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Impact of Combined Cognitive and Visual Distraction Level on Driving Behavior in Different Traffic Environments

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Abstract
Following behavior is an indispensable part of vehicle driving, and the following behavior under visual and cognitive distraction has become one of the main causes of traffic accidents. The urban, rural, and expressway scenarios were constructed using the PanoSim platform, and experimental data were collected through a driving simulator to study the influence of combined cognitive and visual distraction on driving behavior. The results show that the steering wheel angle increased significantly with the increase of combined distraction, which leads to the weakened lateral stability. The compound distraction levels within the group (MID, MOD, SED) had a small impact on vehicle speed for urban or rural areas, yet a significant difference was obtained under residual light observation (RLO) and head turning observation (HTO) of expressway condition. Compared to RLO, the standard deviation of throttle opening in all three HTO conditions exhibited a marked improvement, which attributed to the dominated contribution from visual distraction rather than cognitive distraction. Moreover, the standard deviation of lateral position gradually increased with the increase of compound distraction levels in expressway scene. Therefore, it can be concluded that these results contribute a significant influence on development of distraction countermeasures and the design of in-vehicle systems.

Keywords Cognitive distraction · Driving simulator · Lateral stability · Secondary task · Traffic safety

1 Introduction

In recent years, various electronic systems in car, including navigation displays and information entertainment, have appeared in the cockpit with the rapid development of information and communication technology (Klauer et al., 2006; Lee & Regan, 2013). But the drivers sometimes divert more attention from operations outside of driving tasks, such as answering phone calls, providing information feedback, and other secondary driving tasks. Therefore, although the electronic system in car brings convenience, it can also cause drivers to become distracted, leading to traffic accidents. Driving distraction can be divided into visual distraction and cognitive distraction (Hanowski et al., 2005). Visual distraction refers to the gaze of driver leaving traffic environment of the road that should be focused on, and drivers in a state of cognitive distraction often occupied by a non-driving task. Both visual and cognitive distractions can bring an impact on driving safety. Therefore, many studies have been conducted to provide more effective strategies (Regan et al., 2008).

The research by Kountoriotis and Liang et al. shows that visual distraction causes drivers to experience longer time off the road, ultimately weakened vehicle retention in the lane and increased speed fluctuations (Kountouriotis et al., 2016; Liang & Lee, 2010). Chen et al. analyzed the relationship between vehicle speed and attention needs during the following process by simulation and actual testing (Chen & Milgram, 2013). They found that the higher the vehicle speed, the lower the degree of visual distraction, indicating a positive correlation between vehicle speed and attention needs within a certain range. By inducing visual distraction, Liu et al. quantified the remaining attention of drivers on the urban, rural, and highway roads, which indicated that urban roads exhibit higher driving attention due to the complex environment compared to highways (Liu et al., 2020). It can

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