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Multinomial logistic regression model for predicting driver's drowsiness using behavioral measures

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Abstract

The aim of this study was to explore the effectiveness of behavioral evaluation measures for predicting drivers' subjective drowsiness. Behavioral measures included neck vending angle (horizontal and vertical), back pressure, foot pressure, COP (Center of Pressure) movement on sitting surface, and tracking error in driving simulator task. Drowsy states were predicted by means of the multinomial logistic regression model where physiological and behavioral measures and subjective evaluation of drowsiness corresponded to independent variables and a dependent variable, respectively. First, we compared the effectiveness of two methods (correlation coefficient-based method and odds ratio-based method) for determining the order of entering behavioral measures into the prediction model. It was found that the prediction accuracy did not differ between both methods. Second, the prediction accuracy was compared among the numbers of behavioral measures. The prediction accuracy did not differ among four, five, and six behavioral measures, and it was concluded that entering at least four behavioral measures into the prediction model is enough to achieve higher prediction accuracy. Third, the prediction accuracy was compared between the strongly drowsy and the weakly drowsy group. The prediction accuracy differed between the two groups, and the proposed method was effective (the prediction accuracy was significantly higher) especially under the condition where drowsiness was induced to a larger extent.

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1. Introduction

According to Japanese traffic accident statistics in 2012, the number of traffic accidents due to drowsy driving amounts to 6.8%. The number of fatal accidents increased to 16.6%, and this is the most crucial cause of fatal traffic accidents. Compared with other factors, drowsy driving is the most crucial risk factor of traffic accidents in particular fatal accidents.

From the viewpoint of automotive preventive safety, effective measures for monitoring drowsiness during driving, detecting a decrease of arousal level, and warning drivers of the risk of causing a traffic accident must be established so as to prevent drivers from driving under drowsy state and causing a disastrous traffic accident. In order to realize the development of such a system, not only the gross tendency of reduced arousal level but also the more accurate prediction of the state when the drowsiness occurs is indispensable. It is not until such accurate methods to predict the occurrence of risky and drowsy driving is established that we apply this prediction technique to the development of automotive preventive safety system which can support so that drivers can avoid unsafe and drowsy driving.

A few studies used psychophysiological measures such as blink, saccade, Electroencephalography (EEG) and Electrocardiography (ECG) and made an attempt to assess drowsiness or fatigue [1]-[3]. These studies showed that psychophysiological measures were to some extent correlated with subjective rating on drowsiness or fatigue especially at the end of the field or laboratory experiment. Kecklund and Waard [3] carried out a field study, and showed that end-of-drive subjective sleepiness and the EEG alpha burst activity were significantly correlated with total work hours. No measures alone can be used reliably to assess sleepiness or drowsiness. Moreover, these studies did not make an attempt to predict but the drowsy state using these psychphysiological measures.

Murata and Hiramatsu [4] and Murata and Nishijima [5] objectively evaluated the drowsiness of participants under simulated driving environment using EEG or HRV (Heat Rate Variability) measures. They succeeded in clarifying the decrease of *EEG-MPF* or the increase of *RRV3* when the participant's arousal level is low. However, it was also not possible for these studies to predict the drowsiness on the basis of the time series of *EEG-MPF* or *RRV3*.

Murata, Matsuda, Moriwaka, and Hayami [6] applied Bayesian theorem and proposed a method to evaluate the arousal level using EEG, heart rate variability, and tracking error during the simulated driving task. However, this study did not make an attempt to prediction the arousal level. Murata, Ohkubo, Moriwaka, and Hayami [7] and Murata, Koriyama, and Hayami [8] applied logistic regression model to mainly physiological measures such as EEG, ECG, or EOG in order to predict the arousal level (the subjective rating on drowsiness) , and attained a prediction accuracy of about 85%.

Such equipments to measure EEG or HRV are too expensive to put these systems into practical use in automotives. The drowsiness prediction system that should be used in automotive cockpit must be less expensive and more convenient. As a more convenient measure for predicting the arousal level, we paid attention to the vertical and horizontal neck bending angle and the change of COP (Center of Pressure) of the sitting surface. Murata, Koriyama, Ohkubo, Moriwaka, and Hayamai [9], Murata, Nakatsuka, and Moriwaka [10], and Murata, Urakami, Koriyama, Ikeda and Hayami [11] used a behavioral measures such as tracking error in simulated driving task, back and foot pressure, and COP during sitting pressure measurement, and demonstrated that behavioral measures are as effective as physiological measures such as *EEG-MPF* or *RRV3*.

As mentioned above, a larger part of studies on drowsiness evaluation or prediction pay attention to both physiological and behavioral measures. In order to prevent traffic accidents due to drowsy driving, a lot of attempts are made to detect the tendency of decreased arousal level using physiological measures such as ECG, EEG, or EOG, or performance measures such as a tracking error. Generally, it has been demonstrated that such physiological measures respond sensitively to the change of arousal level. Until now, there are no useful methods to predict drowsiness with high reliability. Methods using physiological measures are not practical due to expensive price of their measurement apparatus. From the practical viewpoint, only behavioral measures were used for the drowsiness prediction.

The aim of this study was to explore whether only behavioral measures can predict the drowsiness with high accuracy. The neck vending angle (horizontal and vertical), back pressure, foot pressure, COP (Center of Pressure) movement on sitting surface, and tracking error in driving simulator task were taken up as behavioral measures for