

Quality of Door Sounds of Passenger Cars

Sonoko Kuwano¹, Hugo Fastl², Seiichiro Namba³, Seishi Nakamura⁴, Hiroshi Uchida⁴

1 Osaka University, kuwano@env.eng.osaka-u.ac.jp

2 Technical University of Munich, fastl@mmk.ei.tum.de

3 Osaka University, nanba@hus.osaka-u.ac.jp

4 Mazda Motor Co. Ltd., uchida.h@lab.mazda.co.jp, nakamura.se@dev.mazda.co.jp

Abstract

It is reported that the sound of a car door closing is one of the main factors to determine the overall impression of the car. Much effort has been made to improve the quality of this sound. In this study, sounds of the closing of the doors of various passenger cars were recorded and presented via headphones in a sound-proof room. Based on these sounds, German and Japanese groups of participants formed mental images of the cars involved. They were also asked to evaluate the quality of the sounds. Generally speaking, though there were some differences, similar results were obtained with both groups of participants. It was found that the impressions of the sound quality varied considerably and that there was a correlation between the impression of the sound and the mental image of the car. It was suggested that the image of a car is related to the sound of the car.

1. Introduction

The image of a car will be determined by various factors. The sounds of the closing a car door may be one of the determining factors. Much effort has been made to improve the quality of this sound. In this study, the relation between the subjective impression of this sound and the mental image of the car was examined in an

experiment using Japanese participants and the results were compared with the results from German participants [1].

2. Experiment

2.1 Stimuli

Eleven kinds of sound of the closing of passenger car doors were used as stimuli. They were recorded on a DAT tape using a dummy head at a point 85 cm from the door.

2.2 Apparatus

The sounds were reproduced with a DAT recorder and presented to the participants' ears through an amplifier, a free field equalizer and headphones (Beyer DT48) in a sound-proof room. Similar equipment was used in the experiments in Germany and Japan.

2.3 Procedure

The experiment consisted of three parts. In Part 1 the subjective impression of the sounds was evaluated using semantic differential. The sound was presented three times with 1 sec intervals and participants were instructed to evaluate the impression of the sound using semantic differential. Fifteen pairs of adjective scales were selected on the basis of our former studies [2,3].

They are 7-point scales and are listed in Table 1. The adjective scales were presented one after the other on a monitor of a computer in random order. Subjects evaluated the impression and responded using a computer keyboard. They were informed that the sounds were from the closing of car doors. The experiment was conducted after training using two sounds which were not used in the experiment. In Part 2, after listening to the sound again, participants selected the appropriate image of the car. They were given a list of types of car. There were five categories: luxurious sedan, expensive sporty car, economic sedan, pick-up truck and another category of their own description. The participants were also asked to guess the name of the model of the car from the sound. In Part 3 the same sound was presented again and the impression was evaluated using semantic differential, as in Part 1. The three parts were conducted successively.

2.4 Participants

Three females and seventeen males with normal hearing ability, aged between 20 and 40, participated in the experiment. All the participants were Japanese and all of them had experience of driving cars. All the participants except for two had their own cars or drove a family car.

3. Results

The results from the Japanese participants are compared with those from the German participants. High coefficients of correlation between the results of Part 1 and Part 3 were found with the German group ($r=.941$) and the Japanese group ($r=.922$). This suggests that the formation of mental image in Part 2 has no effect on the evaluation of the sounds and that the evaluation of the participants is reliable. The results of Part 1 and Part 3 are combined in the following analyses.

3.1 Cluster analysis of the sounds

The results of the cluster analysis of the sounds are shown in Figs.1 and 2. The sounds were divided into

three clusters for both groups of participants. Cluster 1 consists of Nos.8 and 9 for the German group and Nos.8, 9 and 11 for the Japanese group. Cluster 2 consists of Nos.2, 3, 4, 5 and 6 for the German group and Nos.2, 3, 5 and 6 for the Japanese group. Cluster 3 consists of Nos. 1, 7, 10 and 11 for the German group and Nos.1, 4, 7 and 10 for the Japanese group. Similar results were found with German and Japanese groups of participants, except for sounds Nos.4 and 11.

3.2 Factor analysis of the adjective scales

The results of the factor analysis of the adjective scales are shown in Tables 1 and 2. Three factors were extracted, as was usually found in our former studies [2,3], in both groups of participants though there is some difference. The three factors can be interpreted as “pleasant factor”, “metallic factor” and “powerful/hard factor”.

3.3 Mental image from the sounds

The image of the car was estimated using the sounds in Part 2. The results are shown in Figs.3 and 4.

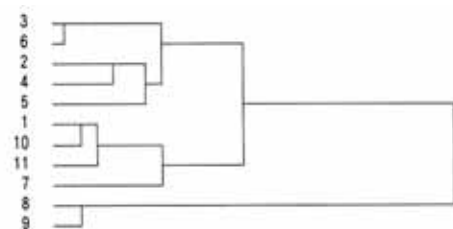


Fig.1 Cluster analysis of German results

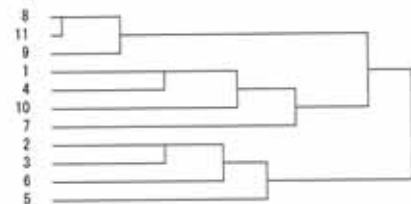


Fig.2 Cluster analysis of Japanese results

Table 1 Result of factor analysis (German)

metallic - deep	.774	-.342	.201
heavy - light	-.803	.239	.301
dark - bright	-.869	.192	-.057
sharp - dull	.740	.091	.404
weak - powerful	.707	-.413	-.348
shrill - calm	.667	-.385	.378
pleasant - unpleasant	-.207	.842	-.241
beautiful - ugly	-.238	.838	-.178
pleasing - unpleasing	-.190	.840	-.210
pure - impure	-.182	.731	.079
noisy - quiet	.163	-.536	.531
loud - soft	-.278	-.163	.777
hard - soft	.187	-.041	.799
gruff - gentle	.137	-.493	.546
rough - smooth	.478	-.356	.502

Table 2 Result of factor analysis (Japanese)

pleasant - unpleasant	-.828	.281	.123
beautiful - ugly	-.823	.231	.134
pleasing - unpleasing	-.825	.115	.058
rough - smooth	.792	.321	.038
noisy - quiet	.779	.222	.277
gruff - gentle	.727	.327	.178
hard - soft	.652	.453	.140
metallic - deep	.389	.652	-.387
dark - bright	.095	-.748	.373
sharp - dull	.134	.788	-.236
pure - impure	-.407	.750	-.078
shrill - calm	.485	.674	-.253
loud - soft	.242	-.208	.781
weak - powerful	.083	.297	-.801
heavy - light	-.058	-.625	.640

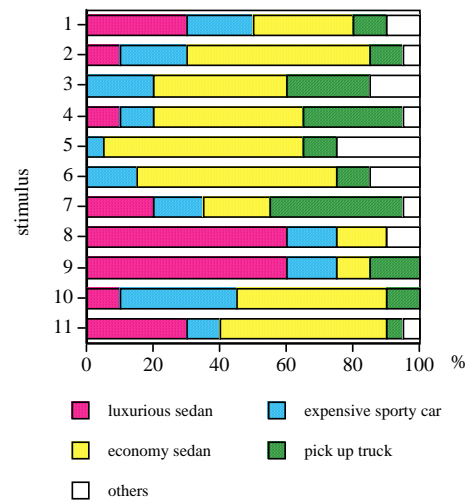


Fig.3 Result of Part 2 by German participants

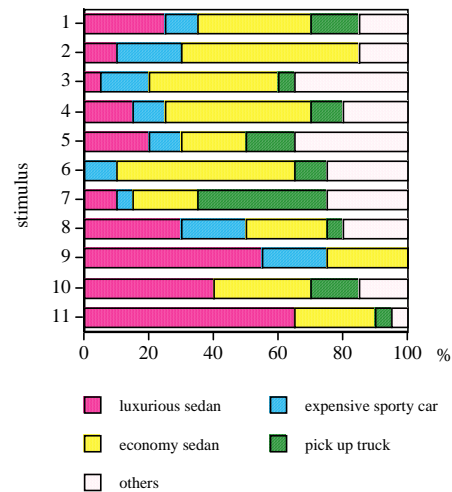


Fig.4 Result of Part 2 by Japanese participants

4. Discussion

Examples of the profiles of each cluster group are shown in Figs.5-7. Generally speaking, high correlation was found between the German and Japanese results. The profiles of sound No.9, shown in Fig.5, indicate that this sound was perceived as being deep, pleasant, gentle and heavy. This suggests that cluster 1 is a group of pleasant sounds. The images from the sounds which belong to cluster 1 were associated with luxurious sedan by high percentages. On the other hand, the profiles of

sound No.6, shown in Fig.6, indicate that this sound was perceived as being metallic, unpleasant, gruff and light. This suggests that cluster 2 is a group of unpleasant sounds. The images of the sounds which belong to cluster 2 were associated with economy sedan by high percentages. The profiles of sound No.7, shown in Fig.7, indicate that this sound was perceived as being unpleasant, gruff, powerful and rough. This sound seems to have conveyed different impression from the other sounds. The image associated with this sound was of a pick-up truck by high percentages in both groups of participants. The sounds which belong to cluster 3 seem to produce different images from the sounds of the other two clusters. Sound No.10 was estimated as the sound from an expensive sporty car by German participants.

5. Final remarks

The results from the German and Japanese groups of participants showed fairly good agreement, though a slight difference was found with some sounds. It was found that the quality of the sound of a car door closing was perceived differently in different cases. A pleasant impression of the sound seems to be related to the qualities, gentle, deep and heavy. It was suggested that the image of a car is related to the sound produced by the door of the car. Further analysis is planned taking temporal factors of the sounds into consideration.

6. References

1. S. Kuwano, H. Fastl, S. Namba, S. Nakamura and H. Uchida, "Subjective evaluation of car door sound", Proceedings of SQS2002 CD-ROM(2002)
2. S. Namba, et. al., Loudness and timbre of broad-band noise mixed with frequency modulated sounds, *J. Acoust Soc Jpn. (E)*, **13**, 229-232, 1992.
3. S. Namba, et. al., The measurement of temporal stream of hearing by continuous judgments - in the

case of the evaluation of helicopter noise. *J. Acoust. Soc. Jpn. (E)*, **14**, 341-352, 1993.

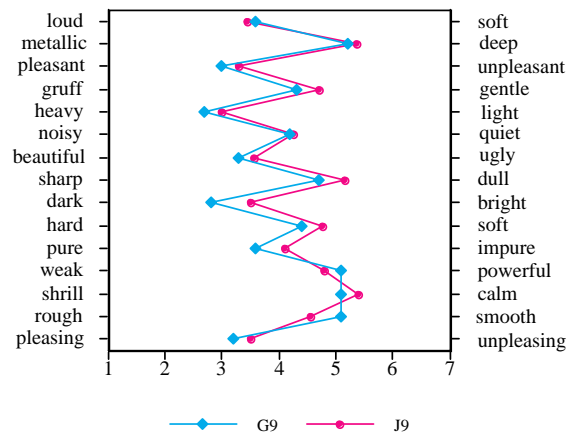


Fig.5

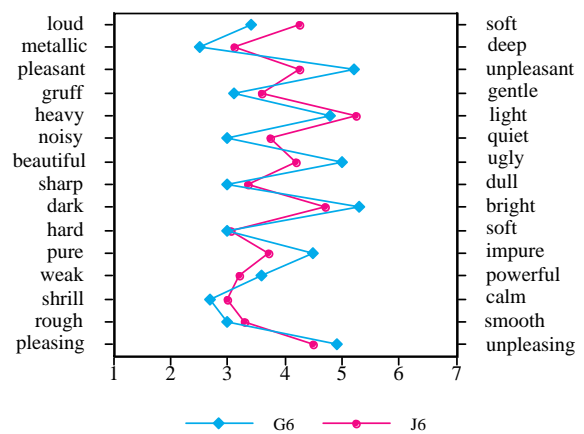


Fig.6

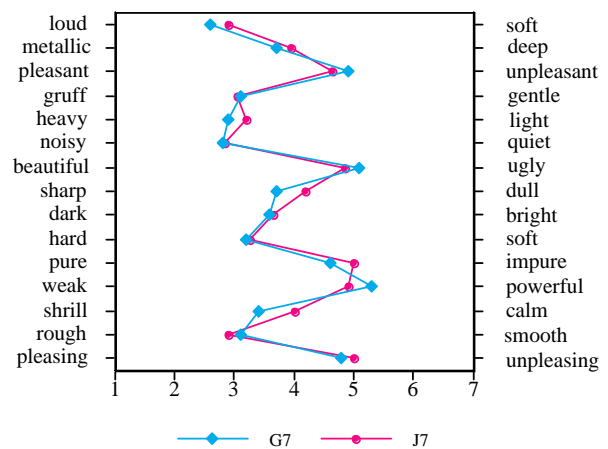


Fig.7