Transportation Research Part F 52 (2018) 62–74

Contents lists available at ScienceDirect

Transportation Research Part F

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

A comparison of motivational and informational contexts for improving eco-driving performance

Katie McConky [a], Roger B. Chen [b,*], Glenn R. Gavi [b]

[a] Kate Gleason College of Engineering, Rochester Institute of Technology, One Lomb Memorial Dr., Rochester, NY 14623-5608, United States
[b] Golisano Institute for Sustainability, Rochester Institute of Technology, 190 Lomb Memorial Dr., Rochester, NY 14623-5608, United States

ARTICLE INFO

Article history:
Received 21 June 2016
Received in revised form 3 August 2017
Accepted 10 November 2017

Keywords:
Commercial vehicle operations
Feedback
Motivation
Incentives
Simulator
Eco-driving

ABSTRACT

Eco-driving, the practice of operating a vehicle with environmentally friendly objectives, has been the focus of an increasing number of driving studies over the past decade, as new forms of vehicle automation and more driver-centric feedback continually emerge. Common benefits range from reducing carbon footprints and emissions to better fuel economy. Studies have also examined the effectiveness of in-vehicle assistance devices and training or education programs for commercial and passenger vehicle operators. Eco-driving strategies in general show significantly smaller impacts in the field relative to their laboratory counterparts. This study further builds on this past work by comparing and disentangling the effects from motivational contexts, for example a competition with prizes, with the effects of informational context, such as tutorials for drivers. To investigate this comparison, laboratory experiments are conducted using a commercial vehicle simulator. The results suggest that motivational contexts are more effective at encouraging eco-driving relative to informational contexts. Furthermore, incentives within competitive contexts had similar positive impacts on reducing carbon dioxide emissions and improving fuel efficiency as experiencing a tutorial on eco-driving. One possible explanation is that drivers have gained knowledge on how to operate vehicles with an eco-driving objective through their driving experience. This result further suggests that with respect to effectively encouraging eco-driving, targeting experienced drivers through a competition is better than presenting information or a tutorial.

1. Introduction and background

According to the Environmental Protection Agency (Environmental Protection Agency, 2015), more than 1750 million metric tons of carbon dioxide (CO_2) were released as a direct result of transportation activities in 2014, accounting for 26% of U.S. greenhouse gas (GHG) emissions. Eco-driving, the practice of operating vehicles with environmentally friendly objectives, has shown promise in reducing these emissions. Studies show reductions in CO_2 emissions and fuel consumption of between 2.7% and 18.4%, resulting from a combination of eco-driving aids and training programs (Barth & Boriboonsomsin 2009; Beusen et al., 2009; Kurani, Stillwater, Jones, & Caperello, 2013; Staubach, Schebitz, Koster, & Kuck, 2014; Zhao, Wu, Rong, & Zhang, 2015). Several studies have focused on the impacts of type, frequency, and mode (or form) of eco-driving information on vehicle performance from both an eco-driving and safety standpoint. Existing work suggests that motiva-

* Corresponding author.
E-mail addresses: ktmeie@rit.edu (K. McConky), rbcgis@rit.edu (R.B. Chen), grg5393@rit.edu (G.R. Gavi).

https://doi.org/10.1016/j.trf.2017.11.013
1369-8478/

tional context may also play a significant role in encouraging eco-driving as studies show greater impacts in vehicle simulation studies versus longitudinal field studies of actual vehicle operations (Barth & Boriboonsomsin, 2009; Beusen et al., 2009; Kurani et al., 2013; Staubach et al., 2014). This paper builds on previous studies by comparing motivational and informational contexts through laboratory experiments using a commercial truck driving simulator. The hypothesis put forth is that the majority of drivers have existing knowledge on how to operate vehicles with an eco-driving objective, resulting in higher miles-per-gallon (MPG) of fuel and lower overall emissions. Consequently, informational contexts, which include tutorials and training programs, may only serve to reinforce existing knowledge, but not significantly improve operations by itself, relative to competitive motivation contexts.

The existing literature on eco-driving roughly fall into four categories regarding the effectiveness of the following: (i) driver assist devices and mechanisms; (ii) information presentation and feedback, including tutorials; (iii) motivational contexts, such as a competition; and (iv) longitudinal field studies over time.

Research on the effectiveness of driver assistive devices and mechanisms show that safety objectives are aligned well with eco-driving objectives, with improvement in safety in some cases (Birrell & Young, 2011; Mollenhauer, Lee, Cho, Hulse, & Dingus, 1994) accompanying improved eco-driving. These studies have examined the effects of frequency, modality and adaptability of information provided to drivers, with several focusing on safety. For example, Kircher, Fors, and Ahlstrom (2014) studied continuous versus intermittent feedback on human factors including eye glance frequency and dwell time, finding that intermittent feedback improves safety by reducing dwell time on the device. Rouzikhah, King, and Rakotonirainy (2013) compared three different device activities: (a) reading an eco-driving related text message; (b) changing a CD and (c) entering a 5-digit number into a PDA. Results indicate that an eco-driving related text has significantly less distraction than the other two tasks, but the messaging did slightly increase driver workload. For these two studies no eco-driving performance was measured, precluding a connection of these factors to eco-driving.

Studies on information presentation and feedback have examined the type, frequency and modality of information provision (Brouwer et al., 2015). While Kircher et al. (2014) found that intermittent feedback increases driver safety by reducing device dwell time, a similar experiment by Jamson, Hibberd, and Jamson (2015) found that continuous real-time visual feedback was more effective than haptic feedback for eco-driving. In a separate study Hibberd, Jamson, and Jamson (2015) evaluated the effectiveness of haptic, auditory and visual displays, finding that haptic feedback was better at controlling over accelerations. While haptic and auditory/visual feedback showed similar eco-driving performance with respect to measured fuel economy, auditory/visual feedback showed a potential increase in driver workload. Dijksterhuis, Stuiver, Mulder, Brookhuis, and deWaard (2012) investigated the delivery of eco-driving feedback on a lane keeping task and found that intermittent feedback performed best, but only when necessary, for example when a driver makes hard accelerations. Similarly, Zhao et al. (2015) showed a 5% improvement in CO_2 emissions and fuel economy when intermittent warnings were used alerting drivers of high accelerations or decelerations, high RPMs, unstable speeds and lengthy idling.

Motivational contexts for eco-driving have also been explored in past studies, though to a smaller degree relative to information. In a simulator study on multiple goals, such as minimizing travel time and eco-driving, the positive impacts on eco-driving declined as more goals were included (Dogan, Steg, & Delhomme, 2011). With respect to existing ability to eco-drive, one study showed that while drivers have an endogenous intention to drive eco-friendly, they are ineffective at translating these intentions into daily driving behaviors (Lauper, Moser, Fischer, Matthies, & Kaufmann-Hayoz, 2015). This study hypothesized that drivers possess eco-driving knowledge, but a gap exists between intention and performance that stems from lack of motivation. In a larger study of 118 drivers along the I-80 corridor in California over two months, examining three eco-driving aids which contained either numbers associated with eco-driving performance or random numbers, no significant improvement (only a 2.7% improvement in fuel economy) was associated with aids (Kurani et al., 2013). This study further suggests that future studies on motivational context are promising.

With respect to informational contexts, such as tutorials, one long-term study on the effectiveness of an eco-driving course examined the performance of ten drivers before and after the course (Beusen et al., 2009). Fuel consumption decreased by 5.8% after the course. Interestingly, leading up to the course, drivers showed a 40% decrease in fuel consumption, suggesting that drivers may already have eco-driving knowledge. Eco-driving performance was best directly after the training course, but these gains diminished over time. Finally, a bus driver study suggests that eco-driving training can have significant impacts on performance in real world driving; however, the experimental design does not allow distinguishing gains in driving performance between training or external motiving factors (Sullman, Dorn, & Niemi, 2015). Two cohorts of bus drivers were recruited, with each experiencing a training session. One cohort experienced a tutorial on eco-driving and the other on first aid. The cohort experiencing the eco-driving tutorial outperformed the other cohort in eco-driving measures. However, the authors of this study hypothesize that the first-aid cohort may have had similar performance if simply asked to drive eco-friendly.

This brief literature review underscores several dimensions of eco-driving that require further investigation. One of these dimensions is distinguishing between improvements in eco-driving from motivational versus informational contexts. Past studies have shown benefits from educational mechanisms, such as tutorials on eco-driving that simply present information on how to eco-drive. Other studies suggest their effectiveness is misleading as the majority of experienced drivers already know eco-driving, but require the proper motivational context. This study addresses this distinction, comparing the eco-driving effects of motivational relative to informational contexts. More specifically, this study compares a competitive context with prizes with one where information is presented through performance feedback post-trip and tutorials.