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Assessing Chinese coach drivers' fitness to drive: The development of a toolkit based on cognition measurements

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ABSTRACT

Road traffic accidents resulting in group deaths and injuries are often related to coach drivers' inappropriate operations and behaviors. Thus, the evaluation of coach drivers' fitness to drive is an important measure for improving the safety of public transportation. Previous related research focused on drivers' age and health condition. Comprehensive studies about commercial drivers' cognitive capacities are limited. This study developed a toolkit consisting of nine cognition measurements across driver perception/sensation, attention, and reaction. A total of 1413 licensed coach drivers in Jiangsu Province, China were investigated and tested. Results indicated that drivers with accident history within three years performed overwhelmingly worse ($p < 0.001$) on dark adaptation, dynamic visual acuity, depth perception, attention concentration, attention span, and significantly worse ($p < 0.05$) on reaction to complex tasks compared with drivers with clear accident records. These findings supported that in the assessment of fitness to drive, cognitive capacities are sensitive to the detection of drivers with accident proneness. We first developed a simple evaluation model based on the percentile distribution of all single measurements, which defined the normal range of "fit-to-drive" by eliminating a 5% tail of each measurement. A comprehensive evaluation model was later constructed based on the kernel principal component analysis, in which the eliminated 5% tail was calculated from on integrated index. Methods to categorizing qualified, good, and excellent coach drivers and criteria for evaluating and training Chinese coach drivers' fitness to drive were also proposed.

1. Introduction

Along with its rapid economic growth and urbanization in the past decade, China has been recognized for its leading status in the worldwide automobile industry. Until the end of 2014, the population of licensed automobile drivers and car owners in China has reached 246 million (the largest in the world) and 154 million (the second largest in the world), respectively (Ministry of Public Security of the People's Republic of China, 2015). However, as the largest developing country, China has a severe traffic safety situation, which has become one of the top public health issues. In recent years, the annual road accident fatality has been approximately 60,000, which considerably exceeds the sum of other industrial accident fatalities (National Bureau of Statistics of the People's Republic of China, 2014). More seriously, considering the difference of statistical rules about road accident fatality between China and the World Health Organization (WHO), the actual number of fatalities in road accidents may be three times larger if the WHO statistical rule is applied (Hu et al., 2011).

Coach is the most important mode of public transportation in China. In 2014, commercial coaches in China served 19,082 billion passenger trips, accounting for 86.4% of the total 22,094 billion passenger trips in the country (Ministry of Transport of the People's Republic of China, 2015). However, it is often related to severe road traffic accidents involving group deaths and injuries. Among the 16 severe road accidents (≥10 fatalities per accident) that caused 195 deaths in 2013, 11 accidents involving 154 deaths were coach-related, and coach drivers were fully and partly responsible for 7 accidents involving 99 deaths, which was almost half of the total number of deaths (Traffic Management Research Institute of the Ministry of Public Security, 2014). Therefore, the recruitment and

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management of coach drivers is critical for reducing severe road traffic accidents in China. The current qualification standard of coach drivers' fitness to drive in China (Ministry of Public Security of the People's Republic of China, 2013) defines only specific requirements on drivers' driving skills (examined by special road and simulator exams designed for complex driving scenarios and emergencies) and health condition (e.g., age: 21–60 for medium coach and 26–60 for large coach; height: ≥150 cm for medium coach and ≥155 cm for large coach; vision: ≥5.0; no physical disability; no diseases like organic heart disease, epilepsy, Meniere's disease, vertigo, hysteria, tremor paralysis, psychosis, dementia, etc.). It ignores the cognitive and psychological aspects of their fitness to drive. This study aims to investigate Chinese coach drivers' general cognition capacities on perception/sensation, attention, and reaction and suggests reference standards for categorize their fitness to drive.

Research about fitness to drive has been closely related to accident proneness for a long time (Visser et al., 2007), but its evaluation is traditionally applied for special driver populations, such as older drivers (Mathias and Lucas, 2009; Wagner et al., 2011; Bieri et al., 2014) and patient-drivers with brain injury, chronic diseases, stroke, Parkinson disease, etc. (Sommer et al., 2010; Akinwuntan et al., 2006; Devos et al., 2007; Bliokas et al., 2011); rarely on commercial drivers. The importance of drivers' cognitive capacities is constantly highlighted in various evaluation toolkits for fitness to drive (Sommer et al., 2010; Asimakopulos et al., 2012; Chen et al., 2011; Marino et al., 2013; Bieri et al., 2014). Bieri et al. (2014) have developed a computer-aided cognition testing toolkit, the Bern Cognitive Screening Test (BCST), to help examine older drivers' cognitive capacity, including their visuo-spatial attention, executive functions, eye–hand coordination, distance judgment, and speed regulation. Contrast sensitivity, cognitive capacity, motion functions and many other cognitive features were also used in the evaluation toolkits to assess the fitness to drive of patient drivers in clinics (Akinwuntan et al., 2006; Devos et al., 2007; Bliokas et al., 2011). Nevertheless, studies investigating additional comprehensive cognitive features for fitness to drive continue to disregard the general driver population, particularly commercial drivers.

The cognitive capacities discussed in this study can be categorized to three key elements, namely, perception/sensation, attention, and reaction (Endsley, 1995). Five measurements, namely, dark adaptation, dynamic visual acuity, velocity estimation, depth perception, and field dependence, selected through an expert panel were grouped to represent drivers' perception/sensation capacity. They were all proved important to safe driving. For example, dark adaptation is vital when the light condition of the environment changes since drivers take twice longer to adapt to a dark environment than to a bright environment (Plainis et al., 2005). The detection ability in driving substantially relies on drivers' dynamic visual acuity (the visual acuity when in motion or observing moving objects), which is considerably worse than static visual acuity (the one we used mostly when observing static objects or their details) (Vujko Muždalo, 2013). Depth perception and velocity estimation are important for drivers to judge their position relative to other moving objects on the road; insufficient or overestimated depth perception and velocity estimation could induce wrong decisions of passing and following behaviors and subsequently cause accidents (Kobayashi, 1967; West et al., 2003; Korteling and Kaptein, 1996). Field dependence style refers to the extent of subjective inclination when people's cognition and behavior are influenced by an objective environment. Drivers with field independent style have better perceptual performance than drivers with field dependent style (Goodenough, 1976). From another perspective, the quality of attention decides the amount of useful traffic information on the road and the driver's capacity to collect such information. Approximately 78% of crashes are related to drivers' failure of attention (Klauer et al., 2006). Three measurements, namely, extent of concentration, allocation, and span, were grouped to evaluate drivers' attention capacity in this study. Reaction, which signifies speed and accuracy, is another important capacity for drivers' ability to avoid crash and near crash; it is positively correlated with accidents (Kotterba et al., 2004).

To determine the measurements that should be used in the fitness to drive evaluation toolkits, most previous studies have applied comparison (Grace et al., 2005; Alexandersen et al., 2009), correlation analysis (Akinwuntan et al., 2006; Amick et al., 2007; Cordell et al., 2008), and regression analysis (Lundqvist et al., 1997; Klavora et al., 2000) to find single measurements. Comprehensive index-integrated multiple measurements are less explored. Chen et al. (2011) have proposed such a measurement using fuzzy analytical hierarchy process. However, this method requires a large dataset with normal or linear distribution, which is difficult to achieve in practical data collection. Based on a detailed analysis of single measurements, the present study also employed kernel principal component analysis (KPCA) in modeling a comprehensive index for the evaluation of drivers' fitness to drive. KPCA is an emerging feature extraction method that is tolerant toward data structures. The principle of KPCA is to use kernel function in reducing data dimension and achieving a nonlinear transformation among feature space, data space, and category space (Schölkopf et al., 1997).

In summary, to enhance the qualification standard and psychological training of Chinese coach drivers, this study initially established an evaluation toolkit consisting of nine cognition measurements, then collected testing data from more than 1000 real coach drivers and analyzed the difference between safe and accident drivers. A single measure-based evaluation model and a comprehensive index-based evaluation model (built through KPCA) were later proposed by observing the percentile distribution of data.

2. Methodology

2.1. Participants

A total of 1413 licensed commercial coach drivers running on intercity lines daily were recruited from local coach transportation companies in five cities (Yancheng, Huai'an, Yangzhou, Nantong, and Changzhou) in Jiangsu Province, China. Qualified participants were required to be equal or younger than 55 years old, have a driving experience of more than 3 years (for all vehicles, not just coach), have an education level equal or higher than junior school, have a normal or corrected normal visual acuity (≥1.0 in LogMAR scale). Drivers with corrected normal visual acuity need to bring their own glasses during the experiment. The transportation companies also need to provide completed driving history data of the recruited drivers for the past three years. Drivers in lack of three years' driving history data were excluded in the study. Finally, all tested participants are male drivers, aged 27–55 (*mean* = 39.83, *st.d.* = 5.30), with a driving experience as a coach driver of 1–40 years (*mean* = 17.27, *st.d.* = 6.03). With participants' consent, the demographic information and accurate driving records were collected from employee registration forms in their companies. Data indicated that 309 drivers (21.9% of the total) were responsible for at least one or more accidents in the past three years (i.e., the accident group), whereas the remaining 1104 drivers (78.1% of the total) had completely clear accident records in the same period (i.e., the safe group).

2.2. Measurements

A group of 18 measurements was originally collected from the relevant literature, namely, field dependence, memory span, simple

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