論 文 の 内 容 の 要 旨

論文題目　Effect of In-Vehicle Traffic Signals on Driving Behaviors

（車内交通信号が運転行動に与える効果）

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Intersections are one of the most common components in modern transport systems, which can normally be classified as signalized and unsignalized intersections. How to improve traffic efficiency and driving safety at intersections is an essential issue to be solved. Traffic signals are considered to be one of the most important factors for maintaining traffic efficiency and safety at intersections. Emerging vehicular communication makes it easier to provide traffic signal information to drivers, and in-vehicle displays can be applied to provide these information inside vehicles. However, the effects of this method on driving behaviors are still unclear, and there is a concern that the application of in-vehicle traffic signals may result in driver distraction. This study, therefore, tried to investigate the influences of the proposed in-vehicle traffic signal system on driving behaviors, considering driver models and the penetration rate of the system at signalized and unsignalized intersections.

For the application of in-vehicle traffic signals in full deployment scenarios, the analysis of driving behaviors was mainly performed with driver models considering the influences of look ahead information. At signalized intersections, two modes of in-vehicle traffic signals were proposed to assist drivers: a “current” mode providing real-time information of the upcoming ground traffic lights, and a “predicted” mode offering look ahead information regarding ground traffic lights, taking into account the time to arrival at the upcoming intersection. Two kinds of in-vehicle displays were also compared for displaying these in-vehicle traffic signals: a normal 4.3-inch display and a head-up display. Driving simulator experiments were executed for eleven participants, and driving behaviors were evaluated for driving operations and eye-gaze behaviors. The results demonstrated that disruptive braking and accelerating operations were significantly reduced when look ahead information of traffic signals were provided and glance time was significant shorter for the head-up display than for the normal 4.3-inch display. It can be concluded that the predicted mode easily prompted drivers to better driving performances, and that the head-up display was reliable for providing in-vehicle traffic information.

For the application of in-vehicle traffic signals in full deployment scenarios at unsignalized intersections, two types of in-vehicle traffic signals were proposed to assist drivers, which were corresponded to two-way and all-way stop-controlled intersections. The gap acceptance theory and a first-come-first-served strategy were adopted to determine the passing priority for the two types of intersections, respectively. Driving simulator experiments involving twenty-three participants were conducted, to investigate the driving behaviors elicited by the proposed system. Four experimental conditions were prepared with a combination of in-vehicle traffic signals and auditory warnings. The results indicated that in-vehicle traffic signals were associated with significant longer post-encroachment time and a significant shorter maximum brake stroke. In terms of eye-gaze behaviors, the percentage of gaze concentration to the road center area and the mean glance durations were deemed acceptable for the avoidance of visual distraction, when in-vehicle traffic signals were presented via a head-up display. Therefore, the analysis of driving behaviors indicated that the in-vehicle traffic signals could effectively provide driver assistance at unsignalized intersections. Moreover, it was considered that the availability of in-vehicle traffic signals at unsignalized intersections might be influenced without considering the waiting time of drivers. Hence, the analysis of waiting time on driver behaviors were performed for intersections which consist of one major and two minor roads. A gap acceptance theory considering waiting time was adopted in the implementation of in-vehicle traffic signals, to assist minor-road drivers in passing through unsignalized intersections by selecting appropriate major-road gaps. Driving simulator experiments involving twelve participants were performed on the minor and major roads, by applying the in-vehicle traffic signals with and without the consideration of waiting time, respectively. The results demonstrated that the maximum gas pedal strokes of minor-road vehicles were significantly reduced, indicating a smaller possibility of aggressive driving while the in-vehicle traffic signal considering waiting time was applied. Meanwhile, an improved steering stability could also be observed at intersections, as the maximum lateral accelerations of minor-road vehicles significantly decreased when the waiting time was considered.

Penetration rate is one of the essential issues that need to be considered for the application of in-vehicle traffic signals. For the application of in-vehicle traffic signals in partial deployment scenarios, the analysis of driving behaviors was mainly performed with driver models considering the influences of look ahead information, the car following behaviors at signalized intersections, and drivers' trust on the system at unsignalized intersections. To analyze the influences of penetration rate on the effects of in-vehicle traffic signals at signalized intersections, this study presented actual vehicle experiments involving twelve participants and two electric vehicles, considering three different deployment conditions of in-vehicle traffic signals: both the two vehicles unequipped, only the preceding vehicle equipped, and only the following vehicle equipped. Meanwhile, two scenarios were prepared since a vehicle would either stop at or pass through an intersection: a stop scenario in which vehicles would encounter a red traffic signal at the intersection, and a pass scenario that a green traffic signal would be presented to drivers when they arrived at the intersection. As the predicted mode which provided look ahead information of traffic signals had been proved to be effective in the previous driving simulator experiments, the applied in-vehicle traffic signals in the actual vehicle experiment adopted the predicted mode only. It was found that, for a vehicle equipped with in-vehicle traffic signals, the maximum braking deceleration would significantly decrease, compared to the condition when no in-vehicle traffic signal was provided. As for a vehicle without in-vehicle traffic signals, the maximum braking deceleration might also be significantly reduced if its preceding vehicle was in-vehicle traffic signals equipped. The results indicated that the application of in-vehicle traffic signals might significantly improve the driving performances even in a partial deployment environment. Meanwhile, simulations were performed for signalized intersections to evaluate the influences of penetration rate on the traffic flow. It was verified that the higher the penetration rate was, the more the travel time might be reduced. Finally, for analyzing the influences of penetration rate on driving behaviors at unsignalized intersections, a driver model considering drivers' trust was applied. Driving simulator experiments were performed to investigate drivers' initial trust on the system and the changes of trust while experiencing successful and failed usages of the system. Simulations and driving simulator experiments were then conducted to analyze the times of near miss accidents while applying the in-vehicle traffic signals in different penetration rates. It was found that the near miss accidents at intersections could be reduced even with a low penetration rate of the system, compared to the condition when no in-vehicle traffic signal system was applied.

It can be concluded from the results that the application of in-vehicle traffic signals will significantly improve driving safety and easily prompt driving performances at intersections, without inducing undesired driver distractions. Meanwhile, the applicability of this method in both full and partial deployment scenarios has also been demonstrated by experiments and simulations.