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Traffic noise: Annoyance assessment of real and virtual sounds based on close proximity measurements

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ABSTRACT

The negative impact of noise on human health is well established and a high percentage of environmental noise is related with traffic sources. In this study, we compared annoyance judgments of real and virtual traffic sounds. Virtual sounds were generated through an auralization software with input from close proximity tyre/road noise measurements and real sounds were recorded through a Head and Torso Simulator. Both groups had sounds generated at two speeds and from three urban pavement surfaces (asphalt concrete, concrete blocks and granite cubes). Under controlled laboratory conditions, participants rated the annoyance of each real and virtual stimulus.

It was found that virtual stimuli, based on close proximity tyre/road noise, can be used to assess traffic annoyance, in spite of systematic lower rates than those found for real stimuli. The effects of type of pavement and speed were the same for both conditions (real and virtualized stimulus). Opposed to granite cubes, asphalt concrete had lower annoyance rates for both test speeds and higher rate differences between real and virtual stimuli. Additionally, it was also found that annoyance is better described by Loudness than by LAmax. This evidence is stronger for the virtual stimuli condition than for the real stimuli one. Nevertheless, we should stress that it is possible to accurately predict real annoyance rates from virtual auralized sound samples through a simple transformation model.

The methodology developed is clearly efficient and significantly simplifies field procedures, allowing the reduction of experimental costs, a better control of variables and an increment on the accuracy of annoyance ratings.

1. Introduction

Transportation is and will remain in the foreseeable future a major source of environmental noise. The negative impact of noise on human health is well established. In the western European countries the range of the burden disease due to environmental noise would be 1.0–1.6 million DALYs1[1], 587,000 years of which are related to traffic annoyance (WHO, 2011).

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[1] The EBD is expressed as disability-adjusted life years (DALYs). DALYs are the sum of the potential years of life lost due to premature death and the equivalent years of "healthy" life lost by virtue of being in states of poor health or disability.

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In this context, several annoyance studies have been carried out over the last few years. The recent ones were more concerned with health-related quality of life as, for instance, studies on the annoyance caused by different noise sources, including road traffic noise exposure (Héritier et al., 2014) or on the noise annoyance of residential transportation related to physical activity and its change over time (Foraster et al., 2015).

Previous studies, more concerned with road-traffic noise generation, addressed the impact of pavement type on annoyance (Sandberg and Ejsmont, 2002 and Golebiewski et al., 2003). Other authors addressed annoyance taking into account traffic characteristics (Griefahn et al., 2008; Paunović et al., 2009), powered-two-wheelers and heavy vehicles (Gille and Marquis-Favre, 2015; Morel et al., 2016), but overlooking the influence of the type of road surface.

In the scope of road-traffic noise generation, the most recent studies analysed annoyance considering the interactions of several types of pavements with relevant traffic parameters such as speed, type of vehicle, and vehicle composition (Freitas et al., 2012). However, the main issue is that the experimental procedure to measure tyre-road noise is very complex and time-consuming. Moreover, the field recordings are subjected to contamination by other noise sources, thus limiting considerably the number and type of parameters which could be manipulated or even the feasibility of the studies. Therefore, to avoid these drawbacks, a more straightforward procedure that combines noise acquisition close to the tyre (close-proximity measurements) with auralization of these acquisitions in a virtual scenario, must be tested and validated. Moreover, by manipulating the sound measured in the source (the tyre), it will be possible to manipulate and analyse a wider set of traffic parameters and other road environment features.

Recently, the suitability of close proximity measurements was examined (Freitas et al., 2015). In this work, a relation between subjective annoyance ratings and traffic noise levels described by acoustic and psychoacoustic indicators (LAmax, LAeq and Loudness)[2] as a function of speed was established. However, the use of virtual sounds, built from close proximity records, to assess traffic annoyance is still not a fully explored area and results are insufficiently documented in the literature.

This paper intends to address two main questions: (1) ascertain if it is possible to use close proximity tyre road noise measurements to rate traffic annoyance, and (2) verify if virtual sounds generated from these noise measurements can be used to rate annoyance correctly.

Tyre-road noise Close Proximity (CPX) and Head and Torso Simulator (HATS) samples were recorded simultaneously from several combinations of pavement and speed. According to the Controlled Pass-By method (CPB) (Freitas et al., 2012), CPX samples were then edited and auralized to create realistic pass-by noise near the traffic lanes. This allowed generating the virtual stimuli. HATS recordings were used for the real stimuli.

Under controlled laboratory conditions, participants rated the annoyance of each real and virtual traffic noise in a within-subject design. To better establish a relation between the subjective annoyance ratings of real and virtual traffic noise conditions, both traditional and psychoacoustic parameters were considered such as Lamax and Loudness. These parameters are not currently used with CPX measurements however in a previous study they showed a good correlation with annoyance ratings (Freitas et al., 2012). Furthermore, LAmax was preferred as acoustic parameter in the calibration procedure of CPX and CPB sounds, because it captures better the fast sound level variations in the CPB sounds.

2. Materials and methods

2.1. Pavement surfaces

The types of pavement surfaces selected for the study were: granite cubes, concrete blocks, and asphalt concrete with a maximum aggregate size of 16 [mm] (Fig. 1). Granite cubes and concrete blocks are frequently used in urban areas for aesthetical reasons and as a traffic calming measure, particularly in city centres. Asphalt concrete is used in a wide range of situations in both urban, rural, and highway roads. This kind of pavement is the most common type in western countries and thus it is often used as a reference surface.

2.2. Recordings

The tyre-road noise used for stimulus in the virtual stimuli condition was recorded with a Brüel & Kjaer Pulse Analyzer type 3560-C and two microphones were assembled by the Close Proximity method (CPX) according to ISO/CD 11819-2. The sound recordings of the stimuli used in the real stimuli condition were obtained using a Brüel & Kjaer Pulse Analyzer type 3560-C and a Brüel & Kjaer Head and Torso Simulator (HATS) type 4128-C located at 7.5 m from the road centre and at a height of 1.7 m following the procedure adopted in previous studies (Freitas et al., 2012).

The same vehicle was used for both measurements at two different speeds – 30 and 50 km/h. The tyre used in the vehicle was the ContiEcoContact3 195/65-R15 with acceptable performance when compared to other recommended reference tyres (Morgan et al., 2009).

[2] Traffic noise and tyre/road noise are currently assessed by acoustic indicators in decibels (dB) as the A-weighted equivalent mean sound pressure level (LA, eq) and the A-weighted maximum sound pressure Level (LAmax). Psychoacoustic indicators are also used, such as Loudness. Loudness is the attribute of auditory sensation in terms of which sounds may be ordered on a scale extending from soft to loud. The 'loudness level' of a sound is defined as the sound pressure level of a 1 kHz tone in a plane wave and frontal incident that is as loud as the sound; its unit is "phon". The sone scale is based on the observation that a 10 phon increase in a sound level is most often perceived as a doubling of loudness.