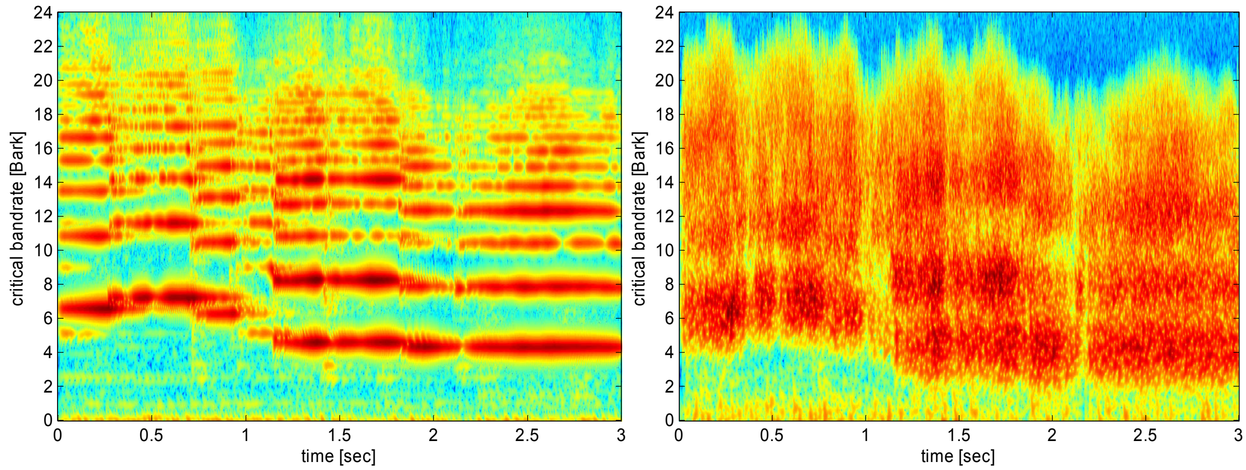

Figure 3: Original (left) versus processed FTT spectrum (right) for the violin-sound used.

Figure 4 shows the FTT spectra for the original and processed sounds of an electric drill. The left part shows line spectra with harmonics due to the rotation of the electric drill. This detailed spectral information is largely blurred in the right part of figure 4 leading to the perception of continuous noise.

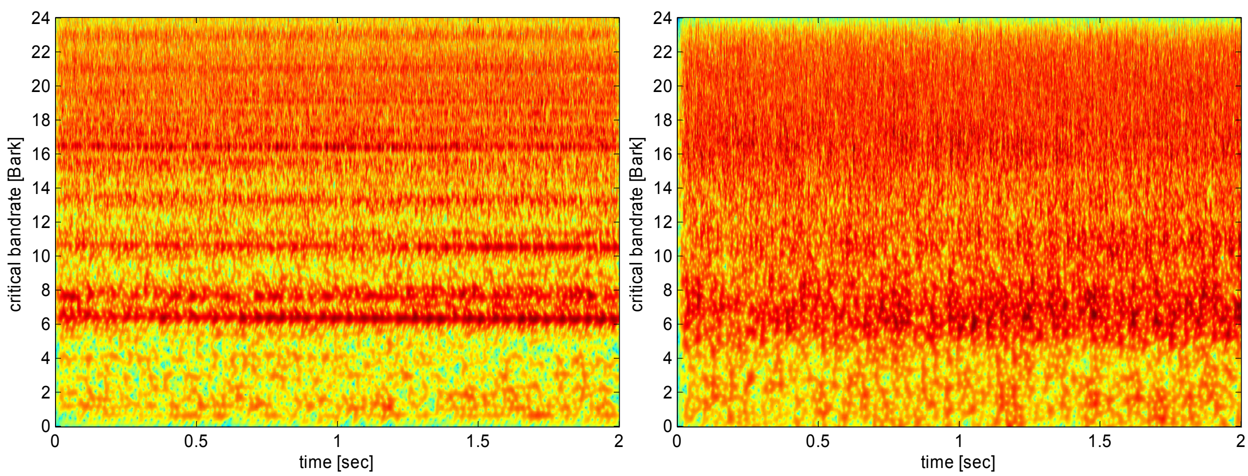

Figure 4: FTT spectra of original (left) and processed sound (right) of an electric drill.

4 EXPERIMENTS

Nine normal hearing subjects with an age between 21 and 28 years (median 25 years) participated in the experiments. Sounds were presented diotically at their original level via electro-dynamic headphones (Beyer DT48) with free field equalizer according to [11], page 7.

Subjects were seated in a soundproof booth. A magnitude estimation procedure with anchor sound (see e.g. [11], p. 9) was used. Subjects had to enter their magnitude estimates into a computer. As anchor sound, the sound from a hair dryer (sound 5) was used; its loudness was assigned the numerical value 100.

From a larger set of sounds [6], for the experiments 19 sounds were chosen, which are listed in table I.

Table I: Sounds evaluated

1	children at play
2	ringing telephone
3	urban road noise
4	vacuum cleaner
5	hair dryer
6	church bells
7	waterfall
8	highway
9	train station
10	commuter train
11	electric razor
12	door bell
13	piano
14	violin
15	electric drill
16	trumpet
17	passing train
18	passing motorcycle
19	jack hammer

For all sounds, using the procedure outlined in figure 2, a processed version was realized leading essentially to the same loudness-time-function. For all sounds considered, the percentile loudness N_5 differed less than 5% between original sound and processed sound.

5 RESULTS AND DISCUSSION

For the 38 sounds used (19 original and 19 processed), figure 5 shows the results of the magnitude estimation experiments. Each subject rated each sound four times in different order. Therefore the columns in figure 5 represent medians from 36 data points each, and the interquartile ranges are given by whiskers.

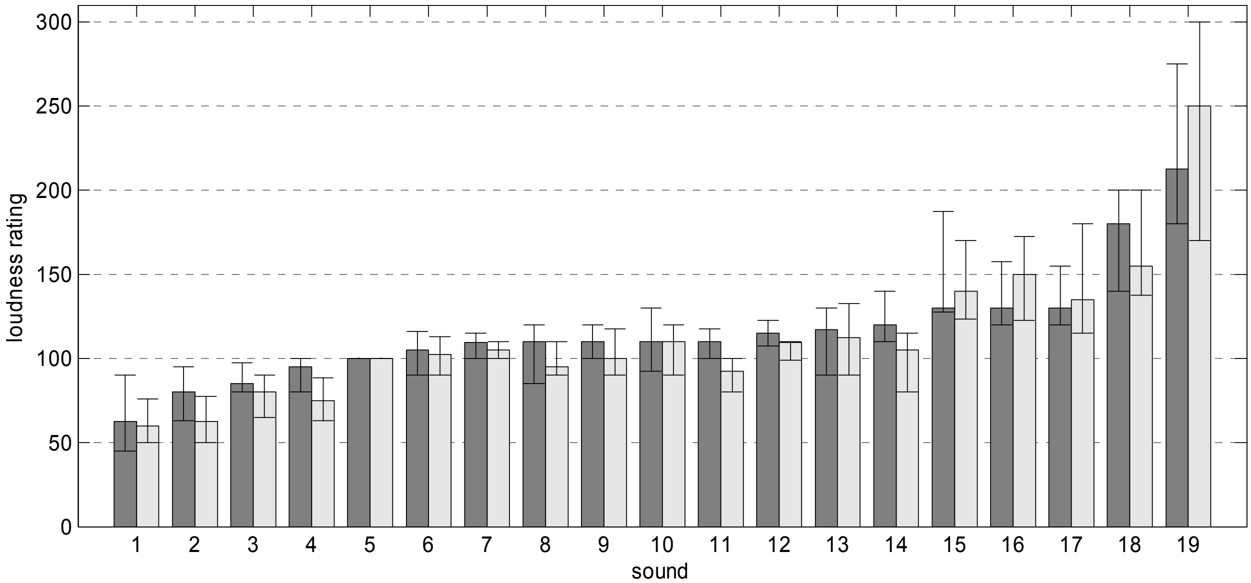

Figure 5: Loudness rating of sounds 1 through 19. Original sounds are indicated by dark shaded columns, processed sounds by light shaded columns.

The results displayed in figure 5 show that the subjects in all cases rated the anchor sound (sound 5) perfectly, i.e. assigned the number 100. This holds true for both original sound and processed sound.

Regarding the other sounds for which the results are illustrated in figure 5, there is only little difference in the loudness rating between original versus processed sounds. In all cases except one (sound 11), the inter-quartile ranges overlap. Statistical treatment of the data (Wilcoxon Rank Sum Test) shows different rating between original and processed sound for sounds 2, 4, and 11 on the 0.1% level.

The results displayed in figure 5 can be interpreted in such a way that the information about the sound source has little influence on the loudness rating. Considering the medians, in four out of 19 cases the processed sounds produce a larger loudness than the original sounds. In the remaining 15 cases, the original sounds produce a larger loudness than the processed sounds or both sounds produce the same loudness. However, as already indicated, because of the overlap of the interquartile ranges, these differences should not be overestimated.

In view of the hypothesis that the recognition of the sound source may influence the rating, those sounds are of particular importance, for which the original sound source is identified in all cases, whereas for the processed sound the original sound source is not identified at all. In order to assess this question, the subjects where asked to name the sound sources in two different runs of an experiment. In the first run, they had to name the sound source for the processed sounds, and in a second, separate run they had to name the sound source for the original sound. Results for the crucial cases of this experiment are displayed in figure 6.

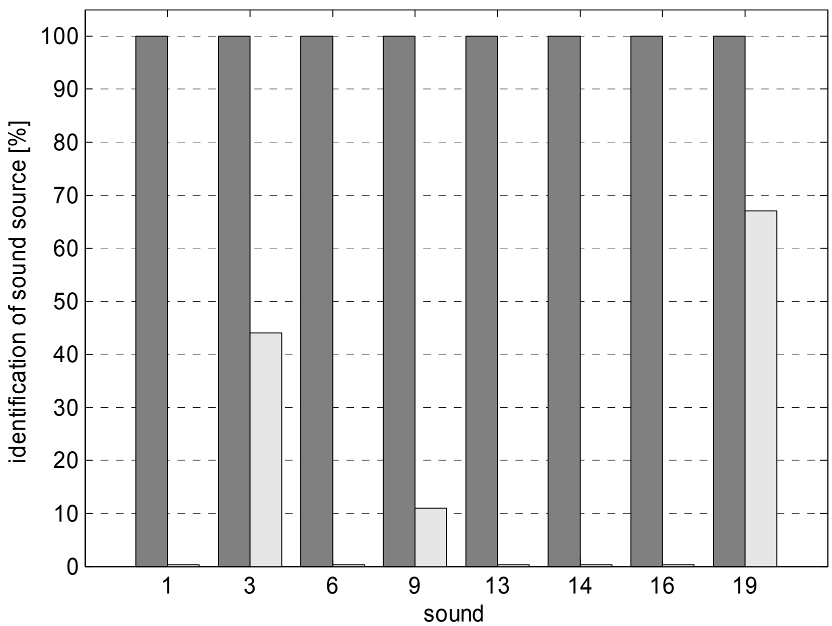

Figure 6: Identification of sound source for original sounds (dark shaded columns) versus processed sounds (light shaded columns)

The data plotted in figure 6 indicate those sound sources, for which the original sounds were recognized by all subjects. An optimum effect might be expected for sounds 1, 6, 13, 14, and 16, where all subjects can identify the original sound source, whereas for the processed sounds not a single sound source is correctly identified. For sounds 3, 9, and 19 all subjects recognize the original sound source, and also for the processed sounds, sometimes the original sound source can be identified. This is particularly pronounced for sound 19, where 67% of the responses indicate that the jack hammer was recognized even in the processed version.

Since for sounds 1, 6, 13, 14, and 16 the original sounds are recognized in all cases but the processed sounds not in a single case, possible cognitive effects on loudness should be most pronounced for these sounds. Regarding the data displayed in figure 5 for those sounds mentioned, with respect to the loudness of the original versus the processed sounds no large differences can be seen. In contrast, in all cases there is strong overlap of the interquartile ranges. This means that for sounds of same loudness-time-function which clearly differ in the recognition of the sound source, only little effects on the loudness evaluation can be verified. This result can be interpreted that cognitive effects may play a minor role with respect to loudness evaluation.

6 CONCLUSION

The data displayed in this paper would seem to suggest that cognitive effects like recognition of the sound source play a minor role for loudness evaluation. This result is in line with data from [7], [8], [10], and [3] who all showed that recognition of the sound source does hardly influence loudness evaluation. In contrast, [2] could demonstrate some influence of the recognition of the sound source on annoyance rating. For example, the original sound of a coffee machine, brewing fresh coffee, was preferred in comparison to the processed version, despite same loudness-time-function. Also the sound of clinking wineglasses produces much less annoyance for the original sound than for the processed sound. On the other hand, however, for many other sounds studied by [2] not only the loudness rating but also the annoyance rating was only little influenced by the effect whether the sound source could be identified.

In summary then this means that cognitive effects due to the recognition of a specific sound source seem to play a minor role in loudness evaluation. However, in some cases, the knowledge about the sound source can strongly influence the annoyance rating.

7 ACKNOWLEDGEMENTS

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