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SUBJECTIVE EVALUATION OF CAR DOOR SOUND

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INTRODUCTION

Sounds when the door of a car is closed tell us whether the door is properly closed. At the same time, the sound is one of the main factors to determine the impression of the car and much effort has been made to improve the sound quality. In this study, the images of cars were estimated from the sounds and the relation between estimated images and subjective impression of the sounds was examined.

EXPERIMENT

Stimuli. Eleven kinds of sound when the door of a car was closed were recorded using a dummy head at a point of 85 cm from the door. All the cars used were passenger cars.

Apparatus. The sounds were reproduced with a DAT recorder and presented to the subjects' ears through an amplifier, an attenuator, a free field equalizer and headphones in a sound proof room.

Procedure. The experiment consisted of three parts. In part 1, the sound was presented three times with 1 sec interval. Subjects were instructed to judge the impression of the sound using semantic differential. They were informed that the sounds were from the doors of cars. Fifteen pairs of adjective scales were selected on the basis of our former studies [1.2]. They are listed in Table 1. The adjective scale was presented one after the other on a screen of a computer in random order. Subjects judged the impression and responded using a computer keyboard. The experiment was conducted after training with two sounds which were not used in the experiment. In part 2, the image of the car was estimated after listening to the sound again. A list of types of cars was prepared. There were five categories; luxurious sedan, expensive sporty car, economic sedan, pick up truck and others. The subjects were also asked to guess the name of a car from the sound. In part 3 the same sound was presented again and the impression was judged using semantic differential as in part 1. The three parts were conducted in this order with each sound for each subject.

Subjects. Three females and seventeen males with normal hearing ability, aged between 26 and 57, participated in the experiment. All the subjects were German. Two subjects did not have cars and all the other subjects had cars.

RESULTS AND DISCUSSION

The coefficient of correlation was calculated between the adjective scale values in parts 1 and 3. High correlation was found in all the stimuli (r=.825 - .994). The effect of the estimation of the images of cars was not found, but high correlation suggests that the judgments by subjects are reliable.

The result of factor analysis is shown in Table 1. Three factors were extracted as usually found in our former studies. Factor 1 showed high loadings with the adjective scales, "metallic – deep", "heavy – light", etc and can be interpreted as "metallic" factor. Factor 2 showed high loadings with the adjective scales, "pleasant – unpleasant", "beautiful – ugly" and can be interpreted as "pleasant" factor. Factor 3 showed high loadings with the adjective scales, "loud – soft", "hard – soft", etc. and can be interpreted as "powerful" factor. The result of cluster analysis with stimuli is shown in Fig.1. The stimuli were classified into four groups. The profiles of typical groups are shown in Fig.2. It was found that the stimuli 8 and 9 were perceived as being pleasant, heavy, powerful, etc. The sound quality of these sounds seems to be appropriate as a door sound of a car. On the other hand, the stimuli 3 and 6 were found to have negative connotation, such as unpleasant and metallic. These sounds seem inappropriate as a door sound.

Table 1 Result of factor analysis

	Factor 1 "Metallic"	**Factor 2 "Pleasant"**	**Factor 3 "Powerful"**
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

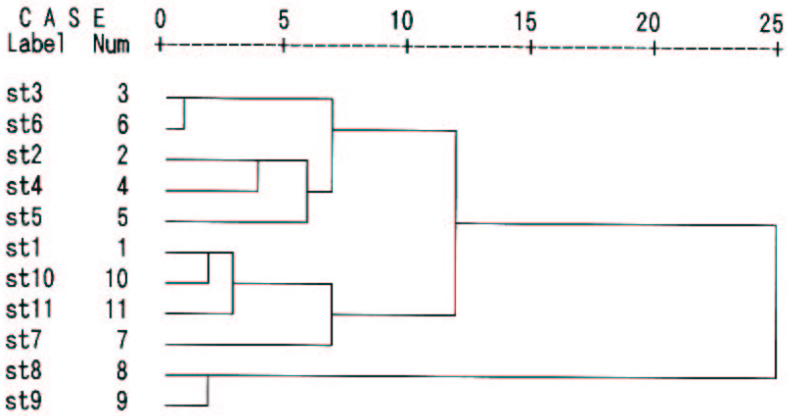

Figure 1: Cluster analysis of the stimuli

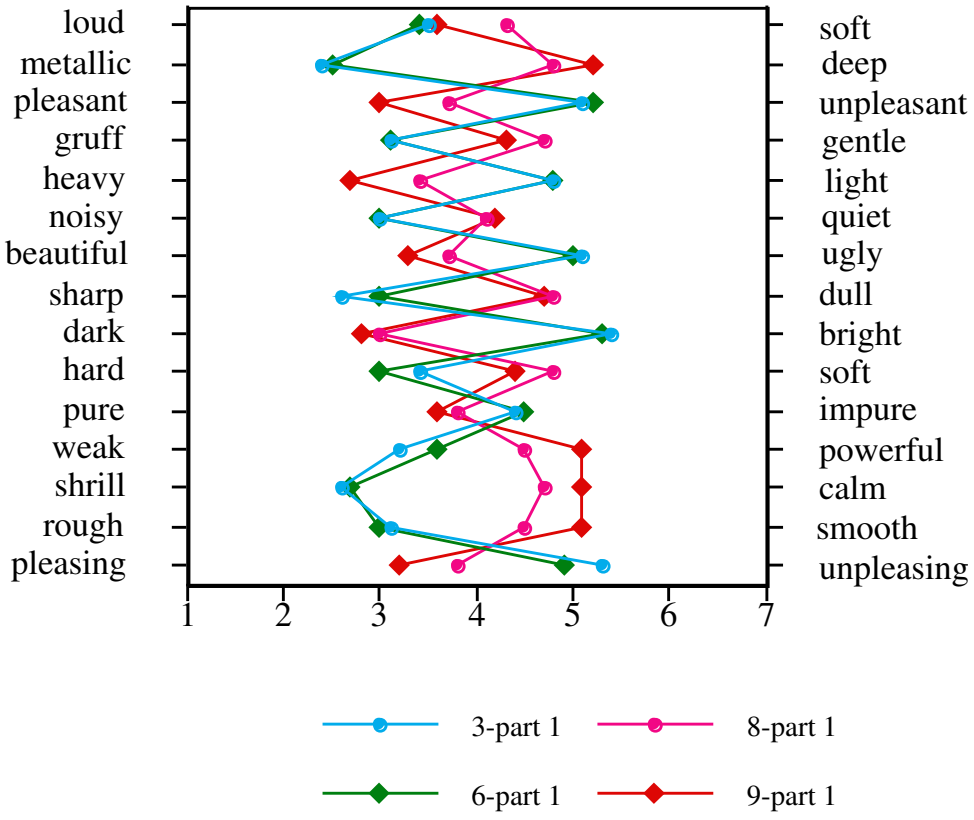

Figure 2: The profiles of typical groups of stimuli.

The result of the estimation of the images is shown in Fig.3. It was found that the stimuli 8 and 9 which were perceived as being pleasant were estimated as the sounds from luxurious sedan in high percentages. On the other hand, no body estimated the stimuli 3 or 6 were from luxurious cars. Instead, these sounds were estimated as the sounds from economy cars. It is

also noticed that the percentages are relatively high that stimulus 7 were estimated as the sounds from pick up trucks and stimulus 10 those from expensive sporty car.

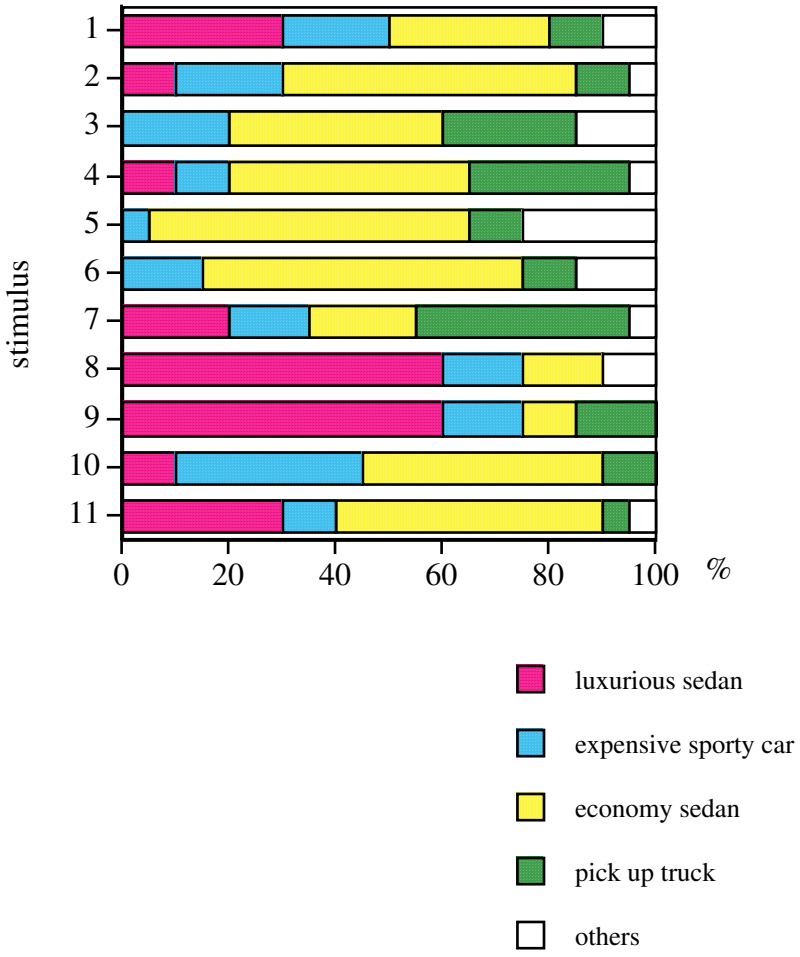

Figure 3: The estimates of the image of the car.

The physical properties of the sounds were examined in relation to the subjective impression.. High correlation was found between powerful score and loudness level as shown in Fig.4. Usually sound exposure level shows good correlation with the loudness of impulsive sounds [3]. When loudness level based on ISO 532B [4] is applied to impulsive sounds, the total energy of one-third octave band can be used as the representative value of temporal variation [5]. The loudness level (*LL*p) shown in Fig.4 was calculated by integrating loudness level of every 2 ms on energy basis. The impression of sharpness showed some correlation with maximum value of calculated sharpness (r=.554) [6,7]. It was found that the impression of pleasantness showed relatively high correlation with *LL*max of one-third octave band centered at 500 Hz as shown in Fig.5 as well as *LL*p.

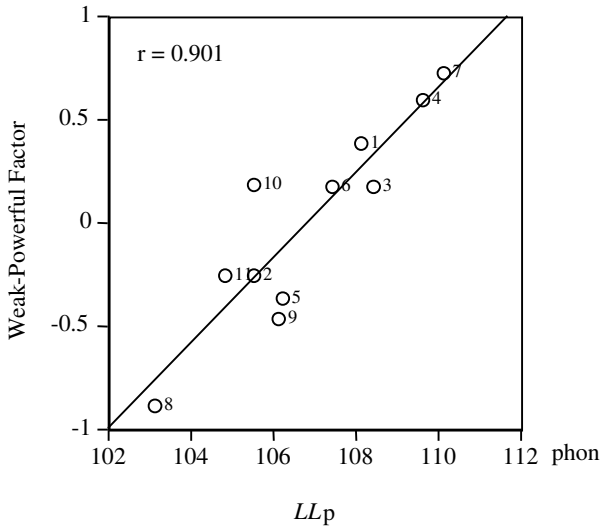

Figure 4: Relationship between Weak-Powerful Factor and loudness level.

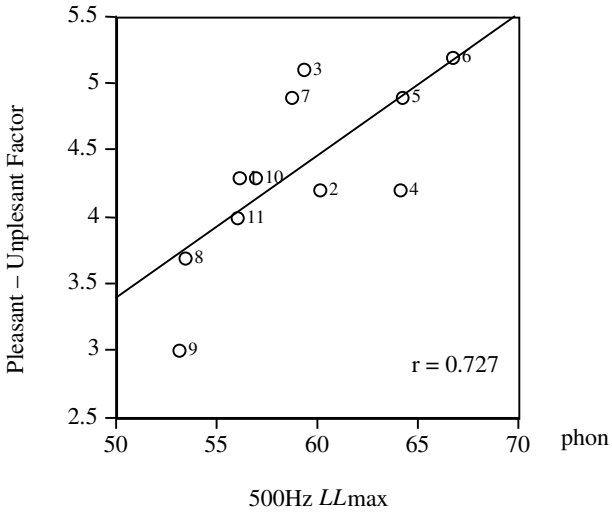

Figure 5: Relationship between the Pleasantness-Unpleasantness Factor and maximum loudness in the 500 Hz one-third octave band.

FINAL REMARKS

It was found that the sound quality of sounds when a door of a car was closed was perceived differently from each other. It was suggested that the image of a car is related to the sound of the car. Further investigation is being planned with Japanese subjects taking the temporal factors into consideration.

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