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Annoyance due to railway noise and vibration: A comparison of two methods of collecting annoyance scores

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ABSTRACT

An experiment has been conducted in order to determine if the method of collecting partial and overall annoyance scores – during separated sessions or during the same session – has an influence on the participants' answers. The experiment used controlled noise and vibration stimuli corresponding to a train pass-by, recorded inside a house in the vicinity of a railway track. 32 participants attended 4 sessions A, B, C and D during each of which they were presented with 16 combinations of noise and vibration. They had to evaluate partial annoyance due to noise in the presence of vibration (session A), partial annoyance due to vibrations in the presence of noise (session B) or overall annoyance (session C). Lastly, they were asked to rate partial and overall annoyances in a same session (session D). Results show that partial and overall annoyance scores, simultaneously collected during session D, were quite similar to the ones respectively collected during dedicated sessions. Furthermore, this method is convenient as a reduced number of stimuli is presented to each participant.

INTRODUCTION

European railway network has spread out over the last decades. The number of passenger and freight trains should increase in the future, mainly for environmental reasons [1]. Yet railway transport is a source of nuisance. Railway noise has been designated as less annoying than road traffic noise or aircraft noise and therefore benefits from a "railway bonus" in noise regulations. This bonus may not be justified for any type of trains: high-speed trains or freight trains, for instance [2]. In the latter case, annoyance due to noise is generally linked to vibration nuisance also. Some studies have been conducted to establish dose-effect relationships between railway induced noise level and annoyance (e.g. [3]). Some other ones focused on the relationships between vibration level and annoyance (e.g. [4]). But only few studies have focused on annoyance due to combined noise and vibration.

Laboratory studies and *in situ* studies

Gidlöf-Gunnarsson et al. [5] have studied annoyance due to combined noise and vibration through *in situ* enquiries. In these studies, annoyance scores resulting from a long-term exposition were collected. Howarth and Griffin [6], Paulsen and Kastka [7] and Lee and Griffin [8] have undertaken laboratory experiments. In these studies, annoyance scores were collected under controlled conditions. Laboratory studies aim at understanding perceptual mechanisms linked to a potential interaction between noise annoyance and vibration annoyance. Noise (respectively vibration) annoyance expressed when noise (resp. vibration) is in isolation is referred to as *specific* noise (resp. vibration) annoyance. Noise (resp. vibration) annoyance expressed when noise (resp. vibration) is not in isolation is referred to as *partial* noise (resp. vibration) annoyance [9]. Lastly, annoyance due to the global situation with combined noise and vibration is referred to as *total* annoyance.

Partial and total annoyance scores: collecting method

Measuring partial and total annoyance leads to the question of which method should be used to collect annoyance scores. As a small number of studies dealing with annoyance due to combined railway noise and vibration has been conducted, it is necessary to have a look at literature on annoyance due to combined noise sources. In field studies, total annoyance due to combined noise sources (e.g. road traffic noise and railway noise) and partial annoyances are assessed using a questionnaire (e.g. [10]). Different works mentioned that a potential effect of the order of questions on responses may occur during the interview process ([11], [12]). In laboratory studies, partial and total annoyance scores are collected during a same session (e.g. [13]). In combined noise and vibration studies, the procedure used to collect partial and annoyance scores is quite different. Partial and total annoyance scores are collected during separated sessions dedicated to each “kind” of annoyance. To our knowledge, no studies sought to investigate potential influence on the participants’ answers of collecting annoyance scores during the same session or during separated sessions. This paper presents an experiment built up to address this methodological issue. During a perceptual experiment, participants evaluated partial noise annoyance, partial vibration annoyance and total annoyance due to combination of railway noise and vibration. On the one hand, annoyance scores were collected during three dedicated sessions and on the other hand, the same scores were collected during one session.

FIELD MEASUREMENTS OF NOISE AND VIBRATION STIMULI

Several train pass-bys were recorded inside a dwelling nearby a railway track (**cf. Figure 1**). Distance from source to receiver was approximately 10 meters. Acoustic recordings were made using a stereophonic system (Schoeps MSTC 64 U). Vibration signals were simultaneously recorded using a triaxial accelerometer (PCB 393B12) working in the useful frequency range (i.e. 1 to 80 Hz for whole-body vibration). Vibration measurements were made in accordance with ISO 2631-2 [14]. A passenger train pass-by was selected for the perceptual experiment.

The A-weighted sound pressure level of the acoustic signal recording (cf. Figure 2), L_{Aeq}, was equal to 44 dB(A). Root-mean-square (rms) acceleration, averaged over the duration of the recorded vibration signal (cf. Figure 3), was 0.0299 m/s².

Figure 1: Stereophonic microphone and accelerometer for recordings inside the dwelling

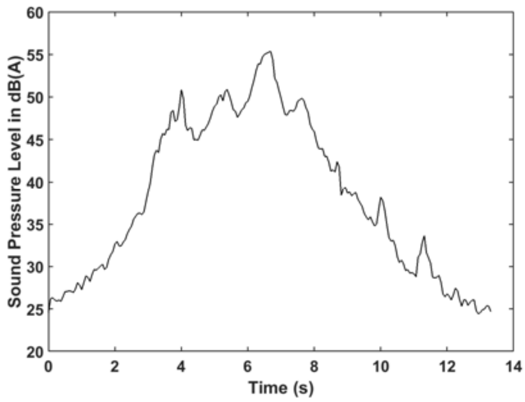

Figure 2: Temporal characteristics of the acoustic recorded signal

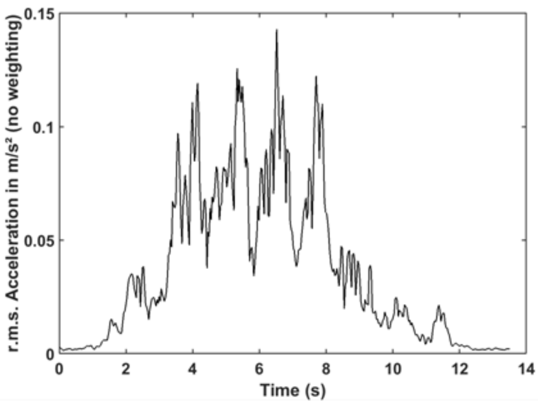

Figure 3: Temporal characteristics of the vibration recorded signal

METHOD

Annoyance due to combined noise and vibration recordings was assessed *via* a perceptual experiment. The goal of this experiment was to study the influence of the method of collecting annoyance scores on the participants' answers.

Apparatus

An experimental set up was built up in order to reproduce acoustic and vibration field measurements in laboratory. The experiment took place in a semi-anechoic chamber (inside dimensions 10,7 m x 8,5 m x 5 m). A spring-suspended platform was vertically moved by an electrodynamic shaker (LDS-V650). A rigid stool was attached to the platform in order to efficiently transmit vibration intensity. The whole structure was provided with a security guardrail. Stereophonic noise signal was reproduced by two loudspeakers (Tapco S5) placed at the height of the participant's ears. The loudspeakers and participant formed an equilateral triangle with the distance between each element equal to 2.5 meters. Background noise was below 30 dB(A).

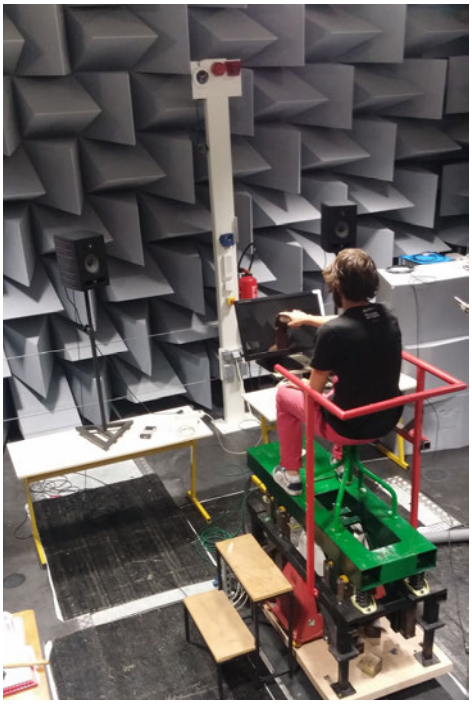

Figure 4: Experimental set up of the perceptual experiment.

Stimuli

From the recorded acoustic signal, four sound stimuli were generated with L_{Aeq} ranging from 44 dB(A) to 62 dB(A) in 6 dB(A) steps. Four vibration stimuli were derived from the original vibration signal as well. Unweighted rms accelerations of vibratory stimuli were 0.0299, 0.0543, 0.0714 and 0.0943 m/s². There were 16 possible combinations of noise and vibration for the train pass-by. Total duration of the train pass-by was 13.5 seconds.

Procedure

Partial noise annoyance, partial vibration annoyance and total annoyance were evaluated for each of the 16 combinations of noise and vibration. A continuous numerical scale ranging from 0 to 10 was used to evaluate annoyance. Labels "not annoying at all" and "extremely annoying" were displayed under the values 0 and 10, respectively. Before the experiment began, participants were provided with instructions and signed a consent form. Verbal instruction was also given to imagine themselves at home during the experiment, doing a relaxing activity (e.g. reading). Two examples of an imaginary situation were suggested to participants: sitting in their living room or outside on their balcony for instance. Finally, participants were told to maintain their body in a vertical position as much as possible during the experiment.
To get familiar with stimulus range and annoyance scale, participants were first presented with a series of four stimuli. This series was made up of one combination of the lowest noise and vibration levels, one combination of the highest noise and vibration levels as well as one stimulus composed of noise alone and one stimulus composed of vibration alone.

The experiment consisted in four sessions. The order in which participants attempted each session was balanced in order to avoid any potential bias. Tasks during these sessions were:

- Session A: evaluation of partial noise annoyance for each of the 16 combinations. During this session, specific annoyance due to every four levels of noise alone was also collected (20 stimuli in total).
- Session B: evaluation of partial vibration annoyance for each of the 16 combinations. During this session, specific annoyance due to every four levels of vibration alone was also collected (20 stimuli in total).
- Session C: evaluation of total annoyance for each of the 16 combinations (16 stimuli in total).
- Session D: evaluation of partial noise annoyance, partial vibration annoyance and total annoyance for each of the 16 combinations (16 stimuli in total).

Stimuli were presented in random order. At the end of each session, participants were also asked to evaluate how difficult the task was, using the same numerical continuous scale. Total duration of the experiment was about 45 minutes.

Participants

Thirty-two people with normal hearing abilities participated to the experiment. Twenty of them were males and twelve were females. Mean age was 33.2 years, with standard deviation 9.7 years. None of the participants was aware of the goal of the study. Questions related to the objective of the experiment were not answered.

RESULTS AND CONCLUSION

Preliminary analysis of the data shows that no significant effect of the method of collecting annoyance scores exists. More in-depth results will be given during the oral presentation.

Acknowledgements

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