



# Influences of Vehicle Exterior Images on Sound Quality Ratings: German vs. 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, Japan

<sup>2</sup> AG Technische Akustik, MMK, Technische Universität München, Germany

<sup>3</sup> MMK, Technische Universität München, Germany

## ABSTRACT

In this study, influences of vehicle exterior images on sound quality ratings of acceleration sounds were investigated. Luxury and sporty vehicle images were presented to German or Japanese frequent drivers, while listening to acceleration sounds. Subsequently, loudness, luxury, and sportiness of the sounds were rated. The results indicate that the German drivers tended to rate loudness lower and luxury higher when the sounds were presented with images of luxury cars, compared to images of sporty vehicles. As expected, sportiness was rated higher when an image of a sporty vehicle was presented. Oppositely the Japanese drivers indicated higher loudness and lower luxury when the sounds were combined with luxury vehicle images. Further, comparable to the German drivers, they rated higher sportiness when presented with sporty vehicle images. Consequently, it appears that sound quality ratings can be affected by the vehicle exterior design, but the average tendencies suggest different effect directions for German vs. Japanese drivers.

Keywords: Sound Quality, Vehicle Exterior Image I-INCE Classification of Subjects Number(s): 63.7

## 1. 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 has been investigated. Various sound quality indices have been developed based on auditory perception characteristics and some of them considered the difference of the nationality of the drivers (1-3). 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 auditory evaluations (4-9).

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 sound quality ratings of vehicle-interior sounds may be affected by the impression of the exterior design. In addition, the influences may be different among countries according to the differences of the cultural background, regarding vehicle and sound (2,10,11).

In the present study, these hypotheses were addressed by presenting exterior images of different vehicles to Japanese and German drivers who were asked to evaluate the sound quality of vehicle acceleration sounds.

## 2. 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 sound quality rating experiments.

### 2.1 Procedure, Stimuli, and Participants

Thirty exterior images of vehicles sold in the EU, USA, and Japan were employed as visual stimuli.

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<sup>1</sup> yoshida@med.oit.ac.jp

<sup>2</sup> yos@mmk.ei.tum.de

All vehicles were selected with similar colors (white or silver), in order to minimize the influence of color on the sound quality rating (7). 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. Twenty Japanese and sixteen German drivers in age between twenty and sixty years (average 27 years) participated in this test.

## 2.2 Results

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 Japanese (a) and German (b) drivers (small circles).

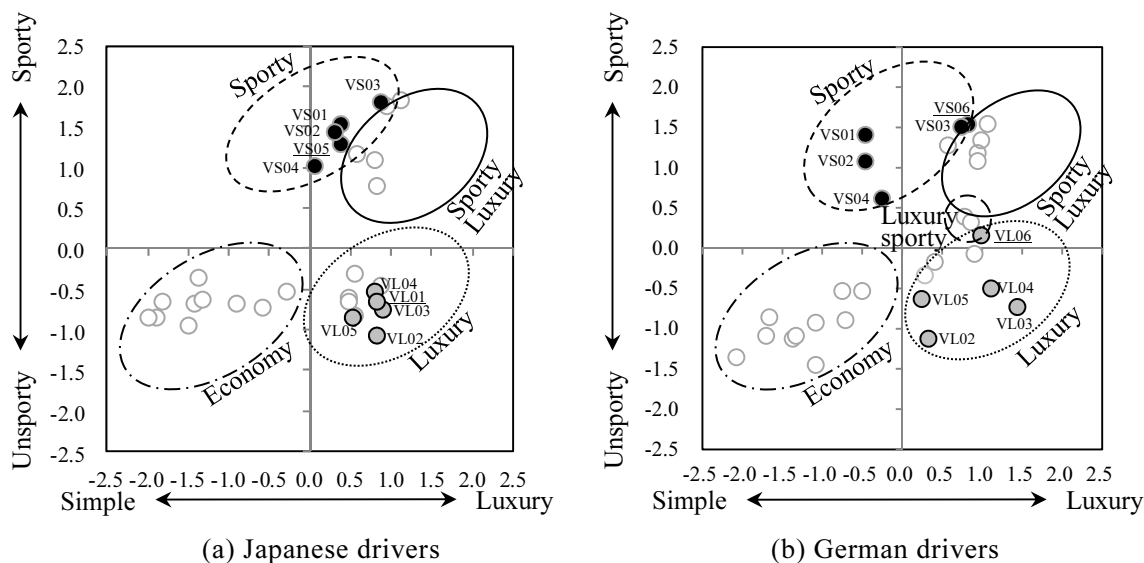


Figure 1 – Vehicle exterior image impression maps resulting from rating experiment 1. Small and big circles indicate vehicle image and group, respectively. Filled small circles are selected images for the subsequent sound quality rating experiments.

As indicated in Fig. 1 (a), four impression groups (luxury, sporty-luxury, sporty, and economy) were observed in the Japanese map, which are marked by circles. The sporty and sporty-luxury groups were close, presumably because sporty vehicles are typically considered also expensive. Additionally, more expensive sporty vehicles were included in the sporty-luxury group. In the German map in Fig. 1 (b), the distribution for the vehicle images was similar to the Japanese map, and the same four groups are observed. However, an additional group (luxury-sporty) was found in the German map. Luxury vehicles having high driving performance belonged to this group. These vehicle images in the group were included in the luxury group in the Japanese map. The difference is considered to be generated by the differences of the driving situation and cultural background of vehicles among both countries.

Based on these impression maps, five vehicle images from the luxury group (filled gray circles) and five images from the sporty group (filled black circles) were selected for the subsequent sound quality rating experiments, because the sounds impressions between luxury and sporty vehicles were considered clearly different. Eight images were selected from both maps, the two remaining images were different (underlined labels in Fig. 1).

## 3. SOUND QUALITY RATINGS (AUDIO-VISUAL TEST)

The sound quality of ten acceleration sounds and audio-visual interactions regarding exterior-vehicle images were evaluated in this experiment.

### 3.1 Procedure, Stimuli, and Participants

The evaluation parameters “luxury” and “sporty” were used as indicators of the sound quality as they have been used also during the visual test (2). In addition to these parameters, “loudness” was

also included for being a fundamental parameter of the sound quality.

Only frequent drivers (driving at least twice a week) participated in the test, nine Japanese and five Germans. The same ten acceleration sounds recorded binaurally (HEAD acoustics HMS) inside of vehicles at the passenger seat position were used in both countries. The vehicles for the recordings were similar class vehicles to those evaluated in the visual test. Five of the ten sounds were sounds of luxury vehicles (SL01–SL05), the others were sounds of sporty vehicles (SS01–SS05). As the sounds were intended to provide the impression of an accelerating vehicle, acceleration sounds from low to high engine rotational speeds were used (about 1000 to 6000 rpm). Also, fade-in and fade-out processing was applied to the beginning and the end of each sound, in order to avoid click artifacts. The sounds were edited to durations of about 10 s and presented dichotically at their original  $L_{Aeq}$  (between 64 and 83 dB) by Sennheiser HD600 headphones (12).

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 was still being displayed. By clicking another button, the participants rated the sound quality using categories. For instance in the loudness evaluation, the participants rated the loudness within 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”. The luxury and sporty ratings were carried out using the same procedure. After the rating had been completed, the next vehicle image was presented and so on. The image number, sound number, and the rating of each parameter were automatically saved to a file. All participants practiced the evaluation procedure before the test results were actually recorded.

### 3.2 Audio-visual Stimuli

In the audio-visual test, changes of the sound quality ratings of the ten acceleration sounds were evaluated when the presented vehicle image was changed from luxury to sporty and vice versa. Hence, two stimulus patterns were composed of the images and sounds: In pattern 1 (matching), each of the luxury-vehicle sounds SL01,...,SL05 was combined with one of the luxury-vehicle images, and each of the sporty-vehicle sounds SS01,...,SS05 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. The resulting combinations for both nationalities are shown in Table 1.

Table 1 – Presentation patterns of sounds and images

(a) Patterns for Japanese drivers										(b) Patterns for German drivers											
Pat. 1	Luxury vehicle sound					Sporty vehicle sound					Pat. 1	Luxury vehicle sound					Sporty vehicle sound				
	SL01	SL02	SL03	SL04	SL05	SS01	SS02	SS03	SS04	SS05		SL01	SL02	SL03	SL04	SL05	SS01	SS02	SS03	SS04	SS05
	VL01	VL02	VL03	VL04	VL05	VS01	VS02	VS03	VS04	VS05		VL06	VL02	VL03	VL04	VL05	VS01	VS02	VS03	VS04	VS06
Pat. 2	Luxury vehicle image					Sporty vehicle image					Pat. 2	Luxury vehicle image					Sporty vehicle image				
	Luxury vehicle sound					Sporty vehicle sound						Luxury vehicle sound					Sporty vehicle sound				
	SL01	SL02	SL03	SL04	SL05	SS01	SS02	SS03	SS04	SS05		SL01	SL02	SL03	SL04	SL05	SS01	SS02	SS03	SS04	SS05
	VS01	VS02	VS03	VS04	VS05	VL01	VL02	VL03	VL04	VL05		VS01	VS02	VS03	VS04	VS06	VL06	VL02	VL03	VL04	VL05
	Sporty vehicle image					Luxury vehicle image						Sporty vehicle image					Luxury vehicle image				

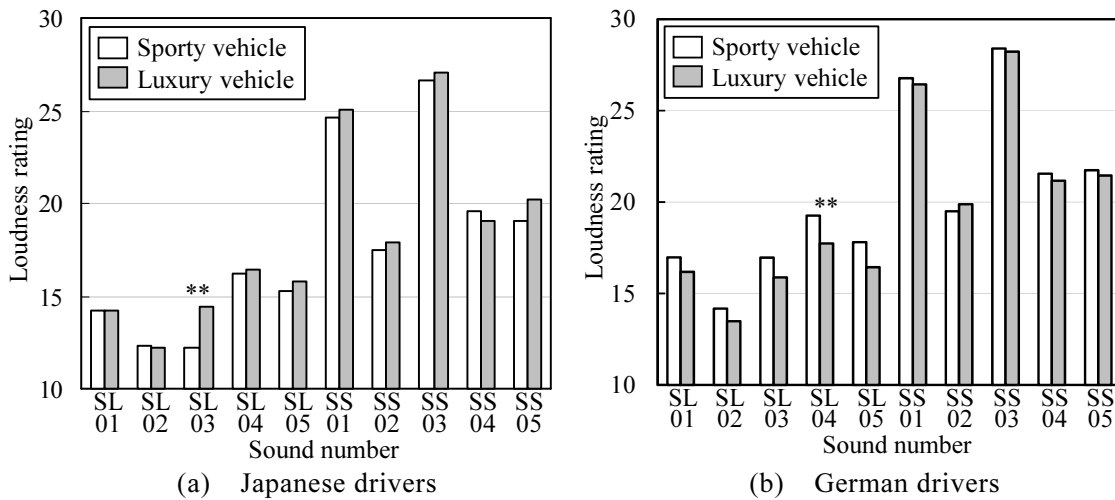
In the luxury-vehicle sound group, the difference of the sound quality ratings from pattern 1 to pattern 2 shows the difference of sound quality evaluation when the vehicle image changed from luxury to sporty. In the sporty-vehicle sound group, the difference of the ratings from pattern 1 to pattern 2 shows the sound quality evaluation difference when the design changed from sporty to luxury.

A single sound quality evaluation including loudness, luxury and sportiness ratings was carried out in a trial, and a series of trials was performed in a session in both countries. A number of sessions were conducted for each participant. 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 participant performed 200 trials (two test patterns x 20 trials x five iterations), resulting in a total number for the Japanese drivers of 1800 (200 trials x nine participants) and for the German drivers of 1000 (200 trials x five participants). About 10 minutes were required to complete one experimental session.

### 3.3 Results

#### 3.3.1 Loudness Rating

Figure 2 shows the average loudness ratings (ordinates) of the Japanese and German drivers for ten different sounds (abscissae, SL: Luxury vehicle sound, SS: Sporty vehicle sound).



(a) Japanese drivers (b) German drivers  
 Figure 2 – Loudness rating results for different vehicle exterior designs.  
 SL: Luxury vehicle sound, SS: Sporty vehicle sound; Inserts: Visual stimuli.

The white and gray bars indicate the loudness ratings while watching sporty and luxury vehicles, respectively. The Japanese drivers (Fig. 2a) rated the loudness of most sounds presented with luxury-vehicle images on average somewhat higher than the loudness of the same sounds presented with sporty-vehicle images. The difference between the loudness ratings of sound SL03 (double star marks in Fig. 2a) is statistically significant ( $p < 0.05$ , t-test; double asterisk in Fig. 2a).

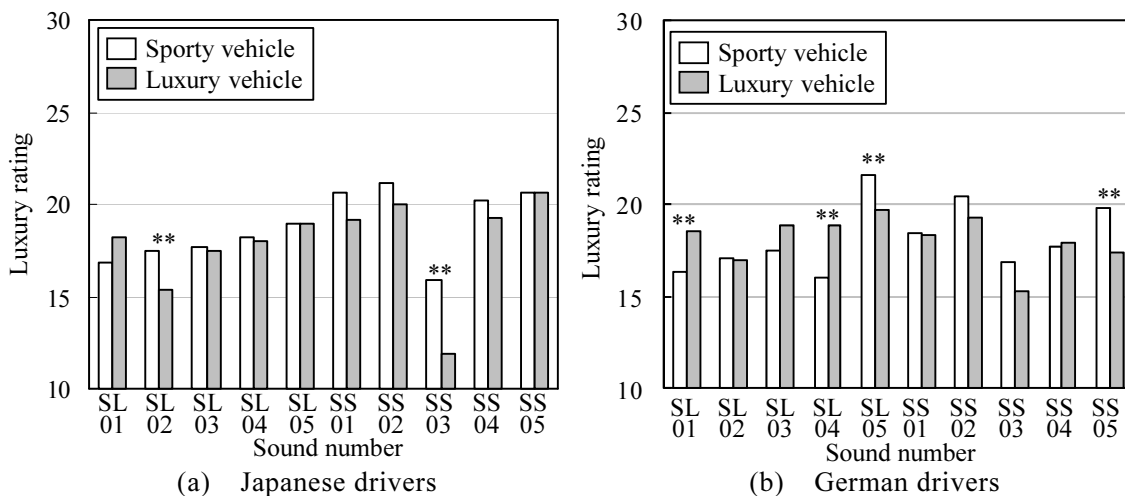
Based on these results, the Japanese drivers were found to rate the loudness of the same acceleration sound somewhat higher when presented combined with the exterior image of a luxury vehicle than with the exterior image of a sporty vehicle.

Different from the Japanese, German drivers (Fig. 2b) tended to judge the loudness while looking at the image of luxury vehicles lower than with the images of sporty vehicles. The difference of the loudness ratings of sound SL04 is significant ( $p < 0.05$ , t-test; double asterisk in Fig. 2b).

These results provide evidence that the impression of vehicle-exterior design can affect the rating of the loudness of vehicle acceleration sounds. However, the effect showed opposite directions for Japanese vs. German drivers.

#### 3.3.2 Luxury rating

Figure 3 shows the average luxury ratings (ordinates) of the Japanese and German drivers for ten different sounds (abscissae).



(a) Japanese drivers (b) German drivers  
 Figure 3 – Luxury rating results for different vehicle exterior designs.  
 SL: Luxury vehicle sound, SS: Sporty vehicle sound; Inserts: Visual stimuli.

The white and gray bars indicate the luxury ratings while watching sporty and luxury vehicles, respectively. The results indicate that the Japanese drivers (Fig. 3a) rated the luxury of most sounds presented with luxury-vehicle images lower than the luxury of the same sounds presented with sporty-vehicle images. Double asterisks in the figure show significant differences. These results indicate that the impression of a luxury vehicle decreases the luxury ratings of sounds in Japanese drivers. As a reason, interrelations of loudness and luxury evaluation is considered. In a previous study of vehicle sound quality, loudness was reported as one of the main factors to decrease the luxury (2). The Japanese drivers rated the loudness of sounds presented with luxury-vehicle images higher than the loudness of the same sounds with sporty-vehicle images. Hence, the luxury rating of the sounds is expected lower for increased loudness ratings.

On the other hand, the German drivers rated sounds SL01 and SL04 significantly more luxury when presented with luxury-vehicle images than with sporty-vehicle images (Fig. 3b). These sounds were rated lower in loudness when presented with luxury-vehicle images (Fig. 2b). This loudness rating tendency is considered to be related to the luxury rating change, as for the Japanese. However, luxury ratings of SL05 and SS05 decreased significantly in the same situation. In the sound quality ratings of both sounds, the exterior images of VS06 and VL05 were used as the sporty and luxury vehicle images, respectively, as shown in Table 1. While VS06 belonged to sporty-vehicle group and VL05 belonged to the luxury-vehicle group, VS06 was rated more sporty and also more luxury than VL05 by the German drivers (impression map shown in Fig. 1b). This indicates that the image of VS06 was perceived more luxury and more sporty by the German participants. Therefore, the luxury ratings of sounds SL05 and SS05 are considered to be increased by presenting luxury and sporty vehicle images.

These results suggest that the German drivers tended to rate vehicle sounds more luxury when presented with vehicle images eliciting a luxury impression, contradictory to the Japanese. The relationship between luxury rating and loudness was similar in both countries.

### 3.3.3 Sportiness rating

Figure 4 shows sportiness ratings of Japanese and German drivers. The white and gray bars indicate the ratings while watching sporty and luxury vehicles, respectively.

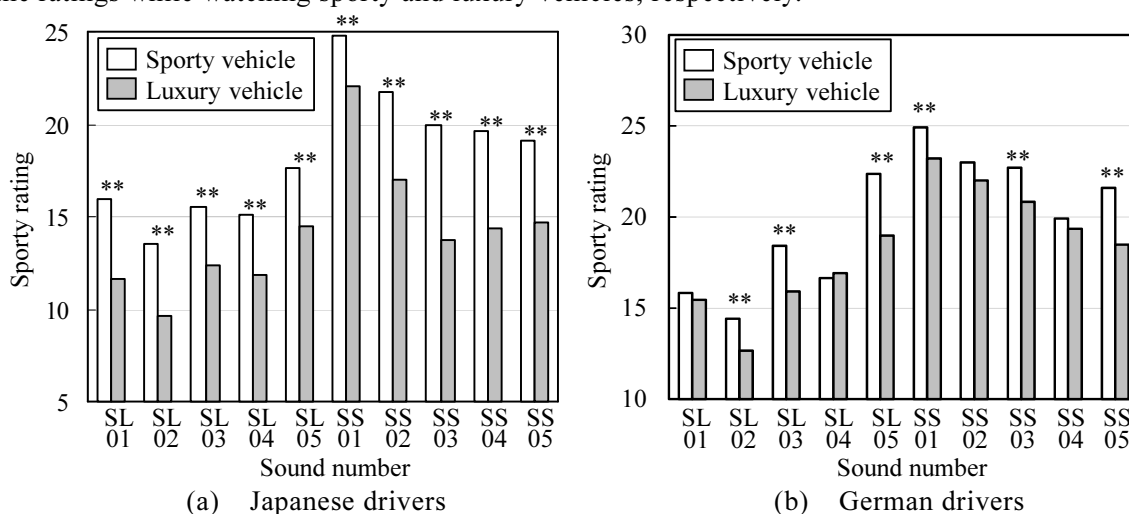


Figure 4 – Sportiness rating results for different vehicle exterior designs. SL: Luxury vehicle sound, SS: Sporty vehicle sound; Inserts: Visual stimuli.

The sportiness ratings of most sounds were increased when presented with sporty vehicle images in both countries, as shown by Fig. 4. The differences were much larger compared with the luxury and loudness ratings. The differences of most sounds presented with sporty and luxury vehicle images were significant. This result shows for the German drivers, where the sporty rating was increased by watching sporty vehicle images, the same tendency as the luxury rating. The German drivers rated the sounds presented with sporty-vehicle images louder than the sounds presented with luxury-vehicle images. The increase of the loudness may be related to the increase of the sportiness. The results suggest that the German drivers had the tendency that the sound quality ratings were pulled by the vehicle exterior image impression (matching effect).

The Japanese drivers rated sounds more sporty when watching sporty-vehicle images, as did the German participants. However, this tendency is different from the change of ratings in the luxury evaluation. Even though Japanese drivers rated less luxury while watching luxury-vehicle images (conflicting effect), they rated the sounds more sporty when watching sporty-vehicle images, comparable to the German participants (matching effect). These results indicate that the influence of vehicle exterior design on sound quality ratings is different in Japanese depending on the sound quality parameter actually studied (luxury and sporty ratings).

#### 4. DISCUSSION AND SUMMARY

In this study, influences of the vehicle exterior design on sound quality ratings in Japanese or German drivers were investigated and the following tendencies obtained (Table 2).

Table 2 – Influence of vehicle design on sound quality rating

	Japanese drivers	German drivers
Loudness	Conflicting	Matching
Luxury	Conflicting	Matching
Sporty	Matching	Matching

As shown in the white boxes of Table 1, Japanese drivers rated slightly higher loudness when watching luxury-vehicle images, which has been also found by previous research (9). They also rated less luxury when the sounds were presented with luxury vehicle images. These tendencies conflict with the impression of the luxury-vehicle exterior images (conflicting effect). The reason is assumed as follows (Fig. 5).

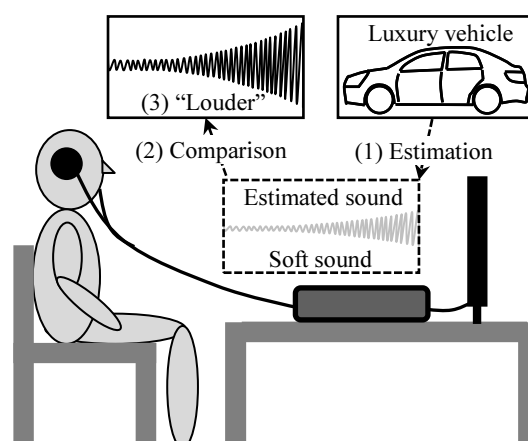


Figure 5 – Influence of luxury vehicle image on loudness and luxury ratings of sound.  
Explanation attempt for the primary process occurring for Japanese drivers.

The Japanese drivers participated in the test were frequent drivers, therefore, they may have expected a soft sound when looking at the luxury-vehicle image (before listening to the sound), as shown in Fig. 5. In the evaluation process, they compared the impression of the actually presented sound with the expected softer impression (Fig. 5, cf. 2). As a result, the sounds were rated louder and less luxury when presented with the luxury vs. the sporty vehicle images (Fig 5, cf. 3).

The influences of vehicle exterior images on luxury and loudness ratings of German drivers and on sporty ratings by both nationalities were different, as indicated by the gray boxes in Table 1. The participants rated the sounds less loud and more luxury with the luxury-vehicle images and more sporty with the sporty-vehicle images. These tendencies reflect the impression when just looking at the vehicle images (matching effect). The participants seem to have rated higher sportiness (luxury) by integrating the impression of a sporty (luxury) vehicle elicited by the sporty (luxury) vehicle image in the sound rating, as shown by Fig. 6.

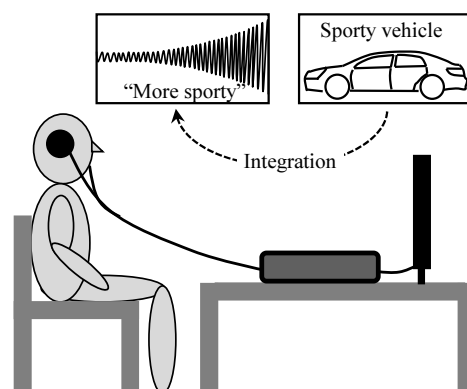


Figure 6 – Influence of sporty vehicle image on sporty ratings of sound.  
Explanation attempt for the primary process occurring for German drivers.

The German drivers rated all sound quality parameters integrating the impression of the vehicle image (matching effect), while different rating strategies occurred for different parameters for Japanese drivers. This indicates that the influence of the visual image on sound quality ratings was stable in the German drivers but unstable in the Japanese drivers.

In addition, sporty rating differences between the sounds presented with luxury and sporty vehicle images were much larger than those of luxury and loudness ratings. This result may indicate that luxury and loudness are mainly rated based on the sound itself, and are consequently less affected by the visual images. The sportiness ratings of the sounds however, are affected more and similar in both countries by the visual image. Therefore, it seems important to take into account the influence of the vehicle exterior design on the sportiness rating of vehicle sounds for the development of vehicles intended to sound sporty.

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