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# Assessing the Perceived Annoyance of High-Speed Trains with an Experience Sampling Method

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**Abstract.** Annoyance caused by high-speed trains (HST, > 250 km/h) seems to be not completely modelled by current indicators (e.g.,  $L_{DEN}$ ). For example, the suddenness, spectral content, temporal fluctuations of pass-by noises, and the density of peaks seem to play a significant role that is not fully understood [1]. To better understand these effects, we report on the results of a pilot study aiming to test experimental protocol that allows for a detailed analysis of short-term annoyance due to high-speed trains. We used an experience-sampling method (ESM): volunteer participants living nearby French high-speed lines were instructed to report their annoyance level right after a train pass-by with a remote device. This method has the potential to combine ecological validity with a precise control of the sound experienced by participants. As this method has never been used for railway noise assessment, residents were recruited to take part in the study and received two protocols in two different periods, to determine which ESM parameters are the most efficient.

**Keywords:** High-speed trains, noise, annoyance, experience sampling method

## 1 Introduction

One drawback of railway transportation is noise pollution for communities living close to railway infrastructures. In France, the social cost of railway noise pollution has been estimated to be 11.2 billion euros per year [2]. After years of constant progress in decreasing noise levels around railway infrastructure (rolling stock design, noise barriers, dwelling insulation), further global level reductions are becoming increasingly costly. It is therefore utterly important for railway stakeholders to better understand which aspects of noise emissions impact people living near high-speed lines (HSL) the most, to focus noise abatement measures more precisely.

Two main approaches are reported in the literature to assess annoyance caused by railway noise: in-situ social surveys and laboratory experiments. *In situ* social surveys ask residents living alongside railway tracks to rate annoyance experienced

(retrospectively) at home over a long time period. In contrast, laboratory experiments are designed to focus on the characteristics of a small number of acoustic events, in a laboratory setting. Despite their differences in scope and methods, both social surveys and laboratory experiments have yielded the following results:

- Loudness indicators are often the main factor contributing to annoyance [1], [3]–[7];
- Annoyance is higher for high-speed (HST) than for conventional trains [1], [8]–[10];
- The number of passages also influences annoyance [7], [11]–[13];
- There is no clear consensus as to whether indicators based on averaged or maximal levels better model long-term annoyance [1], [14], [15];

Here, we focus on the short-term annoyance caused by HST and a method combining the advantage of in-situ and laboratory experiments: the experience sampling method (ESM). It involves the repeated measurements of human beings' daily-life experiences, perceptions, or behaviors in situ at different moments over a certain period of time [16]. To our knowledge, this method has mostly been used to assess aircraft noise annoyance [17]–[19] but not for railway noise. Through this diary study methodology, participants evaluate annoyance from pass-by noise in response to notifications. Responses are then associated with data on sound exposure.

The study reported here is part of a larger project aimed at better understanding the acoustic factors contributing to annoyance experienced by people living alongside an HSL. Overall, its goal was to compare different parameters of an ESM. Particularly, we sought to identify the best method to send notifications to participants so that they can assess the annoyance of specific train passages. More precisely, we wanted to select protocol settings that: generates enough data, allows to study the influence of the number of passages on perceived annoyance, allows to combine annoyance judgements with trains' acoustical characteristics, is acceptable for participants (not too burdensome, not too intrusive), is easy to use, and does not interfere with participants' daily life. Therefore, two protocols (A and B) with different parameters were compared in a pilot study.

## 2 Materials and methods

### 2.1 Selection of participants

This pilot study was conducted in the vicinity of the French HSL "Atlantique" (West of France). We selected 122 residential buildings with a railway noise exposure  $L_{DEN} > 55$  dB(A) (corresponding to a maximum of distance of about 1 km). The selected dwellings had also to be not exposed to other sources of transportation noise. Topography and noise barriers were also considered in the simulation. A recruitment agency contacted potential participants by phone or by visiting them in person. As the aim of this pilot was purely methodological, we were not looking for significant quantitative results. We were therefore aiming for around ten participants. Some of the selected dwellings were in fact not canvassed. Eight people between 26 and 67 years old with no reported hearing issue were finally hired (3 women and 5 men). Each participant received financial compensation of 150 €.

## 2.2 Setup

A remote response device made of a LCD with Bluetooth Low Energy and a buzzer was used to send out notifications at predefined times based on theoretical train passages. Participants used it to fill in an annoyance questionnaire, either by scanning QR code that sent them to a web page (protocol A), or directly on the device (protocol B).

## 2.3 Procedures

The first 3 days, participants used protocol A. On the 4th day, a telephone interview took place to debrief the first three days. The next 3 days, participants used protocol B. A last telephone interview was scheduled at the end of this week. The whole study will lasted 7 days for each participant.

**Protocol A** was designed to interfere as little as possible with participants' daily lives. They selected a two-hour slot each day, and notifications were sent after certain train passages (that were preselected) during these slots. The notification times were selected to vary the number of train passages experienced before each judgement.

Participants were instructed to carry on their daily activities as usual. When they received a notification, they were invited to fill in a brief online questionnaire. The first two questions concern whether the participant heard the train passing before the notification, and whether they were inside their home. Then, the questionnaire presents an ISO 11-points numerical scale of annoyance (focused on the last train passage). Three additional questions concern the activity being carried out at the time of the passage, whether the window was opened or closed, and the level of noise inside the dwelling.

**Protocol B** required participants to stop their activities during a 15-min slot each day and listen carefully and assess noise annoyance for every train passing by during this slot. It used only the annoyance scale. In this protocol, participants answer directly on the remote response device, using physical buttons to move a cursor on the ISO 11-points numerical scale.

# 3 Results and discussion

## 3.1 Amount of data and statistics

For protocol A, considering only participants with no impediments or technical issues (5 participants out of 8), 74 notifications were sent during the study. Sixty-five answers were obtained (87.8%). Forty-two answers (64.6%) mentioned that the participant had not noticed the train (and hence could not rate annoyance). It may be partly due to the poor synchronization of the notification with the actual train passages, based only on train schedule. Details are given in Table 1. For protocol B, a total of 20 quarter-hours were studied and 38 annoyance ratings were collected. Details are given in Table 2.

**Table 1.** Quantitative results for protocol A

Participant	1	2	5	6	8	Total
Number of notifications received	13	12	21	12	16	74
Number of answers provided	13	12	16	8	16	65
Number of “no train heard” answers	7	12	10	3	10	42
Number of annoyance ratings	6	0	6	5	6	23

**Table 2.** Quantitative results for protocol B

Participant	1	2	3	4	5	6	7	8	Total
Number of slots	3	3	2	1	2	3	3	3	20
Numb. of ratings	5	7	4	2	5	8	1	6	38

### 3.2 Acceptability, ease of use and interference with daily-life activities

The analysis of the interviews highlighted that asking for two hours a day may have scared participants away (protocol A). This protocol can be perceived as more restrictive as it requests participants to stay in their main room during the whole time slot. Moreover, seven participants express a preference for protocol B, because of the shorter time slot, the careful listening, and the response directly on the device.

During the interviews, six out of eight participants mentioned that the notification was not loud enough, so they had to change their habits (e.g., not listening music or TV) to detect it. Discussions with the participants also revealed that most of them have become accustomed to the noise of trains and hardly notice them in their daily life. Only certain passages were perceived as very annoying. In their opinion, the potential sources of annoyance are the weather, the speed, the vibrations, and the type of train.

## 4 Conclusion

This pilot study aimed at testing different methodologies to develop an in-situ study of the acoustic factors driving the short-term annoyance experienced by residents living close to HSL. It compared two variations of the Experience Sampling Method. Protocol A was designed to interfere as little as possible with the situation: it requested participants to carry out their daily activities as usual and rate the annoyance of train passages signaled by notifications sent throughout 2-hour periods, whenever they had noticed them (signal contingent). In contrast, in protocol B requested participants to stop their daily activities for 15 minutes, listen carefully and rate the annoyance of every train passing by (event contingent). The main methodological results are:

- Protocol A seems to be more representative of participants’ real-life annoyance than protocol B. It allows to consider the number of passages that participants did not notice, and thus, to study its influence on annoyance, considering not only the scheduled number of train passages but also the number of passages heard by participants.

This will allow us to determine the acoustic characteristics of the passages heard by the residents as well as other external factors such as weather conditions.

- Consequently, in protocol A, many notifications did not yield any annoyance rating, as participants had not noticed the train passage. In contrast, in protocol B, participants rated every single passage. This striking contrast suggests that protocol B was clearly not representative of the annoyance experienced by participants
- However, protocol A also has some drawbacks: for example, participants were often not in the same room as the response device when they received notifications. In addition, participants found it difficult to be available 2 hours each day (and preferred the shorter protocol B).

These methodological results will now be used to design a new protocol at a larger scale, which will combine annoyance ratings and acoustical characteristics.

Protocol A seems to be more representative of participants' real-life annoyance as it allows to consider the passages that participants did not notice. However, the drawbacks it presents could be improved in the future. First, the 2-hours' time requested in protocol A is restrictive. This may explain why recruiting eight participants was already difficult. In order to roll out an experiment on a larger scale, we will have to reduce the constraints by letting them choose their time slots from day to day. Moreover, a louder notification will be developed to ensure that participants' lifestyle is not changed. Finally, annoyance responses would be synchronized to trains' passages thanks to a microphonic device (equipped with a Raspberry Pi) who automatically detects trains' passages. The goal of our next studies will be to develop a new protocol including these improvements, and then to relate and analyze the impact of the acoustical characteristics of the trains passing-by on annoyance judgements.

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