

Structure of Model to Quantify Psychological Aspects of Tactile Feedback of Switches (Fourth Report)

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Automotive cockpit switches are required to provide tactile feedback appropriate to their intended functions. In previous studies, we identified that the perceived comfort of switch operation is primarily associated with two psychological factors, namely operational certainty and lightness, using the Evaluation Grid Method. However, the neural processes through which tactile sensations are related to higher-order subjective impressions have not been sufficiently investigated. Therefore, this study aimed to explore the neural representations associated with switch tactile experiences using functional magnetic resonance imaging (fMRI) and to investigate the feasibility of to investigate the effectiveness of a neuroscientific approach.

We assumed that tactile evaluations are formed through multiple neural processes, including sensory processing, emotional evaluation, value judgment, and decision making. To investigate the neural basis of switch operating feel, an fMRI study was conducted in collaboration with Tohoku University. Thirty-nine university students participated in the experiment, and data from thirty-four participants were included in the group-level analysis after exclusion of subjects with excessive head motion. Participants repeatedly operated ten push-button switches with different mechanical characteristics while blood-oxygen-level-dependent (BOLD) signals were measured. Following the fMRI session, subjective evaluations were collected using a seven-point semantic differential questionnaire consisting of twenty-one adjective pairs.

Exploratory factor analysis of the subjective evaluation data identified three sensory dimensions associated with switch tactile perception: Operational Load (F1), Tactile Texture Quality (F2), and Operational Certainty (F3). F1 was characterized by impressions related to physical effort and difficulty, F2 by affective impressions of tactile quality, and F3 by impressions of confidence and clarity during operation.

Parametric modulation analysis revealed distinct patterns of brain activity associated with these sensory dimensions. Higher F1 scores were positively associated with activity in the basal ganglia and insular cortex, regions potentially related to motor effort and internal bodily perception. Variations in F2 scores were associated with activity in the precuneus and thalamus. In addition, higher F3 scores were positively associated with activity in the prefrontal cortex and thalamus, suggesting a relationship between clear click feedback and neural processes involved in executive control and sensory integration. Across all switch conditions, common activation was observed in the primary motor cortex (M1), primary somatosensory cortex (S1), and supplementary motor area (SMA), reflecting sensorimotor processing during switch operation.

The results suggest that different dimensions of switch tactile feedback are associated with distinct patterns of brain activity. In particular, operational load, tactile texture quality, and operational certainty were related to activity in different sensory, emotional, and value-related brain regions.

The present findings indicate that subjective impressions of switch tactile feedback are associated with distinct patterns of brain activity measurable using fMRI. Although further investigation is required, these results provide fundamental knowledge toward developing objective assessment frameworks for tactile quality based on neural indices. The present findings indicate that subjective impressions of switch tactile feedback are associated with distinct patterns of brain activity measurable using fMRI. These results support the usefulness of a neuroscientific approach for investigating tactile quality and provide fundamental knowledge for understanding the relationship between sensory dimensions and brain activity.