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Railway bonus and aircraft malus for different directions of the sound source?

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Abstract
Even for same LAeq, noise immissions from different types of traffic noise elicit not always the same loudness and annoyance. Frequently, railway noise is perceived as less annoying than road traffic noise (railway bonus), whereas aircraft noise can be perceived as more annoying than road traffic noise (aircraft malus). As one possible reason for the aircraft malus - in addition to differences in spectral distribution and temporal structure - sometimes the hypothesis is put forward that sounds which come from above a person are perceived as particularly dangerous and annoying. In order to challenge this hypothesis, psychoacoustic experiments were performed in which the same immissions of equal LAeq from railway noise, road traffic noise, and aircraft noise were presented by loudspeakers in front of versus above the subjects. They had to rate the overall loudness of the noise immissions by category scaling, magnitude estimation, and line length. Results are presented in which the magnitude of bonus or malus is given as a function of the direction of the sound sources. For presentation in front of the subjects, both railway bonus and aircraft malus were found. However, for “natural" situations like road traffic noise from front and aircraft noise from above, no aircraft malus showed up.

1. INTRODUCTION

At same energy equivalent A-weighted level, railway noise may be less annoying than road traffic noise. This effect, called railway bonus, has been found in field studies (e.g.[1], [2]) and could be confirmed in laboratory studies [3]. On the other hand, at same energy equivalent A-weighted level, aircraft noise can be more annoying than road traffic noise. The corresponding aircraft malus has been reported for field studies (e.g. [4], [5]) as well as laboratory studies [6]. As one possible reason for the aircraft malus - in addition to differences in spectral distribution and temporal structure - sometimes the hypothesis is put forward that sounds which come from above a person are perceived as being particularly dangerous and annoying. This hypothesis was challenged in psychoacoustic experiments. Noise immissions from railway noise, road traffic noise, and aircraft noise were presented to subjects by loudspeakers either in front of or above them. If the hypothesis is valid, presentation of railway noise above and road traffic noise in front should reduce the railway bonus. Likewise, for aircraft noise *and* road traffic noise from above, the aircraft malus should be reduced. However, when dealing with these predictions it has to be kept in mind that rather “unnatural” situations are involved. Therefore, it is of particular interest whether for a “natural" situation like road traffic noise from front and aircraft noise from above, an aircraft malus will show up.

2. EXPERIMENTS

Nine subjects (6 male, 3 female) with normal hearing ability and an age between 21 and 27 years (median 25) took part in the experiments. Sounds were presented in the sound proof room of the Department of Environmental Psychology at Osaka University. Loudspeakers of identical type (DIATONE DS-800ZX), hidden by acoustically transparent fabric, were located 185 cm in front of as well as 185 cm above the entrance to the ear canal of the subject.
Sounds used were noise immissions from railway noise, road traffic noise, as well as aircraft noise, each with a duration of seven minutes and an A-weighted energy equivalent level of 61 dB(A). The loudness-time-functions of the noise immissions are given in Fig. 1.

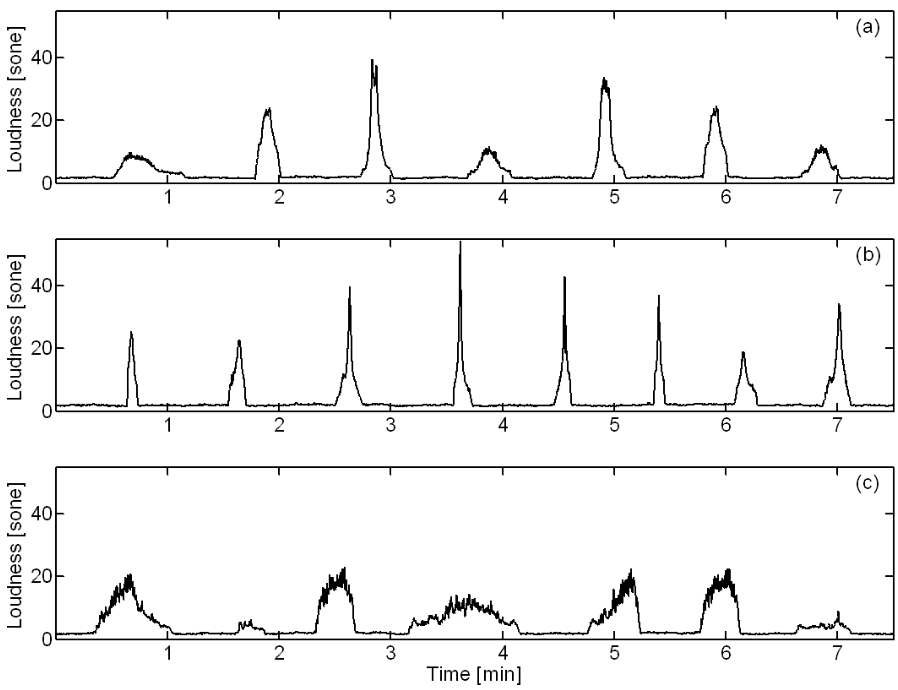

Figure 1: Loudness-time-functions of noise immissions from (a) railway noise, (b) road traffic noise, and (c) aircraft noise, each with 7 minutes duration and an energy equivalent A-weighted level of 61 dB(A).

During the presentation of the sounds, subjects had to rate the instantaneous loudness by continuous category scaling (e.g. [7], [8]). At the end of a run, subjects were given a questionnaire and had to rate the overall loudness of the previous seven minutes by category scaling, magnitude estimation as well as the method of line length (for details see e.g. [9], [10], [11]). For category scaling and line length, for each situation, medians and interquartiles were calculated from the respective nine datapoints. For magnitude estimates, first data were normalized with respect to the maximum number given by each subject, before medians and interquartiles were calculated.

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3. RESULTS AND DISCUSSION

Ratings of the noise immissions which were presented in front of or above the subjects are discussed separately for the psychophysical methods line length, magnitude estimation and category scaling.

3.1 Line length

In Fig. 2, the ratings of overall loudness of noise immissions by railway noise, road traffic noise, and aircraft noise are given for the method of line length. Circles represent data collected for presentation of the sounds in front of the subjects, triangles for presentation of sounds above the subjects.

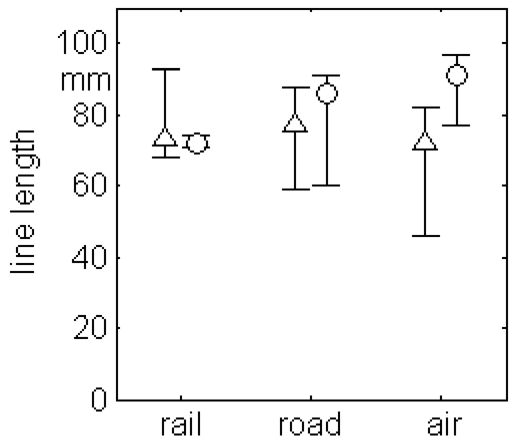

Figure 2: Evaluation of noise immissions from railway noise (rail), road traffic noise (road), and aircraft noise (air) at same energy equivalent A-weighted level of 61 dB(A). Presentation of sounds in front (circles) versus above (triangles) the subject. Method of line length.

For presentation of sounds in front of the subjects (circles) effects of railway bonus and aircraft malus show up. As concerns the medians, the overall loudness of railway noise, corresponding to 72 mm line length is lower than the overall loudness for road traffic noise corresponding to 86 mm line length, a result which is in line with the concept of railway bonus. The line length of 91 mm corresponding to the overall loudness of aircraft noise is larger than the 86 mm line length for road traffic noise, in line with the concept of aircraft malus. For presentation of sounds above the subjects (triangles), there is little difference in the overall loudness of railway noise (73 mm), road traffic noise (77 mm), and aircraft noise (72 mm). In this case, data suggest neither a railway bonus nor an aircraft malus. The hypothesis that presentation of sounds from above may *increase* the rating is not supported. On the contrary, for road traffic noise and aircraft noise, rating for sounds presented from above the subjects (triangles) is *lower* than for presentation in front of the subjects (circles). For “natural” presentation of the sounds, i.e. road traffic noise in front of the subjects (circle 86 mm) and aircraft noise above the subjects (triangle 72 mm) the data would rather seem to suggest an aircraft bonus! On the other hand, “natural” presentation of railway noise (circle 72 mm) and road traffic noise (circle 86 mm) in front of the subjects would support the concept of railway bonus.

3.2 Magnitude estimation

Fig. 3 shows the data collected by the method of magnitude estimation. Again, presentation of sounds in front of the subjects is indicated by circles, presentation above the subjects by triangles.

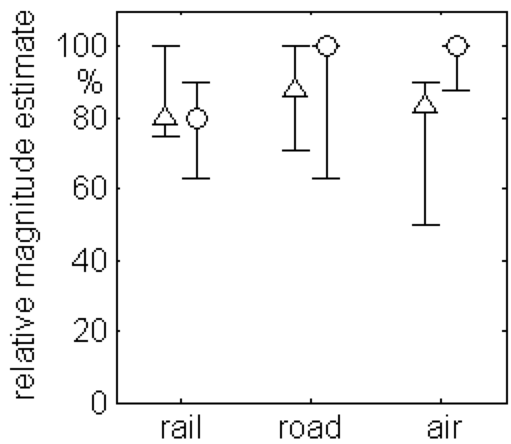

Figure 3: Evaluation of noise immissions from railway noise (rail), roadtraffic noise (road) and aircraft noise (air). Presentation of sounds in front (circles) versus above (triangles) the subjects. Method of magnitude estimation.

Results displayed in Fig. 3 for frontal presentation (circles) are in line with the concept of railway bonus, but show no aircraft malus. Relative magnitude estimates (medians) amount to 80 % for railway noise and to 100 % for road traffic noise, and also 100 % for aircraft noise. Again, the hypothesis that presentation of sounds above the subjects would increase their rating is rejected (cf. triangles vs circles). For “natural” presentation of road traffic noise in front (circle 100 %) and aircraft noise above (triangle 83 %) the subjects, the data again would seem to suggest an aircraft bonus! For “natural” presentation of railway noise verus road traffic noise in front of the subjects (circles 80 % vs 100 %), the concept of railway bonus seems to be confirmed.

3.3 Category scaling

In Fig.4, the ratings for the method of category scaling are displayed. Categories used are very soft (VS), soft (S), sligthtly soft (SS), neither soft nor loud (NL), slightly loud (SL), loud (L), and very loud (VL). . Again, presentation of sounds in front of the subjects is indicated by circles, presentation above the subjects by triangles.

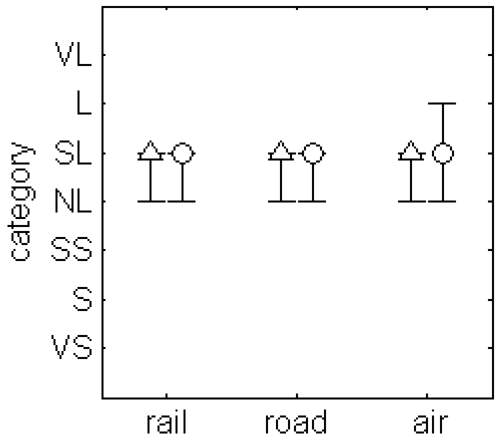

Figure 4: Evaluation of noise immissions from railway noise (rail), roadtraffic noise (road) and aircraft noise (air). Presentation of sounds from front (circles) versus above (triangles). Method of category scaling.

The data displayed in Fig. 4 indicate that the overall loudness of all sounds was on the average (medians) assigned to the category slightly loud (SL), irrespective of the presentation of sounds in front of vs above the subjects. Taking into account the interquartiles, for presentation of road traffic noise and aircraft noise in front of the subject (circles), a slight indication of an aircraft malus might be interpreted into the data. However, it has to be recalled that this is an “unnatural” situation with aircraft noise presented in front.

4. CONCLUSIONS

The hypothesis that sounds presented from above a subject are perceived as louder and more annoying is *not* supported by the data reported in this paper. These results may be partly due to the “unnatural” presentation of railway noise or road traffic noise *above* the subject. In addition it should be recalled that even for identical signals from the loudspeakers in front versus above the subject, because of HRTFs, the signals at the eardrums are different.

For presentation of sounds in front of the subjects – in line with data from the literature – effects of railway bonus as well as aircraft malus showed up. However, for “natural” presentation of road traffic noise in front, but aircraft noise above the subject, *no* aircraft malus could be ascertained. On the contrary, the data would seem to suggest for this situation an aircraft bonus.

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