A Method to Assess the Ecological Validity of Laboratory-Recorded Car Horn Sounds

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Introduction

The perception of car horn sounds has been studied in order to assist in the design of new sounds [2] [3] [4]. Prior to these studies the problem of the ecological validity of the sound corpus was investigated.

A car horn is a self-oscillating electroacoustical device, the sound of which is strongly influenced by its fixation. One issue may be to record the horns fixed on the body of the car (*car recordings*). The problem is that it may not be very practical to manipulate a car in an semi-anechoic chamber every time a device has to be tested. The usual procedure to record a horn (*laboratory recordings*) is to fix it on a heavy metal bar in an anechoic chamber. But the sound emitted by this horn-bar device is fairly different from the sound perceived when the device is fixed to the car. Hence the question arises, "can the conclusions drawn from experimental studies using these laboratory-recorded sounds be generalized to real-life situations?"

The goal of this paper is to present a method designed to answer this question.

1 Method

The basic principle of the method is to let listeners compare laboratory and car recordings, in order to assess the perceived influence of the fixation condition.

Car horns were recorded in different fixation conditions (laboratory and car), with different microphone positions (the influence of which will not be discussed here). Listeners were asked to rate the perceived dissimilarity between every pair of sounds. The analysis is two-fold [?]. The first step uses a multidimensional scaling (MDS) analysis. This allows us to represent the dissimilarity ratings in a Euclidian space with a small number of dimensions. This space is called the *perceptual space* and the dimensions correspond to the basic auditory attributes on which the dissimilarity judgements are based [6]. This analysis is used here to visualize the perceptual structure that underlies the listener's perception, but not to identify precisly the acoustic correlates of the perceptual dimensions. Rather, it makes it possible to qualitatively understand how the perceptual space is altered by the fixation condition. This representation leads to assumptions concerning the influence of the fixation condition.

To quantitatively test these assumptions in the second step, data are submitted to two analyses of variance (ANOVA). Each of these analyses is focused on a restricted part of the data, selected on the basis of the MDS results. The interpretation of the ANOVA results compares the effect magnitudes (R^2).

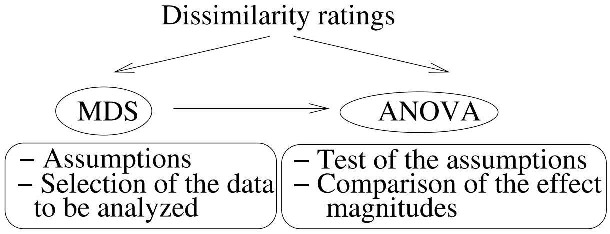

Figure 1: Analysis principle

Experimental setup

Sounds Eighteen sounds were recorded from:

- three models of car horns (m_1, m_1, m_3),
- two microphone positions (p_1: in front, p_2: -30°);
- three fixation conditions (c_1: laboratory, c_2: big car, c_3: small car).

The recordings were made either in an anechoic chamber (laboratory recordings) or in a semi-anechoic chamber (car recordings). The sounds all last approximatly 550 ms, and are equalized in loudness [4].

Subjects Twenty-nine subjects (13 males and 16 females) took part in the experiment. None of them reported any hearing loss.

Setup Subjects sat in a sound-attenuated booth, wearing a Sennheiser HD520 II headphone (diotic listening). The interface was implemented under the PsiExp environment [7]. Subjets listened to all pairs of sounds (171 pairs, the order of which were randomly ordered, including identical pairs). They were asked to rate the dissimilarity between the two sounds with a cursor labeled from "very similar" (O) to "very dissimilar" (1). The cursor resolution was 0.005. They could listen to each pair as many times as they wished.

Raw results

The raw data was arranged in a lower triangular matrix (18*18), including the diagonal. Among subjects correlations ranged from 0.01 to 0.81 (the mean is 0.39). An average-link hierarchical clustering (UPMGA algorithm [1]) analysis showed that all subjects could be included. The mean dissimilarity for pairs of two identical sounds is 0.0143.

2 Analysis

Multidimensional scaling analysis

The CLASCAL model and algorithm [8] was used to analyse the results (the diagonal was not used for this). The stable solution has three latent classes of subjects, three dimensions and no specificities. The perceptual

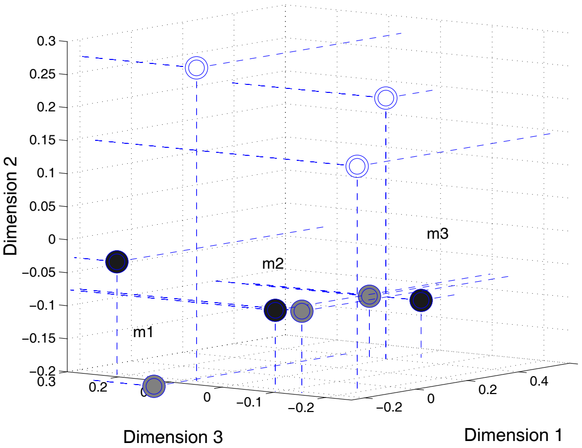

Figure 2: Perceptual space for the 18 sounds (the two microphone positions are added for each model and fixation condition). White circles: c_1; black circles : c_2; grey circles: c_3.

space is represented in Figure 2. The two first dimensions distinguish the three devices, while the third one separates the conditions c_2 and c_3 on the one hand (car recordings), and c_1 on the other (laboratory recordings). This supports the assumption that the perceptual structure that underlies the perceptual dissimilarities among the three models of devices, for a given fixation condition, is represented by the hyperplane (d1/d2). The influence of the fixation condition is thus a translation of this hyperplane along the third dimension. To statistically test this assumption, an analysis of variance was performed.

Analysis of variance (ANOVA)

Two sub-analyses were performed. In the first, only the dissimilarities between two sounds produced by the same device were analysed. In the second one, the sounds were produced by two different models of device.

Identical models This analysis only deals with the vertical displacement of the sounds in the perceptual space of Figure 2. Only a part of the data is submitted to a repeated-measures ANOVA, with factors Condition of fixation (6: c_1c_1, c_2c_2, c_3c_3, c_1c_2, c_1c_3, c_2c_3)*Model (3: m_1m_1, m_2m_2, m_3m_3)*Position (3: p_1p_1, p_2p_2, p_1p_2). The two most significant effects are due to the fixation condition (F(5,140)=110.2, p<0.01, R^2 experimental=79.2%), and to the interaction between the model and the condition (F(10,280)=5.86, p<0.01, R^2 experimental=6.24%). This means that when subjects listen to two sounds produced by the same horn model, but fixed in different conditions, they hear a clear difference between the two sounds, obviously due to the fixation condition. This difference depends on the model of horn. But this dependence is very weak compared to the main effect of the fixation condition.

Different models Only a part of the data is exploited here and submitted to a repeated-measures ANOVA, with factors Condition of fixation (6: c_1c_1, c_2c_2, c_3c_3, c_1c_2, c_1c_3, c_2c_3)*Model (3: m_1m_2, m_1m_3, m_2m_3)*Position (3: p_1p_1, p_2p_2, p_1p_2). The most significant effect is due to the model (F(2,56)=37.6, p<0.01, R^2 experimental=77.1%). Most of the variance within the data is thus due to the differences between models. The interaction between model and fixation condition is also significant (F(10,280)=4.61, p<0.01, R^2 experimental=6.13%). This shows that the fixation condition has an influence on the perceptual structure of the dissimilarities between different models of horns (within each hyperplane d1/d2), but that this effect is approximatively ten times weaker than the main effect of the model.

Conclusion

The two-fold analysis led us to compare the effect magnitudes of the experimental factors which influence the car horn sounds, on limited data sets.
For a given fixation condition, the dissimilarities perceived between the three horn models are subtended by two perceptual dimensions. The effect of the fixation condition is mainly to translate this 2D-structure along a third independent perceptual dimension. This means that conclusions based on the dissimilarity ratings obtained for a set of car-recorded devices will not be altered for the same set of devices, recorded in the laboratory. Conclusions can thus be generalized to real cases.

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