Journal of Safety Research 50 (2014) 11–15

Contents lists available at ScienceDirect

Journal of Safety Research

journal homepage: www.elsevier.com/locate/jsr

The impact of continuous driving time and rest time on commercial drivers' driving performance and recovery

Lianzhen Wang [a,*], Yulong Pei [b]

[a] School of Transportation Science and Engineering, Harbin Institute of Technology, Harbin 150090, China
[b] Traffic College, Northeast Forestry University, Harbin 150040, China

ARTICLE INFO

Article history:
Received 16 March 2013
Received in revised form 11 January 2014
Accepted 15 January 2014
Available online 28 January 2014

Keywords:
Fatigue driving
Driving performance
Commercial coach drivers
Driving time
Rest time

ABSTRACT

Problem: This real road driving study was conducted to investigate the effects of driving time and rest time on the driving performance and recovery of commercial coach drivers. *Methods:* Thirty-three commercial coach drivers participated in the study, and were divided into three groups according to driving time: (a) 2 h, (b) 3 h, and (c) 4 h. The Stanford Sleepiness Scale (SSS) was used to assess the subjective fatigue level of the drivers. One-way ANOVA was employed to analyze the variation in driving performance. *Results:* The statistical analysis revealed that driving time had a significant effect on the subjective fatigue and driving performance measures among the three groups. After 2 h of driving, both the subjective fatigue and driving performance measures began to deteriorate. After 4 h of driving, all of the driving performance indicators changed significantly except for depth perception. A certain amount of rest time eliminated the negative effects of fatigue. A 15-minute rest allowed drivers to recover from a two-hour driving task. This needed to be prolonged to 30 min for driving tasks of 3 to 4 h of continuous driving. *Practical implications:* Drivers' attention, reactions, operating ability, and perceptions are all affected in turn after over 2 h of continuous driving. Drivers should take a certain amount of rest to recover from the fatigue effects before they continue driving.

1. Introduction

In China, 20,648 people were killed in 2011 in road accidents involving commercial vehicles, accounting for 33% of all road deaths (The Ministry of Public Security of the People's Republic of China, 2012). Fatigue driving has been acknowledged as a major risk factor in road accidents, with about 15% of road accidents in China caused by fatigue, in particular that of long-distance commercial coach drivers (Dan, Hongting, & Wenshu, 2012). Since commercial coach drivers generally engage in frequent and long driving tasks, they are susceptible to fatigue driving. And to make matters more concerning, accidents involving coaches usually result in serious casualties.

Fatigue may deteriorate the drivers' ability to control their vehicles by affecting such things as attention, reaction, and vigilance, which increases the probability of road traffic accidents. Several studies have revealed that driving performance worsens with the amount of driving time (Campagne, Pebayle, & Muzet, 2004; Feyer, Williamson, & Friswell, 1997). Driving time has been proven to be negatively associated with avoiding dangers (van der Hulst, Meijman, & Rothengatter, 2001). Long-distance drivers exhibit worse driving performance than ordinary drivers, with driving time the main factor affecting their driving ability (Otmani, Pebayle, Roge, & Muzet, 2005; Philip et al., 2003). The duration of the driving task, the monotonous environment, and circadian effects have been shown to negatively influence driving performance (Rossi, Gastaldi, & Gecchele, 2011). Perceptual–motor performance has been shown to deteriorate with the increase in fatigue caused by prolonged driving, while reasonable time schedules have been shown to disrupt the negative effects (van der Hulst et al., 2001). The most frequently reported symptoms of sleepiness in driving revealed by a questionnaire of 154 lorry and bus drivers were "eye tiredness, yawning, difficulties concentrating on the road, and difficulties keeping one's thoughts together" (van den Berg & Landström, 2006). Also, drivers develop much of the same subjective level of fatigue before wanting to quit driving (Nilsson, Nelson, & Carlson, 1997). Some indicators of driving performance have been found to begin to deteriorate after 8 to 9 h of driving in the case of truck and bus drivers, while the frequency of accidents during the last half of the journey has been shown to be twice that during the first half of the journey (Mackie & Miller, 1978). Changes in driving performance have been found to include increased variability of speed and lateral lane position (MacLean, Davies, & Thiele, 2003). The speed coordination of drivers following another car has been shown to deteriorate after 2.5 h of driving (Brookhuis, De Waard, & Mulder, 1994). Reaction and attention abilities have been shown to decrease significantly after 8 to 12 h of driving, while perceptions and operating abilities are not significantly affected for commercial drivers (Bin, Meng, Lin, & Honghai,

* Corresponding author at: Room229, School of Transportation Science and Engineering, Harbin Institute of Technology, No. 73, Huanghe Rd., Harbin 150090, China. Tel.: +86 18686824737.
E-mail address: rock510@163.com (L. Wang).

0022-4375/$ – see front matter © 2014 National Safety Council and Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jsr.2014.01.003

Table 1
Indicators and instruments of driving performance.

Driving performance	Indicators	Instruments
Perception	Speed perception (s)	Speed-perception tester
	Depth perception (mm)	Depth-perception tester
Attention	Attention allocation value	Attention-allocation testing instrument
Reactions	Choice reaction time (s)	Reaction-time tester
Operating ability	Number of correct light reactions	Attention-allocation testing instrument
	Number of incorrect action judgments	Action-judgment instrument

2007). However, it has been found that the subjective feeling of fatigue is no longer accurate after 3 h of driving (Schmidt et al., 2009). In a four-hour driving task, a time schedule in which the drivers rested for 10–20 min every 2 h prevented fatigue compared to a schedule with no rest (Haitao, 2009).

In their study, Friswell and Williamson (2008) suggested that fatigue was an issue for some light and short-haul road transport drivers. This study aims to examine the impact of driving time and rest time on drivers' performance and recovery. To achieve the objective, 33 commercial coach drivers were recruited and a real road driving study was conducted using an experimental psychology method and the Stanford Sleepiness Scale (SSS; Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973). One-way ANOVA was used to analyze the data.

2. Method

2.1. Participants

Thirty-three healthy male commercial coach drivers (mean age: 35.08 years, range: 32–53) with at least eight years of driving experience (mean: 13.83 years, range: 8–28) participated in the study. All the drivers had coach-driving licenses and at least three years of work experience as commercial coach drivers. In China, there are formal license tests organized by the Traffic Police Department, including driving theory and actual driving tests, for all drivers before a license is granted. However, drivers applying for a coach license must meet stricter conditions: they must be over 26 years old and must not have been involved in a serious traffic accident in the last three years. All of the drivers were married and had slept well (mean: 7.98 h, range: 7–12) the day before taking part in the experiment. They did not drink alcohol or take drugs within the 24 h before the experiment. All were professional drivers from the Hailun Highway Passenger Transportation Company in the Heilongjiang Province.

2.2. Dependent variables

The driving performance measures included six parameters: (a) speed perception, (b) depth perception, (c) attention allocation value, (d) choice reaction time, (e) the number of correct light reactions, and (f) the number of incorrect action judgments, as shown in Table 1. Speed perception and depth perception were used to quantify the drivers' perception performance, including the estimation of the speed of the vehicle in front and the estimation of the distance between two vehicles. Attention allocation value was used to judge whether the drivers paid enough attention to useful road information. Choice reaction time was recorded to evaluate the drivers' emergency reactions. Both the number of correct light reactions and the number of incorrect action judgments were used to judge the drivers' operational ability.

The SSS was used as a quick and efficient way to assess how alert the drivers were feeling. Alertness state was divided into seven levels, scored from one to seven, as shown in Table 2.

2.3. Apparatus

In the study, a speed-perception tester, depth-perception tester, attention-allocation testing instrument, reaction-time tester, and action-judgment instrument were used to measure the aspects of the drivers' performance, namely perception, attention, reactions, and operating ability. Each instrument recorded different psychological indicators. They could be placed in the vehicle or on a driving simulator. All the instruments were placed in the coach during the trips in order to collect data when the drivers had a rest. Each indicator has been proven to have significant correlation with PERCLOS (Botao, 2012), which could well indicate driving fatigue (Qin, Yiwei, & Xuefeng, 2008).

The SSS is a subjective measure of sleepiness, frequently used for both research and clinical purposes (Shahid, Wilkinson, Marcu, & Shapiro, 2012). The reliability and validity of the SSS has been proven by many researchers and it can be used to predict performance on tasks related to alertness (Broughton, 1982; Hoddes et al., 1973). In this study, it was used to investigate the drivers' subjective feelings of fatigue while driving.

2.4. Procedure and design

The routes selected for the study were three operational routes: (a) from Hailun to Suihua (2 h of driving); (b) from Hailun to Suifenhe (3 h of driving); and (c) from Hailun to Heihe (4 h of driving). All of these cities are located in Heilongjiang Province. Every route went along real roads including a certain amount of expressways and other highways. The speed limits of the expressways and other highways were 100 km/h and under 80 km/h, respectively. Drivers were asked to drive at their own speed in full respect of the driving rules. According to the duration of the driving task, the drivers were divided into 3 groups of 11 people each. All the experiments were completed within two days. On the first day, six drivers from each group took part in the experiments. The first departure time for each group was 7 a.m., the next was 1 h later, and so on. On the next day, the other five drivers

Table 2
The Stanford Sleepiness Scale (SSS).

Degree of sleepiness	Scale rating
Feeling active, vital, alert, or wide awake	1
Functioning at high levels, but not at peak; able to concentrate	2
Awake, but relaxed; responsive but not fully alert	3
Somewhat foggy, let down	4
Foggy; losing interest in remaining awake; slowed down	5
Sleepy, woozy, fighting sleep; prefer to lie down	6
No longer fighting sleep, sleep onset soon; having dream-like thoughts	7

Table 3
Variance analysis of driving performance and subjective level of fatigue (two-hour group).

Indicators	F-value	p-Value	Change rate
Speed perception	4.311	0.072	+2.4%
Depth perception	3.564	0.096	+4.6%
Attention allocation value	7.860	0.023	−15.0%
Choice reaction time	13.744	0.006	+59.4%
Number of correct light reactions	4.956	0.057	−6.9%
Number of incorrect action judgments	6.400	0.055	+8.6%
Subjective level of fatigue	8.333	0.020	+62.5%

"+" refers to "percentage increase", and "−" refers to "percentage decrease".