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IMPACT OF NON-ACOUSTICAL FACTORS IN LABORATORY LISTENING TESTS ON AIRCRAFT NOISE

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It is well known that acoustical factors explain only partly the human perception of aircraft noise. In order to truly understand annoyance ratings, acoustical and non-acoustical factors have to be taken into consideration, making it often complex to analyze studies that treat only one side of the issue. While field studies give a good insight of long-term annoyance in realistic living conditions, laboratory tests are commonly used as means to understand the impact of acoustic factors on noise annoyance and unpleasantness while usually smoothing inter individual differences.

A French project (CIGALE) has set a goal of creating a frame of reference making it possible to include non-acoustical factors into laboratory studies. After an extensive field study and focus groups in the first part of the project resulting in six different profiles of residents, the second part comprises a vast laboratory test campaign in Toulouse and Paris region aiming at evaluating the impact of these profiles on the perception of two common acoustical factors in an ecological experimental setup. Overall more than 300 residents of the Toulouse Blagnac airport area and the Roissy Charles de Gaulle airport area participated in the CIGALE listening test.

Participants were asked to read novels while seated in a listening room with a 3D audio simulation of an everyday soundscape. They were asked to rate their perception of four 15 minutes sequences randomly presented in which the number of aircraft flyovers and the maximum A-weighted sound level of each flyover were varied. Four different scales were used: task interference, mental effort, annoyance and comfort. The results support the hypothesis that profile type and noise sensitivity have an impact on

annoyance ratings. The collected data also highlighted different response strategies regarding acoustical factors that need to be further investigated.

Keywords: Aircraft noise, Laboratory test, Non-acoustical factors

1. Introduction

It is known that acoustical factors explain only partly the human perception of aircraft noise [1-5]. In order to truly understand annoyance ratings, acoustical and non-acoustical factors have to be taken into consideration, making it often complex to analyse studies that treat only one side of the issue. While field studies give a good insight of long-term annoyance in realistic living conditions, laboratory tests are commonly used as means to understand the impact of acoustic factors on noise annoyance and unpleasantness while usually smoothing inter individual differences. Researchers from different disciplines (acoustics, psychoacoustics, environmental psychology, linguistics) got together for the French CIGALE project, funded by the French Civil Aviation Agency, with the goal to develop a methodology to include, up to a certain measure, non-acoustical factors into listening tests, and hence take a step further towards being able to take into account inter-individual differences during analysis.

The first step is to establish whether it is possible to categorize airport residents into typologies, based on societal and attitudinal criteria. These typologies are to be evaluated through two means: a series of focus groups and a listening test in a laboratory environment. The present paper focuses on the second.

During the project a wide field survey was conducted with nearly 1250 respondents around Roissy Charles de Gaulle airport near Paris and Toulouse Blagnac airport in Southern France. Following this field survey, more than 300 of the respondents were invited to participate in a laboratory listening test.

First, a quick overlook of the field survey's main outcomes is given. Then, focus is put on the listening test set-up and first analysis results.

2. Typologies

A broad field survey was launched in 2020 in the areas around Roissy Charles de Gaulle airport and Toulouse Blagnac airport. Nearly 1250 residents answered the questionnaire built on non-acoustical factors extracted from a literature review. After a qualitative and a quantitative analysis of the respondents' feedbacks, six typologies emerged: 1 – Weariness, 2 – Anger, 3 – Sadness, 4 – Not Annoyed, 5 – Pleased, 6 – Joy.

These typologies are structured around 4 families of non-acoustical factors: attitude towards aviation and air traffic, coping strategies, semantic meanings of annoyance, emotions associated to flyovers. Surprisingly, these typologies do not include the person's proximity to an airport. In fact, all typologies seem to co-exist, independently of actual air traffic noise levels.

An example is shown in Figure 1 for the typology "Pleased". An important aspect of this work is the possibility for the typology to tip over to a more positive or more negative one. The detailed presentation and analysis of these typologies are however outside the scope of this paper, and to be published separately in the near future.

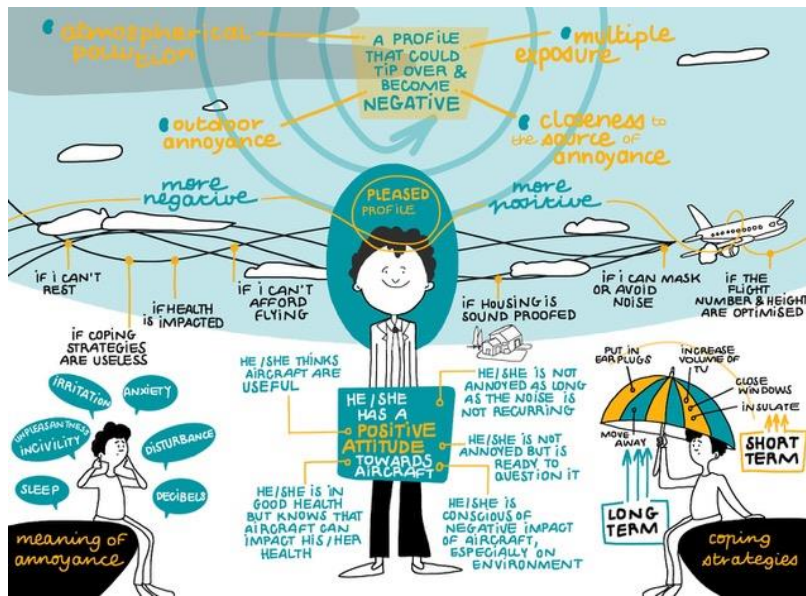


Figure 1: Typology “Pleased”

3. Listening test

The aim of the listening test presented hereafter is to assess the validity of the six typologies in a laboratory environment.

Knowing that a controlled environment usually tends to smooth the influence of non-acoustical factors and inter-individual differences, the idea is to check whether the typology affiliation of the participants influences their results in a laboratory experiment. One might find differences between participants of different typologies but similarities between participants of the same typology.

3.1 Experimental set-up and procedure

3.1.1 Experimental set-up

The listening tests were performed simultaneously at ONERA Châtillon and the PETRA platform of the MSHS-T at Toulouse University [6]. Both rooms are equipped with an 8.1 surround system composed of eight Focal Solo 6Be loudspeakers and a Focal Sub 6 subwoofer. The walls are de-parallelized and are acoustically treated to avoid standing waves and parasite noise sources. A reverberation time of 0.3 to 0.5 seconds was achieved over the classic frequency range for both rooms.



Figure 2: Listening laboratory at ONERA (Châtillon) on the left, and MSHS-T (Toulouse) on the right

3.1.2 Study participants

The participants to this listening tests were all part of the panel that answered the questionnaire evaluated in the first half of the project, and hence, had a known typology affiliation. The initial goal was to invite 30 participants per typology per site, leading to 360 participants (2 sites x 6 typologies). Due to the Covid pandemic, it was extremely difficult to achieve this number, with an unusual number of last-minute withdrawals. On the Toulouse site the situation was made even more complicated by the fact that a much smaller number of people had answered the questionnaire in the first phase (281 compared to 968 in Paris). A publication of this first part of the project is to be published in the near future.

In the end, 176 participants could be accounted for in Paris and 105 participants in Toulouse. Table 1 shows the distribution of typologies for the Paris and the Toulouse panels.

Table 1: Typology distribution of participants

| Typology | Category | Paris | Toulouse | Σ |
|-----------------|----------|-------|----------|----------|
| 1 – Weariness | Negative | 29 | 9 | 38 |
| 2 – Anger | Negative | 30 | 15 | 45 |
| 3 – Sadness | Negative | 28 | 18 | 46 |
| 4 – Not Annoyed | Positive | 29 | 16 | 45 |
| 5 – Pleased | Positive | 30 | 29 | 59 |
| 6 – Joy | Positive | 29 | 18 | 47 |

3.1.3 Background noise

During the whole duration of the listening test, background noise was present in the laboratory. The created sound environment was representative of a living room in a flat or a house near an airport, with an open window overlooking a city street, during day time. No visual setting was created, only the sound situation was simulated in the room. The background noise consisted of an urban environment recorded in Ambisonics, and played back at 40 dBA $L_{A,eq}$ on the 8.1 surround system.

3.1.4 Procedure

As stated previously, the goal of the listening tests was to see how the affiliation to a typology impacts the perception of acoustical factors in a controlled environment. For this study we decided to evaluate the influence of the number of flyovers and their respective $L_{A,max}$ values, these factors being known to have an impact on noise annoyance [7].

Participants were exposed to four sound sequences of 15 minutes each. Each sequence was composed of either 3 or 10 flyovers of the same generic tube and wing aircraft. These flyovers had a $L_{A,max}$ value of either 54 dBA or 60 dBA, this value being the same for all flyovers inside one sequence. The four sequences are visualised in Figure 3 and the respective $L_{A,eq}$ levels are given in Table 2. The number of flyovers and the $L_{A,max}$ values chosen so as to reach similar $L_{A,eq}$ levels for condition 1 and 2. For the sequences 0 and 1 (3 flyovers), $\Delta t = 6$ minutes approximately, and for the sequences 2 and 3 (10 flyovers), $\Delta t = 90$ seconds +/- 5 seconds (randomly).

All flyovers simulated a take-off configuration and were identical with regard to aircraft and trajectory characteristics. By doing so, the authors reduce the addition of signature related variables impacting annoyance reactions. Noise emission and propagation were calculated with the ONERA in-house tool CARMEN [8, 9] based on generic input data, and auralized with the in-house tool FLAURA [10]. The receiver position was chosen so as to achieve an approximate $L_{A,max-10}$ duration of 30 seconds. Spatialisation was achieved with REAPER, from left to right. The varying $L_{A,max}$ values were achieved by a simple gain adjustment in the lab.

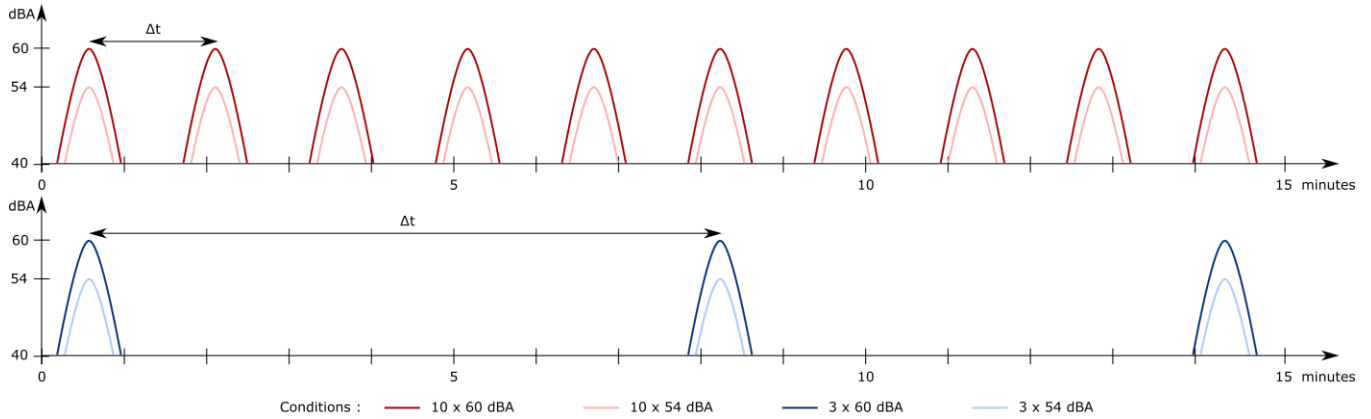


Figure 3: Flyover conditions for the four sequences

Table 2: $L_{A,eq}$ levels

| No° | Condition | L_{Aeq} (dBA) |
|-----|-------------|-----------------|
| 0 | 3 x 54 dBA | 42,9 |
| 1 | 3 x 60 dBA | 46,7 |
| 2 | 10 x 54 dBA | 46,1 |
| 3 | 10 x 60 dBA | 51,3 |

In order to increase the realism of the laboratory setup and to simulate a focussing on a primary task while being overflown by aircraft, the participants were invited to read short stories [11] on a computer screen during the four sequences. After each sequence, four questions had to be answered on a scale of 1 to 6:

- Task Interference: How much were you interrupted/disturbed by the noise during reading?
- Mental Effort: Estimate the effort that was necessary to complete the task of reading.
- Annoyance: How much were you bothered by the noise?
- Comfort: If you were living in this kind of sound environment, how would you describe this environment? (1 = very pleasant, 6 = very unpleasant)

In addition, easy questions were presented on the stories' content in order to encourage thorough reading. At the end of the test, questions on noise sensitivity were presented, following [12], and an indicative hearing test allowed the inclusion of all participants in the following statistical analysis.

Authorization to perform a listening test on human participants was given by the Research Ethics Committee of Paris Saclay University [13].

A thorough statistical analysis was performed. In this paper, however, only an overview is presented with results to the question on annoyance (the third question).

4. Impact of airport and typology on annoyance ratings

As stated before, 176 participants took part in the listening test in Paris and 107 in Toulouse. The left graphic in Figure 4 shows the ratings to the annoyance question, averaged over all participants per airport. So-called negative typologies (i.e. 1, 2, 3) and positive typologies (i.e. 4, 5, 6) are represented in red and blue. A general pattern of increasing annoyance with increasing condition number (and therefore increasing $L_{A,eq}$) can be observed. Most typologies are closely grouped, except for Toulouse contributions (triangles).

A variance analysis on the whole panel shows that the airport effect on annoyance is significant ($p < 0.01$), the interaction between airport and typology as well ($p = 0.022$), typology alone however is not ($p = 0.095$) when looking at all 6. When only considering positive and negative character (negative being the typologies 1 - 3, positive the typologies 4 - 6), typology becomes significant ($p = 0.021$). This significance concerns Toulouse ($p = 0.013$), but not Paris ($p = 0.614$).

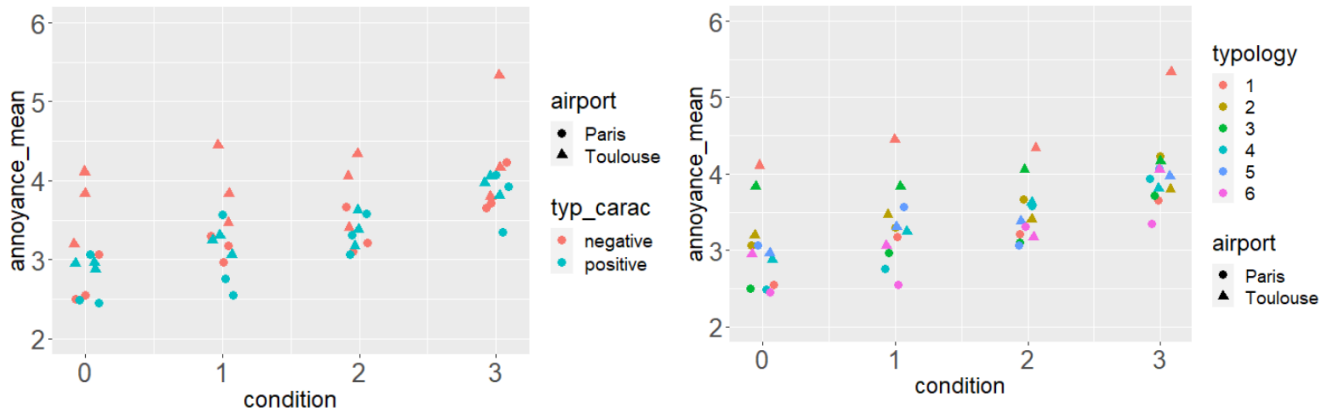


Figure 4: Annoyance ratings per airport for negative and positive typologies (left) and per typology (right)

When looking at all individual typologies (see Figure 4 to the right), one can point out typologies 1 (“Weariness”) and 3 (“Sadness”) for Toulouse airport. A variance analysis per typology shows that the groups of typology 1 and 3 are the only ones for which the airport is a significant parameter. The typology 1 group of Toulouse has to be assessed with care; as was seen in Table 1, this group is composed of only 9 persons. We, therefore, decide not to separate the Paris and Toulouse groups for this typology. The typology 3 group (“Sadness”) is well represented in both cities. It had however already raised questions during the definition of these typologies. Indeed its definition is a little more vague than the others. The decision of separating this typology into two (3.1 for Paris, 3.2 for Toulouse) was then taken. Once the airport taken out as a parameter, the typology becomes significant ($p = 0.042$), leading to the boxplot shown in Figure 6.

A t-test shows that only few pairs are significantly different (2/6, 3.1/3.2, 3.2/4, 3.2/6). This result can be observed through the fact that 3.2 shows, in average, higher annoyance values than the rest.

For all typologies $L_{A,max}$ and number of flights are significant (global ANOVA: $p_{L_{A,max}} < 0.001$, $p_{Number} < 0.001$).

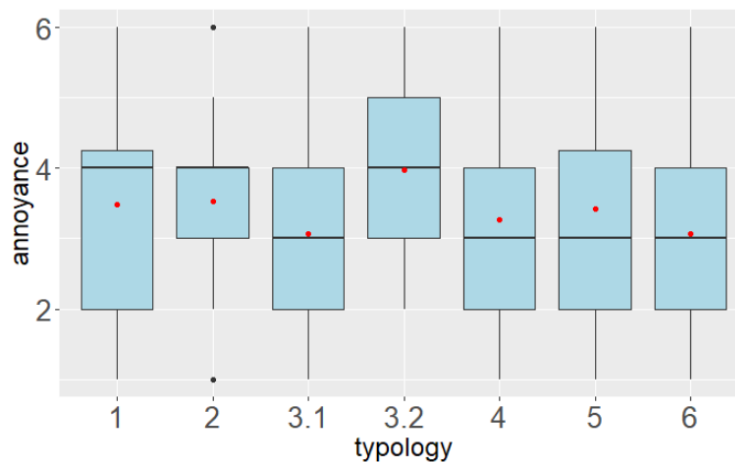


Figure 5: Annoyance per airport and per typology

A more advanced analysis was done on response strategies regarding $L_{A,max}$, number of flyovers and $L_{A,eq}$, by defining sub-groups with the help of a cluster analysis (not shown here). While regulation and operational customs are often based on the $L_{A,eq}$ indicator, these subgroups show distinct response strategies. When looking at median values in Figure 7, the subgroups are either based on $L_{A,eq}$ (Paris G1, 109/174 participants), on $L_{A,max}$, (Toulouse G4, 56/105 participants) on the number of flyovers (Paris outlier, 36/174 participants), or on a combination of all three factors. The presence of these subgroups and the important number of participants they comprise should fuel (again) debate about the use of this integrated metric. Especially when being aware of the diversity of typologies they encompass.

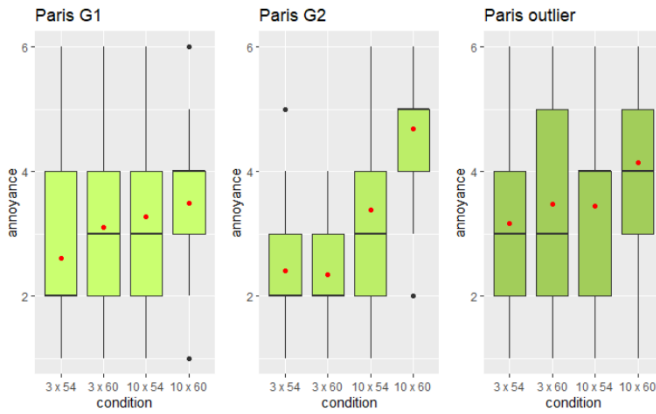


Figure 6: Paris subgroups on annoyance responses

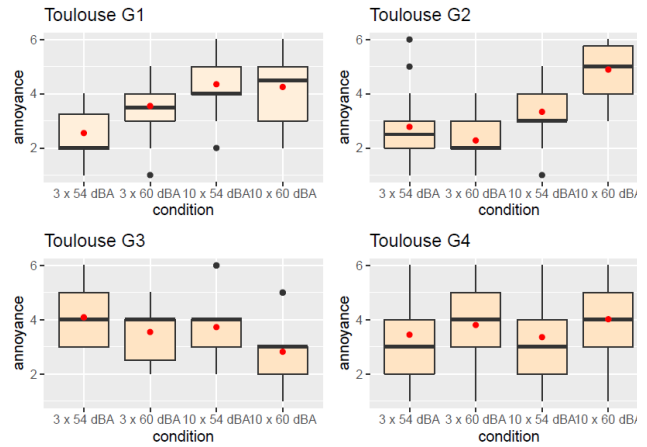


Figure 7: Toulouse subgroups on annoyance responses

One take-away of these cluster analyses is that typologies do not explain these subgroups. Indeed all subgroups consist of a large variety of typologies.

5. Conclusion

A first attempt was made to reconcile field studies and laboratory listening tests in the French National Project CIGALE. After establishing six typologies based on non-acoustical factors, a listening test was performed, evaluating the impact of these typologies on annoyance reaction to the acoustic factors of number of flyovers and their $L_{A,max}$. Although the controlled environment of a laboratory is known to smooth inter-individual differences due to non-acoustical factors, an impact can nonetheless be observed. A first analysis shows that the affiliation to a “positive” or a “negative” typology can have a significant impact on annoyance ratings. The impact of typology on responses strategies, following either $L_{A,max}$, $L_{A,eq}$ or number of flights can however not be clearly established.

6. Acknowledgments

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