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Multimodal approach to automobile driving comfort: The influence of visual setting on assessments of vibro-acoustic comfort in simulators

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ABSTRACT

The growing use of vehicles in urban areas means that comfort in low-speed driving phase is an increasingly important consideration for manufacturers. Examining comfort in such situation requires not only field experiments but also the use of simulators to control the characteristics of the stimuli to which participants are exposed.

Incorporating a visual scene with vibration and sound stimuli is one possible way of improving simulation conditions. Two experiments were conducted to measure the influence of the immersion relating to vibratory, sound and visual modes on comfort assessments. In the first experiment, participants were exposed to different combinations of vibration, noise and road videos (8 vehicles, 2 roads). The visual mode only led to a small bearing on ratings. Regardless of the mode presented, the level of vibration emerged as the crucial factor in assessing overall comfort. Little interactions between sound and vibration modes were also highlighted. The second experiment dealt with context given by the visual mode. Acoustic and vibration stimuli were combined with very different road videos, which modified participants' expectations with regard to the situation. Results demonstrated that combining different visual settings with vibro-acoustic stimuli, no matter how much they were opposed, only exerted a small influence on participants' comfort.

In the end, with regard both to immersion and contextualisation, the effects of the visual mode are so low-scale as to be insignificant. Accordingly, they may be ignored in future similar experiments, which can make the experimental set-up easier.

1. Introduction

The growing use of vehicles in urban areas means that comfort in low-speed driving phase is an increasingly important consideration for manufacturers. In this situation vehicle comfort is tied to vibro-acoustic comfort. The main sources of constraints in the occupant's environment are vibrations and sounds transmitted to the cabin (vibrations from the floor pan, pedals, seats, steering wheels and dashboard and engine and road noise).

Examining comfort in low-speed driving phase requires not only "in situ" experiments but also the use of simulators. Unlike in the real-life situation, in simulations it is possible to control the characteristics of the stimuli to which participants are exposed. Sound and vibration are the basicmodes of this immersion. However, constraints relating to operating costs prevent the identical reproduction of an automobile cabin.

Incorporating a visual scene with vibration and sound stimuli is one possible way of improving simulation conditions. Projecting videos onto a screen is a low-cost method of making the laboratory environment more realistic. While it is legitimate to assume that visual mode cannot directly be involved in assessments of vibro-acoustic comfort, it does provide contextual information on situations that are apt to influence assessments. Therefore, it is worth exploring the role of the information provided by the visual mode: in this precise case, can videos alter participants' feelings or are they merely used to make the situation appear more realistic?

Most of the studies available on automobile driving comfort consist of individual research into each of the vibration, sound and visual modes. This type of study does not factor in people's capacity to integrate stimuli from another mode. Low-speed driving comfort should be studied in conditions as close as possible to those prevailing in an automobile cabin.

Genuit and Fiebig compared the assessment of vehicle noises carried out "in situ", in a simulator (sound + vibrations or just vibrations) and in a listening laboratory (just sounds) [1]. The re-

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sults showed a strong correlation between experiments. Differences in the use of the rating scale emerged, with participants using a lower rating dynamic in the simulator than in vehicles. In addition, results were very similar to those obtained when participants only evaluated vibrations in a simulator. The rating scale was also reduced when sounds were assessed by themselves. The author underlined the fact that contextual differences (driving task, absence of inertia force, visual scene, etc.) constituted a possible explanation for the dispersion of results. In spite of these observations, assessments in simulators remain close to those performed in the field.

Other studies have also shown that vision could exert a strong influence on subjective assessments of sounds. Viollon et al. undertook a laboratory experiment to assess how judgment of an urban environment sound may be affected by the simultaneous presentation of visual scenes representing different level of urbanisation [2]. Generally speaking, it seems from the two scales of assessment used (of a "pleasant" and "stressful" nature) that the more an environment is urban, the less noise is welcome. This effect is not identical for all tested sounds and depends on the semantic context of the noise – it is pronounced for natural sounds and absent for man-made sounds. In the automobile field, Ellermeier and Legarth evaluated the influence of visual contextualisation on the assessment of sounds in a laboratory [3]. Participants assessed the power of sound sequences combined with images of more or less powerful vehicles. It was found that the image of a powerful car induced a positive bias in assessments. The reverse was true for low-power cars. This suggests that participants incorporate the visual mode into their assessments even when explicitly asked to assess only the sound mode.

Other studies also shown that even a basic sound attribute such as loudness can be modified by visual stimuli. Menzel et al. related that the colour of a sports car influence the loudness evaluation of the accelerating sound [4]. A similar effect could be found in the case of high-speed train outside noise ([5,6]), though high inter-individual differences may reduce this assertion [7].

If most documented effects concern visual and sound modes, some interaction can occur between vibration and other modes too [8]. That is why when it comes to automobile driving comfort, we are entitled to expect that seeing a road fault beforehand can alter the degree of disturbance that a participant feels it when the vehicle drives over it.

Two experiments were conducted to measure the influence of the simulated environment on comfort assessments:

- In the first experiment, participants were exposed to different combinations of vibration, noise and road videos during assessments of vibro-acoustic comfort.
- The second experience dealt with context given by the visual mode. Acoustic and vibration stimuli were combined with very different road videos, which modified participants' expectations with regard to the situation.

2. Experiment apparatus

To assess vibro-acoustic driving comfort in a simulator, the vibrations and sounds measured in vehicles' cabins must be accurately reproduced. This reproduction must be accompanied by the projections of videos matching the passenger's field of vision.

2.1. Measurements

The objective is to measure vertical vibrations in the passenger seat, the noise environment in the vehicle interior and the passenger's field of vision on different roads and for several vehicles. To this end, an accelerometer (Type ICP–PCB) is placed vertically on the front screw of the right slider of the seat. The pressure field at passenger's head level is recorded with a dummy head (HMS III – Head Acoustics) fitted onto the seat. The video footage of the road is recorded with a HD digital camera (HDR HC1E – Sony) fitted onto the windscreen. The field leaves out the dashboard so as to avoid including any components that could give away the identity of the vehicles in the videos.

The accelerometer and acoustic head are linked to a front end (Octobox – Head Acoustics). The acoustic and vibrations measurements are saved into a computer (Head Recorder & Artemis

Fig. 1. Vibrating test bench.