Research and Innovation action

NUMBER — 955387 — LEON-T

LEON-T

Low particle Emissions and lOw Noise Tyres

Deliverable No.	D4.2	
Deliverable Title	Results on perceptual and psychoacoustical response to selected tyre sound stimuli	
Dissemination	PU	
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Revision history

REVISION	DATE	DESCRIPTION	AUTHOR (ORGANIZATION)
01	30/06/2022	First complete version of the deliverable	Thibaut Marin-Cudraz (INSA-Lyon)
02	07/09/2022	Modification according to comments of PO	Thibaut Marin-Cudraz (INSA-Lyon)

List of abbreviations and acronyms

Abbreviation	Meaning
dB	decibels
SPL	Sound Pressure Level

Content

1 - Public Executive Summary

This document presents the second set of listening test experiments conducted at INSA Lyon in the context of the Work Package 4. Its main objective is to analyze the influence of tyre noise characteristics on the risk for human cardiovascular disease and potentially other metabolic diseases through sleep disturbances in order to propose measures to mitigate negative health impacts. To create realistic traffic scenarios, it is necessary to determine the key timbre parameter and their effect on listeners beforehand.

The timbre parameters were identified. The goal of the present experiments was to study the relation between these parameters and the noise unpleasantness. Thirty artificial tyre passing-by noises were synthetized, for a given speed of 70 km/h, with different values of frequency, tonality ratio, bandwidth and level. These sounds have been filtered in order to simulate the outdoor to indoor attenuation of a typical building façade. Those sounds were presented to listeners (through high quality headphones). The participants had to assess the perceived unpleasantness of each sound while imagining they were trying to fall asleep in their bedroom.

A tree regression analysis performed on the unpleasantness scores showed that the global sound pressure level and the tonality ratio were the two major factors contributing to unpleasantness. These results will help UGOT in the selection of the stimuli to be used in the sleep experiments.

Results from this deliverable will be compared to results from future deliverable D4.3, where the exposure duration will be greater. This annoyance will be evaluated through assessment given by the participants and physiological data measured while participants will be asked to do a simple, relaxing task (e.g. reading a book). This activity will be reported in D4.3.

2 – Synthesis of tyre sound stimuli

2.1 – Selected psychoacoustics parameters used to synthetize the sounds

The results presented in D4.1 showed that the tonality (amplitude and frequency of an emerging tone) and the loudness (amplitude of a sound in Sone) of tyre rolling noises were the psychoacoustics parameters used by participants to group noises in a free sorting task. We chose to focus primarily on loudness and tonality (amplitude and frequency of an emerging tone). Sounds have been synthesized so as to modify these two parameters: the sound pressure level will be used as an indicator of the loudness and the ratio between the tonal part and atonal part of the synthetized sound (see 2.2) will be an indicator for the tonality.

2.2 – A simple synthesis of tyre noise

2.2.1 – General principle

For a given combination of fundamental frequency (F), bandwidth (Bw) and tonality factor (TF), a stimulus was synthesized as the mix of a noisy part and a tonal part according to (eq. 1):

$$Stimuli_{F,TF,Bw} = (1 - TF) \times Noisy\ part + TF \times Tonal\ part_{F,Bw} \qquad (1)$$

2.2.2 – Synthesis of the noisy part

Recordings of various tyre sounds of a passing by vehicle in a proving ground made by IDIADA showed that the noisy part of external noise is very similar between the different tyres (see Fig. 1).

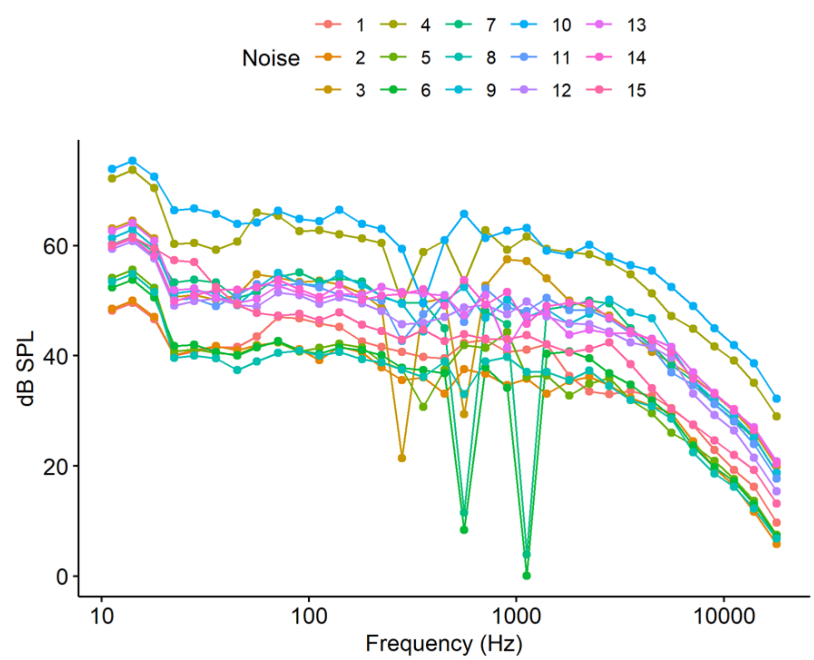

Figure 1: 3rd octave spectra of the atonal (noisy) part of the coastdown recording of HGV tires (C3) made by IDIADA (window type: Hanning, window length: 4096 samples, overlap: 90%). The tonal part of the noises was removed before the analysis, which explains that some frequencies have a very low amplitude in some spectra.

The noisy part is generated using three low-pass filtered white noises which are added using a weighting as shown in (eq. 2):

$$Noisy\ part = Noise_{2000} + 0.35 \times \frac{Noise_{20}}{Max(Noise_{20})} + 0.2 \times \frac{Noise_{450}}{Max(Noise_{450})} \qquad (2)$$

In which:

- $Noise_{2000}$ is a white noise filtered by a lowpass filter (Butterworth, f_c = 2000 Hz, order 2);
- $Noise_{20}$ is a white noise filtered by a lowpass filter (Butterworth, f_c = 20 Hz, order 10);
- $Noise_{450}$ is a white noise filtered by a lowpass filter (Butterworth, f_c = 450 Hz, order 6).

The result gives a good spectral approximation of the mean spectrum of the recorded noises (Fig.2).

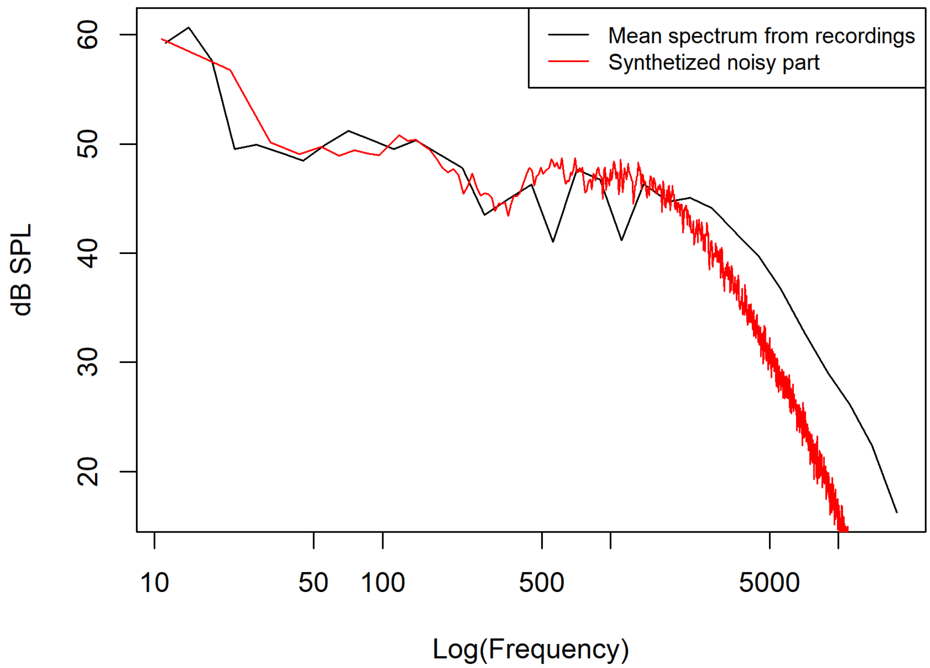

Figure 2: Comparison of the spectra of the synthetized noisy part with the mean 3rd octave spectra of the atonal (noisy) part of the coastdown recording of HGV tires (C3) by IDIADA (window type: Hanning, window length: 4096 samples, overlap: 90%). The frequency scale is logarithmic but the real frequencies are indicated on the x-axis.

To simulate the small random amplitude variations which can be observed in recordings, the amplitude of the noisy part was modulated as follows: 10 points equally spaced in time were generated using a random variable with a standard normal distribution (limited between -1 and 1). Then a cubic spline extrapolation was applied to generate the value of the modulation for the entire duration of the sound (Fig.3). Each sample of the noisy part $Noisy(t)$, is multiplied by the corresponding modulation factor $Mod(t)$ following (eq. 3):

$$Noisy(t) = Noisy(t) \times \left(1 + 0.05 \times Mod(t)\right) \qquad (3)$$

Finally, the modulated noisy part is normalized (divided) by its rms (root mean square) value.

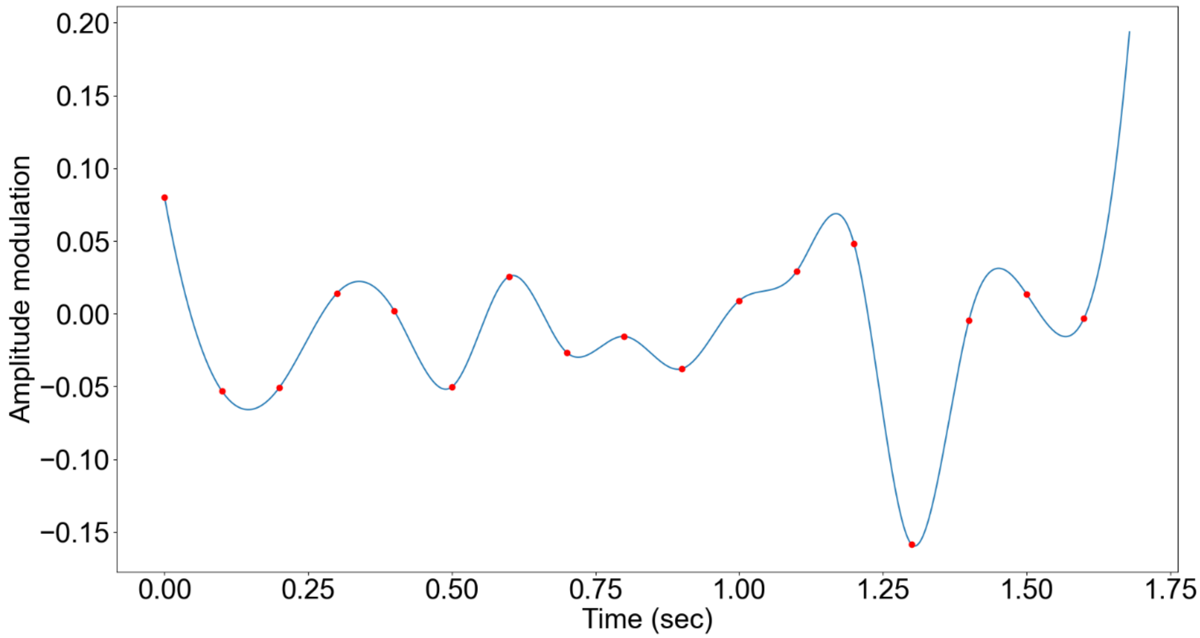

Figure 3: Random amplitude modulation applied to the noisy part (0.05 x Mod(t)). The red points represent the 10 equally spaced points with a random value. The blue line represents the cubic spline interpolation alongside the time axis.

2.2.3 – Synthesis of the tonal part

Due to very slight variations of speed, tonality of a tyre noise is closer to a very narrow band of noise than to a pure tone. The tones were generated with precise frequencies while keeping the randomness generated by the random patterns of some tyres. White noises were filtered with a FIR filters (length = 22001), with a frequency response made of sums of gaussian distributions, each of them being defined by a center frequency f_c and a bandwidth Bw. The frequency response of each filter can be written as (eq. 4).

$$H(f, f_c, Bw) = \frac{1}{Bw\sqrt{2\pi}}\ e^{\frac{-1}{2}\left(\frac{f-f_c}{Bw}\right)^2} \qquad (4)$$

Different spectra were constructed using 2 different fundamental frequencies (F_0 = 300 Hz or 500 Hz) with two harmonics for each fundamental, the level decreasing linearly between the harmonics. In addition, two different bandwidths (Bw = 10 or 25) were used to define the gain of the filter (eq. 5, Fig.4):

$$H(f) = H(f, F, Bw) + 0.5 \times H(f, 2F, Bw) + 0.25 \times H(f, 3F, Bw) \ (5)$$

The values used for Bw roughly corresponds to frequency intervals equal to [F – 8 Hz ; F + 8 Hz] for Bw = 10 and [F – 20 Hz ; F + 20 Hz] for Bw = 25.
Like the noisy part, the tonal part is also normalized by its rms value. Then, the complete stimulus is computed according (eq. 1), for a given tonality factor.

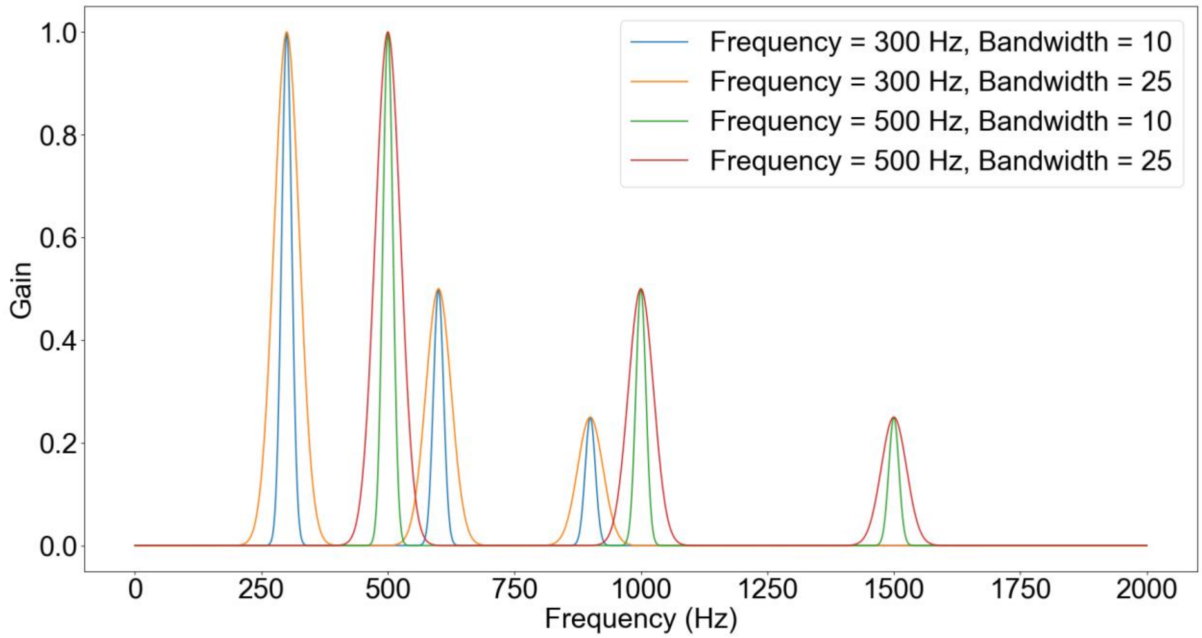

Figure 4: Gain profile of the different filters used in the tonal part of the stimuli for each combination of fundamental frequency and bandwidth.

2.2.4 – Post-process

The noisy and tonal part are mixed together after their synthesis with the corresponding tonality ratio and two effects are then applied to represent the displacement of the vehicle (Fig.5): a Doppler effect and a modification of the amplitude.
The doppler effect is created by interpolating the synthetized noise along the evolution of the duration of the travelling time of the soundwave between the truck and the listener for each point in time t as (eq. 6):

$$effect = \Delta t \times \frac{1}{1 - \frac{V \times x}{c \times r}} \quad (6)$$

With Δt, the time resolution, i.e. the inverse of the sampling frequency of the noise (44100 Hz); V, the speed of the truck in m/s ($V = 70\ kph = 19.4\ m/s$); c, the speed of sound, equal to 340 m/s; $x = V * t$, the position of the truck along the x-axis of the road at the time t (see Fig.5) and $r = \sqrt{d^2 + x^2}$ the distance between the truck and the listener according to d, the distance between the road and the listener.

The amplitude modification represents the increase and decrease in level due the varying distance between the vehicle and the listener. The source is considered omnidirectional, so that the acoustic pressure varies as the inverse of the distance to the listener (i.e we divided the signal by r for each moment in time t).

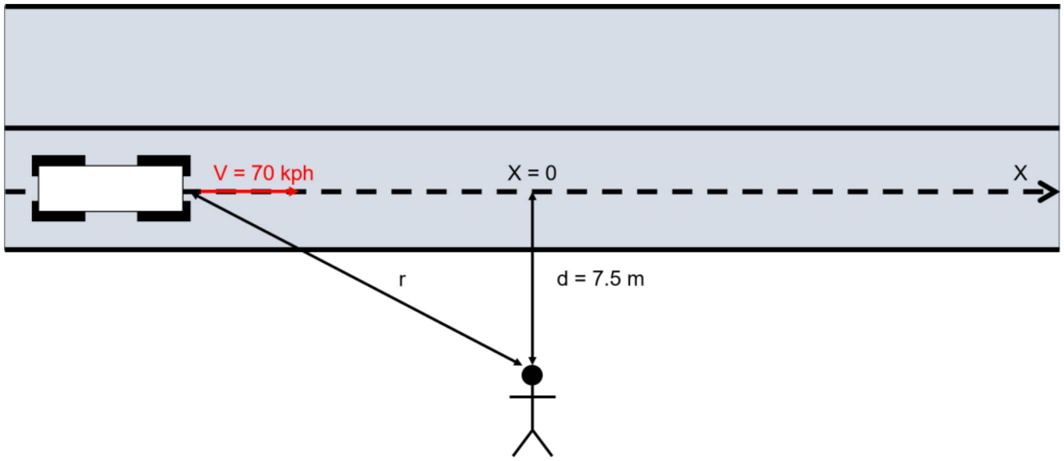

Figure 5: Schematic representation of the doppler effect caused by a fixed listener of a truck moving alongside the x-axis (with the origin centered in front of the listener) with a speed of 70 kph.

The modification of a stimulus after applying these two effects can be seen in figure 6 (top: time signature; bottom: time-frequency analysis).

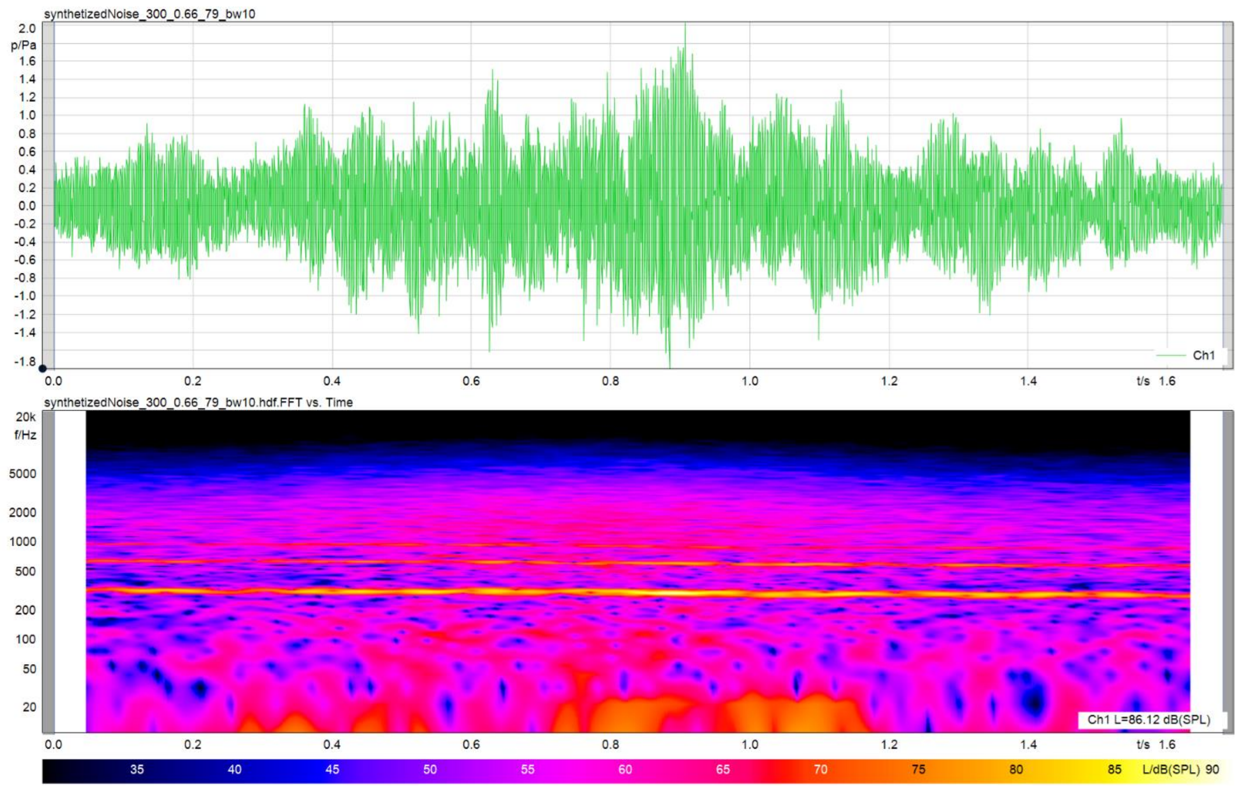

Figure 6: A synthetized stimulus after the application of the frequency and amplitude shifts. The amplitude rises when the truck is approaching and decreases when the truck is getting further away. The frequencies decrease during the entire duration of the sounds.

Finally, the sounds were filtered to simulate the attenuation of a typical facade. The procedure is the same as in D4.1: a FIR (Finite Impulse Response) filter based on the acoustic isolation of a facade was designed and applied (see Appendix 1 for the frequency response of the filter).
The final stimuli were then generated by applying a global amplitude factor to get three different sound pressure levels (L equal to 40 dB(A), 46 dB(A) or 52 dB(A)) from a single combination of fundamental frequency (F), tonality factor (TF) and bandwidth (Bw).

2.2.5 – Final stimuli dataset

The psychoacoustic parameters allow to generate 2 frequencies × 3 *TF*s × 2 bandwidths × 3 levels for a total of 36 stimuli (Tab.1). The stimuli with a *TF* value of 0 do not depend on the bandwidth and fundamental frequency parameters. Some of these stimuli were removed from the dataset to avoid an over-representation of identical atonal sounds. The final dataset was thus composed of 30 stimuli, each corresponding to a wave file (32 bits, sampling frequency equal to 44100 Hz).

Frequency	**Tonality factor**	**Bandwidth**	**Level**
300 Hz	0	[F – 8 Hz ; F + 8 Hz]	40 dB(A)
500 Hz	0.25	[F – 20 Hz ; F + 20 Hz]	46 dB(A)
	0.5		52 dB(A)

Table 1: Summary of the different parameters and their different values.

3 – Material and methods of the psychoacoustic experiment

3.1 – Participants

Thirty-one students (11 women, 20 men) participated in the listening test. They were between 19 and 27 years old (mean ± SD age: 22.06 ± 1.88 years). Their hearing threshold was measured via pure tone audiometry administered using a computer (Dell optiplex 9020), the Eolys Piston XP software, and 3M PELTOR Optime II headphones, in the sound proof booth of the Laboratoire Vibrations Acoustique at INSA Lyon (see deliverable D4.1 for a photo of the booth). The threshold was measured according to the ISO 8253-1:1989 standard (tonal audiometry, 7 frequencies between 125 and 8000 Hz) and showed that all participants had normal hearing (i.e. their hearing threshold was below 20 dB HL at all tested frequencies).

3.2 –Unpleasantness evaluation

The experiment took place in the same sound proof booth and uses the same DELL computer as for the audiometry, linked to an USB audio interface (Echo Gina) and headphones (Sennheiser HD650). The experimental setup was calibrated beforehand, with a binaural recording head equipped with measuring microphones (Neutrik-Cortex Instruments 'MANIKIN MK1') linked to an OROS OR38 system, so that the level corresponds to the one chosen when designing the sounds

The evaluation of the unpleasantness used a graphical interface developed in-house (already used in multiple studies, for example [1], Fig.7). Sounds were presented in a random order and the participant answered by moving a slider on a continuous scale from 0 (‘not at all unpleasant’) to 1000 (‘extremely unpleasant’). Three intermediate endpoints are also indicated to guide participants so that they would finely tuned their answers. Each sound could be played again, as many times as needed by the participant. Participants had to imagine that they were in their bed, trying to fall asleep, when suddenly, a vehicle passed nearby their bedroom. The operation was repeated for 60 sounds, i.e. two pseudorandom repetitions of the dataset described in 2.2.5.

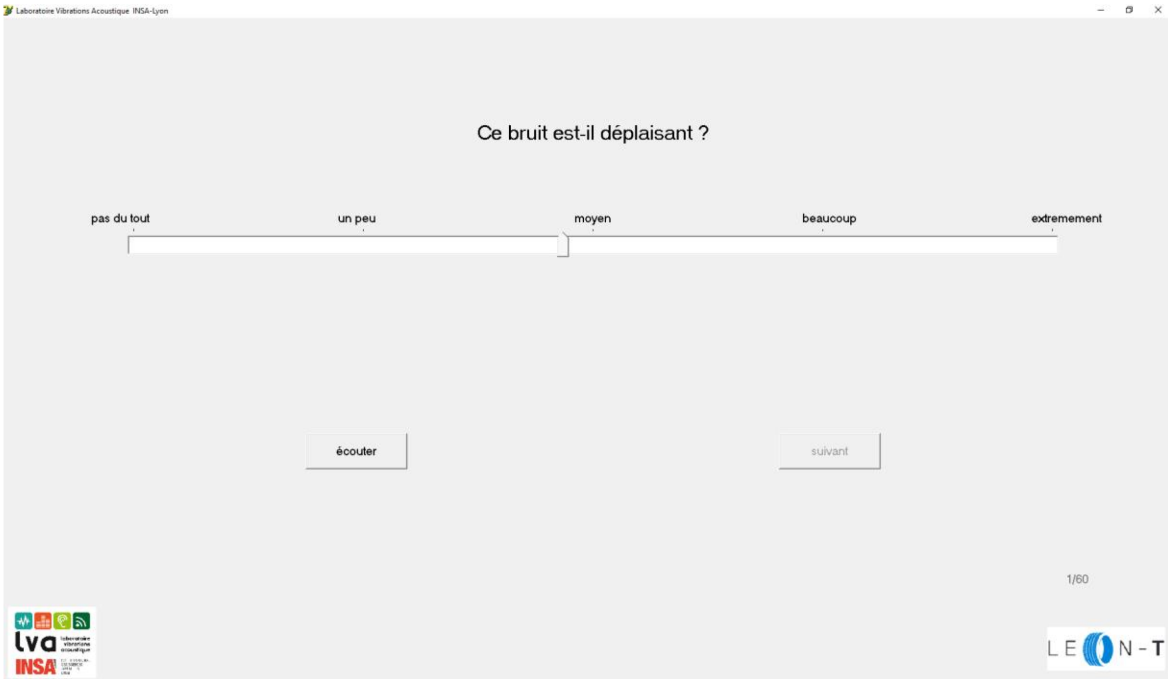

Figure 7: Interface used by participants to evaluate the unpleasantness of the different stimuli (in French). 5 markers on top of the slider helps the participants to precisely evaluate.

3.3 – Ethics

The only personal data collected were the participant's age, gender and hearing threshold. Their personal information was treated to respect their privacy: in the computer running the experiment, participants are referred to as numbers only. The table relating numbers to participants' names and personal information is stored as one file, recorded in the experimenter's personal computer and will be erased at the end of Leon-T project.

Sound stimuli were presented through headphones, with a level lower than 60 dB(A), i.e. the level of a normal speech conversation for a participant. Our exposure time is short as all sounds last 3s and the experiment does not last more than 30 minutes. Thus, the combination of a short exposure time and the low level of the stimuli ensures no risk of hearing damage. Particular care was taken in consideration of the current Covid-19 situation: the sound booth was disinfected and ventilated for at least 5 minutes between participants.

The interior dimensions of the booth were large enough so that participants would feel at ease (3.4 m long, 2.4 m large and 2.2 m high). A window allowed the experimenter to check that everything was fine with the participant. Participants signed a consent form before starting the experiment (Appendix 2) and were informed that they could stop at any time (see the instructions in Appendix 3). These new forms complement annexes 1 and 2 in D1.1.

The experiment was approved by the Ethic Comity of Lyon University (Comité Ethique de l'Université de Lyon) under the number 2022-05-19-001.

4 – Results

The unpleasantness scores for each participant i and each evaluated sound j were corrected by mean normalization: the average of all scores given by the participant i was subtracted and the global mean of the data was added (eq. 7):

$$Centered\ score_{i,j} = score_{i,j} - \frac{1}{n_j}\sum_j score_{i,j} + \frac{1}{n_j \times n_i}\sum_{i,j} score_{i,j} \quad (7)$$

With n_j, the number of stimuli evaluated by a given participant i, i.e $n_j = 60$; n_i, the number of participants, i.e. $n_i = 31$.

The centered unpleasantness scores were used to perform a regression tree [2,3] with the psychoacoustics variables of the synthetized sounds as explanatory variables: the fundamental frequency, the tonality factor, the bandwidth and the global level. The model was fitted using the R language 4.1.2 [4] and the *rpart* library [5]. The resulting models have the form of binary trees (see Fig.9). The partitions are made by consecutive binary splits according to the different explanatory variables, each split divides the data set in two subsets. The splits are found by minimization of the sum of squared error (SS) according to the mean at the node of the split (SS_T, with mean $\bar{y}_T$), the left side of the split (SS_L, with mean $\bar{y}_L$) and the right side (SS_R, with mean $\bar{y}_R$) of the split (eq. 8):

$$minimize\{SS_T - (SS_L + SS_R)\}$$
$$= minimize\left\{\sum_{i \in T}(y_i - \bar{y}_T)^2 - \left(\sum_{i \in L}(y_i - \bar{y}_L)^2 + \sum_{i \in R}(y_i - \bar{y}_R)^2\right)\right\} \quad (8)$$

The full regression tree is drawn according to this criterion: a tree with 26 splits was found. However, the tree needs to be pruned to avoid the risk of overfitting the model, i.e. the model being too complex (over-parameterized) without having a significant increase in explanatory power compared to a simpler tree. For each split of the tree, a 10-fold cross-validation is performed: 90% of the data are randomly selected to fit the model and the 10 other percent are kept to validate the model. The process is repeated 10 times. For each repetition, an analog of the PRESS statistic [6] is calculated as the sum of squares of the differences between the observations of the validation dataset (y_i) and their predicted values ($\hat{y}_i$) (eq. 9):

$$PRESS = \sum_i (y_i - \hat{y}_i)^2 \quad (9)$$

Hence, the mean and standard error of the cross-validation error are calculated for each split. A selection rule (1-SE rule) is recommended in [2]: the selected tree is defined as the smallest (simplest) one within one standard error of the best tree (lowest cross-validate relative error). According to this rule, the tree with 7 splits was selected (Fig.7).

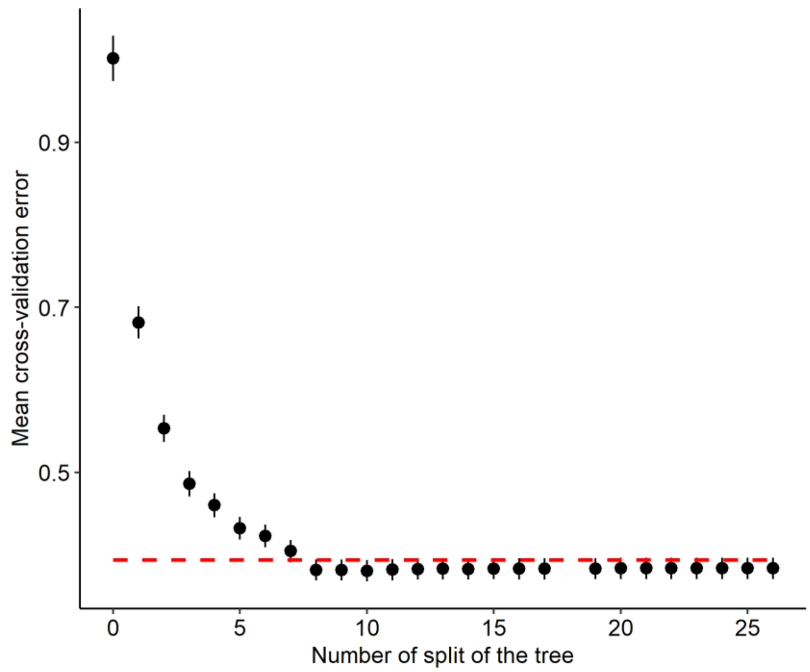

Figure 7: Selection of the number of splits in the tree according to the 1-SE rule. The dashed red line represents the minimum mean cross-validation error plus its standard error. The mean ± SE cross-validation error of trees with 7 or more splits are all within this threshold, i.e. adding more than 7 splits does not add any further explanatory power to the model. The algorithm did not make a tree with 18 splits but jumped instead to a tree with 19 splits.

The final tree (Fig.9) shows that, even though they were included in the analysis, the fundamental frequency and the bandwidth of the tones are not considered, i.e. they do not have a significant influence on the unpleasantness. On the contrary, we can see that the global level and the tonality factor are the only significant factors of unpleasantness. This is consistent with the study of the importance of the different parameters for a simple linear model (Fig.8, *vip* library [7] for the R language 4.1.2). The authors of the library define this metric as *'the extent to which a feature has a "meaningful" impact on the predicted outcome'*. It is also formally defined in [8]. The importance of the fundamental frequency is null and the importance of the bandwidth negligible compared to the tonality and level. The two regression models therefore show that these two parameters have no effect on the unpleasantness.

The regression tree (Fig.9) is hierarchical: the closer a node is to the root of the tree, the higher its importance. The maximum global level (52 dB(A)) versus the other levels (40, 46 dB(A)) separates the data in a first step and, thus, seems to be the prominent factor driving the unpleasantness, as shown by the study of the importance. The presence (*TF* = 0.25,0.5) or absence (*TF* = 0) of a tone then splits the right-hand side of tree (corresponding to a level of 52 dB(A)). For the other levels, the separation is made when the tones are the most present (*TF* = 0.5) against less present or absent (*TF* = 0;0.25).

Further splits are made with the last values of level and tonality factor so that the leaves (end of the tree) correspond to all possible associations of level and *TF*.

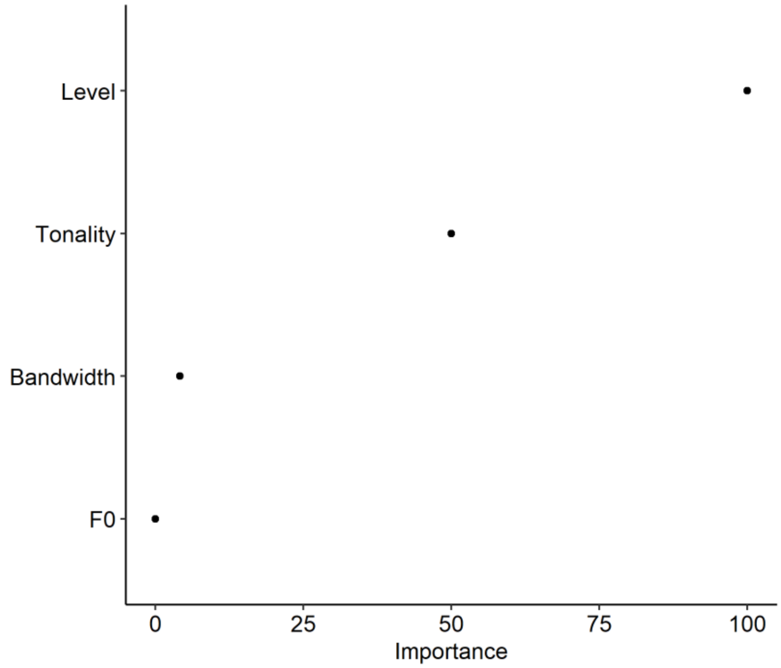

Figure 8: Importance of the different psychoacoustic parameter calculated from a linear model. The importance values are scaled so that the maximum importance equals 100.

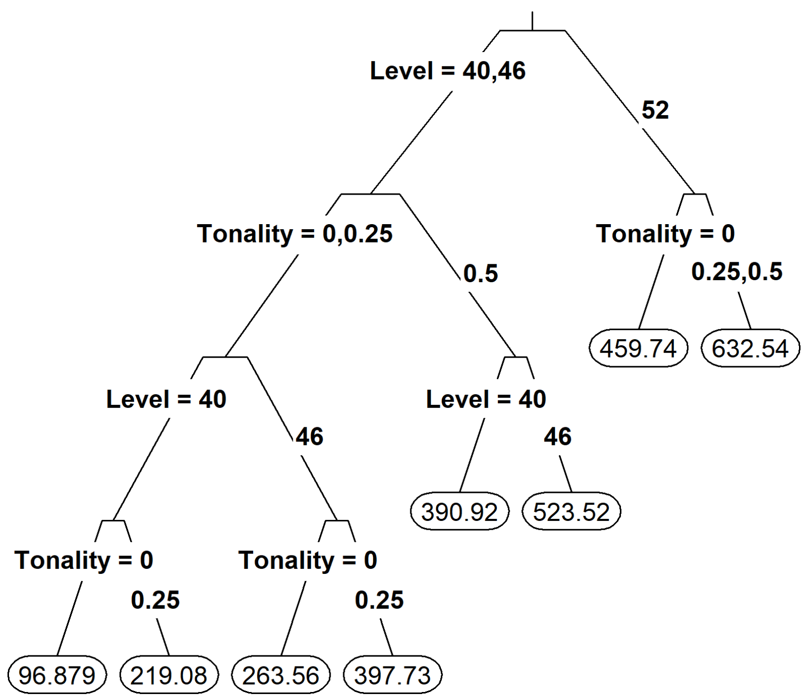

Figure 9: Regression tree of the unpleasantness explained by the global level and the tonality factor. The tree starts at the top of the figure and each branch of the tree ends by a leaf containing the mean unpleasantness centered score of the group. The condition of each split is shown on the branches of each node.

5 – Conclusion

The experiment showed that the global level and the prominence of the tonal component of the synthetized tyre rolling noises were the most important cues for self-assessed unpleasantness of tyre noises, as heard indoors. These results reinforce the results found in deliverable D4.1 where tonality and overall level were the main acoustic parameters used to differentiate tyre noises in a free sorting task.

Unpleasantness evaluations will also be compared with the results of future experiments (focused on annoyance, at INSA-Lyon or to the effect on sleep, at UGOT) in D4.3. For example, the self-assessed unpleasantness will be correlated with physiological changes (heart rate, body temperature and skin conductivity). Such findings could also be correlated with the study of sleep effects.

6 – Bibliography

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Appendices

Appendix 1: Frequency response of the filter corresponding to the wall

Appendix 2: Consent form signed before the listening test (Originally in French)

Laboratoire Vibrations Acoustique

INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

Consent form

Last name :
First name :
Address :

I declare that I do not have any hearing problem that could alter the tests or have an impact on my health.

I agree to participate freely with the help and assistance of the INSA Lyon vibration and acoustics laboratory in a listening test experiment.

This experiment is safe and has no consequences for hearing.

The noise level is controlled by the laboratory and does not exceed that experienced in everyday life or in the vicinity of certain common appliances.

The duration of the tests is also controlled by the laboratory.

This experiment takes place in specially equipped booths or in the presence of everyday sound objects.

I have been informed that I am free to stop the experiment at any time, temporarily (to rest) or permanently.

I agree to assist without remuneration and to answer the questionnaire at the end of the experiment.

The questionnaire and the results of the experiment are the exclusive property of the laboratory, which is free to use them as it wishes, provided that it does not reveal the identity of the person involved.

As a compensation, the laboratory will give me the sum of 10 Euros (ten Euros) corresponding to travel expenses, loss of time, etc. (please attach a bank details form).

Date :

Signature of the participant | Signature of the experimenter

Appendix 3: Information letter (Originally in French)

Laboratoire Vibrations Acoustique

INSA de Lyon

Bâtiment St. Exupéry 25 bis av. Jean Capelle

69621 Villeurbanne cedex – France

Low Particle Emissions and Low Noise Tyres (LEON-T)

Why do I receive this letter?

You have responded to a public advertisement and expressed interest in participating in a laboratory study on the unpleasantness of tire noises based on listening tests. This letter provides more information about this study. You can read through the letter in peace and quiet and you are most welcome to call or email with any questions. You can also ask any questions during your visit to the laboratory before you decide to participate.

The purpose of the study?

The Road traffic noise accounts for the majority of perceived urban environmental noise and has important health consequences. The rolling noise of vehicle tires is a major contributor to perceived road noise. The European project LEON-T aims to minimize the nuisance of heavy vehicle tires, especially noise. Prior to a study of the effects of tire noise on sleep, this experiment is conducted to know how the timbre parameters of such noises influence the unpleasantness perceived by listeners. The stimuli were synthetized to combine all values of the chosen parameters.

How does the study work?

The experiment was approved by the Ethic Comity of Lyon University (Comité Ethique de l'Université de Lyon)

The study involves you coming to the laboratory for 30 minutes during the day and entering a soundproof booth to complete the following tasks: hearing threshold measurement and self-evaluating the unpleasantness of synthetized tire noises.

Your hearing threshold will be measured using headphones and a button that you will need to push whenever sounds is eared. A computer graphic interface will be used to evaluate the unpleasantness. Headphones will be used throughout the duration of the experiment to hear the sounds.

You will stay in a soundproof booth during the experiment under the supervision of an experimenter. You are free to leave the room at any time, without any reason. There is never a good or wrong answer for the unpleasantness. However, when a response is validated, it is definitive.

At the end of the experiment, you will have a brief interview with the experimenter to know if the tasks were hard, if yes, which parameters were the most unpleasant?

Risks or benefits of participating?

This experiment is safe for you and has no consequences for your hearing. The noise level is controlled by the laboratory and does not exceed that experienced in everyday life or in the vicinity of certain common appliances. Sound stimuli were presented through headphones, with a level lower than 60 dB(A), i.e. the level of a normal speech conversation for a participant. Our exposure time is short as all sounds last 3s and the experiment does not last more than 30 minutes. Thus, the combination of a short exposure time and the low level of the stimuli ensures no risk of hearing damage. Particular care was taken in consideration of the current Covid-19 situation: the sound booth was disinfected and ventilated for at least 5 minutes between participants.

The inside dimensions of the booth are large enough so that you would feel at ease (3.4 m long, 2.4 m large and 2.2 m high). A window allows the experimenter to check on everything that could happen to you.

Insurance and compensation

You will receive 10€ after completing the experiment as a financial compensation for your time. You will receive the compensation if you finish the experiment or if you stop before the end for valid reasons, confirmed by the experimenter (e.g. discomfort, medical urgency, …).

How is the information collected handled?

Your responses to the experiment will be processed so that no unauthorised persons can access them and the access is restricted only to authorized researchers at the LVA. Results are stored in the computer used in the experiment but your name or other personal data are not stored in that computer, as participants are labelled as ID numbers only. There will only be one file with the relationship between your ID and your personal information. This file will have limited access and will be stored inside the experimenter's computer for the duration of the LEON-T project (36 months) and then destroyed.

All personal data is processed in accordance with the EU General Data Protection Regulation (GDPR). According to the EU Data Protection Regulation, you have the right to access the information about you handled in the study free of charge, and if necessary to have any errors corrected. You can also request that data about you be deleted and that the processing of your personal data be restricted. To access the information, please contact the project manager: Etienne Parizet, who can be reached by phone: +33 (0)4 72 43 81 21 / by email: etienne.parizet@insa-lyon.fr.

Data Protection Officer at INSA Lyon can be reached by e-mail: dpo@insa-lyon.fr. If you are dissatisfied with how your personal data is processed, you have the right to lodge a complaint with the French Authority for Privacy Protection, which is the supervisory authority.

How do I get information about the results of the study?

The results of the project will be reported in scientific journals and at conferences. A summary of the results will also be published on the department's website (https://recherche.insavalor.fr/) and the project's website (www.leont-project.eu/) once the results are compiled. All reporting takes place at the group level where individual answers cannot be determined.

Volunteering

Participation in the project is voluntary. You can cancel your participation at any time, without having to provide any specific explanation. You can also ask to have collected data and personal data deleted or anonymised by competent researchers. You can do this by contacting the project manager – see below.

Responsible

The research principal is the INSA de Lyon. The responsible researcher is Etienne Parizet, Professor at the Laboratoire Vibrations Acoustique at the INSA de Lyon. The principal experimenter is Thibaut Marin-Cudraz, PhD, post-doctoral researcher at the Laboratoire Vibrations Acoustique at the INSA de Lyon.

With kind regards,

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