

# Effect of Multimodal Input to the Perception of Car Interior Noise

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## ABSTRACT

In order to see the effect of various inputs other than sound to the perception of car interior noise, subjective experiments were conducted. The input signals other than sound were seat-floor vibration, visual scenery with its variations of brightness. Seat-floor vibration levels were varied in three steps including original and the other parameters such as interior noise level and brightness of the moving scenery were the same as the vibration input, that is to say, each parameters were varied their input signals in three steps including the original condition. After finishing the subjective experiments inside the sound proof room, trade off level of the parameters added together with the sound input was obtained to see the effect on evaluation.

**Keywords:** Car Interior Noise, Multimodal Input, Sound Quality, Trade off Level **I-INCE Classification of Subject Number:** 63

## **1. INTRODUCTION**

Our previous study on this subject dealt with the similar experiment compared with this time on the variation of sound quality of car interior noise under the simultaneous exposure of multimodal input such as car interior noise, seat-floor vibrations and moving sceanary from the front wind screen. For that experiment, variations of the stimuli were noise and vibration levels and each of them were varied in three steps, namely, original level and  $\pm 3dB$  conditions while the brightness of the moving sceanary was fixed at one condition, namely, the original brightness recorded at the collection of expterimental stumuli[1]. As a result, the effect of simultaneous exposure of seat-floor vibrations together with the interior noie strengthen the subjective impression on sound. That is to say, powerfulness and booming sensation increased and pleasantness of the sound decreased compared with the sound alone condition. The effect of moving scenery presented on the screen in flont of the jury weakend the

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sensation of sound provided that the brightness of the sound was fixed at the original condition at the recording.

This time, we have varied the brightnes of the moving sceanary in three conditions, namely, original, brighter than the original and darker than the original as well as the noise and vibrarion levels to see the effect of the brightness to the perception of sound quality. This condition is practical when someone drives a car under different time segment during a day. Namely, in a day time, you can expect the atomosphere will be under sun shine and surounded by daylight and during night time, you could expect the atmosphere will be dark. And under these different conditions of brightness, our perception on sound will be different provided that sound itself is remained the same.

As a result, we could find significant difference of subjective impression of car interior noise with the variation of the brightness of the moving sceanary.

## 2. EXPERIMENT

Experiments were conducted by presenting recorded car interior noise through a headphone with the aid of woofer for help strengthen the low frequency contents of sound to make the sound atmosphere more realistic. Seat/floor vibrations were reproduced using the two vibrators set under the seat and transducers fixed behind the seat-back, under the bottom seat and the under the floor panel. Vibrations were also reproduced by fixing the transducers at the column potion of steering wheel system. The moving scenery through the wind screen was projected on the screen set in front of the jury through a liquid crystal display. The instantaneous judgment on sound quality in 7 categories was put into the PC through a ten key box fixed center part of the steering wheel. The schematic representation of the experimental apparatus is shown in Fig.1. The subjects participated in the experiments were 17 mail aged between 21 and 57 with normal hearing.



Fig.1 Experimental setup

#### 2.1 Recording of Experimental Stimuli

Experimental stimuli such as interior noise, seat-floor vibrations and moving scenery from the front wind screen were recorded under real driving on the test field. The drive mode of the vehicle was shown in Fig.2.



Fig.2 Vehicle driving mode for recording of experimental stimuli

## **3. EVALUATION OF PLEASANTNESS**

For the test to see the effect of the brightness of moving scenery to the perception of pleasantness, the following experimental conditions were provided to the juries participated. For describing the original sound level and original seat-floor vibration condition at the recording, the expression 0dB was introduced here. Namely in case of interior noise, 0dB condition means the sound level is the original sound pressure level. This expression is also true for seat-floor vibration as well. Namely, 0dB expression in case of seat-floor vibration means the vibration level is original vibration level.

For sound alone condition: -1dB up to +3dB with 0.5dB fine increment step, namely 9 conditions.

For original interior noise plus moving scenery and seat-floor vibrations condition, the brightness of the moving scenery was varied in three steps. Namely high brightness is set as 151.9 cd/m<sup>2</sup>, and the original brightness(middle brightness) is set as 97.7 cd/m<sup>2</sup> and low brightness is set as 43.5 cd/m<sup>2</sup>. Seat-floor vibration level is also varied in three steps, namely 0dB,  $\pm 3$  dB compared with the original vibration level. For this condition  $3 \times 3 = 9$  conditions. So, total of 18 conditions were applied to the test juries for evaluation of pleasantness to see the effect of the variation of brightness as well as the effect of seat-floor vibration.

## 3.1 Result of Evaluation on Pleasantness

The results obtained in case when we apply low seat-floor vibration level, i.e. - 3dB compared with the original vibration was applied and while the brightness of the

moving scenery was varied in three steps to the test juries were shown in the following figures.



Fig.3 effect of high brightness for pleasantness (seat-floor vibration -3dB)



Fig.4 effect of original brightness for pleasantness (seat-floor vibration -3dB)



Fig.5 effect of low brightness for pleasantness (seat-floor vibration -3dB)

The effect of brightness to the evaluation of pleasantness is as follows. In case of seatfloor vibration condition fixed at -3dB, then for the high brightness, it amount to the reduction of interior noise level in 1dB in case of sound alone condition, for middle brightness, the amount is 0dB, namely there is no effect and for low brightness the effect is the increase of 0.5dB compared with the original sound alone condition. According to the results obtained the decrease of brightness decreases pleasantness.

The total effect for the pleasantness when we vary the brightness of the moving scenery while varying seat-floor vibration levels the result is summarized in the Fig.6.



Fig.6 Trade-off level in SPL(dB) for pleasantness of the sound under variations of seat-floor vibration and brightness of the moving scenery

As a result, the effect of seat-floor vibration is the same as we have obtained before, namely, if the vibration level increases the sound is more unpleasant so the trade-off level increase with the increase of vibration level due to the fact that the existence of seat-floor vibration is equivalent for the level increase and it relates to louder sound and the sound is unpleasant. In case of brightness of the moving scenery, the effect is significant in case of high brightness condition. Under the same seat-floor vibration level, the interior noise becomes more pleasant when the brightness of the moving scenery increases than with the case for the decrease of the brightness.

#### 4. EVALUATION OF POWERFULNESS

In case of evaluation of powerfulness of the interior noise, similar experiment was conducted as for the pleasantness of the sound shown in the previous result. The stimulus condition for powerfulness is the same as for pleasantness. So, one jury evaluated 18 different experiments for the evaluation of powerfulness while the interior noise level, seat-vibration level and brightness of the moving scenery are varied.

#### 4.1 Result of Evaluation on powerfulness

The results obtained under the original seat-floor vibration while the brightness of the moving scenery varied were shown in the following figures.



Fig.7 effect of high brightness for powerfulness (seat-floor vibration 0dB)



Fig.8 effect of original brightness for powerfulness (seat-floor vibration 0dB)



Fig.9 effect of low brightness for powerfulness (seat-floor vibration 0dB)

The effect of the variation of brightness of the moving scenery to the perception of powerfulness of the interior noise is similar to the perception of pleasantness. Namely, in case of original brightness, as the brightness increases the perception of powerfulness decreased, namely the impression is equivalent to the reduction of sound pressure level.

The total effect for the pleasantness when we vary the brightness of the moving scenery together with the variation of seat-floor vibration level, the result is summarized in the Fig.10.



Fig.10 Trade-off level in SPL(dB) for powerfulness of the sound under variation of seat-floor vibration and brightness of the moving scenery

The effect of the variation of brightness of the moving scenery for the powerfulness is similar to the perception of pleasantness but the tendency is similarly strong for the high and original(middle) brightness under the same seat-floor vibration level. The amount is equivalent decrease of sound pressure level between 0.5dB $\sim$ 1dB. The effect is less for the low brightness condition.

#### 5. EVALUATION OF BOOMING SENSATION

As like the evaluations for pleasantness and powerfulness, we have conducted the experiment for the evaluation of booming sensation while varying the interior noise level, seat-floor vibration level and brightness of the moving scenery. The experimental condition for the variation of seat-floor vibration and brightness of the moving scenery is the same as the previous two experiments. But in case of sound alone condition, the condition is different from the former two. Namely, for sound alone condition, the sound presented to the juries starts from -1.5dB from the original and it is up to +2dB in 0.5 dB fine increase step. So the total of 8 conditions for sound alone condition. As a result, for this experiment, the jury conducts total of 17 experiments for the evaluation of booming sensation under the variation of experimental stimuli.

## 5.1 Result of Evaluation on Booming Sensation

The results obtained under the high seat-floor vibration condition were shown in the following figures.



Fig.11 Effect of high brightness for booming sensation (seat-floor vibration +3dB)



Fig.12 Effect of usual brightness for booming sensation (seat-floor vibration +3dB)



Fig.13 Effect of low brightness for booming sensation (seat-floor vibration +3dB)

The effect of brightness to the evaluation of booming sensation is similar to the previous two experiments for pleasantness and powerfulness. Namely, if the brightness increases the evaluation of booming sensation decreases.

The effect of brightness by varying brightness and seat-floor vibration levels simultaneously was summarized in the fig.14.



seat/floor vibration condition

Fig.14 Trade-off level in SPL(dB) for booming sensation of the sound under the variation of seat-floor vibration and brightness of the moving scenery

As like the result obtained for powerfulness, the effect of brightness affects more in cases of middle and high brightness compared with the low brightness and it amounts to equivalent decrease of 1dB SPL compared with low brightness condition.

#### 6. CONCLUSIONS

Through the jury test for the evaluations of pleasantness, powerfulness and booming sensation while the different seat-floor vibration and brightness of the moving scenery were applied, the following conclusions were obtained.

- 1. The effects of the seat-floor vibration to the perception of pleasantness, powerfulness and booming sensation are the same as our former experiment. Namely, for the increase of seat-floor vibration level, the evaluations become more unpleasant, more powerful and more booming.
- 2. In our previous experiment, only the moving scenery was presented to the juries for evaluation of interior noise. And the result eased the sensation. In this experiment, we have varied the brightness of the moving scenery in three steps including the original brightness condition. And the variation of brightness related to the decrease of pleasantness, powerfulness and booming sensation when the brightness increases. It means that, during day time with sunshine, our perceptions are less compared with that during the night time.

## 6. REFERENCE

1. Takeo Hashimoto, "Trade off level of the visual scenery and seat/floor vibrations to the perception of sound quality of car interior noise", Inter-Noise paper, pp.1-6 Inter-Noise 2004