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# A Method for Estimating Changes in Drivers' Sense of Safety and Confidence During On-Road Driving Using Physiological Data from Wearable Devices

**Koki Yasuda [1)] Mayu Kurozumi [1)] Seishi Takagi [2)] Takuya Izumiguchi [2)] Kento Mera [2)] Miwa Nakanishi [3)]**

*1) Keio University, Graduate School of Science and Technology, School of Informatics, Management and Human Sciences*
*3-14-1 Hiyoshi, Kouhoku-ku, Yokohama, Kanagawa, 223-8522, Japan (E-mail: kk.y2003@keio.jp)*
*2) Penstone*
*1-2-15 Shinmachi, Yano, Aki, Hiroshima, Hiroshima, 736-0084, Japan*
*3) Keio University, Faculty of Science and Technology, Department of Industrial and Systems Engineering*
*3-14-1 Hiyoshi, Kouhoku-ku, Yokohama, Kanagawa, 223-8522, Japan*

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Recent developments in advanced driver-assistance systems emphasize the importance of not only ensuring physical safety but also addressing the psychological well-being of drivers. Providing a positive experience that fulfills drivers' sense of safety and confidence (DSSC) is essential for delivering high product value to vehicles. While previous studies have evaluated DSSC in controlled driving simulator environments, estimating it in noisy, real-world driving environments remains challenging. In this study, we investigate a method to estimate dynamic changes in DSSC during on-road driving using physiological data obtained from wearable devices.

To accomplish the aim of this study, we conducted a real-world driving experiment with 10 participants navigating an urban route. We collected continuous physiological data, external environmental data, and subjective ratings of DSSC. Participants were tasked to drive naturally while verbally reporting their DSSC for the preceding 30 seconds on a 5-point scale, which was recorded using a smartphone mounted in the vehicle. We synchronized and integrated these data streams to assess how physiological and environmental factors reflect changes in DSSC.

In this experiment, we used wearable sensors to capture various physiological and eye-movement indices, focusing on electrocardiogram (ECG), electrodermal activity (EDA), blood volume pulse (BVP), and gaze behavior (e.g., fixation dispersion and saccade velocity). Furthermore, external environmental data, such as the presence of forward vehicles, pedestrians, and intersections, were extracted from footage recorded by the eye tracker's scene camera. To estimate DSSC, we constructed a 4-class classification model using a Support Vector Machine (SVM). The model incorporated median imputation for missing values and the Synthetic Minority Over-sampling Technique (SMOTE) to handle class imbalance, utilizing original features without non-linear transformations.

Results showed that the SVM model achieved an accuracy of 42.7%, significantly outperforming the chance level of 25% for 4-class classification. Figure 1 shows the confusion matrix of the model. Fatal misclassifications to opposite classes were rare, and most errors occurred between adjacent classes. This implies that the model successfully learned the continuous gradient of DSSC intensity.

Furthermore, we identified the factors contributing to DSSC estimation by analyzing permutation feature importance. Both physiological/eye-movement metrics and external environmental factors contributed to the predictions, highlighting the necessity of integrating internal human responses with actual environmental contexts. However, detailed performance metrics revealed extremely low accuracy for Class 1 (the lowest DSSC score). This was primarily due to the overwhelmingly small number of ground-truth samples for Class 1, which prevented SMOTE from establishing a sufficient foundation for oversampling, as the unique feature space of this class was not adequately covered.

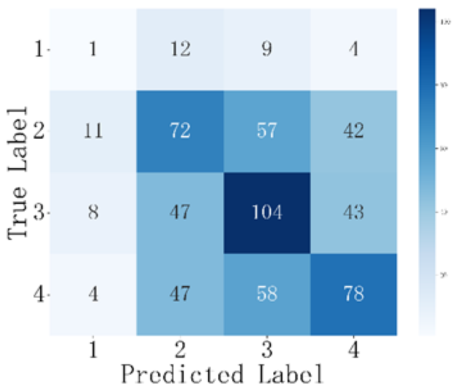


Fig.1 Confusion Matrix
for the Top-Performing Models

Overall, our findings suggest that, moving beyond a mere binary estimation of safety versus anxiety, a multi-level DSSC with high resolution on the positive safety spectrum can be practically estimated even in noisy real-world environments by integrating physiological and ocular measures with environmental context. This study provides guidelines for developing adaptive driver monitoring systems capable of detecting even subtle drops in DSSC in real-time and triggering appropriate interventions to enhance the driver's psychological state.