



# 1396: On the Estimation of Psychological Stress Caused by Road Noise in a Vehicle Cabin

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## [Highlights]

- The purpose is to achieve **human-adaptive sound design** in a vehicle cabin based on pulse waves and brain waves of passengers.
- The effect of **psychological stress on the passengers** due to road noise was investigated.
- The psychological stress to the passengers could be **clearly evaluated by their pulse waves and brain waves**.
- Decreases in the sudden change in road noise around **120 Hz reduced their psychological stress** more than decreases around 40 Hz.

## [Introduction]

- The **model-based development technology** of automobiles has greatly evolved.
- However, guidelines for noise and vibration design **have not yet been established** due to its difficulty.
- From these backgrounds, we examined **a method for quantitatively evaluating the discomfort** of individuals to generated noise.

## [Experimental]

- **Targeted noise :** Road noise in a vehicle cabin  
 → One of the major noises inside electric and automatic cars

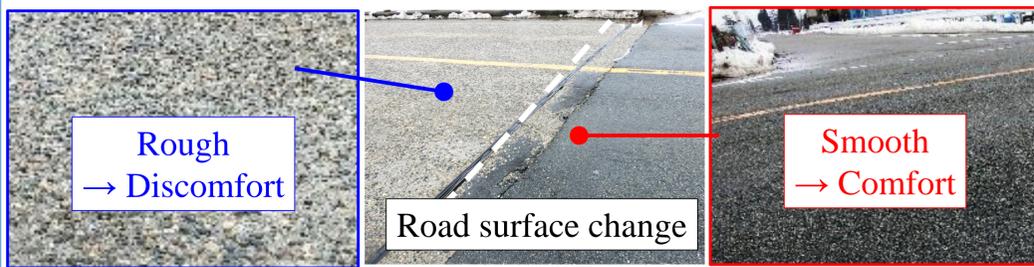


Fig. 1 Photographs of the point where road surface is suddenly changed.

- **Road noise measurement :** Directly measured in a cabin



Fig. 2 Photographs of test vehicle.

- **Measured road noise :**

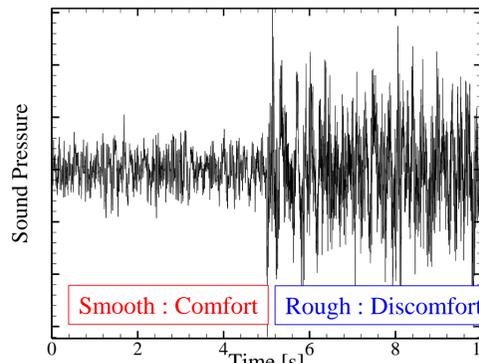


Fig. 3 Time series of road noise.

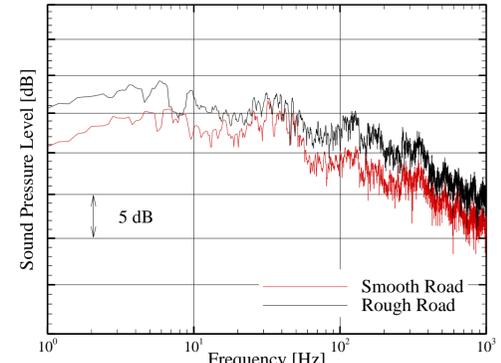


Fig. 4 Frequency characteristics of road noise.

- **Equations : Pulse waves**

$$HF = 1 - \left( \frac{HF_{rough}}{HF_{smooth}} \right)$$

$$\frac{LF}{HF} = \frac{\left( \frac{LF}{HF} \right)_{rough}}{\left( \frac{LF}{HF} \right)_{smooth}} - 1$$

- **Equations : Brain waves**

$$\alpha = \left( \frac{\alpha_{rough}}{\alpha_{smooth}} \right)$$

$$\beta = 1 - \left( \frac{\beta_{rough}}{\beta_{smooth}} \right)$$

## [Results]

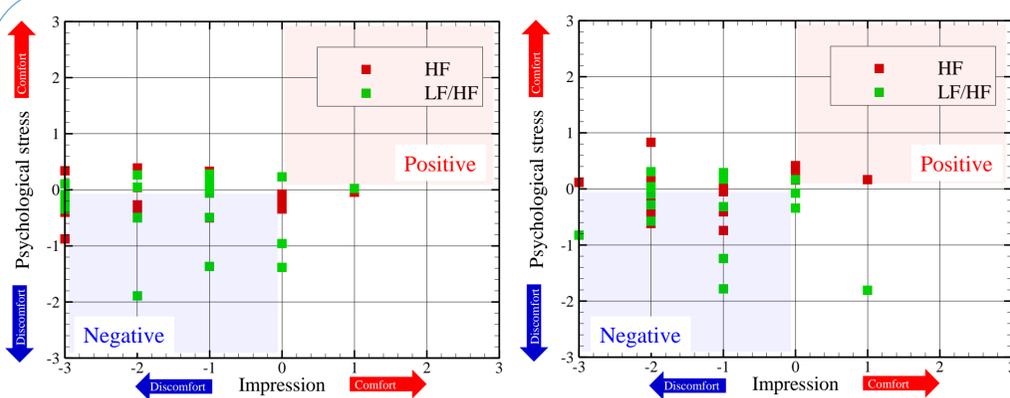


Fig. 5 Psychological stress measured by pulse waves and impression evaluations in auditory tests for the road noise of the rough road (Left) and the sudden change at the road joint (Right).

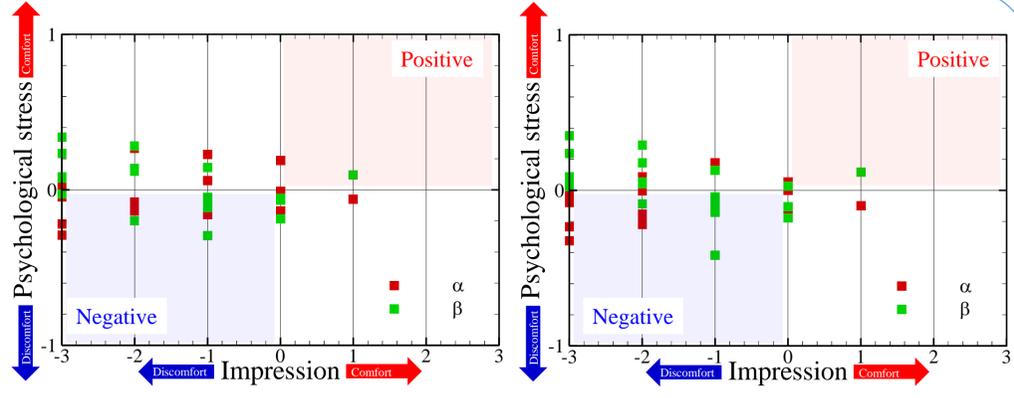


Fig. 6 Psychological stress as measured by brain waves and impression evaluations in auditory tests for the road noise of the rough road (Left) and sudden change at the road joint (Right).

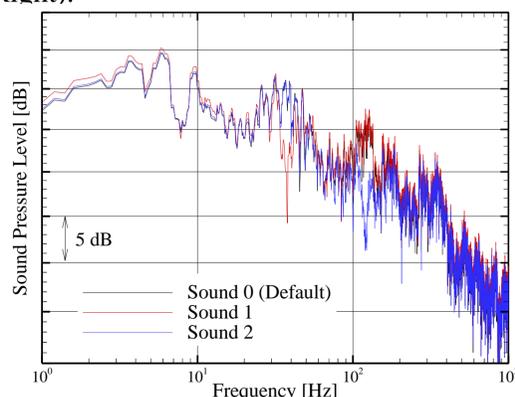


Fig. 7 Frequency characteristics of controlled road noise on the rough road.

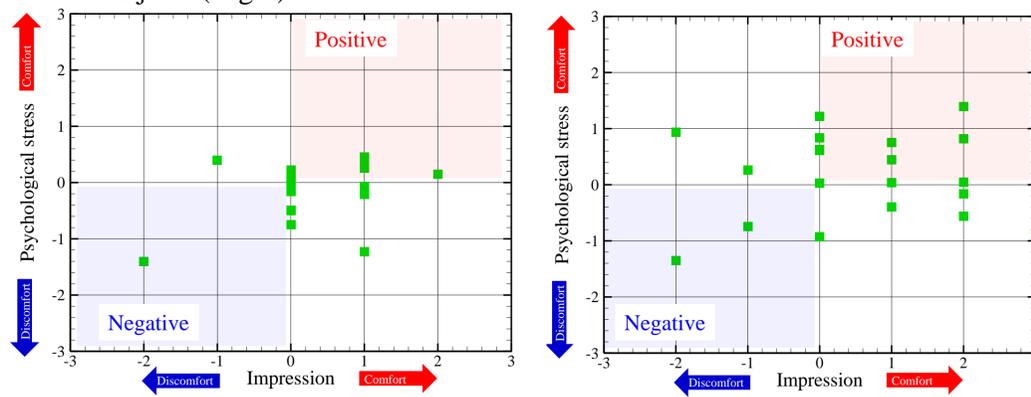


Fig. 8 Psychological stress measured by the LF / HF component for Sound 1 (Left) and Sound 2 (Right) at the road joint.

## [Conclusions]

- (1) The degree of psychological stress caused by the road noise could be evaluated using the **LF / HF component** of the pulse wave.
- (2) Subjects were psychologically stressed due to sudden changes in road noise from the **road surface change** at the road joint
- (3) The psychological stress in (2) could be mitigated by controlling and reducing the road noise **around 120 Hz**.