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TEMPORAL CHANGE IN THE DRIVING PERFORMANCE OF PROFESSIONAL DRIVER: A DRIVING SIMULATOR STUDY

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In Hong Kong, there are more than 150 thousand registered commercial vehicles, including taxis, minibuses, buses and goods vehicles. Although commercial vehicles only constitute to about 20% of the total vehicle fleets, over 70% of crashes involve at least one commercial vehicle. It is essential to identify the factors contributing to the crashes involving professional drivers. This study aims to examine the degradation of driving performance of professional drivers, after driving for a prolonged period, using the driving simulator approach. Effects of driver characteristic, road environment and traffic condition on the performance degradation were evaluated. Preliminary results indicated that professional drivers tended to perform better than the non-professional counterpart, in the term of lateral control. For the effect of road environment, the driving performance on the urban road was better than that on the motorway, regardless of the driver group, in the term of lateral stability. In particular, remarkable degradation of lateral stability could be revealed, after driving for an hour on the motorway. In the extended analysis, differences in driving performance between driver groups will be evaluated using Analysis-of-Variance (ANOVA) approach. Besides, the interaction effects by road environment and traffic condition on the association between driver group, driving time and driving performance will be examined.

Keywords: Road safety, driving simulator, professional driver, driving performance.

1 Introduction

Road traffic crash results in approximately 1.25 million death every year. It is expected to be the seventh leading cause of death by 2030 if no action is taken (WHO, 2016). In the five year period from 2011 to 2015, there were 79,484 road crashes in total in Hong Kong, 70% of which involved at least one commercial vehicle (including taxi, bus and good vehicle) and resulted in 78,556 casualties. Crash involvement rates of taxi, public bus and public light bus were approximately seven times higher than that of general motor vehicles (Transport Department, 2017). In this sense, the behavior and capability of professional drivers could be of concern, in particular, human factors are recognized to be the most dominant factors to road crashes.

A professional driver refers to a person who is paid to drive for the transport of passengers and/or goods. They are more vulnerable to fatigue or inattention due to the prolonged period of driving. Professional drivers are therefore more likely involved in crashes attributed to the sleepiness, as compared to the counterpart (Bunn et al., 2005). Otmani et al. (2005) suggested that the level of sleepiness, both subjective and objective, of male professional drivers increased over time, in a 90-minute simulated driving scenario. In Hong Kong, of the killed and seriously injured (KSI) crashes occurred in 2015, 29% were found attributed to driving inattentively and sleepiness/fatigue (Transport Department, 2017). Drivers' sleepiness is recognized to be a significant contributory factor to road crashes, in particular serious injury and death (Connor et al., 2002; Kecklund et al., 2012). Bunn et al., (2005) suggested that the likelihood of incurring a fatal crash increased with the level of fatigue and distraction of drivers.

It is believed that monotonous road environment could induce driver sleepiness and fatigue. Motorway environment is often considered as undemanding and monotonous, while the urban road environment is relatively stimulating. Likelihood of sleep-related crashes on the motorways was found higher than that on the urban roads (Horne and Reyner, 1999; Maycock, 1996). Thiffault and Bergeron (2003) examined the effects of monotonous road environments on the driving performance on a straight two-lane rural motorway, using the driving simulator experiment. In particular, differences in the driving performance between different road environments and levels of visual stimuli were evaluated. Results indicated that the mean amplitude of steering wheel movement (SWM) and frequency of large SWM both increased with time. This suggested that the prevalence of instability of steering increased with time. Moreover, large SWM was more prevalence in the monotonous driving environment than the counterpart (Thiffault and Bergeron, 2003). To evaluate the degree of drivers' fatigue, other possible performance indicators were the standard deviation of lateral position (SDLP), standard deviation of vehicular speed (SD-SPEED), and standard deviation of steering wheel angle (SDSWA) (Brookhuis and De Waard, 1993; Brown, 1997; Lenné et al.,1998; Cantin et al., 2009; Shanmugaratnam et al., 2010; Li et al., 2016). Results of a driving simulator experiment indicated that the instability of lateral control, in the terms of increase in SDLP, was associated with the increase in the level of sleepiness and fatigue, after the prolonged driving (van der Hulst et al., 2001).

The proposed study aims to evaluate the degree of deterioration in driving performance over time, and the interaction effects of possible risk factors on the degradation. Objectives of this study are: (1) To evaluate the change in driving performance in the terms of lateral control and steering control over time; (2) To evaluate the differences in the changes between driving in different road environment and traffic flow conditions; (3) To evaluate the differences in the changes between drivers of different characteristics. Results of the proposed study should be indicative to management strategy of transport operators, and thus the safety of professional drivers.

2 Method

2.1 *Participants*

60 participants are expected to be recruited. The inclusion criteria are holding a valid and full driving license for at least three years, driving for at least five hours per week, and of good health condition with no symptom of sleep disorder and driving simulator sickness. Informed consent of the participation is obtained, and the participants are rewarded for monetary compensation. A health assessment is conducted prior to the driving simulator experiment. The participants are stratified into groups by occupation (whether they are professional driver or not).

The focus of current study is the performance degradation during driving rather than the fatigue due to long working hour of professional driver. We expect all participants were to be conscious before the start of experiment, therefore, the participants were asked to have a good rest (e.g. normal hours of sleep) on the day before the experiment. Also, they should abstain from the consumption of alcohol and caffeinated beverages 24 hour before the experiment.

2.2 *Apparatus*

The driving simulator experiments are conducted on a fix-based simulator. There are three 32'' full HD LED displays, that provide 100° horizontal field of view. The simulator is equipped with clutch, brake and throttle pedals, force-feedback steering wheel, signaler, dashboard and a sound system. It provides realistic feedbacks, including but not limited to vehicle acceleration, braking and movement on the road shoulder.

2.3 *Driving Scenario*

There were two distinct road environments: (i) Urban roads with numerous roadside activities, signalized intersections and pedestrian crossing; (ii) Three-lane motorway with no roadside activity. The speed limit of urban road and motorway were 50km/h and 80km/h respectively. It is consistent to the actual driving environment in Hong Kong. As shown in Figure 1, there are four combinations of road environments (urban road versus motorway) and traffic flow conditions (low versus high traffic flow).

(a) Motorway Road –High Traffic Flow

(b) Motorway – Low Traffic Flow

(c) Urban Road – High Traffic Flow

(d) Urban Road - Low Traffic Flow

Figure 1. Typical Road Environment for the Simulated Driving Experiment

2.4 *Test Procedure*

Every participant will be invited to participate in two trials. Each trial consists of a 60-minute drive under one of the four road environments as described in previous Section 2.3. The drive time is consistent to that of a typical work trip of professional drivers, i.e. bus drivers, good vehicle drivers, etc. The trials presented (i.e. urban road versus motorway, and low versus high traffic flow condition) were counterbalanced for each driver group. Also, the participant will be invited to complete a questionnaire prior to the simulated driving experiment. Information on driver demographics, driving frequency, years of driving experience, record of traffic conviction, and crash history will be obtained. In addition, a 15-minute test drive will be provided to help the participant to familiarize with the control of simulator and detect the possible syndromes of simulator sickness. Moreover, a 30-minute break will be given between trials.

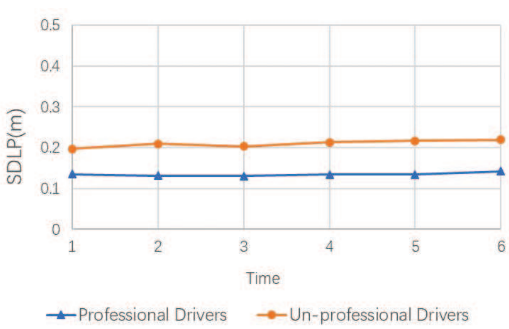
2.5 *Performance Indicators*

In current study, the driving performance indicators considered are: (1) Standard deviation of lateral position (SDLP); (2) Standard deviation of heading error (SDHE). The sampling frequency is 100Hz. For each trial, six estimates of SDLP, SDHE (for the first, second, third, fourth, fifth and sixth 10-minute periods respectively) were deduced.

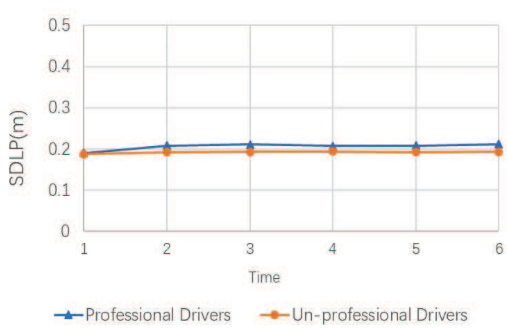
3 Preliminary Results

3.1 *Lateral Position*

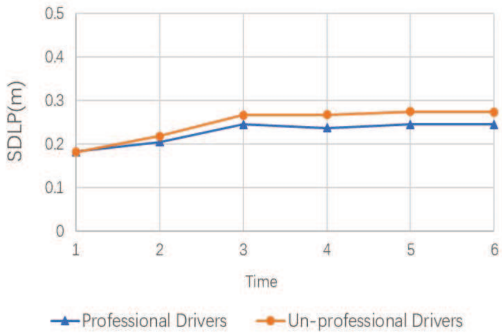
To date, ten participants (five professional versus five non-professional drivers) have completed the trials. Figure 2 illustrated the temporal trends of SDLP over the 60-minute trial for different combinations of road environment and traffic flow condition. In the urban road environment, no remarkable change in SDLP could be observed over time, regardless of the driver type and traffic flow condition (Figure 2(a) and Figure 2(b)). However, values of SDLP of non-professional drivers were higher than that of professional drivers in general, in the high traffic flow condition (Figure 2(a)). As shown in Figure 2(c) and Figure 2(d), in the motorway environment, values of SDLP increased in the first 30 minute, and became stable in the remaining 30 minute, except that the non-professional driver decreased in the first 20 minute. The change in SDLP was seemingly more noticeable in the low traffic flow condition (Figure 2(d)), as compared to the high traffic flow condition. The above results suggested that the driver performance should be better, in the term of stability of lateral control, on the urban road, whereas the stimuli (e.g. presence of pedestrians, cyclists, and traffic signals) were prevalence, as compared to that on the motorway. Besides, professional drivers seemingly outperformed the non-professional counterparts, especially in the high traffic flow condition.



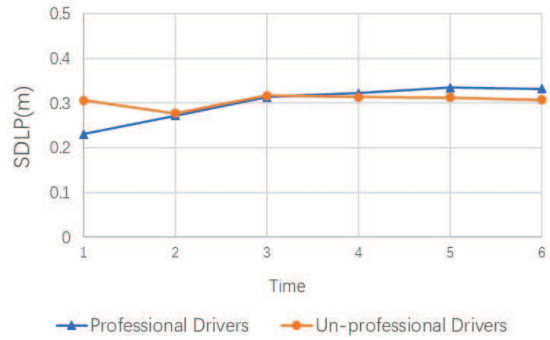
(a) Urban Road –High Traffic Flow



(b) Urban Road – Low Traffic Flow



(c) Motorway – High Traffic Flow

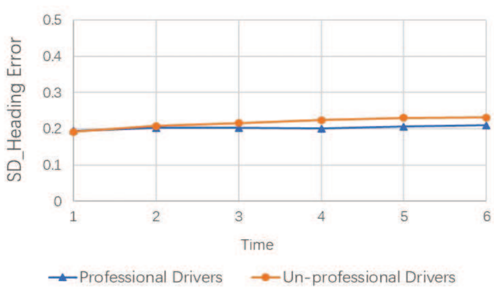


(d) Motorway – Low Traffic Flow

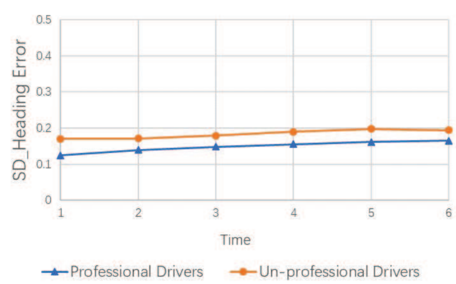
Figure 2. SDLP in Different Road Environment and Traffic Flow Conditions

3.2 *Heading Error*

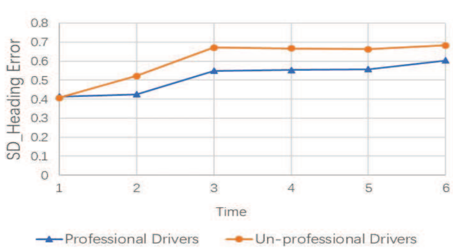
Figure 3 illustrated the temporal trends of SDHE over the 60-minute trial for different combinations of road environment and traffic flow conditions. In the urban road environment, no remarkable change in SDHE could be observed, regardless of the traffic flow condition and driver type (Figure 3(a) and Figure 3(b)). However, in the motorway environment, values of SDHE increased steady over the 60-minute trial, except that for the non-professional driver decreased in the first 20 minute. (Figure 3(c) and Figure 3(d). In general, the professional drivers outperformed the counterpart, in the term of heading error, except that in the motorway environment and low traffic flow condition.



(a) Urban Road –High Traffic Flow



(b) Urban Road – Low Traffic Flow



(c) Motorway – High Traffic Flow

(d) Motorway – Low Traffic Flow

Figure 3. SDHE in Different Road Environment and Traffic Flow Condition

4 Concluding Remarks

The proposed study attempted to examine the degradation of driving performance of professional drivers using driving simulator approach. The possible performance indicators were stability of lateral position and steering control. Besides, the interaction effects by road environment (urban road versus motorway), traffic flow condition (low versus high traffic flow condition), and driver type (professional driver versus general driver) on the degradation were examined. Preliminary results indicated that possible degradation of driving performance, in the terms of lateral position and steering control, could be revealed in the motorway environment, where stimuli and roadside activities were minimal. Besides, the professional drivers possibly outperformed their counterpart. In the extended analysis, the difference in the degradation of driving performance between different independent variables would be evaluated, using the statistical methods including single factor and multi-factor ANOVA.

Acknowledgments

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