

Emotional Evaluation of a Cross-Modally Aware Forward-View Video Driving Support System

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With the rise of connected cars and the advancement of driver assistance systems, the information provided to drivers through in-vehicle information system HMIs is increasing and becoming more complex. However, an excess of information can increase cognitive load and potentially lead to confusion and distraction. Therefore, it is necessary to explore new guidance methods that allow for intuitive interaction with this diversifying information. Consequently, this study focuses on cross-modal effects—the interaction between visual, auditory, and tactile sensations—and conducts an SD method experiment using adjective pairs selected for affective evaluation to verify the effectiveness of cross-modal effects in automotive guidance. In this experiment, the visual stimulus was fixed to a left-turn guidance scenario, and 16 guidance conditions were established by varying combinations of sound and vibration. Details of each guidance condition are shown in Table 1. Regarding the vibration types listed in Table 1, vibrations where a specific body part vibrates for a fixed duration are defined as “Normal”; vibrations where the vibrating body part repeatedly moves in a fixed direction are defined as “Wave”; and vibrations consisting of several short, repeated pulses are defined as “Knock”. To conduct an accurate survey on sound and vibration in this experiment, the playback order of the 16 guidance conditions was divided into four patterns, taking order effects into account. To grasp the overall trend, we extracted the results for the top four and bottom four conditions based on the average of the overall ratings. The results showed that, in specific situations, higher ratings were associated with lower scores on vibration stimulus items such as “Strong Vibrations”, “Wide Vibration Range”, “Long Vibration Duration”, “High-frequency Vibrations”, and “Vibration Location Moves”. Regarding the vibration location, higher ratings were associated with higher scores for “Vibration in The Upper Body (Back)”, while lower ratings were associated with higher scores for “Vibration in The Lower Body (Seat)”. These results suggest a tendency for higher ratings when the vibration stimulus is weak and localized to the upper body, and lower ratings when the vibration stimulus is strong and localized to the lower body. For psychological items, conditions with higher scores across all items received higher ratings, indicating that psychological stability and comfort strongly influence the overall evaluation. Furthermore, focusing on the sensory comprehension items, it is evident that in conditions receiving high ratings, the scores for “Easy to Find Way Around” and “Helps Focus on Driving” were high. On the other hand, items that received particularly high scores under the low-evaluation conditions included “Easy to Notice”, “Feels Unnatural”, “Feels Dangerous”, “Annoying”, “Ticklish”, and “Clear Notification”. These results suggest that, as a general trend, weaker stimuli are preferred for left-turn guidance with a low notification level, and notifications that cause less discomfort or unease are preferred over those that simply improve noticeability.

Table 1 Sound Sources and Vibrations Used in the Experiment

Condition Number	Types of Vibration	Overview of the Audio Source
Condition1	Left-Back Knock①	Button sound (ping)
Condition2	Back Waves①	Button sound (deep resonance)
Condition3	Waist Vibration	Button sound (a crisp electronic tone)
Condition4	Vibration in the Left Thigh	Button sound (beep)
Condition5	Left Thigh Tap	Button sound (deep resonance)
Condition6	Wavy Seat①	Button sound (a crisp electronic tone)
Condition7	Overall Wave①	Show Description
Condition8	Overall Vibration①	Button sound (deep resonance)
Condition9	Overall Wave②	Electronic roulette spinning sound (beep-beep-beep-beep)
Condition10	Overall Vibration②	Button sound (beep)
Condition11	Right-Back Knock②	Electronic roulette spinning sound (beep-beep-beep-beep)
Condition12	Right-side vibration	Button sound (beep)
Condition13	Back Wave②	Warning sound (beep-beep-beep)
Condition14	Seat Vibration	Warning sounds (to heighten a sense of crisis)
Condition15	Left Thigh Tap	Button sound (beep)
Condition16	Wavy Seat②	Warning sound (beep-beep-beep)