

Car Ride Before Entering the Lab Increases Precision in Listening Tests

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ABSTRACT

Subjects who are well aware of what to judge commonly yield more consistent results in laboratory listening tests. This awareness may be raised by explicit instructions and training. However, too explicit instructions or use of only trained subjects may direct experiment results in an undesired way. An alternative is to give fairly open instructions to untrained subjects, but give the subjects a chance to get familiar with the product and context by, for example, riding a representative car under representative driving conditions before entering the laboratory. In this study, sound quality assessments of interior sounds of cars made by two groups were compared. In one group subjects were exposed to the same driving conditions that were later assessed in a laboratory listening test by taking them on a ride in one of the cars to be assessed, just before entering the laboratory. In the other group subjects made the laboratory assessments without prior car riding. In the laboratory, sound quality was assessed for binaurally recorded interior sounds of cars reproduced through headphones. The results showed that even though average sound quality assessments in most cases were the same for both groups, the variances were significantly smaller for the group where subjects had been taken on the car ride before the listening test. A conclusion is that being exposed to the sounds in the right context just before the listening test, e.g. by riding a representative car under representative driving conditions, can increase the precision in laboratory sound quality assessments.

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INTRODUCTION

Laboratory Listening Tests

Laboratory listening tests based on recorded sounds are frequently used to assess interior sound quality of cars. Benefits of such listening tests are that they are efficient and accurate as they allow rapid switching between sounds, back-to-back comparisons and good control of test conditions. They also allow participants to assess many cars at specific driving conditions without the need to move between different cars and without transportation to sections of test tracks to achieve specific speeds and driving conditions. Major drawbacks of laboratory listening tests are that they are typically based on short sound samples, the stimuli are purely auditory, and results may be influenced by how well the driving conditions are explained to the subjects and the subjects' ability to imagine themselves being in the car.

Comprehensive guidelines on how to perform listening tests of automotive sounds are rare. A good exception is an SAE paper by Otto et al. from 1999 [1]. It covers fundamentals of listening test methodology, e.g. choice of subjects, sample preparation, test

preparation and delivery, sound reproduction (headphones, loudspeakers and headphone/subwoofer combinations), some established listening evaluation methods, and analysis methods. However, the technology and praxis have developed since then. There has been an emphasis on tools and techniques allowing multisensory presentation of stimuli. Examples are calibrated vibroacoustic playback devices in car cabins [2], driving simulators [3] and sound simulation vehicles enabling the judgment of sound via headphones while actively driving a real car along a road [2].

Multisensory Perception of Cars

Jennings et al. [4] made thorough studies of customer perception of sound quality in real cars under real driving conditions. They further made laboratory listening tests for exploration of how artificially created target sounds were rated compared to interior sounds of existing cars. From this, they pointed out the importance of using real-world driving for exploration of interior sound quality, but they also stated that laboratory listening tests allow more detailed and rigorous jury evaluations. They further emphasized that



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a major reason for using laboratory listening tests is to be able to assess simulated sounds of not yet existing vehicles, e.g. simulated target sounds.

Dunne et al. [3] pointed out that NVH experts may be trained and able to make proper judgments based on sound stimuli alone. However, decision makers less experienced in sound quality evaluations often express that non-typical driving conditions and lack of interactivity make judgments difficult:

Whilst experienced NVH engineers may be able to relate pre-recorded and digitally filtered sounds to the real-world driving conditions, the key programme decision makers frequently express the concern that the non-typical operating condition and the lack of interactivity makes it very difficult for them to make the link between the non-immersive listening room environment and the real vehicle. [3]

Further, Dunne et al. [3] suggested the use of a driving simulator with simulated sound as a tool allowing multisensory presentation of the driving conditions, and they claimed that the use of such a simulator had reduced late vehicle sound target changes and late hardware changes.

Experience and review of previous research have pointed out the importance of taking multisensory perception into account when doing assessments of product sounds. There is strong evidence for the importance of multisensory effects on the perception of sound [5]. This evidence has led to attempts to provide multisensory stimuli to listening appraisals, either by complementing auditory stimuli with images [6], videos [7] or vibrations [8], or by making listening tests in driving simulators [3], or in stationary cars [9]. All of these techniques lead to limitations in the accuracy and matching of the multisensory stimuli presented to the subject. As multisensory interaction apparently influences subject judgments, these limitations in accuracy must be taken into consideration when designing listening tests. Errors and artifacts in the reproduction of multisensory stimuli may disturb the test, and as the use of multisensory stimuli in some settings may limit some advantages of pure auditory tests, tests should be designed with care. Other ways of training and informing subjects of what they are expected to assess may be beneficial.

Training in the Real Environment

Results from a previous study by Lennström et al. [10] indicated a decrease in variance of listening test assessments of interior electric vehicle noise when laboratory tests were preceded by riding an electric car under the studied driving conditions. In that study it was assumed that participants' unfamiliarity with electric cars would increase the inconsistency of judgments, and by familiarizing them by making judgments in an electric car under the specific driving conditions this inconsistency should decrease. It could not be clarified if the observed larger variance for subjects who were not trained by riding the electric car was caused by unfamiliarity with the new kinds of sounds, or if the reduction in variance is general for subjects who are familiarized with the kinds of cars and driving conditions to be judged. Therefore, this study examines whether the consistency increases also for assessments of familiar combustion engine cars in tests using conventional laboratory listening test methods. Such

results are important for giving good advice on how training and familiarization of subjects with test vehicles and driving conditions should be done.

It was assumed that using training sessions in real cars representative for the objective of the study, driven under representative driving conditions would increase the precision in subsequent laboratory listening tests. Further, the subjects should be asked to do the same listening test appraisal under these driving conditions, either as driver or passenger of the car, immediately before entering the lab. This ensures that the subjects have a complete and correct multisensory experience during training, and this makes the subjects well aware of how they perceive the sound in the multisensory context, without needing to be aware of underlying multisensory integration effects. It also allows experience of long term effects during training. It was assumed that the consistency in listening tests increases if subjects experience examples of the product, become familiar with their impressions, learn what they find attractive or annoying, and then immediately make judgments of sound recordings reproduced in the lab. This combines the advantages of experiencing the product in real life with all the possibilities laboratory tests give, e.g. assessment of many stimuli in short time, back-to-back comparisons, rapid switching between stimuli, and good control of the driving conditions that are assessed. Further, if the consistency among subjects increases, statistically significant results will be reached with fewer subjects. This would make listening tests more time and cost efficient.

Objective

The objective of the study was to investigate how riding in a car before taking part in a laboratory listening test affects mean assessments and variance among subjects in a typical listening test for assessment of car interior sound quality.

METHOD

Evaluation Methodology

Two groups of subjects made the same semantic differential sound quality assessment test in the laboratory. Group A received conventional training in the lab, while Group B was trained by making the same sound quality assessments as they were later doing in the lab while riding in a representative car under representative driving conditions. Means and variances in the sound quality ratings were compared.

Two hypotheses were tested:

1. Training by riding in a car before the laboratory test changes mean ratings in the sound quality assessment.
2. Training by riding in a car before the laboratory test changes the variance among subjects in the sound quality assessment.

Listening Test Design

Seven semantic differential scales were selected from a sound quality assessment sheet suggested by Dunne [11]. The scales were originally developed in English, and were translated to Swedish. The test was

conducted in Swedish using native speaking Swedish subjects. The Swedish attribute pairs used are shown in Table 1, together with the original English attributes. A semantic differential rating scale used by Dunne [11] was translated to Swedish. The translation is shown in Table 2, together with the original English scale. Responses were collected using a computer interface shown in Figure 1.

Table 1. Attribute pairs used in the semantic differential listening test (adopted from Dunne [11]).

Swedish translation used in the test		Original English attribute pairs	
Tyst	Högljudd	Quiet	Loud
Elegant	Grov/rå	Refined	Harsh
Obesvärad	Ansträngd	Effortless	Strained
Kraftfull	Vek	Powerful	Weak
Sportig	Konservativ	Sporty	Conservative
Tuff, aggressiv	Dämpad	Tough, Aggressive	Subdued
Behaglig	Besvärande	Pleasant	Annoying

Table 2. Semantic scale used in the semantic differential listening test (adopted from Dunne [11]).

	Original English scale	Swedish translation used in test	Rating
E.g. Quiet	Very	Väldigt	7
	Notably	Märkbart	6
	Slightly	Något	5
	Neither	Ingetdera	4
	Slightly	Något	3
	Notably	Märkbart	2
E.g. Loud	Very	Väldigt	1

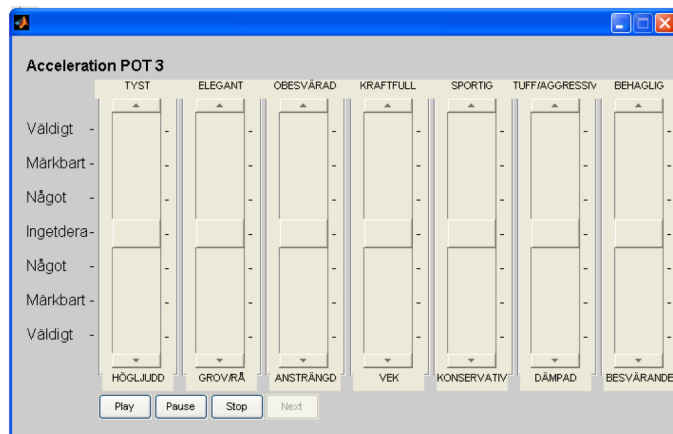


Figure 1. Computer interface used for collecting responses in the listening test.

Sound Stimuli

Binaural recordings of sound stimuli were made in four different cars under four different driving conditions; two constant speeds (50 km/h and 80 km/h), 3rd gear partially open throttle (POT) acceleration and

2nd gear wide open throttle (WOT) acceleration. The recordings were made in the front passenger seat using an artificial head (Head Acoustics HMS III or Head Acoustics HMS IV). Car models, driving conditions and artificial head used are listed in Table 3.

The recordings were made between October 2011 and November 2012. Car 2, 3 and 4 were recorded on dry asphalt roads using standard tires for the cars. Car 1 was recorded on dry asphalt road with studded winter tires.

In the laboratory listening test the stimuli were reproduced through equalized headphones (Head Acoustics PEQ V amplifier and Sennheiser HD600 headphones). Stimuli were played once, but could be repeated any number of times by pressing the play button.

Table 3. Sound stimuli used in the listening test.

Car nr.	Car model	Driving condition	Length of stimuli	Artificial head
1	Renault Megane 1.6 Hatchback 2012	50 km/h 80 km/h 3 rd gear POT acc. 2 nd gear WOT acc.	20 s 20 s 23 s 3 times 7 s	Head Acoustics HMS IV
2	Renault Megane 1.2TCe Sport Tourer 2012	50 km/h 80 km/h	20 s 20 s	Head Acoustics HMS III
3	BMW F20 120d 2011	3 rd gear POT acc. 2 nd gear WOT acc.	25 s 4 times 5 s	Head Acoustics HMS III
4	Nissan Juke 1.6 DIG-T 2011	50 km/h 80 km/h 3 rd gear POT acc. 2 nd gear WOT acc.	20 s 20 s 32 s 2 times 12 s	Head Acoustics HMS III

Subjects

In total, 38 subjects participated. The subjects were university students aged from 20 to 28 years with self-reported normal hearing. The subjects were divided into two groups. Subjects in Group A did both the training and the test in the lab. Subjects in Group B were given training in one of the cars recorded for the listening test (Car 1). Group A consisted of 18 subjects (11 women and 7 men) and Group B consisted of 20 subjects (5 women and 15 men).

Training

Subjects in Group A did both the training and the test in the lab. The training consisted of listening to and assessing all stimuli using the same procedure as later was used in the test. The presentation orders of the stimuli were independently randomized for the training session and the listening test. The subjects were informed that the purpose of the training session was to familiarize them with the sounds and the task, and that no results from the training session were saved or used for subsequent analysis.

Subjects in Group B were given training in one of the cars recorded for the listening test (Car 1). They were seated in the front passenger seat, and were assessing the interior sound quality under all studied driving conditions, using the same attribute pairs and semantic scale. Responses during this training were collected using pen and paper. The subject did the laboratory listening test immediately after having completed the training in the car.