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Evaluating the effectiveness of Behavior-Based Safety education methods for commercial vehicle drivers

Xuesong Wang[a,b,c,*], Yilun Xing[a], Lian Luo[a], Rongjie Yu[a,b]

[a] College of Transportation Engineering, Tongji University, Shanghai, 201804, China
[b] The Key Laboratory of Road and Traffic Engineering, Ministry of Education, Shanghai, China
[c] National Engineering laboratory for Integrated Optimization of Road Traffic and Safety Analysis Technology, China

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ABSTRACT

Risky driving behavior is one of the main causes of commercial vehicle related crashes. In order to achieve safer vehicle operation, safety education for drivers is often provided. However, the education programs vary in quality and may not always be successful in reducing crash rates. Behavior-Based Safety (BBS) education is a popular approach found effective by numerous studies, but even this approach varies as to the combination of frequency, mode and content used by different education providers. This study therefore evaluates and compares the effectiveness of BBS education methods. Thirty-five drivers in Shanghai, China, were coached with one of three different BBS education methods for 13 weeks following a 13-week baseline phase with no education. A random-effects negative binomial (NB) model was built and calibrated to investigate the relationship between BBS education and the driver at-fault safety-related event rate. Based on the results of the random-effects NB model, event modification factors (EMF) were calculated to evaluate and compare the effectiveness of the methods. Results show that (1) BBS education was confirmed to be effective in safety-related event reduction; (2) the most effective method among the three applied monthly face-to-face coaching, including feedback with video and statistical data, and training on strategies to avoid driver-specific unsafe behaviors; (3) weekly telephone coaching using statistics and strategies was rated by drivers as the most convenient delivery mode, and was also significantly effective.

1. Introduction

A large proportion of severe injury and fatal crashes are attributed to commercial vehicles. In Queensland, Australia, 37% of fatal crashes between 1997 and 2000 involved commercial vehicles (Meers, 2002), and in the U.S., 46.5% of fatal crashes in 2014 involved trucks (NHTSA, 2016). In China in 2011, 28% of severe crashes leading to more than 8 fatalities per incident were caused by intercity buses (Traffic Administration Bureau of Ministry of Public Security, 2011). Crashes involving commercial vehicles constitute obvious occupational risk to the commercial vehicle drivers, as well as to the driving public, but the many legislation-focused efforts have not always been successful in reducing crash rates. Therefore, the causes of crashes involving commercial vehicles have been heavily investigated.

Risky driving behavior is the primary cause of commercial vehicle crashes, as demonstrated by many crash causation analyses. Hickman et al. (2005), for example, found 91.5% of commercial vehicle crashes were attributed to risky driving behavior. The U.S. Federal Motor Carrier Safety Administration (2006) found that 87.3% of large truck crashes were caused by driver errors, including non-performance errors, decision errors, recognition errors, and performance errors. In order to build a safer driving environment, especially for commercial drivers, it is essential to reduce commercial drivers' risky driving behavior.

Safety education is a key measure taken to improve commercial drivers' behavior. In China, however, traditional driver education has had limited effectiveness (Fu et al., 2012). Drivers are traditionally educated by attending group meetings, of varying quality, where they are instructed on general safety rules without consideration of their individual exposures; whereas education research has revealed that learning increases when individual features are considered (Connor et al., 2009, 2010). Behavior-Based Safety (BBS) is a behavioral approach to improving safety in the workplace, and has been extensively used for one-on-one employee safety education (Geller, 2001). According to Connor et al. (2009, 2010) and Choudhry (2014), BBS education considers individual features, and has two further improvements over traditional safety education: (1) it concentrates on observable individual safety behaviors rather than unobservable attitudes

* Corresponding author at: School of Transportation Engineering, Tongji University, Shanghai, 201804, China.
E-mail address: wangxs@tongji.edu.cn (X. Wang).

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toward safety, and (2) it focuses on describing and encouraging safe behavior rather than on punishment. Geller (2001) observes that BBS education includes three phases: observation, feedback, and training; and has applied these phases to the safety education of commercial drivers. In the first two phases, risky behaviors of drivers are observed by management and then identified to the drivers one-on-one. Then, training is implemented based on the individual observable risky behaviors. Education methods based on BBS have shown reductions in lasting injuries (Wirth and Sigurdsson, 2008), and other studies (Hickman and Hanowski, 2011; McGehee et al., 2007) have found BBS education specifically effective in reducing risky driving behavior. However, BBS methods vary in their combinations of delivery frequency, mode and content, all of which may influence effectiveness. Chapman and Underwood (2000), for example, found that drivers forget over 80% of their near-crashes after a month's time, which suggests that the frequency of education may be an important factor. Some studies have compared BBS methods, but none have compared the methods as used with commercial vehicle drivers. As commercial vehicle crashes continue to be a problem, there is great need to find the most promising methods.

This study was therefore conducted (1) to further investigate the relationship between BBS education and driver at-fault safety-related events, and (2) to evaluate and compare the effectiveness of three selected BBS education methods with commercial vehicle drivers.

2. Literature review

2.1. BBS education methods

Previous research on safety education's effect on safety-related events for commercial vehicle drivers has studied various methods. In a study by Hickman and Hanowski (2011), commercial vehicle drivers were instructed with flexible frequency, i.e., "when necessary," using risky driving behavior videos of extreme gravitational force (g-force) events. Lotan and Toledo (2006) collected videos of participating drivers' own risky driving behaviors; when the drivers were involved in safety-related events, the researchers had the drivers view their videos online. Musicant et al. (2007) used real-time telephone warnings and provided drivers with monthly web-based safety reports and driving behavior analyses. As is common, before-after analyses were used in these studies to evaluate the various methods' effectiveness in reducing event occurrence rates. In all three studies, the safety-related event rate reduced significantly as measured by *t*-test (Hickman and Hanowski, 2011; Musicant et al., 2007; Lotan and Toledo, 2006). The variety in methods and absence of comparison, however, make it difficult for safe driving professionals to select the best methods.

Researchers have been working on identifying the best BBS education approaches in workplace situations other than driving. Verbal delivery is advocated by most behavioral safety experts (Wirth and Sigurdsson, 2008), as information can be delivered quickly and without interruption. Traditionally, verbal delivery is accomplished through face-to-face mode, but the effectiveness of verbal delivery through telephone mode, which is more convenient than face-to-face interviews, has not yet been evaluated. Graphic content, as compared, e.g., to written, is the most promising type of content proposed by behavioral experts (Wirth and Sigurdsson, 2008) for its advantage in helping workers more accurately recall the safety event scenario. Video, graphic content that records the worker's continuous manipulation, has been specifically found to be effective (Alvero and Austin, 2004). As for frequency, some studies have found that more frequent education leads to greater effectiveness, while others have found a continuous education schedule produces tension in the staff and increases resistance (Alavosius and Sulzer-Azaroff, 1990). One study of nurses' glove-wearing found optimal an education frequency of 12–14 days (Devries et al., 1991). This implies the possibility of finding an optimal frequency for other specific fields.

2.2. Safety-related events

Safety-related events include crash, near-crash and critical incident events (CIE) (Dingus et al., 2006). Dingus et al. (2006) defines *near-crash* as "any circumstance that requires a rapid evasive maneuver by the subject vehicle to avoid a crash." CIE is defined as a non-crash safety event marked by a high acceleration/deceleration rate or other kinematic signature (Guo and Fang, 2013). Near-crash and CIE have both been demonstrated to have significant correlation with crashes (Guo et al., 2010; Guo and Fang, 2013). Due to the much larger number of all safety-related events over strictly crash events, safety-related events are generally used as crash surrogates and indices for driver safety assessment (Hickman and Hanowski, 2011; Guo and Fang, 2013; McGehee et al., 2007).

The relationship between safety-related event rates and driver characteristics has been investigated by Guo and Fang (2013) with a negative binomial model and by Wu et al. (2014) with a Poisson model. Results from both studies showed that young drivers were more likely to be involved in safety-related events than older drivers. Considering that safety education might be particularly beneficial in certain cases, such as for younger drivers, this study used a random-effects negative binomial (NB) model to investigate not only the relationship between safety education and safety-related event rate, but also the driver characteristics, such as age, that may influence the event rate.

3. Experimental design

3.1. Participants

Forty-five commercial vehicle drivers were recruited randomly from a Shanghai logistics company. However, 10 drivers failed to complete the experiment because they changed to other divisions, and another's data was removed from the study due to a suspected equipment malfunction (see below in this section). The final analysis used event data from 34 drivers. The sample size is small but typical for experiments using individual monitoring, as it is expensive, and excessive time from participants is required. Sample sizes of similar studies (Hickman and Hanowski, 2011; Musicant et al., 2007; Lotan and Toledo, 2006) were all around thirty.

The drivers in this study were divided into three groups, each of which would receive one of three different BBS education, or coaching, methods. Two questionnaires were collected from each driver. The first was given prior to the experiment, and requested demographic information (age, driving years, gender, etc.) that was used for data management and model building. The second questionnaire was given after the experiment for the purpose of investigating participants' preferred coaching method (mode, frequency and content). All participants were male drivers between the ages of 22 and 48.

All drivers drove short-haul carriers, 8 of which were light trucks, and 27 were vans. A light truck is defined as weighing less than 4500 kg; a van is a small or medium-sized vehicle with one row of seats at the front and a space for carrying goods behind (Ministry of Public Security of the People's Republic of China, 2014). The difference in vehicle type was considered, but it was determined that vehicle type would not introduce an additional influence on driver behavior for the following reasons: (1) drivers were similar, as the company recruited all drivers according to the same criteria; for example, the mean age for light truck drivers and van drivers were 31.8 and 32.9 respectively (no significant difference, $F(2, 31) = 0.07$, $p = 0.9302 > 0.05$); (2) the two types of vehicles are both used as short-haul carriers driven in the same urban driving environment; and (3) no significant difference ($F(2, 31) = 2.08$, $p = 0.1419 > 0.05$) among the three groups was found in the safety-related event rate of the baseline phase. Therefore, while behavior could vary for the different types of vehicles, the influence can be omitted. Participants' age detail by group is shown in Table 1.

Fig. 1 below shows the distribution of the number of safety-related