

## Influences of vehicle exterior design on loudness ratings by German versus Japanese drivers.

Junji Yoshida<sup>1,2</sup>, Florian Völk<sup>2</sup>, Hugo Fastl<sup>2</sup>, Gerhard Rigoll<sup>3</sup>

<sup>1</sup> *Osaka Institute of Technology, 5-16-1, Omiya, Asahi-ku, Osaka, 535-8585, Japan, Email: yoshida@med.oit.ac.jp*

<sup>2</sup> *AG Technische Akustik, MMK, Technische Universität München, Arcisstr. 21, 80333 München, Deutschland*

<sup>3</sup> *MMK, Technische Universität München, Arcisstr. 21, 80333 München, Deutschland*

### Introduction

Quietness is one important aspect of vehicle performance. In recent years, not only the amount of quietness respectively loudness, but also the quality of vehicle sounds have been investigated. Different sound quality indices were developed based on auditory perception characteristics [1, 2]. In most of these studies, auditory evaluation tests were performed by presenting sounds without designated visual stimuli. However, more recent studies revealed that non-acoustical factors can affect loudness evaluations [3, 4]. In actual driving situations, when hearing the interior sound, the drivers are aware of the vehicle design and have an impression of whether they are driving, for example, a sporty or luxury model.

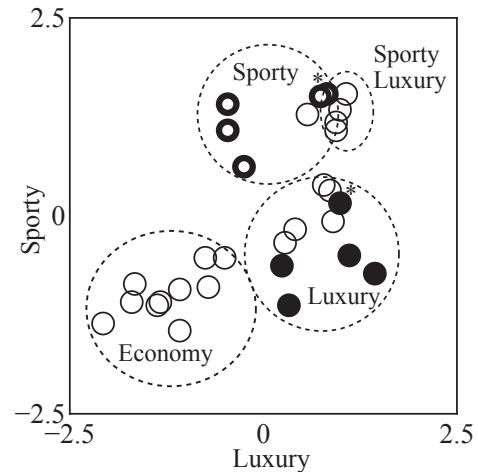
This leads to the hypothesis that the loudness ratings of vehicle interior sounds may be affected by the impression of the exterior design. In addition, the influence may be different among countries according to the differences of the cultural background, regarding vehicle and sound [5]. In the present study, these hypotheses were addressed by presenting exterior images of different vehicles to German and Japanese drivers, who were asked to evaluate the loudness of vehicle acceleration sounds.

### Ratings of Vehicle Exterior Images

Character ratings of vehicle exterior images were carried out in order to determine the participants' overall impression of the images and to select the images for the following loudness rating experiment.

Thirty exterior images of vehicles sold in the EU, USA, and Japan were employed as visual stimuli. All vehicles were selected with similar colors (white or silver), in order to minimize the influence of color on loudness. The evaluation parameters "luxury" and "sporty" were used as indicators of the impression. The participants rated these parameters on separate integer scales from  $-3$  to  $+3$ , with negative values indicating weak impressions. Sixteen German and twenty Japanese drivers in age between twenty and sixty years (average 27 years) participated in this test.

For obtaining the resulting overall judgment (impression) of each vehicle image, the scores of each vehicle were averaged among all participants per country and normalized to achieve a standard deviation of one for the distributions of luxury and sporty scores. Figure 1 shows the so-called impression map, composed of the luxury and sporty ratings of the German drivers (small circles).



**Figure 1:** Vehicle impression map of German drivers. The axes represent the luxury and sporty scales, small circles the ratings of vehicle exterior images (bold and filled used for the loudness ratings). Dashed circles indicate the grouping.

Four impression groups (luxury, sporty-luxury, sporty, and economy) were observed in the map and are marked by dashed circles in figure 1. Based on the impression map, five vehicle images from the luxury group (filled circles) and five images from the sporty group (bold open circles) were selected for the subsequent experiment. The result for the Japanese drivers was similar, and five luxury and five sporty vehicle images were selected based on the vehicle impression map of the Japanese drivers. Eight of these images were also selected based on the German impression map, the two other images were different (marked by stars in figure 1).

### Loudness Ratings – Procedure

The loudness of ten acceleration sounds was evaluated in this experiment. Only frequent drivers (driving at least twice a week) participated in the test, five in Germany and nine in Japan. The same ten different acceleration sounds recorded binaurally (HEAD acoustics HMS) inside of vehicles at the passenger seat position were used in both countries.

Similar class vehicles to those evaluated regarding their visual impression were recorded. For the experiment, the sounds were edited to durations of about 10s and presented dichotically with original  $L_{Aeq}$  between 64 and 83 dB by Sennheiser HD 600 headphones.

The auditory-visual test was conducted using a control

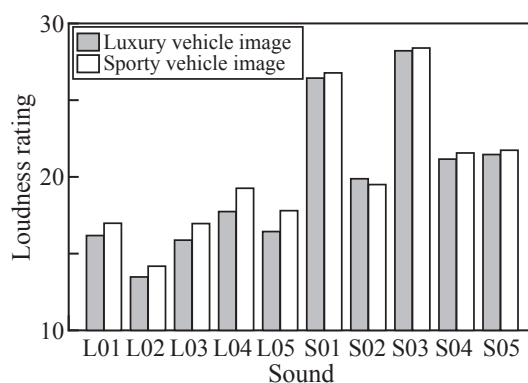
software, sequentially displaying the images selected as described in the previous section on a PC monitor and instructing the participants to imagine driving the vehicle. After clicking a button in the software, the acceleration sound was presented while the vehicle image still being displayed. By clicking another button, the participant rated the loudness using the categories “very soft,” “soft,” “relatively soft,” “neither soft nor loud,” “relatively loud,” “loud,” and “very loud”. Each of these major categories was subdivided in four sub-categories, resulting in 31 steps. For the analysis, integer numbers from 1 to 31 were appointed to the categories from “very soft” to “very loud”.

Two stimulus patterns were composed of the images and sounds: In pattern 1 (matching), each of the luxury-vehicle sounds L01, . . . , L05 was combined with one of the luxury-vehicle images, and each of the sporty-vehicle sounds S01, . . . , S05 with one of the sporty-vehicle images. In pattern 2 (conflicting), sporty-vehicle sounds were presented with luxury vehicle images and luxury-vehicle sounds with sporty-vehicle images. In a session, all sounds in a single test pattern were evaluated twice in randomized order, resulting in 20 judgments. For each pattern, each participant carried out five separate sessions. Hence, each subject performed 200 trials (two test patterns  $\times$  20 trials  $\times$  five iterations), resulting in a total number for the German drivers of 1000 (200 trials  $\times$  five participants) and for the Japanese drivers of 1800 (200 trials  $\times$  nine participants).

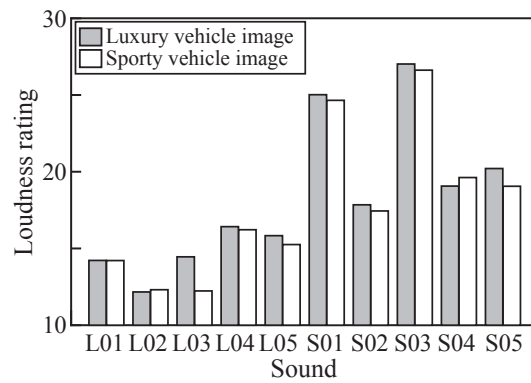
## Loudness Ratings – Results

Figure 2 shows the average loudness ratings (ordinate) of the German drivers for ten different sounds (abscissa). The gray and white bars indicate the loudness ratings while watching luxury and sporty vehicles, respectively.

The results indicate that the German drivers on average rated the loudness of the acceleration sounds somewhat lower when presented combined with images of luxury vehicles (gray bars) than they did when the sounds were presented together with images of sporty vehicles (white bars). The amount of the effect is comparable to those



**Figure 2:** Average loudness ratings (ordinate) of German drivers for five luxury (L) and five sporty (S) sounds (abscissa). The bar colors indicate the visual stimulus class.



**Figure 3:** Average loudness ratings (ordinate) of Japanese drivers for five luxury (L) and five sporty (S) sounds (abscissa). The bar colors indicate the visual stimulus class.

found with German subjects in previous studies, for example on railway noise and train images [3].

Figure 3 shows the loudness ratings of the Japanese drivers for the same sounds and comparable images (cf. first section). The data reveal that the Japanese drivers on average tended to rate the loudness of a vehicle acceleration sound, while looking at images of luxury vehicles (gray bars), higher than when looking at images of sporty vehicles (white bars). While the direction of the tendency is opposite for the German drivers, the direction was comparable in a previous study using similar auditory-visual stimuli and Japanese drivers [4].

These results show that the exterior design of vehicles may affect loudness ratings. However, opposing trends were found for German vs. Japanese drivers.

In the loudness evaluation, the German drivers may have integrated the impression of luxury vehicle design (associated with a soft sound) with the presented sound and rated the sound softer. On the other hand, Japanese drivers may have expected a soft sound by looking at the luxury vehicle image presented prior to the sound, and rated the sound somewhat louder by comparing the actually presented sound with the expected soft sound.

## References

- [1] Fastl, H., Zwicker, E.: Psychoacoustics – Facts and Models. 3<sup>rd</sup> edition, Springer, Berlin, 2007
- [2] Bispin, R., Giehl, S., and Vogt, M.: A standardized scale for the assessment of car interior sound quality, SAE Transactions, 106, 6, Part 2, (1997), 2924-2928
- [3] Patsouras, C., Filippou, T. G., and Fastl, H.: Influences of color on the loudness judgment, Proc. of Forum Acousticum Sevilla, (2002), 1-6
- [4] Yoshida, J., and Igata, T.: Dependence of loudness evaluation by drivers on vehicle styling. J. Acoust. Soc. Am., 132, 6 (2012), 3866-3873
- [5] Namba, S., Kuwano, S., and Schick, A.: Cross-cultural study on noise problems, J. Acoust. Soc. Jpn. (E), 7, 5, (1986), 279-289