Influence of Train Colour on Loudness Judgments

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Title : **Influence of train colour on loudness judgments**

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Abstract :

This study replicates an experiment described by Patsouras et al. [5] or Rader et al. [8] in which subjects had to evaluate the loudness of a passing-by train noise while watching pictures of the train, the colour of which being varied. In contrast to these studies, no influence of train colour on loudness evaluation could be found. This discrepancy might be due to cultural differences (French subjects vs. German or Japanese ones). But a more realistic reason can be a jury sampling effect, as this influence can exist for very few subjects (one among twenty-two in this experiment).

Classification : 66.002 : Cb – Loudness, absolute threshold
66.010 : Lj – Perceptual effects of sound

1. Introduction

Influence of visual inputs on sound quality has been noticed in different situations, e.g. soundscapes [1], concert-hall evaluation [2], judgements of the quality of loudspeakers [3] or of the powerfulness of a car sound [4]. Similar effects have also been reported for a more elementary psychoacoustic quantity as loudness. Fastl and colleagues asked subjects to evaluate the loudness of a passing-by ICE train sound [5, 6, 7]. When listening to the sound, subjects could see a picture of the train, the colour of which being varied. It appeared that a red coloured train lead to a higher estimation of loudness than a green coloured one, though this effect was small. This study was conducted with German subjects and later confirmed with Japanese ones [8]. More recently, a similar effect was related for the sound of a sports car [9].

Nevertheless, this colour effect was small and the experiments were conducted with a rather low number of subjects (e.g. 9 in [5]). Therefore, we intended to replicate the experiment involving ICE train stimuli with a larger number of subjects.

2. Procedure

2.1 Stimuli

Audio-visual conditions were similar to those used in the above mentioned experiments [5 , 6, 7, 8]. A passing of an ICE train was monophonically recorded at a distance from 25 m. Signal duration

was 11 seconds. The level was adjusted to match three different values (the A-weighted sound pressure level being 82 dB, 78 dB and 74 dB). This level modification was realized using the output potentiometer of the soundcard of the computer (Gina24 from EchoAudio), the maximum output setting being selected for the maximum desired sound level. Sounds were diotically presented to listeners through electrostatic headphones (Stax SR-303) in a sound proof booth.
During sound presentation, a fixed picture of the train could be seen by the listener. The train could have four colours (white, i.e. the original colour of the ICE train, red, blue and green). This picture was presented on a screen at approximately 2 meters in front of the subject. The picture was approximately 1.5 meters wide and 1 meter high.

2.2 Experiment

The three levels of the sound and four images lead to twelve different combinations. Each combination was randomly presented three times to the subject. Loudness of sound was evaluated using a "free magnitude estimation" procedure : the first stimulus had to be evaluated absolutely and each stimulus was considered as a standard for the evaluation of next one [10]. Subjects were asked to use positive numbers (integer or not) to give their answer. They typed this value using the keyboard of the computer running the experiment.

2.3 Subjects

22 normal-hearing subjects (19 men and 3 women) participated to this experiment. They were students (15) or staff from the laboratory (7). Their age varied from 22 and 58 (average : 32.5).

3. Results and discussion

In a first step, the influence of the two factors was investigated using an analysis of variance. For each couple of factors, the geometric mean of the three evaluations given by a subject was computed. An ANOVA (repeated measures) was conducted using the set of data thus obtained. It appeared that the only significant factor was level ($F(2; 42) = 14.9$, $p < 0.001$). Colour was not significant ($F(3; 63) = 1.75$, $p = 0.165$), nor the interaction between factors ($F(6; 126) = 1.3$, $p = 0.25$).

In order to directly evaluate the influence of colour, the influence of level and the inter-individual variability was eliminated. For each subject and each sound level, the ratio between the geometric mean obtained for a given train colour and that one of the white train was computed (the actual colour of the ICE train being selected as a reference). For each colour, a set of 66 (3x22) values was thus available. The mean, median and interquartile range of these data are presented in figure 1. Differences between median values were not significant (Wilcoxon test, $p = 0.01$).

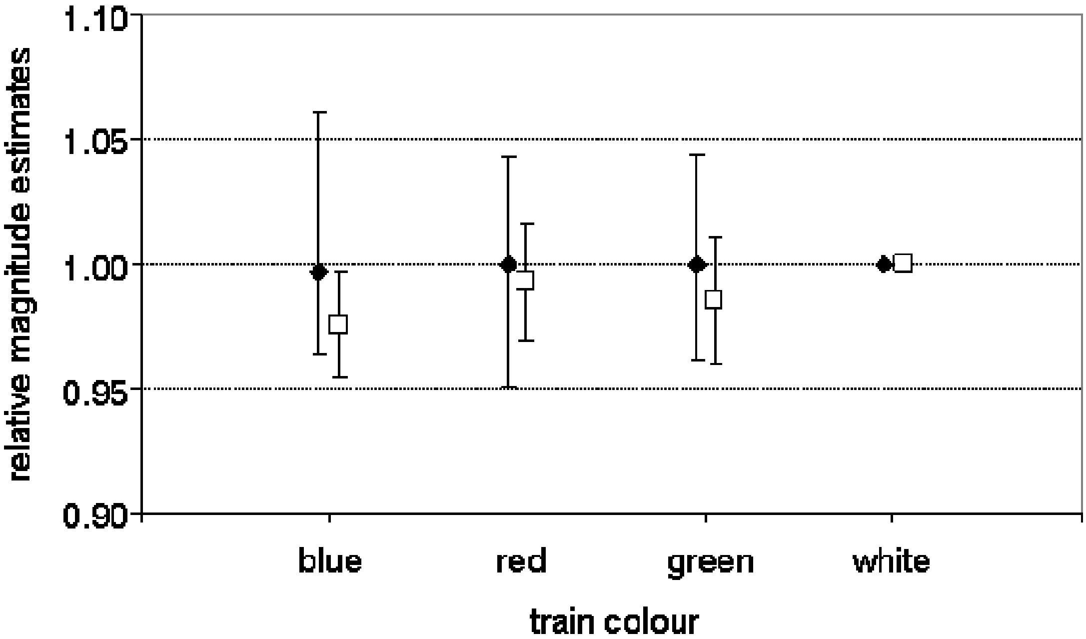

Figure 1 : relative loudness (ref : white train). Closed circles : median values and interquartile ranges. Open squares : mean values in their 0.95 confidence intervals.

Therefore, it seems that train colour did not influence the loudness of the sound. As this could be true for some subjects, ANOVAs were conducted using each individual's set of data (including the three repetitions of each couple of stimuli). It appeared that a significant influence of colour was found for one subject only ($p = 0.01$). For this subject, the sound from the red train was evaluated as a little less loud than the one from the white train (post-hoc comparison using Scheffe's correction, $p = 0.017$).

This result is quite different from the ones already published by German and Japanese colleagues. Using the same procedure (with the exception that another set of stimuli was without any image of the train), these papers related significant influence of the train colour. One noticeable effect was that the red train appeared louder than the green one [4].
This discrepancy could be due to cultural effects (French subjects vs. German or Japanese ones). Such a cultural effect has already been found in some other topics (e.g. booming noise of a car [11], or the negative or neutral connotation of the word "loudness" [12]). But such differences were mainly found between Japanese and European subjects – the perception within Europe being homogeneous.

Another possible reason for this discrepancy can be a sampling effect. Several limitations of our study can be pointed out:

- A few women (3) participated to the experiment. It has been shown that women and men perceive colours in a slightly different way [13, 14], which is due to some physiological differences in the retina. But, in this experiment, train colours were so different that we think no gender effect could be expected. Some other gender differences are related to colour preferences [15]. But, as no preference was asked to subjects, this effect can also be neglected;
- Some subjects were very used to sound experiments (7 of the 22). Such people may have paid their whole attention to the sound, without taking images into account. However, the subject who proved to be influenced by the train colour was one of these people (he was a staff member).

- Finally, the number of subjects could be increased.

Indeed, all these limitations also apply to previous studies, which concluded that the colour of the noise source influenced the evaluation of loudness. The number of subjects was 9 in [5], between 13 and 15 in [8], 16 in [9]. All subjects were trained in psychoacoustic experiments in [5] – no information is provided in [8] and [9]. In [9], 4 women participated to the experiment, which is also true for one experiment related in [8], while the gender distribution is not mentioned in [5]. Therefore, it can be concluded that some more investigations are needed, using larger and better gender-balanced listener panels, before concluding that the colour of the sound source can influence the loudness of the sound.

On the other hand, the influence of loudness was quite close to what could be expected. Loudness values were averaged over the four train colours. The highest sound pressure level was used as a reference and the relation between loudness and the relative pressure of each stimulus can be seen in figure 2. The curve is a power-law adjusted to these data. The exponent of this power-law was best fitted to 0.52, which is quite close to the expected value (0.6 according to Stevens' power law [16]).

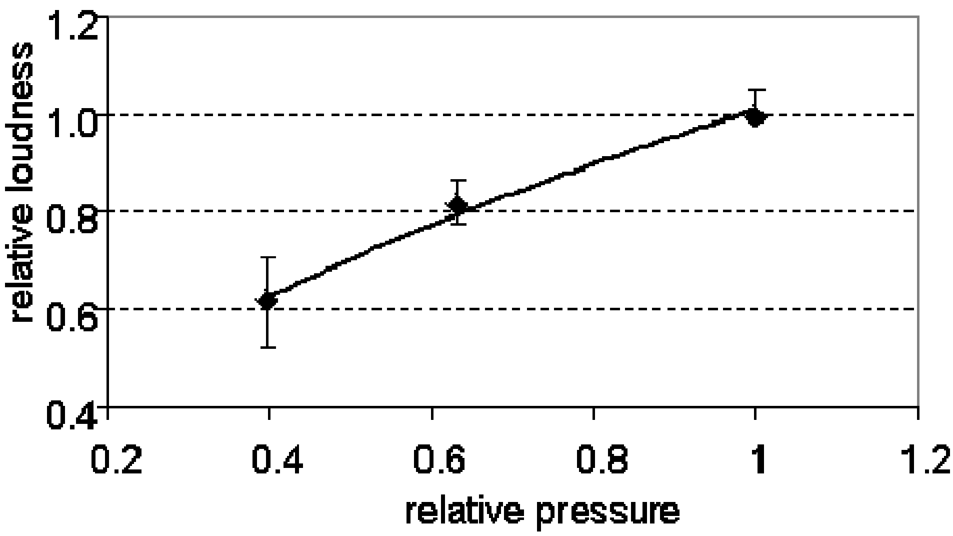

Figure 2 : relative loudness of stimuli, represented as a function of the relative A-weighted sound pressure level. Median values are shown in their interquartile range.

4. Conclusion

In this experiment, no influence of train colour on loudness evaluations could be found. Such an effect is very subject-dependent and appeared for one subject only in the panel of 22 persons used in the experiment. We think that it can be neglected when averaging over a group of people – though audio-visual interactions certainly exist for more complex sound features.

A limitation of this study is the rather low number of subjects, which could bias the results. This is also true for the referenced studies. Therefore, it appears that more investigations are needed to confirm any of these contradictory results.

Moreover, the realism of the experiment could be improved, as the visual stimulus was just a picture and the sound was diotically presented, without any spatial effect. Using more realistic stimuli could modify these conclusions.

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