New indicators for time patterns of combined noise sources (road and railway)

Manon Raimbault[1], Eva Walker[2], Catherine Lavandier[3], Cora Cremezi-Charlet[2]
[1] *Inrets-Lte - Case 24, 69675 BRON Cedex, manon.raimbault@inrets.fr*
[2] *SNCF-DRT - 45, rue de Londres 75379 Paris Cedex*
[3] *LMRTE Univ. Cergy-Pontoise, Dept. Génie Civil - Rue d'Eragny, Neuville/ Oise 95031 Cergy Pontoise*

Introduction

Many social surveys and laboratory experiments concerning transportation noise annoyance have studied whether railway or road traffic assessments [1; 2; 3; 4]. However, few studies investigate on-site evaluation of combined noise sources in our daily life [5]. This latter study shows an ambiguity in the evaluation of the temporal characteristics of road traffic noise (*continuous* but also *discontinuous* for short periods) versus railway noise (*short*, *abrupt* but also *recurring* for a long period). The present study thus aims at evaluating time pattern assessments of road and railway combined noises.

For this experiment, sound stimuli of combined noise sources were shaped mixing noises of trains (high speed train, regional or suburban trains, freight) with various road traffic (with or without truck presence).

Listening tests were carried out in a quasi sound-proof room. The test comprise of in two tasks: verbal answers to open question and verbal scales evaluation of specific acoustic features. Finally, psycholinguistic and statistical analyses of the answers gave complementary results to understand how people assessed road and railway combined noises.

Method

Stimuli: Nine soundtracks of 30 seconds were composed of different types of train and road traffic noises (presented in Table 1). Both train and road traffic noises were separately recorded, respectively at 30m perpendicular from the middle of the way (railway or road). All stimuli have been equalized considering N_{10} measures in the quasi sound-proof room.

	Types of train	Types of road
1	Regional train ('TER')	Main road without truck presence
2	High speed train, double deck, 300km/h	Highway with truck presence
3	Freight train	Main road without truck presence
4	High speed train, 300 km/h	Main road with truck presence
5	High speed train, double deck, 350 km/h	Main road without truck presence
6	Regional train ('Corail')	Highway with truck presence
7	Regional train ('TER')	Main road with truck presence
8	Goods train	Main road with truck presence
9	Suburban train	Main road with truck presence

Table 1: Description of both road traffic and railway types for each mixed stimulus.

Equipment: Subjects answered questions through a user interface in a quasi sound-proof room. The stereophonic system was adjusted referring to measures of pink noise emission also considering the sitting subject's situation and the loudspeaker disposition (out of sight).

Procedure: Before starting the test, subjects were given instructions which outlined the experiment purpose and the user interface functionality. Each subject was then alone in the room to take part in the test which consisted of two tasks.

First, participants answered open questions concerning selection of only one stimulus among three (stimuli 1, 2, 3 presented randomly). The questions consisted of the description of the stimulus through the detail of its effects.

Secondly, participants went onto a psychophysical test (for all other stimuli presented randomly): identification and labelling; evaluation of verbal scales constituted of six items related to time patterns: *short*, *abrupt*, *continuous*, *homogeneous*, *erratic* and *recurring* and related judgements. Presentation of time pattern items also varied randomly. Verbal scale for time pattern evaluation was the French equivalent of *not at all*, *slightly*, *moderately*, *sufficiently* and *highly*. Simultaneously, the verbal scale items for related judgement were: *unconcerned*, or *bearable*, *unpleasant*, *very unpleasant* and *unbearable*.

After the test, participants answered further information about themselves: quality of their everyday ambient sound environment, proximity of railway and road of their home.

Participants: 17 women and 20 men, living in the suburb of Paris, aged between 18 and 55 (average 30 years old) participated in the experiment. Very few subjects were used to doing any activities which implied a high exposure to noises. 51% of subjects live or have lived nearby a railway and 38% nearby main road traffic. 59% of subjects feel concerned about environmental noises but only 49% think that they are exposed to noises at home, such as traffic (car, truck, train or airplane) or neighbourhood noises.

Results

Acoustic analyses of the stimuli

Various acoustic descriptors were tested: global indices (equivalent level L_{Aeq}, percentile levels L_{A10}, L_{A90}, spectrum gravity centre, sharpness) and specific indices (specific equivalent level L_{Aeq}, L_{A10} and SEL, number of event and percentage of rising time) for the coded sources train and emergences for the rest of the signal (calculated considering a threshold equivalent to 5 dB above the measured L_{A90}).

A multidimensional analysis (ACP) was made to observe which descriptors characterise the stimuli differences more. Distribution of the acoustic descriptors mostly distinguishes the stimuli according to the kind of train: high speed trains, regional trains or freights. These differences are mainly due to the type of coding used. Indeed, exclusive coding of noise

sources (train or other but not "both") limits the comparative analysis of the sound emergences.

Verbal analyses of the first task

Psycholinguistic analysis showed a lack of consensus between subjects concerning the appraisal and the noisiness of stimuli: participants either chose to describe a soundtrack because it was the '*loudest'* as well the '*softest'* or the more '*bearable'* as the more '*unpleasant'* than the others. Comparatively, descriptive judgments of stimuli allowed distinguishing the three soundtracks which were described as '*usual'*, '*familiar', 'steady flow'* and '*easy to describe*' (stimuli 1 and 3) *versus* '*unusual'* and '*short'* (stimulus 2). Moreover, all subjects described soundtrack referring to sound situations, meaning an activity in a location for a specific moment, such as: '*perpetual noise of train nearby a traffic road*'; '*train passing by close to a road*'. Listening to stimuli of combined noises, subjects thus distinguished both sources (railway and traffic road) but used two different ways of description. The assessment of railway noise is characterised by the identification of a noise source, related to specific time patterns such as "*the train passing by*" or "*the passing of the train*", whereas road traffic noise is mainly described through expressions related to space, such as "*close to the road*" or "*near a thoroughfare*" or "*adjacent to a motorway*".

Statistical analyses of the second task

Over 80% of the subjects were able to identify *slightly* and *completely* all the soundtracks and over 60% were familiar with these sound ambient environments. These results thus strengthened the ecological validity of the test.

The statistical analysis of time pattern items shows that answers concerning the judgement (*unconcerned* to *unbearable*) fluctuate according to the order of appearance of stimuli as well as the attribute, whereas the responses of the item evaluation (*not at all* to *highly*) remain similar. Judgements of appreciation associated to the item evaluation vary in both ways, positive or negative. Judgements thus depend on what was heard before the evaluation of the stimuli. Which stimulus is more or less *abrupt* than the others can be observed but it is difficult to affirm if it is *bearable* or not. This result tallies with the conclusions scrutinised in the verbal analyses of the first task.

Moreover, the analysis of the interactions between item evaluations and judgements shows divergences between attributes describing similar physical characteristics, such as *short* (more it is in *short* more it is *bearable*) vs. *abrupt* (the more *abrupt* it is, the less it is *bearable*).

Multidimensional analyses of time pattern scale evaluation confirm the distinction of high speed trains with other conventional trains in view of *short* and *abrupt* items opposed to *continuous* and *homogeneous* items. Nevertheless, both high speed trains stimuli (300 km/h and 350 km/h) were opposed considering the distinction of road traffic noises characteristics. The identification of truck presence is then a second criterion for characterising various categories of traffic.

Discussion and conclusion

Analysis of the time pattern judgements shows variations between subjects which are problematic for shaping annoyance indicators. Individual differences in sensitivity to noise have been widely recognized [6; 7]. Concurrently, a verbal analysis of the answers allows us to distinguish two different ways of description: railway noise is characterized by the identification of a noise source, related to specific time patterns, whereas road traffic noise is mainly described through expressions related to space. Even in combined stimuli, railway and road temporal patterns are thus evaluated in a different way.

Either the measure or the test analysis showed that temporal patterns appeared more prominent to distinguish the noises of trains. The recognition of truck noise is then a second characteristic criterion of various road traffic.

In addition, the study of acoustic descriptors reveals the inadequacy of the usual codings of noise sources, based on the analysis of the L_{Aeq} temporal evolution. If the L_{Aeq} temporal evolution is coded in an exclusive way, there is no possibility of analysing the masking phenomena, or other interactions between combined noise sources. Consequently, the studied descriptors could be limited and/or inaccurate due to this exclusive coding [8]. To better evaluate acoustic phenomena, other systems of coding must be intended.

To sum up, if railway and road temporal patterns are evaluated in a different way, new relevant indicator should be distinct: such as a descriptor of time presence for the train passing and another of repeated emergences for the road traffic. In term of operational planning, these findings are opposed to lawful concerns, which aim at a standardization of indicators in order to compare in a systematic way the environmental effect of various transportations.

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