Applied Ergonomics 52 (2016) 135–141

Contents lists available at ScienceDirect

Applied Ergonomics

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

Evaluation of the effectiveness of a multi-skill program for training younger drivers on higher cognitive skills

Yusuke Yamani [a, *], Siby Samuel [b], Michael A. Knodler [b], Donald L. Fisher [b]

[a] Old Dominion University, USA
[b] University of Massachusetts Amherst, USA

ARTICLE INFO

Article history:
Received 28 April 2014
Received in revised form
12 June 2015
Accepted 9 July 2015
Available online xxx

Keywords:
Driver training
Cognitive skills

ABSTRACT

Training programs exist that prove effective at teaching novice drivers to anticipate latent hazards (RAPT), mitigate hazards (ACT) and maintain attention (FOCAL). The current study (a) measures the effectiveness of a novel integrated training program (SAFE-T) that takes only a third as long to complete compared to the three individual training programs and (b) determines if integrating the training of all the three higher cognitive skills would yield results comparable to the existing programs. Three groups were evaluated: SAFE-T, RAPT and Placebo. The results show that the drivers in the SAFE-T-trained group were more likely to anticipate hazards, quicker and more effective at responding to hazards, and more likely to maintain glance durations under a critical threshold of 2 s as compared to drivers in the Placebo-trained group who received a control program that does not actively train on any of the three cognitive skills. Moreover, the results show that the drivers in the SAFE-T trained group were just as likely to anticipate hazards as the drivers in the RAPT trained group. Finally, when compared with prior studies, the drivers in the SAFE-T trained group showed similar effects of attention maintenance training.

Young novice drivers are overrepresented in automobile fatalities when compared to older, more experienced drivers. For example, per 100 million miles traveled in 2008, the fatal crash rates for drivers aged 16–19 was approximately 4.6 times higher than that for drivers aged 30–69 (IIHS, 2012). Some of the increase in the crash rates for novice drivers can be attributed to their willingness to engage in risky driving behaviors, such as speeding (Ivers et al., 2009). Strikingly, however, an analysis of 1000 crashes involving novice drivers identifies cognitive factors such as attentional and visual search failures as key contributors to over 65% of vehicular crashes while the risk-seeking behaviors account for only approximately 5% of such crashes (McKnight and McKnight, 2003). Moreover, although failure to modulate speed under various traffic conditions accounts for about 21% of the crashes, this may be partly due to the novice drivers' inability to perceive critical hazards while driving (e.g. Mourant and Rockwell, 1972). Other studies have identified such cognitive factors as particularly critical to novice drivers' safety (e.g. Treat et al., 1979), and shown that age-related differences in visual scanning performance are more likely a result of inexperience than they are of an increased willingness to accept the risks that arise from not scanning (Gregersen, 1996).

Recent driving simulator studies which record driver and vehicle behaviors have focused on examining and developing specific training programs for improving driver performance across three cognitive skills that are known to be critical to driver safety, *hazard anticipation*, *hazard mitigation*, and *attention maintenance*. First, hazard anticipation (HA) is defined as the ability to scan the areas of the roadway in order to identify and react to a hazardous event, especially those events that are latent (have not yet materialized). Novice drivers glance less frequently towards areas with latent (potential) hazards, compared with experienced drivers (Pradhan et al., 2005). Such glances are important because they can reduce the risk of a crash. Pradhan et al. (2009a,b) developed and evaluated a PC-based driver training program in the field, *Risk Awareness and Perception Training* (RAPT; Fisher et al., 2004), which aims to improve scanning behavior in novice drivers, especially for potential hazards even when the hazards do not materialize. The program allows trainees to see a top-down view of each scenario where hazards are predictable, but hidden from the driver by the built or natural environment (i.e., latent hazards). No hazards actually materialized in any of the scenarios. The trainees were asked to identify the area of the scenario that could contain a latent

* Corresponding author.
E-mail address: yyamani@odu.edu (Y. Yamani).

http://dx.doi.org/10.1016/j.apergo.2015.07.005
0003-6870/

hazard by using the mouse to place an icon on the potential target zone (the area where the latent hazard is located). In a subsequent on-road evaluation (Taylor et al., 2013), RAPT-trained drivers correctly glanced at the target zone about 64% of the time (vs. 37% for Placebo-trained drivers), proving the effectiveness of the RAPT program in increasing novice drivers' hazard anticipation abilities.

Second, hazard mitigation (HM) is defined as any action that a driver undertakes in an attempt to respond to potential or actual hazards on the road. As with HA, novice drivers performed worse than experienced drivers in evaluations of HM. For example, in various scenarios involving curves (Muttart et al., 2013) and intersections (Muttart et al., 2014), the novice drivers made fewer anticipatory glances and began mitigating markedly later than their experienced counterparts. *Anticipate*, *Control*, *and Terminate* (ACT) is a training program that teaches drivers first to anticipate and then to mitigate a hazard successfully. ACT-trained novice drivers' performance on hazard anticipation and mitigation at curves improved to a level similar to that of the experienced drivers' performance, showing the effectiveness of the ACT training program (Muttart, 2013).

Lastly, attention maintenance (AM) is defined as the ability of drivers to maintain their attention on the forward roadway. Off-road glances longer than 2 s elevate the risk of a crash (Klauer et al., 2006). As with the other skills, novice drivers perform more poorly, in this case being more likely to show longer off-road glances compared to more experienced drivers (Chan et al., 2010). Specifically, in several in-vehicle tasks (finding a CD and dialing a phone number, for example), novice drivers glanced inside the vehicle for a duration greater than the 2 s-threshold more frequently than the experienced drivers (Chan et al., 2010), especially later in a sequence of in-vehicle glances (Yamani et al., 2015). *FOrward Concentration and Attention Learning (FOCAL)* is a program that aims at training novice drivers to limit their glances inside the vehicle to no longer than 2 s. The program has been shown to be effective in reducing in-vehicle glance durations both in a simulator (Divekar et al., 2013) and on the open road (Pradhan et al., 2011).

Of current interest is the evaluation of an integrated training program, SAFE-T, developed by Hamid (2013), that has been shown to reduce the effect among nurses long periods of wakefulness have on each of the above three critical driving skills (e.g., Hamid et al., 2014). The nurses were all experienced drivers. The current study addresses whether the integrated training program will prove as effective among novice drivers at mitigating the effects of inexperience as it does among nurses at mitigating the effect of long periods of wakefulness. As discussed above, although individual skill-specific programs are now available to effectively train novice drivers to anticipate hazards (RAPT), to mitigate hazards (ACT), and to maintain attention (FOCAL) on the forward roadway while driving, it remains to be shown whether novice drivers can be trained on all the three skills within a single integrated training program with greater efficiency taking only a third of the time compared with the three individual training programs.

First, among novice drivers as opposed to nurses, with SAFE-T the time devoted to each skill may not be enough. Novice drivers simply may not have the experience that can speed their learning, something that the nurses did have. Second, there could be both retroactive and proactive interference when SAFE-T is used with novice drivers (e.g., Underwood, 1948). That is, the three areas could potentially interfere with one another retroactively or proactively in the learning process because the skills are similar. This potentially is especially high among novice drivers when the learning of three different skills is crammed into a relatively short period of time. Third, the fact that training can reduce the effects of long periods of wakefulness in each of the three skills does not mean that training can reduce the effects of inexperience on all the three skills.

The current study aims to evaluate an integrated program from both a theoretical and applied standpoint. Theoretically, the evaluation will answer the above three questions. Practically, a training program that addresses all the three critical skills and requires only 40 min of a novice driver's time is much more likely to be used than are three separate training programs, each of which requires more time individually than does the integrated program overall.

SAFE-T uses a training method (e.g. error management approach; Gist et al., 1989) similar to the existing programs (RAPT, ACT, and FOCAL). Thus, assuming that neither the decrease in exposure, the potential for interference, or the different domain of application entirely negate the effect of training, we hypothesize that novice drivers trained on the SAFE-T program are more likely to anticipate hazards, are quicker to mitigate them, and are more likely to maintain their attention on the forward roadway while driving than are a control group of novice drivers. Moreover, we have decided to compare the effect size of SAFE-T with the effect size of one of the training programs, RAPT, to determine whether the decrease in exposure and potential for interference decrease the size of the effect of SAFE-T on hazard anticipation (the same skills that RAPT is designed to train).

1. Method

1.1. Participants

Forty-eight students between 16 and 18 years old (9 males and 7 females, mean age = 17.9 years, mean years since licensure = 2.2 years for the Placebo group; 8 males and 8 females, mean age = 18.3 years, mean years since licensure = 2.3 years for the RAPT group; 7 males and 9 females, mean age = 18.0 years, mean years since licensure = 2.1 years for the SAFE-T group) were recruited from the University of Massachusetts and surrounding areas and participated in the study. All participants held a valid driver's license including a junior operator's license. Drivers were paid for their participation.

1.2. Apparatus

Driving Simulator – The STISIM (System Technology, Inc.) simulator system housed within the Human Performance Laboratory at the University of Massachusetts Amherst was used for the experiment. The system hardware consisted of a built-up cab, three 60″ screens, three projectors, a sound system, and three computers that controlled graphic images. The built-up cab consisted of an adjustable driver's seat, a steering wheel, and accelerator and brake pedals. Graphic images were projected at the resolution of 1024 by 768 pixels with a refresh rate of 30 Hz.

Eye Tracker – An ASL Mobile Eye (Applied Science Laboratories, Inc.) monocular eye-tracker was used for tracking glance durations and scanning behavior. It consisted of safety goggles tacked with optics – a camera that records the driver's eye, a camera that records the scene image, an ultraviolet light source, and a small reflective spectacle. The data were sampled at 30 Hz. The system software integrated the recorded scene and eye images into a single video of the scene with a superimposed crosshair representing the location of gaze in each frame.

1.3. Training programs

1.3.1. SAFE-T training program

The SAFE-T program (Hamid, 2013) was used for training the three higher cognitive skills. The program was delivered via MS