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Designing Fatigue Warning Systems: The perspective of professional drivers

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ABSTRACT

Professional drivers have been characterized as experiencing heavy fatigue resulting from long driving time in their daily work. This study aimed to explore the potential demand of Fatigue Warning Systems (FWSs) among professional drivers as a means of reducing the danger of fatigue driving and to examine their opinions regarding the design of FWSs. Six focus groups with 35 participants and a questionnaire survey with 600 respondents were conducted among Chinese truck and taxi drivers to collect qualitative and quantitative data concerning the current situation of fatigue driving and opinions regarding the design of FWSs. The results revealed that both truck and taxi drivers had a positive attitude toward FWSs, and they hoped this system could not only monitor and warn them regarding their fatigue but also somewhat relieve their fatigue before they could stop and rest. As for warning signals, participants preferred auditory warnings, as opposed to visual, vibrotactile or electric stimuli. Interestingly, it was proposed that verbal warnings involving the information regarding consequences of fatigue driving or the wishes of drivers' family members would be more effective. Additionally, different warning patterns, including graded, single and continuous warnings, were discussed in the focus group. Finally, the participants proposed many other suggestions, as well as their concerns regarding FWSs, which will provide valuable information for companies who wish to develop FWSs for professional drivers.

1. Introduction

In recent years, the Chinese road transportation system has been developing rapidly, with the quantity of licensed drivers increasing to more than 200 million, and the vehicle population rising to 120 million (China Statistic Yearbook, 2013). At the same time, although the number of traffic accidents in China has been declining every year since 2002, it remains at a high level. The reports of China Road Traffic Accidents Statistics (2010) indicated that approximately 4 million crashes occurred in China, causing more than 65 thousand fatalities, more than 250 thousand injuries, and 930 million (RMB) (approximately 136.8 million USD) in direct economic losses (CRTAS, 2010). Driving fatigue is a major contributing cause to road traffic accidents. It is estimated that fatigue is involved in 10–20% of serious accidents worldwide (Maycock, 1997; Sagberg, 1999; Fletcher et al., 2005; Horne and Reyner, 1995; Karrer and Roetting, 2007). The actual figure may be much higher because sometimes drivers involved in crashes may fail to recognize or acknowledge the effects of fatigue (Gander et al., 2006; Karrer and Roetting, 2007).

Fatigue is associated with a decrease in physiological arousal, slowed sensorimotor functions and impaired information processing, which can diminish a driver's ability to respond effectively to unusual, unexpected, or emergency situations (Williamson et al., 1996; Kaplan and Prato, 2012; Tzamalouka et al., 2005). However, previous studies have noted that drivers typically underestimated the impact of driving fatigue on driving performance (Reyner and Horne, 1998; Ting et al., 2008). Thus, one of the major challenges in addressing the impact of driving fatigue is the difficulty in detecting fatigue and issuing a warning, particularly when fatigue is likely to increase the incidence of crashes (Williamson and

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Chamberlain, 2005).

To stress this challenge, there has been an increasing interest in the development of Fatigue Warning Systems (FWSs) over the past two decades (for a review, see Hartley et al., 2000; Williamson and Chamberlain, 2005). Several automobile manufacturers have included FWSs in their vehicles. For example, Volvo has developed a system called Driver Alert Control, which can alert a drowsy driver long before he or she dozes off at the wheel (Arellano, 2009). Similar systems can also be found in other vehicles, such as the Driver Monitoring System in Toyota (Williams, 2008) and the Attention Assist System in Mercedes-Benz (Philips, 2008). In general, to date, the available FWSs consist of two major components: the first component is a driving sensor that gathers and processes information regarding the driver and vehicle and later infers the driver's fatigue level (for example, see Eriksson and Papanikolopoulos, 2001; Ji et al., 2004; Schleicher et al., 2008; Senaratne et al., 2011; Singh et al., 2011; for a review, see Wright et al., 2007); the second component is a warning system that delivers an alert to the driver based on the current fatigue level (see Azmi, 2012).

It is believed that the best approach to prevent a driver's fatigue at the wheel is to ensure that the driver is sufficiently rested before the journey commences and to take regular breaks from driving (Horne and Reyner, 1996). The FWSs can promote the driver's awareness of fatigue while driving and encourage the driver to have a short recuperative break (Gillberg et al., 1996) or consume caffeine (Horne and Reyner, 1996). Many studies have reported that FWSs could reduce fatal and injurious crashes (Kulmala, 1997; Regan et al., 2001; Rumar et al., 1999; Young et al., 2003), which means a considerable reduction in the loss of life and property. For example, Rumar et al. (1999) suggested that FWSs have the potential to reduce fatal and injurious crashes on motorways by 10–15% and may reduce injurious crashes on rural roads by more than 10% (Rumar et al., 1999). Young et al. (2003) also estimated that an FWS could reduce 4% of all single vehicle crashes and result in a savings of $64 million annually in Australia (Young et al., 2003). Estimations based on the data in Germany suggested that FWSs would lead to a 35% reduction in fatigue-related crashes, equal to a 2.9% reduction in all crashes (see Commission, 2006).

Currently, FWSs remain new technology devices for Chinese drivers. The available FWSs in market are mainly equipped in several high-end models of private automobiles. Given the significant difference in driving characteristics between private and professional drivers, the available FWSs may not be suitable and acceptable for professional drivers. Firstly, professional drivers are usually exposed to long duration and distance driving, and thus they would feel tired more frequently than private drivers. A recent questionnaire survey to Netherlands drivers indicated that professional drivers reported more frequently to sometimes having fallen asleep while driving (23% of the professional drivers v.s. 10% of the private drivers) (see Goldenbeld et al., 2011). Our previous survey of Chinese professional drivers regarding driving fatigue experience also indicated that approximately one-third (32.4%) of truck drivers and two-thirds (68.5%) of taxi drivers worked for 60 or more hours per week, and 16.1% and 30.1% of the accidents were reported to be related to fatigue driving by truck and taxi drivers, respectively (Meng et al. 2015). Secondly, professional drivers usually cannot get timely rest while driving, in spite of feeling fatigue (Brown, 1997). For example, truck drivers are under considerable pressure to reach their scheduled destination, and taxi drivers have to take passengers to the destinations before they can stop and have a rest. Thirdly, professional drivers could tolerate more fatigue in driving as compared to private drivers. It has been reported that professional drivers indicated more frequently than private drivers that during the past year they sometimes started or continued to drive when they actually felt too tired to do so (37% v.s. 20%) (see Goldenbeld et al., 2011).

Professional drivers account for a large proportion in the driver population; therefore, it can be expected that professional drivers will be promising users in the future market for FWSs. On the other hand, a technical product must be properly designed to meet the preferences of potential users before it is popularized. There will be little demand for the device unless it is acceptable to the users (Young et al., 2003). At present, most engineers are devoting effort to investigating the technological aspect of FWSs, i.e., which technology should be used to detect drivers' fatigue accurately. Few studies investigate drivers' opinions and preferences about the features of FWSs, although they play a decisive role in the acceptability of this device.

The present study conducted a survey to Chinese professional drivers (including truck drivers and taxi drivers) using both qualitative and quantitative methods. The reason of involving both truck and taxi drivers is that these two types of professional drivers differ from each other in terms of work characteristics. For example, truck drivers frequently drive on long, monotonous, high-speed highways during both daytime and night (McCartt et al., 2000; Larue et al., 2011; Sallinen et al., 2004; Thiffault and Bergeron, 2003), while taxi drivers primarily drive at daytime, in urban road environments which involve a constantly changing scenarios and plenty of potential hazards (Dalziel and Job, 1997). This difference in work characteristic may produce diverse opinions and demands regarding the design of FWSs. The purpose of the survey was twofold: first, exploring the driving fatigue situation in professional drivers to examine whether there was promising demand for FWSs in the market; second, investigating the opinions of professional drivers regarding FWSs design, and providing some references for the future FWSs development. In the first part, a focus group method was used to explore the opinions of truck and taxi drivers regarding FWSs, and the data were also used to develop a questionnaire. In the second part, questionnaire data were collected from truck and taxi drivers who did not participate in the focus group to provide additional quantitative information. The qualitative data (focus group information) and the quantitative data (questionnaire survey data) were combined to understand the opinions of professional drivers concerning the FWSs.

2. Method

2.1. Focus group

A total of 35 professional drivers (18 truck drivers and 17 taxi drivers) took part in a total of six 1-h focus groups (see Table 1). Each group contained five or six drivers. The truck drivers were recruited from a logistics center in Beijing, where these truck drivers transported cargo between other provinces and Beijing. They usually had several rest hours when waiting for cargo loading or unloading. The taxi drivers were recruited from Beijing International Airport, where these drivers had to wait for approximately 2 h to pick up passengers traveling to the city center.

Data were collected through six focus groups (for detailed description of focus group method, see Bruseberg and McDonagh-Philp, 2002; Krueger, 2009; Newman, 2002), consisting of three truck driver groups and three taxi driver groups. The focus groups were facilitated by a trained research assistant facilitator, and each group had an observer who also took detailed notes about the discussion. A semi-structured interview format was used, and a set of open-ended questions was developed for the focus group discussion (see Table 2). The questions were developed by the consultant with professional drivers and experts in road safety research. The well-established pattern of focus group questions was