A closed-loop for driver mental state monitoring based on EEG signals

Shengguang Lei, Jinhao Zhang, & Matthias Roetting
Technische Universität Berlin
Berlin, Germany

Abstract

This paper documents an experimental study in which an electroencephalography (EEG) based closed-loop was integrated in the simulated driving environment for driver adaptive task allocation. The Lane Change Task (LCT) combined with a working memory load task, n-back task, was used in the present study. Task loads were adjusted in two dimensions, the driving task load (adjusted by driving speed) and working memory load (adjusted by n-back task). Two experiment modes, non-control (without EEG adaptive aiding) and control (with EEG adaptive aiding), were used in this study. In the control mode, EEG signals were collected to detect the driver's mental workload state in real-time and the driving speed was dynamically adjusted according to workload states. The comparison between the control mode and non-control model showed that the closed-loop could help to improve the driver's n-back performance and also reduce the driver's workload in the high task load condition. Therefore, this study integration of physiologically driven adaptive aiding in vehicle system is potentially beneficial for improving the vehicle safety.

Introduction

The increasing implementation of the in-vehicle technologies (IVTs), e.g. navigation system and cellular phone, poses a new challenge for driver to cope with multiple attention-demanding tasks which might not relate to primary driving task (Lenneman & Backs, 2009). In such situation, driver overload might occur, especially in a complex driving environment (i.e. high traffic density or poor weather) where the likelihood of driver error would increase. One concept addressing the shortcomings of the IVTs is to adaptively modulate the information flow from IVTs (e.g. change the availability) and reallocate the tasks between driver and vehicle according to the driver's functional states (e.g. workload), termed adaptive task allocation (Parasuraman, 1999). However, the basic issue for this concept is how to dynamically monitor driver's functional states.

In last decades, the assessment of operator's workload has been investigated using various methods including subjective measurement (e.g. NASA-TLX: NASA Task Load Index, Hart and Staveland 1988; Subjective Workload Assessment Technique, Reid & Nygren 1988), performance measurement (De Waard, 1996), and psychophysiological signals, such as, electroencephalography (EEG), electrocardio-

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