

## LOCAL DETERMINANTS OF DRIVING BEHAVIOURS: INSTALLATION THEORY INTERVENTIONS TO REDUCE FUEL CONSUMPTION AMONG TRUCK DRIVERS IN COLOMBIA

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**Abstract.** Eco-driving has been linked to considerable reductions in negative externalities and costs for transportation companies, employees and communities (including fuel consumption, safety and emission benefits). Nevertheless, some of the biggest challenges to its implementation are related to promoting behavioural change among drivers. This paper presents the results of three behavioural field interventions that were successful to improve fuel efficiency in heavy freight transportation. The interventions brought further improvement even though the target company already had strong training, incentive, control and feedback procedures in place. The Installation Theory framework and the Subjective Evidence-Based Ethnography (SEBE) technique were used to systematically analyse determinants of driving behaviours, and to design cost-effective behavioural interventions based on social norms. The effects of three interventions were then tested using a pre-test post-test control group design among 211 drivers of the company. Results show significant decreases in average monthly fuel consumption of up to 4% in month 1 and up to 4.5% in month 3. Our findings show (with certain qualifications), that the Installation Theory framework and social norm interventions can be a cost-effective method to improve fuel efficiency in road freight transport companies, even when strong training, incentive, control and feedback procedures are already in place.

**Keywords:** eco-driving, fuel consumption, driving behaviour, installation theory, subjective evidence-based ethnography, social norms, behavioural interventions, field experiment.

### Notations

DPA – driving parameter alert;  
EBO(R/I) – exposure to behaviours and opinions  
(remote/in-situ) intervention;  
FPP – first-person perspective;  
GPS – global positioning system;  
GSI(R) – groups summary information (remote)  
intervention;  
GSI+EBO(R/I) – groups summary information + expo-  
sure to behaviours and opinions (re-  
mote/in-situ) intervention;  
LED – light-emitting diode;  
LSE – London school of economics and politi-  
cal science;  
M – mean;

MASL – meters above sea level;  
RIW – replay interviews;  
ROI – return on investment;  
SD – standard deviation;  
SEBE – subjective evidence-based ethnography;  
SMS – short message service.

### Introduction

Implementing driving behaviours that promote fuel efficiency (broadly called eco-driving in the literature) have been linked to significant reductions in negative externalities and costs for both transportation companies (such as fuel and maintenance costs and accidents), employees (as

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they have been linked to noise reduction and overall job satisfaction, beyond reduced accidents) and communities (such as noise and emissions) (Bristow *et al.* 2008; Gosnell *et al.* 2016; Walnum, Simonsen 2015). Researchers estimate that changing driving behaviours can achieve reductions in fuel consumption and emissions of around 10 to 15% without any infrastructure or technological change (Barkenbus 2010; Hari *et al.* 2012). Furthermore, studies in countries like the UK predict that “[...] only combinations of technological developments and behavioural change can deliver the deep cuts [...] required [...]” (Bristow *et al.* 2008) to meet international goals on reduction of emissions in the transport sector. In the road transport sector, which is responsible for around 16.5% of global CO<sub>2</sub> emissions (WHO 2011) and can spend up to 70% of its operating budget in fuel costs (Kot 015), this could mean enormous financial and environmental benefits. And yet, the role of driving behaviour tends to be ignored in most energy and environmental policy making processes (Sanguinetti *et al.* 2017). One reason is the scarcity of actionable directives on how companies can make their drivers eco-drive.

Research has shown how interventions based on low-cost mechanisms like incentives, goal setting, training or feedback have been successful to influence driving behaviours and reduce fuel consumption (Basarić *et al.* 2017; Ho *et al.* 2015; Jeffreys *et al.* 2018; Lai 2015; Saboohi, Farzaneh 2009; Sullman *et al.* 2015). These interventions can be effective and cost-efficient even in companies that already apply well-structured training, incentive, control and feedback procedures to influence the behaviour of drivers. Unfortunately, many initiatives are applied for opportunistic or incidental reasons without an analysis of drivers’ behaviours, which often leads to ineffective or inefficient interventions. Installation Theory provides a framework to systematically analyse and redesign the physical, psychological and social determinants of activity from the user’s perspective (Lahlou 2015, 2018). This can contribute to better focus limited resources and increase their effectiveness to influence driving behaviours.

In this paper, we present the results of two field experiments that were designed to test whether behavioural interventions designed using the Installation Theory framework (Lahlou, 2015, 2018) and based on the concept of social norms (Legros, Cislighi 2020; Tankard, Paluck 2016; Yamin *et al.* 2019) could be effective (and cost-effective) to improve fuel efficiency even when strong training, incentive, control and feedback procedures were already being applied to this end. A medium-sized road freight transport company in Colombia was chosen as intervention context. After a section where we outline the main conceptual elements that guided our studies, we then turn to presenting the context of our intervention, and the methods and results of each of the two studies we conducted. Finally, we present a general discussion about how the Installation Theory framework and these interventions are a cost-effective alternative for road transport companies to reduce fuel costs and other negative externalities for themselves, their employees and the communities they work in.

## 1. Background

### 1.1. Eco-driving and behavioural change interventions

Definitions of eco-driving vary a lot in both academic and popular sources, broadly linking it to driving behaviours associated with fuel saving, reductions of CO<sub>2</sub> emissions (as correlation with other harmful emissions is not clear), and safety improvements (Sanguinetti *et al.* 2017). In an attempt to synthesize, the inconsistent definitions of what observable behaviours constitute eco-driving in both academic and popular sources, Sanguinetti *et al.* (2017) did a broad review to find a comprehensive typology that includes six categories: driving, cabin comfort, trip planning, load management, fuelling and maintenance. Driving behaviours consisted of six further sub-classes: accelerating, cruising, decelerating, waiting, driving mode selection, and parking.

While there is a considerable literature on the basic technical and behavioural characteristics of eco-driving (Pampel *et al.* 2015; Saboohi, Farzaneh 2009; Sanguinetti *et al.* 2017) and on the main tools that can be used to diagnose it (Krishnamoorthy, Gopalakrishnan 2008), some of the biggest challenges to its implementation are related to how to promote compatible behavioural changes among drivers (Thijssen *et al.* 2014), including an exploration of demographic characteristics associated with this challenge. Furthermore, there is evidence that most drivers (including those of trucks) already have a practical knowledge of how to drive more efficiently and many tend to value environmental and resource saving goals, but that they rarely put that knowledge to practice while driving, as Lauper *et al.* (2015); Pampel *et al.* 2015; Schweitzer *et al.* (2008), have shown.

Different studies have focused on reducing fuel consumption in transportation companies through behavioural change interventions, including bus (Af Wählberg 2007; Strömberg, Karlsson 2013), van (Hari *et al.* 2012; Siero *et al.* 1989) and truck drivers (Schall *et al.* 2016; Sullman *et al.* 2015; Thijssen *et al.* 2014), and even airline pilots (Gosnell *et al.* 2016). These studies focus mainly on the effects and potential of goals and incentives (Gosnell *et al.* 2016), education and training (Schall *et al.* 2016; Sullman *et al.* 2015; Thijssen *et al.* 2014) and personalized feedback technologies (Gilman *et al.* 2015; Harvey *et al.* 2013; Joo, Lee 2014; McIlroy *et al.* 2017; Vaezipour *et al.* 2015; Vagg *et al.* 2013) to reduce fuel consumption.

In line with this body of literature, transportation companies often apply different methods to try to influence drivers in order to decrease the incidence of behaviours that are related to safety and efficiency concerns, such as speed excess and sudden braking and acceleration (Farmer *et al.* 2010; Harbluk *et al.* 2007). These include training and re-training protocols, direct incentives or penalties to the best/worst drivers, and feedback and control mechanisms based on technological sensors and devices that measure performance (Bristow *et al.* 2008; Gosnell *et al.* 2016; Walnum, Simonsen 2015). Nevertheless, these

initiatives are often based on opportunistic or incidental reasons rather than on a systematic analysis of the specific determinants that influence their drivers' behaviour, which can lead to ineffective or inefficient interventions. As our paper aims to demonstrate, exploring in a more integral manner the current physical, psychological and social determinants that influence driver's activity can help to better focus scarce intervention resources and increase their chances of success. Installation Theory provides such a framework.

## 2. Theory

### 2.1. Installation Theory and behavioural change

Installation Theory (Lahlou 2009, 2015, 2018) is a framework that emerged from decades of empirical research into human behaviour and activity in local settings (especially those related to work) and that explores the mechanisms that complex societies rely on to produce expected behaviours among millions of people in millions of different local contexts. According to Installation Theory, the world around us is made of installations, which are "[...] specific, local, societal settings where humans are expected to behave in a predictable way [...]" (Lahlou 2018). Classrooms, restaurants, or the cabin of a truck are all examples of installations, that can be understood "[...] in the artistic sense of assembling patterns in space and time to modify the way we experience this situation [...]" (Lahlou 2015). In turn, the way the situation is experienced by the subject channels them into behaving in the "appropriate" way: something we can witness for most behaviours in everyday life. Installation Theory describes in detail how this behavioural compliance is obtained.

Each installation is composed of three layers that come together locally to channel activity: the material physical environment (physical layer), the embodied interpretive systems (psychological layer) and social regulation (social layer). Together, the three layers support at the point of delivery of behaviour, the process through which "[...] individual needs, desires and will combine with the reality of the context to produce a behavioural outcome [...]" (Lahlou 2018). Since behaviours are determined locally together by the three layers, the interventions that seek to transform those behaviours cannot expect strong and durable effects by modifying only one of the layers. Unfortunately, this is the case with many interventions: they focus partially on the physical, such as design-centered approaches and certain nudging techniques (Sunstein 2016), on the psychological (such as training programs and those based on attitudes and beliefs only (Ajzen, Fishbein 1980; De Leeuw et al. 2014) or on the social layer, such as many of the social norm interventions that are limited to providing normative information and/or feedback (Miller, Prentice 2013). Others focus on limited aspects of these layers, or ignore their local and situated dimensions altogether to concentrate on indirect interventions (Yamin et al. 2019).

Installation Theory also includes a general framework to analyse and redesign installations in order to achieve

sustainable behavioural changes. SEBE (Lahlou et al. 2015b) is a technique that is especially suited to collect this kind of information. Users (here: drivers) wear at eye level (on glasses) a miniature camera as they operate. These FPP recordings are reviewed in RIW, where users, with their memory aided by the recording, are able to explain in great detail their decisions and experience; and especially why exactly they behaved how they did. These elements can be used to redesign the three layers of the installation in order to produce the desired behaviour, "taking into account opportunity windows and costs, but also the potential undesired effects, which each level of intervention may bring along" (Lahlou 2018). The power of SEBE resides in the outstanding quality of self-analysis enabled by the technique, which goes into minute details. This technique has produced spectacular results in other domains (Franks et al. 2017).

### 2.2. Context, diagnostics and intervention design

In order to test the efficacy of the Installation Theory framework to analyse and design cost-effective interventions to influence driving behaviours and fuel efficiency, we chose a medium-sized road transportation company in Colombia. Employing around 220 drivers full-time, the company specializes in the transportation of heavy cargo to and from the port of Buenaventura, one of the major commercial ports in the country. The roads the company uses to access the port from the company's headquarters and from the capital of the country consist of steep mountains (going from sea level to 1000 MASL in the 120 km between the port and company headquarters, and then from there to a road that alternates between 500 and 3250 MASL in 450 km). The company fleet consists mostly of *International Eagle 9400* and *Kenworth T800* truck trailers (models 2013 with *Cummins ISX435* diesel engines and 2015 with *Cummins ISX450* diesel engines respectively, and alternating *Randon* and *Great Dane* 3-axis trailers with a maximum load of 34 tones). Being one of the main cost drivers of the company, the fuel consumption of each individual truck and driver is closely monitored on a monthly basis.

Designing an effective and cost-efficient behavioural change intervention requires an analysis of the main physical, psychological and social local determinants of behaviour that are relevant for the activity of interest (driving). Because of this, a diagnostic of the intervention context was conducted using the SEBE method described above. FPP videos and detailed RIW were conducted with five drivers, totalling 2 h 29 min of FPP and 2 h 40 min of RIW footage. As argued by Lahlou (2011), relatively small samples such as these are often enough in the SEBE method to collect relevant qualitative data. SEBE showed the potential impact of the family as a motive for safety, rather than the external financial incentives used by the company, the existence of some classic expressions related to driving culture (see below: the flip-flop), and a series of motivating elements that could be used for persuasion. In-

stallation Theory showed that the social layer was under-used while it could have great impact and pointed towards a social norm intervention, as well as the necessity to design an intervention that would remind the norm at the point of delivery, in the driving cabin. Several possibilities were considered (e.g., radio, technical prompt based on telemetries...), and the choice (below) was made on the rationale of being cheap and simple.

Detailed interviews were also conducted with the Chief Executive Officer of the company, as well as with managers

and employees of the operations, security, purchases and maintenance areas. Demographic, fuel consumption and driving behaviour data were also collected. The main diagnostic dimensions and insights are presented in Table 1, which details relevant driver demographics, behavioural trends, current company initiatives to influence driving behaviours, and main determinants of driving behaviours according to participants.

After identifying some of the main physical, psychological and social affordances that support current activi-

Table 1. Diagnostic dimensions and main insights

Diagnostic dimension	Main insights						
Driver demographics	At the start of the interventions, drivers in the company: <ul style="list-style-type: none"> <li>– were all male, with most (66%) aged between 31 and 45 years and having worked in the company for 2 years or less (67%);</li> <li>– without related professional education. The company does not require previous experience or specialized training, just the relevant driving license, which is expensive but not difficult to get in Colombia</li> </ul>						
Current company initiatives to influence driving behaviours	<ul style="list-style-type: none"> <li>– incoming drivers undergo a 2 week full-time driving and mechanics training;</li> <li>– re-training sessions are held once or twice a month and typically last 4...8 h each;</li> <li>– drivers are only allowed to re-fuel in the company-owned or pre-approved fuel stations, and special plastic seals are installed in tanks to prevent fuel theft;</li> <li>– a telematics device that measures and reports in real time to the company the local of each vehicle and certain driving parameters. Specifically, it records and produces an auditory alert when the driver exceeds pre-set speed excess, acceleration and braking parameters (of 80 km/h, 0.29·g and -0.47·g, respectively, where g is gravitational acceleration);</li> <li>– the number of DPAs that each driver receives are stored by the company and combined with reports from different areas of the company (i.e., accounts, maintenance, etc.) to calculate a personal rating. Each month, the best drivers get a certificate and a gift card to buy clothes and other household items;</li> <li>– drivers that exceed a certain number of DPAs per week are assigned an expert driving instructor, who accompanies them and provides feedback in 1...2 long trips</li> </ul>						
Local determinants of driving behaviours:	The most important physical, psychological and social determinants of driving behaviours for participants can be described as: <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td data-bbox="189 1272 397 1389">Physical</td> <td data-bbox="405 1272 1422 1389"> <ul style="list-style-type: none"> <li>– internal (controls to operate the truck, mirrors to augment the field of vision, music to avoid boredom and sleepiness, and personal decorations to make the truck feel like a second home);</li> <li>– external (outside mechanics of the truck, road environment and traffic signs and information, other road users);</li> </ul> </td> </tr> <tr> <td data-bbox="189 1400 397 1655">Psychological</td> <td data-bbox="405 1400 1422 1655"> <ul style="list-style-type: none"> <li>– formal and informal training and education: drivers seem somewhat influenced by formal company training, but their main skills and knowledge comes from learning to drive trucks informally with their families and friends (most come from trucker families);</li> <li>– drivers rely strongly on their acquired habits and skills, which is much more valued than new information or formal instructions;</li> <li>– drivers display a very detailed technical knowledge of the truck and fuel saving but have different and often contradictory versions of what works;</li> <li>– avoiding tiredness and distractions is an important source of anxiety for drivers, with many anecdotes about accidents showing its importance;</li> </ul> </td> </tr> <tr> <td data-bbox="189 1666 397 1991">Social</td> <td data-bbox="405 1666 1422 1991"> <ul style="list-style-type: none"> <li>– national traffic laws and company regulations are enforced regularly by the police and company's security area;</li> <li>– drivers rarely interact with each other, except when charging and discharging trucks in some locations and through small <i>WhatsApp</i> groups, which they use to inform of traffic conditions and communicate informally;</li> <li>– drivers rarely speak, and do not have much information about how their own driving behaviour and fuel consumption compare to the rest of the company (descriptive norms). For many, the company is seen as only caring about saving money on their expense, so spending more fuel than necessary and theft are seen as justifiable;</li> <li>– when making driving and work decisions, important considerations for drivers include their families, the opinions they get from other drivers, which are very limited, and their perceived status among other drivers</li> </ul> </td> </tr> </table>	Physical	<ul style="list-style-type: none"> <li>– internal (controls to operate the truck, mirrors to augment the field of vision, music to avoid boredom and sleepiness, and personal decorations to make the truck feel like a second home);</li> <li>– external (outside mechanics of the truck, road environment and traffic signs and information, other road users);</li> </ul>	Psychological	<ul style="list-style-type: none"> <li>– formal and informal training and education: drivers seem somewhat influenced by formal company training, but their main skills and knowledge comes from learning to drive trucks informally with their families and friends (most come from trucker families);</li> <li>– drivers rely strongly on their acquired habits and skills, which is much more valued than new information or formal instructions;</li> <li>– drivers display a very detailed technical knowledge of the truck and fuel saving but have different and often contradictory versions of what works;</li> <li>– avoiding tiredness and distractions is an important source of anxiety for drivers, with many anecdotes about accidents showing its importance;</li> </ul>	Social	<ul style="list-style-type: none"> <li>– national traffic laws and company regulations are enforced regularly by the police and company's security area;</li> <li>– drivers rarely interact with each other, except when charging and discharging trucks in some locations and through small <i>WhatsApp</i> groups, which they use to inform of traffic conditions and communicate informally;</li> <li>– drivers rarely speak, and do not have much information about how their own driving behaviour and fuel consumption compare to the rest of the company (descriptive norms). For many, the company is seen as only caring about saving money on their expense, so spending more fuel than necessary and theft are seen as justifiable;</li> <li>– when making driving and work decisions, important considerations for drivers include their families, the opinions they get from other drivers, which are very limited, and their perceived status among other drivers</li> </ul>
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ties, the Installation Theory framework allows for interventions to be “[...] opportunistic and target what seems the easiest layer to work on considering the available resources and the agency of the change agent [...]” (Lahlou 2018). This is because the same target behaviour can be supported by several layers at a time (and each layer can take different configurations), but interventions will generally achieve much better effectiveness and sustainability in time with close support and control by the three layers simultaneously (Lahlou 2018; Lahlou et al. 2015a). That is because the redundancy of the layers makes the installations resilient.

In this case, we detected a shortcoming on the social layer of installations that could complement the current initiatives of the company, which were largely focused on the physical and psychological aspects. Specifically, while drivers reported that some regulations by the company exist on driving behaviours and fuel consumption, they were not aware of how their own consumption compares to that of their peers. But what is more, they also believed that their peers judged negatively those that saved fuel (because it made the others look bad and you’re only helping the company and not yourself). These elements are part of the concept of social norms (Legros, Cislighi 2020; Tankard, Paluck 2016; Bicchieri 2017), which are a popular behavioural change intervention method in the academic literature (Miller, Prentice 2016; Paluck 2009; Yamin et al. 2019), but which, as the Installation Theory framework, has rarely been applied to driving behaviors and fuel efficiency problems.

Social norm interventions are based on changing the perceptions that people have about how typical (how many people do or do not do something) and desirable (how many people think it is acceptable or not to do something) behaviours are for a reference group in certain situations. Recent reviews have shown how behavioural change interventions based on social norms have been effective to transform the behavior of people in a wide variety of contexts and for a wide variety of target behaviours (Darnton 2008; John et al. 2014; Yamin et al. 2019). Indeed, social norms produce influence and group pressure.

Previous research on the topic suggests that important dimensions of these interventions include (Yamin et al. 2019):

- the context where the intervention was applied relative to where the target behaviour happens (with *remote* interventions being applied away from that context and *in-situ* interventions being applied in it);
- the type of normative information given (with *group summary information* consisting of messages, usually percentages, that describe the perceptions and behaviour of a group, and *exposure to behaviours and opinions* in which people see or hear other people).

Based on this framework, we decided to test the effects of two configurations that are popular in the social norm intervention literature:

- GSI(R) – one based on giving people summary information about how their own behaviour compares to that of others, away from the context where the

behaviour happens – a *Remote Group Summary Information* intervention, specifically using the *Personalized Normative Feedback* method (Miller, Prentice 2016). In our study, this was done by distributing cards to each driver in the company headquarters with information on their own fuel consumption and how it compared to the company’s average;

- EBO(R/I) – another based on exposing people to the behaviours and opinions of others, both away and in the context where the target behaviour happens – a *Remote and In-situ Exposure to Behaviours and Opinions* intervention. In our study, this was done through a workshop in which drivers watched a 4-minute video in the company headquarters (*remote*), and then received some campaign materials to decorate their trucks (*in-situ* keychains and small cabin decoration). The delivery of the information involved theatrical elements easily remembered, which the decoration used as a reminding cue.

While often used interchangeably, these two types of interventions respond to different assumptions about human behaviour, social influence, and behavioural change. An important gap in the social norm literature relates to exploring the differential effects on behaviour that each type of intervention can achieve in different intervention contexts (Bergquist et al. 2019; Tankard, Paluck 2016; Yamin et al. 2019). We present here two case studies, which were successive attempts to design the most effective intervention.

Case Study 1 compares remote and in-situ interventions. Case Study 2 combines both interventions in an attempt to increase effect and its durability.

### 3. Case Study 1

#### 3.1. Research methods and experimental design for Case Study 1

Therefore, following the results of the diagnostics of the context, we applied a first study to test whether a social norm intervention that addressed the social layer of installations could be effective to reduce further fuel consumption and problematic behaviours. Following previous research about intervention dimensions in social norm interventions (Tankard, Paluck 2016; Yamin et al. 2019), we aimed to test whether interventions addressing the social layer of installations would be more effective in this context by including GSI(R) or EBO(R/I). While we are aware that our design is not fit to test the discrete influence of psychological factors, our aim here was to test the cost-effectiveness and practical viability of this method of intervention for the road transportation industry. Our focus is on testing realistically two variants of a specific method of intervention design in a particular industry, rather than clear-cut and simple interventions that allow to isolate psychological confounds in laboratory.

Taking all this into account, our first study aimed to test the following hypotheses:

- H1.1 – by addressing the social layer of installations, a GSI(R) intervention will significantly reduce average fuel consumption;
- H1.2 – by addressing the social layer of installations, an EBO(R/I) intervention will significantly reduce average fuel consumption;
- H1.3 – by being applied closer to the target installation and using interactions rather than “argument-based” messages, an EBO(R/I) intervention will be more effective to reduce average fuel consumption than a GSI(R) intervention;
- H1.4 – by being applied only a single time (i.e. each participant will be exposed to the interventions on one occasion), the effects of both GSI(R) and EBO(R/I) interventions will fade over time.

### 3.1.1. Participants and procedure

A total of 138 drivers of the company above successfully completed the first study (with 83 in treatment conditions and 55 in control). During the time of the study, the regular training, incentive, control and feedback procedures of the company described above continued to be applied to all drivers, which were randomly assigned to one of three conditions:

- *Intervention control.* Drivers that were not selected for treatment conditions 1 or 2 were included in the control group and did not receive any communication or information on our part ( $n = 55$ ). Rather than a no-intervention, this condition includes the drivers that only received the regular procedures implemented by the company. Because treatments 1 and 2 were not applied in the same time periods (Figure 1), and because our analysis required the exclusion of participants that had missing data periods (see data analysis below), the number of drivers selected for control measures was different for each of the treatments ( $n = 43$  for GSI(R) and  $n = 42$  for EBO(R/I), respectively);
- *Treatment 1* (GSI(R) intervention). Remote group summary information ( $n = 36$ ). Drivers in this condition received a small business card with their own consumption for the last month compared to the company’s average. In order to increase retention of

the card, we included a calendar with some of the most popular festivals in the country behind it. The cost factored in this intervention included printing the cards and the time necessary to design and distribute them (as the company already had the information required), and amounted to €70;

- *Treatment 2* (EBO(R/I) intervention). Direct/remote exposure to behaviours and opinions ( $n = 39$ ). When stopping at the company headquarters, drivers in this condition attended a 10 min session in which they watched a 4 min video and received a keychain and decoration for their truck. To make it appealing and engaging like previous successful interventions (Mockus 2002; Yamin 2015), the intervention was based on a popular saying that emerged from the RIW interviews above. In Colombia, “giving the flip-flop” (*darle chanqueta*) to a car means accelerating and generally driving fast. The intervention asked drivers to “reduce the flip-flop” (*bajele a la chanqueta*, i.e. accelerating less and driving more calmly). The video displays a few of the company’s drivers in their trucks asking others to “reduce the flip-flop” (Figure 1 – a subtitled video version can be accessed here: <https://youtu.be/wylYeNZWpSQ>).

After the video, drivers received a flip-flop keyring and a flip-flop decoration to hang in their truck. The cost of this intervention included the production of the video, the keyrings and decorations, and the work time required to produce the materials and implement the workshop, and amounted to €300.

Figure 2 presents the intervention procedures for this study.

### 3.1.2. Measures and analysis

In order to test the hypotheses defined for this study, we collected an outcome measure related to the average monthly fuel consumption per driver. This was measured in [km/US gal] by the company using the total distance covered by each truck and the total fuel supplied to it in a given month (that is, the number of km travelled with one US gallon of fuel). The data was collected to build baseline, which because of monthly averages were calculated from the average of the two months prior to the intervention,

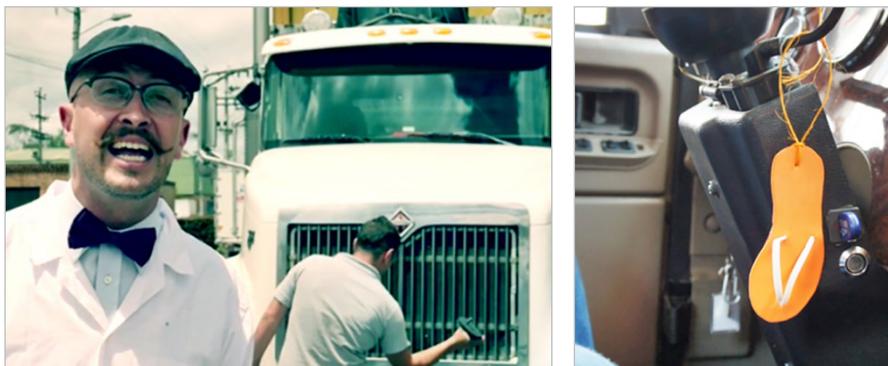


Figure 1. The EBO(R/I) intervention (a subtitled video version can be accessed here: <https://youtu.be/wylYeNZWpSQ>)

		2018							
		June	July	August	September	October	November	December	
Treatments	GSI(R) intervention (treatment 1)								
	Baseline (2 month average)			Application			Month 1 post-test	Month 2 post-test	Month 3 post-test
	EBO(R/I) intervention (treatment 2)								
	Baseline (2 month average)			Application			Month 1 post-test	Month 2 post-test	Month 3 post-test
Controls	Control for GSI(R)								
	Baseline (2 month average)			GSI(R) application period			Month 1 post-test	Month 2 post-test	Month 3 post-test
	Control for EBO(R/I)								
	Baseline (2 month average)			EBO(R/I) application period			Month 1 post-test	Month 2 post-test	Month 3 post-test

Figure 2. Intervention procedures for Case Study 1

and post-test measures (at 1, 2 and 3 months after the intervention was over – Figure 2), which were then analysed to test for significant differences. Because data was only available as monthly averages and because considerable logistic difficulties meant interventions took some time to be delivered to all participating drivers, we did not take into account “application” periods in the analysis.

As for the analysis of the data, we checked for normal distribution and applied paired  $t$ -tests and difference-in-differences technique. To define the data distribution law empirical skewness and kurtosis of the datasets were compared with critical values depending on the size of the sample only. The critical value of skewness  $s_{sk}$  was calculated using method proposed by Sivilevičius *et al.* (2017) and Sivilevičius, Vansauskas (2013):

$$s_{sk} = \sqrt{\frac{6 \cdot n \cdot (n-1)}{(n-2) \cdot (n-1) \cdot (n+3)}}, \quad (1)$$

where:  $n$  is the sample size.

The critical value of kurtosis  $s_{ku}$  was calculated (Sivilevičius *et al.* 2017; Sivilevičius, Vansauskas 2013):

$$s_{ku} = \sqrt{\frac{24 \cdot n \cdot (n-1)^2}{(n-3) \cdot (n-2) \cdot (n+3) \cdot (n+5)}}. \quad (2)$$

It is known that distribution law is normal if the conditions  $|sk| \leq 3 \cdot s_{sk}$  and  $|ku| \leq 5 \cdot s_{ku}$  are true (Sivilevičius *et al.* 2017; Sivilevičius, Vansauskas 2013), where  $sk$  is skewness and  $ku$  is kurtosis, both of them are calculated using empirical data. Mean values and standard deviations of distance travelled with one gallon of fuel (km/US gal) in all the groups were calculated. If the mean value was outside the confidence interval  $\pm 3 \cdot \sigma$  it was not taken into account, here  $\sigma$  is the standard deviation. There were 14 data samples in 3 cases out of 6 in which such data was outside the confidence interval, for a total number of samples of 247. Exceptions were eliminated from the data after research, as it turned out the deviation from the

mean represented the effect of changes in the driving route (strong variability in MASL) rather than the influence of intervention, and thus cannot be considered as a relevant comparison. After these quality control procedures, it was found that the rest of the data in 6 cases is distributed according to the normal law. That means that a Student's  $t$ -test can be used to understand whether the difference in means within the same group is significant and to understand whether the intervention was effective. There are three types of  $t$ -test that can be used when data distribution law is normal: variance of two samples is equal; the variance is unequal, and samples are paired. In the case under investigation paired type of  $t$ -test was used, the same drivers were investigated, just at a different point in time (before/after). To make it possible sample size should be equal. For the investigation only drivers who had fuel consumption data recorded for all the months that the experiment lasted were taken into account, which allows to track each individual accurately and control for individual differences. Unfortunately, due to the high driver rotation of the company, this was translated into an attrition rate of around 35% for both control and intervention groups.

### 3.2. Results for Case Study 1

#### 3.2.1. Hypotheses H1.1, H1.2 and H1.3: effectiveness of interventions for fuel saving relative to control

As discussed in the methodology, average fuel consumptions of drivers in the intervention groups was collected to test the effects of interventions, measured in [km/US gal]. The first three hypotheses (H1.1, H1.2 and H1.3) were posed to test whether our GSI(R) and EBO(R/I) would significantly reduce fuel consumption compared to control groups, which were only receiving the usual fuel saving program of the company, and which one of the two would produce larger effects. Figure 3 present the average distances travelled with one gallon of fuel on periods 0 and 1 for GSI(R) and EBO(R/I) treatments.

Taking these results, a first statistical analysis was conducted to test for significant differences between baseline and month 1 values (pre-post). We did this by applying paired *t*-tests between pre and post measures in intervention and control groups. The difference can be considered significant if the calculated numerical value of *t*-test is less 0.05. Results for GSI(R) (treatment 1) from baseline ( $M = 6.13$ ,  $SD = 0.58$ ) and month 1 post-test ( $M = 6.38$ ,  $SD = 0.61$ ) indicate that interventions resulted in a significant increase in average distance travelled per US gallon (which is equivalent to a significant decrease in average monthly fuel consumption),  $t(35) = -2.544$ ,  $p = 0.016$ . As these results show, for  $n - 1$  degrees of freedom (35, where  $n$  is the sample size for the test), results show a rather large negative *t*-score of  $-2.544$ , which indicates a large difference between groups expressed through the ratio of the difference between the means of the two sets and the variation within the sets. Likewise, for EBO(R/I) (treatment 2) baseline ( $M = 6.01$ ,  $SD = 0.42$ ) and month 1 post-test ( $M = 6.15$ ,  $SD = 0.37$ ) also show a significant increase in distance travelled,  $t(38) = -2.12$ ,  $p = 0.041$ . On the other hand, differences in control conditions for both GSI(R),  $t(42) = -0.678$ ,  $p = 0.501$ , and EBO(R/I),  $t(41) = 1.082$ ,  $p = 0.286$ , were not significant. Calculations for effect sizes using Klauer’s method (Klauer 2001), which corrects for unequal standard deviations and sample sizes, yield medium effects of  $d_{Korr} = 0.439$  for GSI(R) and  $d_{Korr} = 0.458$  for EBO(R/I). According to Coe’s calculations, this means that at least 66% of the control group would be below the average driver in either of the treatment groups (Coe 2002). These results suggest that there was a significant reduction in fuel consumption in the treatment groups, but not in control ones. Table 2 summarizes these results.

Then, to study the differential effect of treatments on control groups the difference-in-differences statistical technique was applied. Results show comparable increases of about 4% for both treatments in the first month after each application (with GSI(R) = 3.92% and EBO(R/I) = 3.74%). In respect to our first hypotheses, then, these results indicate that both treatments are associated with significant reductions in fuel consumption (in line with our H1.1 and H1.2), but that both achieved comparable effects (contrary to hypothesis H1.3).

**3.2.2. Hypothesis H1.4: the duration of the effects of interventions relative to control**

Finally, our last hypothesis was designed to explore how sustainable in time the fuel savings reached by interventions GSI(R) and EBO(R/I) were. Specifically, we hypothesized that because these two interventions were applied a single time (each driver received only one card or attended only one 10-minute workshop), fuel savings would fade after over time. To test this, we analysed the average fuel consumption data for periods 2 and 3 after the intervention. Figure 4 presents the average distances travelled with one gallon of fuel on periods 0 to 3 for GSI(R) and EBO(R/I) treatments.

Results show that compared to GSI(R) baseline ( $M = 6.13$ ,  $SD = 0.58$ ), there wasn’t a significant reduction in fuel consumption (or increase in average distance travelled) for month 2 ( $M = 6.29$ ,  $SD = 0.75$ ),  $t(35) = -1.860$ ,  $p = 0.071$ , but there was for month 3 ( $M = 6.37$ ,  $SD = 0.76$ ),  $t(35) = -2.529$ ,  $p = 0.016$ . Likewise, EBO(R/I) doesn’t show significant differences between baseline ( $M = 6.01$ ,  $SD = 0.42$ ) and month 2 ( $M = 6.02$ ,  $SD = 0.43$ ),  $t(38) = -0.126$ ,  $p = 0.901$ , but they do between baseline and month 3 ( $M = 6.25$ ,  $SD = 0.54$ ),  $t(38) = -3.011$ ,  $p = 0.005$ . For both, differences between control measures

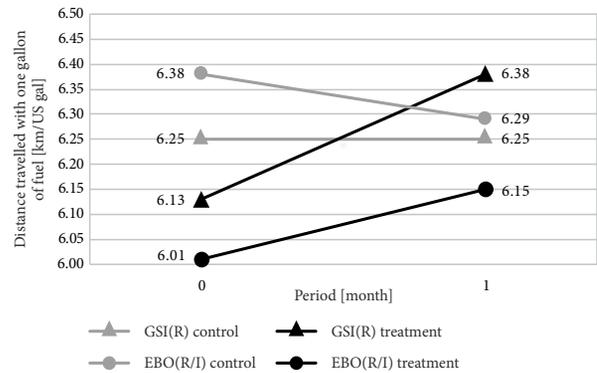


Figure 3. Distance travelled with one gallon of fuel for periods 0 (baseline) and 1 (month 1 post-test)

Table 2. Distance travelled in km with one gallon of fuel (month 1)

	GSI(R) (treatment 1)		EBO(R/I) (treatment 2)	
	Period 0	Period 1	Period 0	Period 1
Control				
Average	6.25	6.25	6.38	6.29
SD	0.49	0.58	0.53	0.51
<i>t</i> -test		0.501 (>0.05)		0.286 (>0.05)
Treatment				
Average	6.13	6.38	6.01	6.15
SD	0.58	0.61	0.42	0.37
<i>t</i> -test		0.016 (<0.05)		0.041 (<0.05)
Effect size $d_{Korr}$		0.439		0.458

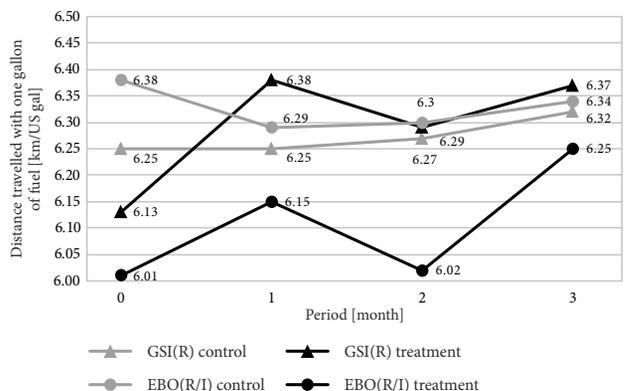


Figure 4. Distance travelled with one gallon of fuel for periods 0 (baseline) and months 1, 2 and 3

Table 3. Distance travelled in km with one gallon of fuel (months 1...3)

	GSI(R) (treatment 1)				EBO(R/I) (treatment 2)			
	Period				Period			
Control	0	1	2	3	0	1	2	3
Average	6,25	6.25	6.27	6.32	6.38	6.29	6.3	6.34
SD	0.49	0.58	0.80	0.78	0.53	0.51	0.79	0.78
<i>t</i> -test		0.501 (>0.05)	0.813 (>0.05)	0.498 (>0.05)		0.286 (>0.05)	0.509 (>0.05)	0.732 (>0.05)
Treatment	0	1	2	3	0	1	2	3
Average	6.13	6.38	6.29	6.37	6.01	6.15	6.02	6.25
SD	0.58	0.61	0.75	0.76	0.42	0.37	0.43	0.54
<i>t</i> -test		0.016 (<0.05)	0.071 (>0.05)	0.016 (<0.05)		0.041 (<0.05)	0.901 (>0.05)	0.005 (<0.05)
Effect size $d_{Korr}$		0.439	0.247	0.287		0.458	0.335	0.637

were all non-significant again. For month 3, these results yield larger effect sizes of  $d_{Korr} = 0.637$  for EBO(R/I), but rather small effects of  $d_{Korr} = 0.287$  for GSI(R). According to this, at least 76% of the control group would be below the average driver in EBO(R/I). Taking into account the tests for hypotheses H1.1, H1.2 and H1.3, we can conclude that both treatments are associated with significant reductions in fuel consumption for months 1 and 3, but not for month 2. The difference is more significant for EBO(R/I) than for GSI(R). This is because the amount of fuel reduction is more important and durable in EBO(R/I) as expected (almost twice as much on month 3). Table 3 summarizes these results.

As before, we also studied the differential effect of treatments on control groups the difference-in-differences statistical technique (Figure 5). After period 1, results show fuel savings being reduced to 1% in period 2, and then increasing again in period 3 (reaching about 2.5% savings for GSI(R) and about 4.5% savings for EBO(R/I)).

Together, these results show that while treatment effects (savings) do seem to fade in month 2 after the intervention (in line with hypothesis H1.4), significant savings in both treatment groups appear again for month 3

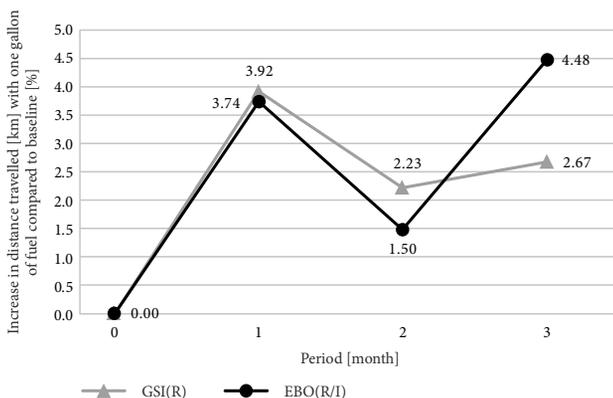


Figure 5. Increase in distance travelled with one gallon of fuel (months 1...3)

(contrary to hypothesis H1.4). They also provide additional evidence around hypothesis H1.3, which referred to finding larger savings associated with EBO(R/I) than with GSI(R). According to this data, larger effects can be associated with EBO(R/I) in month 3.

### 3.2.3. Cost-effectiveness and ROI of the interventions

We analysed the cost effectiveness of the intervention. We calculated the total cost of each intervention (including estimated person-hours required to design and apply the intervention, but not specialized behavioural consulting), which amounted to the equivalents of €70 for GSI(R) and €300 for EBO(R/I). Then, using average consumption, average distance and average fuel prices in Colombia, we estimated average savings compared with expected values of baseline tendencies.

For this particular company and these particular intervention groups (with 44 vehicles for GSI(R) and 39 vehicles for EBO(R/I)), we estimate the savings of the company at the end of month 3 at nearly 3700 US gallons of fuel (which amounts to around 14000 L) or €8500 per treatment condition (i.e. 7400 US gallons and €17000 for both). This amounts to returns on investments of 12.418% for GSI(R), and 2.821% for EBO(R/I). If applied in the whole company (rather than just the intervention groups), similar savings could amount to around 19000 US gallons of fuel (or 72000 L) and €42000. While it may appear excessive to calculate the ROI without including the consulting costs (which in this case were indeed zero for the company as the work was part of an LSE research project), the total amount of fuel savings per year (€42000) amounts to 12 times the Colombian average annual salary.

As reference for other companies, total savings in months 1...3 would amount for around 130 US gallons of fuel (around 500 L) per vehicle for 10000 km, or nearly 132000 US gallons of fuel saved for a 1000 vehicle fleet (in the same distance per vehicle). Table 4 presents the average US gallons of fuel saved per 1000 km/truck for each treatment.

Table 4. Average fuel savings in [US gal/1000 km]

Average US gallons of fuel saved, compared to baseline and control tendencies, per 1000 km/truck	Month 1	Month 2	Month 3	Total savings months 1...3
GSI(R) (treatment 1)	5.28	2.64	5.28	13.20
EBO(R/I) (treatment 2)	5.28	2.64	7.93	15.85

## 4. Case Study 2

### 4.1. Research methods and experimental design for Case Study 2

After analysing the results of Case Study 1, we decided to conduct a second study in order to test whether a more integral intervention (using relevant elements from both GSI(R) and EBO(R/I) combined) in which participants were exposed to intervention messages on more occasions could increase the magnitude and duration of the effects. To do this, we designed a single intervention condition with several components to test the following hypotheses:

- H2.1 – by addressing the social layer of installations with elements from previous GSI(R) and EBO(R/I) combined, the intervention will significantly reduce fuel consumption and problematic driving behaviours compared to control;
- H2.2 – by including continuous feedback and periodic messages, the effects of the intervention will remain significant for longer than those in Case Study 1 compared to control.

#### 4.1.1. Participants and procedure

Nine months after the interventions in Case Study 1 had taken place, a total of 73 drivers of the company took part in the second study (100% male). Once again, the regular training, incentive, control and feedback company procedures continued to be applied to all drivers, which were assigned randomly to the following two conditions:

- intervention control ( $n = 47$ ). Drivers that were not selected for treatment 3 did not receive any communication or information on our part;
- treatment 3 (GSI+EBO(R/I) intervention) ( $n = 26$ ). Integral intervention including both GSI(R) and EBO(R/I), as well as continuous driving feedback and messages linked to the intervention. The same flip-flop concept and video were used. This time, selected drivers attended a 15 min session in which they watched the 4 min video of actual drivers of the company (with a few modifications to include new materials).

But then, this was also complemented with:

- a short discussion about why it was important to “reduce the flip-flop” and what everyday actions could help achieve it;
- a technological device installed in selected drivers’ truck, the *LightBox 1*, which was specifically created for this intervention by us using the open-source Arduino language. It consisted of a small plastic box that would flash 6 red LED lights around a flip-flop

and a “reduce the flip-flop message” when drivers would accelerate suddenly. The hardware consisted of an *Arduino Uno* board and GY-521 accelerometer-gyroscope connected to 6 LED lights (Figure 6);

- SMS messages sent to drivers’ mobile phones 4, 7 and 9 weeks after the video sessions including how each driver’s consumption in the last month compared to the company’s average (as in GSI(R)) as well as promotional messages linked to the flip-flop concept (e.g., a popular song with lyrics transformed to “I want to see you reduce the flip-flop”).



Figure 6. The *LightBox 1*

#### 4.1.2. Measures and analysis

In order to test the hypotheses defined for this study, we collected average fuel consumption information as before. However, in order to test whether we could identify more direct effects on driving behaviours as well, we collected data on the DPAs that are ordinarily registered for each individual driver by the telematics devices used by the company. Consequently, our outcome measures consisted in:

- average monthly fuel consumption per driver measured in [km/US gal] (see Case Study 1);
- average DPAs associated with number of speed excesses, sudden accelerations and sudden braking event per 10000 km. The data was collected from the telematics devices that draws the data in real time from each truck computer and assigns it to specific drivers.

As before, baselines (two-month averages) and post-test measures (at 1, 2 and 3 months after the intervention) were collected. Figure 7 presents the details about how the two interventions were applied and measured.

For the analysis, the same procedures as for Case Study 1 were used. Average fuel consumption data was once again found to be normally distributed, with 11 cases not being taken into account for being outside the confidence interval  $\pm 3 \cdot \sigma$  (once again, because deviation from the mean represents the effect of changes in the driving route rather than the influence of intervention and cannot be considered as reliable). Nevertheless, average DPA data was not found to be normally distributed (see results below).

2019				
April	May	June	July	August
GSI+EBO(R/I) (treatments 3)				
Baseline (2 month average)		Month 1 post-test	Month 2 post-test	Month 3 post-test
		Quick application		
Control				
Baseline (2 month average)		Month 1 post-test	Month 2 post-test	Month 3 post-test

Figure 7. Intervention procedures for Case Study 2

## 4.2. Results for Case Study 2

### 4.2.1. Hypothesis H2.1: effectiveness of intervention for fuel saving and reduction of problematic behaviours relative to control

In the same way as in Case Study 1, average fuel consumption data was used to test the effects of the intervention. *t*-test results from the baseline ( $M = 5.75$ ,  $SD = 0.39$ ) and month 1 post-test ( $M = 5.91$ ,  $SD = 0.45$ ) indicate that interventions resulted in a statistically significant decrease in average monthly fuel consumption (or increase in average distance travelled with one US gallon of fuel),  $t(25) = -2.623$ ,  $p = 0.015$ . On the other hand, differences in the control condition were not significant,  $t(46) = 0.853$ ,  $p = 0.398$ . These results yield medium effect sizes of  $d_{Korr} = 0.551$ . According to this, at least 69% of the control group would be below the average driver in either of the treatment groups. As before, results suggest that there was a significant reduction in average fuel consumption in the treatment group, but not in control one. Table 5 summarizes these results.

Then, the difference-in-differences statistical technique was applied again to explore the differential effect of treatments on control groups (Figure 7). Results here show once again increases in km travelled with one gallon of fuel of around 4%, which are comparable to the ones achieved in Case Study 1. In respect to average fuel consumption, then, results indicate that the GSI+EBO(R/I) intervention is associated with significant reductions in fuel consumption, and that this reduction is comparable to the one achieved in Case Study 1.

As for DPAs, speed excesses, sudden acceleration and sudden braking events were also analysed. Results show that unlike average fuel consumption, DPAs data is not normally distributed and looks like a log-normal distribution. The majority of drivers registered 0 events during the research. Results are summarized in Table 6, Figures 8 and 9 are summarized data distribution.

Following these results, we decided to investigate whether the speed excess, sudden braking and sudden acceleration data correlates with fuel consumptions. By doing this, we should have found a negative correlation: the less DPAs you receive, the more distance you will be able to travel per each gallon of fuel. Nevertheless, results show that in all the cases when averages of the group were taken into account the value of correlation coefficients were

Table 5. Distance travelled in km with one gallon of fuel (month 1)

	GSI+EBO(R/I) (treatment 3)	
	Period	
Control	0	1
Average	5.8	5.74
SD	0.37	0.38
<i>t</i> -test	-	0.398 (>0.05)
Treatment	0	1
Average	5.75	5.91
SD	0.39	0.45
<i>t</i> -test	-	0.015 (<0.05)
Effect size $d_{Korr}$	-	0.551

Table 6. DPAs for Case Study 2

		Control				GSI+EBO(R/I) (treatment 3)			
		Period				Period			
		0	1	2	3	0	1	2	3
Distance travelled with one gallon of fuel [km]	Average	5.80	5.74	5.61	5.82	5.75	5.91	5.63	5.92
	SD	0.37	0.38	0.48	0.38	0.39	0.45	0.49	0.43
Sudden braking [events]	Average	0.55	0.40	0.39	0.50	0.82	0.65	0.39	1.68
	SD	0.93	0.64	0.64	0.77	1.80	0.87	0.57	1.90
Speed excesses [events]	Average	0.85	0.52	0.36	0.91	0.74	0.63	0.38	1.55
	SD	1.80	1.20	0.70	1.84	1.81	0.88	0.57	1.91
Sudden acceleration [events]	Average	0.88	0.67	0.80	0.78	0.59	0.58	0.61	0.81
	SD	0.86	0.57	0.59	0.65	0.41	0.42	0.49	0.58

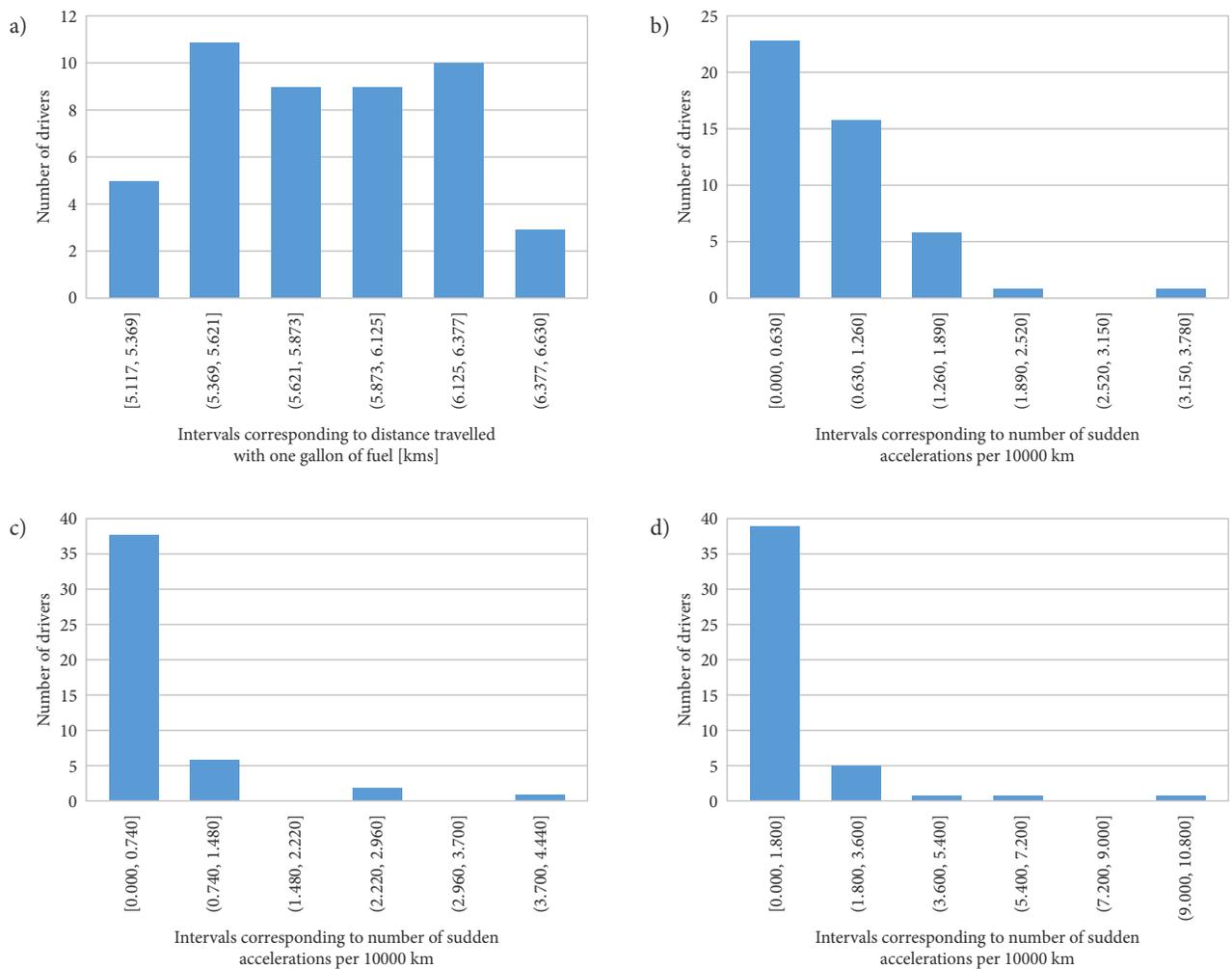


Figure 8. Data distribution for GSI+EBO(R/I) control group: a – distance travelled with one gallon of fuel; b – sudden accelerations [events/10000 km]; c– sudden braking [events/10000 km]; d – speed excesses [events/10000 km]

positive (Table 7). Such results are not appropriate, this means that thresholds of data loggers used during the investigation should be reset in such a way that data distribution law would be normal.

In Table 8, we compared the correlation coefficients of distance travelled and the other measures for each driver (not just averages as in Table 7). It can be seen that in many cases value of correlation coefficient is negative, as it should be. However, absolute values are small, so it means that there is no linear correlation between these two parameters.

In this sense, our results show that these DPAs, at least in the way they are collected and analysed in this particular company, which uses the device manufacturer’s factory settings, are not appropriate to evaluate fuel consumption savings.

#### 4.2.2. Hypothesis H2.2: the duration of the effects of interventions relative to control

As for Case Study 1, average fuel consumption data for months 2 and 3 after the intervention was also analysed to explore how sustainable in time the savings were after the GSI+EBO(R/I) intervention. Following a similar trend

than in Case Study 1, data shows that after the reductions on month 1 after the intervention, mean fuel consumption increased again for month 2 (and was higher than baseline level), but showed fuel savings again for month 3. Consequently, results show that compared to baseline ( $M = 5.75$ ,  $SD = 0.39$ ), there wasn’t a significant change in fuel consumption for month 2 ( $M = 5.63$ ,  $SD = 0.49$ ),  $t(25) = 1.369$ ,  $p = 0.183$ , but there was a significant reduction in consumption for month 3 ( $M = 5.92$ ,  $SD = 0.43$ ),  $t(25) = -2.644$ ,  $p = 0.014$ . Differences between control measures were significant for month 2 ( $M = 5.61$ ,  $SD = 0.48$ ),  $t(46) = 3.131$ ,  $p = 0.003$ , and significant for month 3 ( $M = 5.82$ ,  $SD = 0.38$ ),  $t(46) = -0.366$ ,  $p = 0.716$ . For month 3, these results yield small effect sizes of  $d_{Korr} = 0.384$ . According to this, only at least 62% of the control group would be below the average driver in the treatment. Table 9 summarizes these results.

And then, as before, we studied the differential effects on treatment on control groups through the difference-in-differences statistical technique (Figure 10). Results show saving for both months in a trend that is similar to that of Case Study 1, reaching around 1% for month 2 and around 2.5% for month 3.

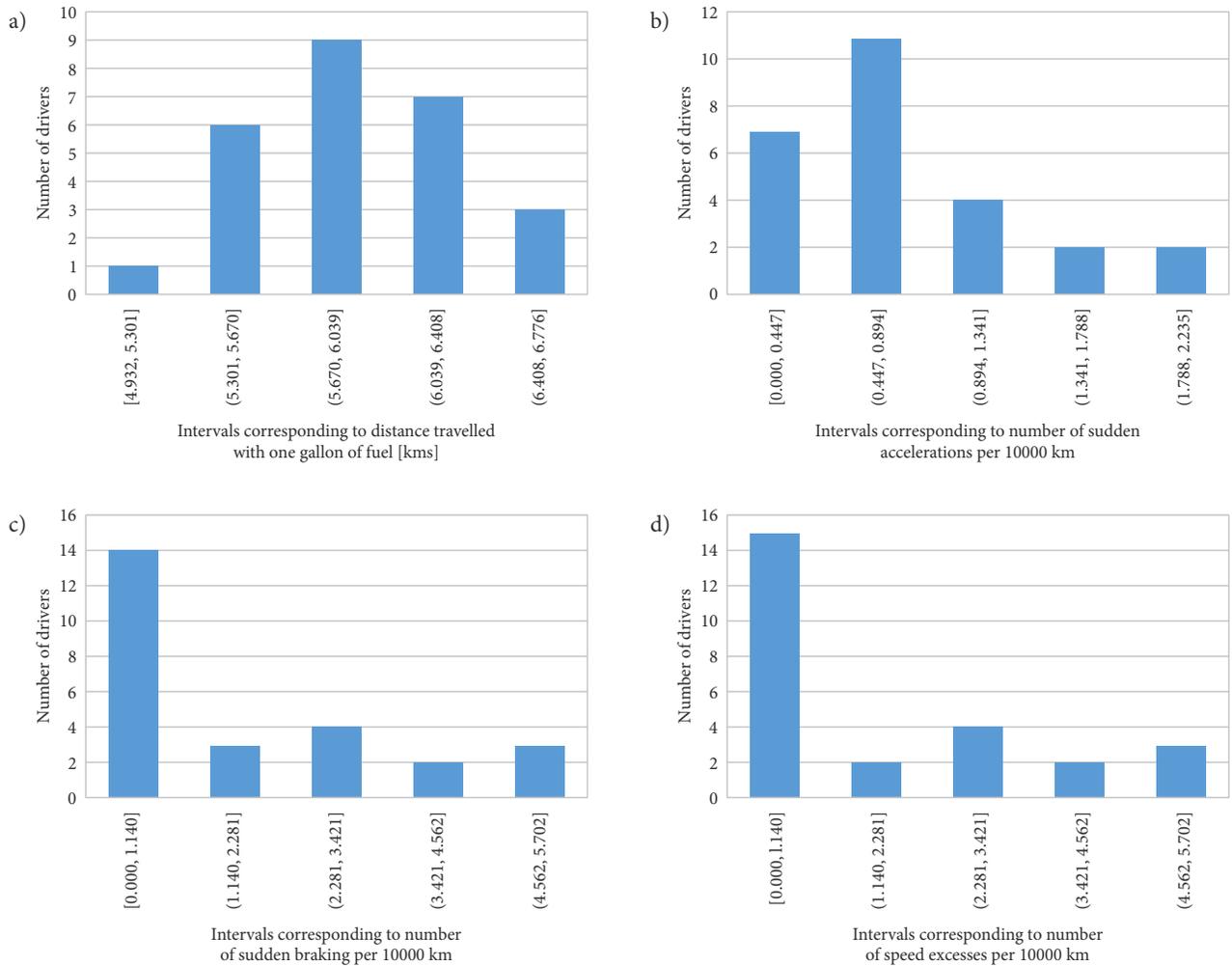


Figure 9. Data distribution for GSI+EBO(R/I) treatment group: a – distance travelled with one gallon of fuel; b – sudden accelerations [events/10000 km]; c – sudden braking [events/10000 km]; d – speed excesses [events/10000 km]

Table 7. Case Study 2, correlation of average values

Period	Control				GSI+EBO(R/I) (treatment 3)			
	Distance travelled [km/US gal]	Acceleration [events]	braking [events]	Speed [events]	Distance travelled [km/US gal]	Acceleration [events]	braking [events]	Speed [events]
0	5.80	0.88	0.55	0.85	5.75	0.59	0.82	0.74
1	5.74	0.67	0.4	0.52	5.91	0.58	0.65	0.63
2	5.61	0.80	0.39	0.36	5.63	0.61	0.39	0.38
3	5.82	0.78	0.5	0.92	5.92	0.81	1.62	1.55
Correlation coefficient	–	0.07	0.79	0.93	–	0.45	0.66	0.67

Table 8. Case Study 2, correlation of all drivers' metrics

Period	Control			GSI+EBO(R/I) (treatment 3)		
	Correlation coefficient			Correlation coefficient		
	Distance travelled to acceleration	Distance travelled to break	Distance travelled to speed	Distance travelled to acceleration	Distance travelled to break	Distance travelled to speed
0	0.146	0.049	-0.116	0.046	0.258	0.239
1	-0.123	0.257	0.087	-0.057	-0.263	-0.300
2	-0.079	0.057	-0.011	0.293	-0.043	-0.048
3	-0.141	0.018	-0.328	0.326	-0.200	-0.234

Table 9. Distance travelled in km with one gallon of fuel (months 0...3)

	GSI+EBO(R/I) (treatment 3)			
	Period			
Control	0	1	2	3
Average	5.80	5.74	5.61	5.82
SD	0.37	0.38	0.48	0.38
<i>t</i> -test		0.398	0.003	0.716
Treatment	0	1	2	3
Average	5.75	5.91	5.63	5.92
SD	0.39	0.45	0.49	0.43
<i>t</i> -test		0.015	0.183	0.014
Effect size $d_{Korr}$		0.551	0.174	0.384

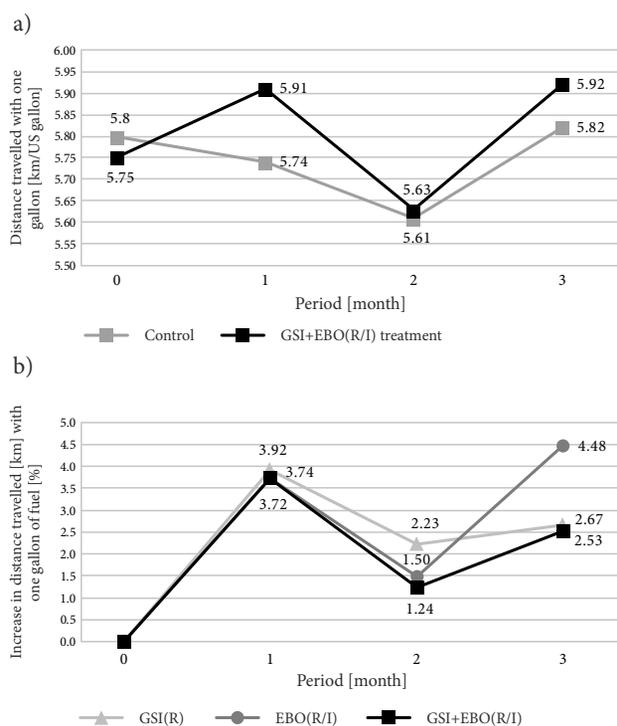


Figure 10. Distance travelled with one gallon of fuel (months 0...3): a – GSI+EBO(R/I); b – effect of the interventions in Case Studies 1 and 2

According to this, our results show that (contrary to our hypotheses) the two interventions are associated with similar savings on the first month, but the EBO(R/I) intervention is associated with larger savings over time than the other two alternatives.

#### 4.2.3. Analysis of the cost-effectiveness and ROI of the interventions

Data in Case Study 2 was analysed using the same procedures in our previous study to explore cost-effectiveness and ROI. The Case Study 2 intervention had a total cost of €550 (including estimated person-hours) and was applied to 26 vehicles. Our calculations estimate total savings of the company at the end of month 3 at nearly 3000 US gal-

lons of fuel (nearly 11400 L) or €6950, which amounts to a 1165% ROI. Estimated savings in US gallons of fuel per km and truck show very similar magnitudes than in Case Study 1 (with a total at the end of month 3 of 13.21 US gal/truck/1000 km).

## 5. Discussion

By applying a field experiment in a real-world heavy freight transportation company in Colombia, this paper examined the efficacy of the Installation Theory framework and social norm interventions to improve fuel efficiency and reduce emissions. Specifically, we tested a total of three treatments, and we measured their results in terms of monthly average fuel consumption and DPAs. Our results provide evidence for four main findings we now discuss.

### 5.1. About the Installation Theory framework and social norm interventions to improve fuel efficiency in freight transport

Our results for hypotheses H1.1, H1.2 and H2.1 show that, as we anticipated, the Installation Theory framework can be a useful method to identify effective areas for behavioural interventions to improve fuel efficiency in freight transport companies, even when training, incentive, control and feedback measures are already in place. Similarly, they show that social norms, our chosen method of intervention, is also effective to improve fuel efficiency in such conditions.

Average monthly fuel consumption is a complex outcome to influence, as it often depends on hundreds, even thousands of small actions performed over the course of a whole month. Taking into account that companies are very often already applying training, incentive, control and feedback measures to influence this outcome, creating and applying effective behavioural interventions is not easy. In addition, although both the Installation Theory framework and social norm interventions have been shown to be effective in other contexts and for other target behaviours, they have rarely been applied to eco-driving and fuel efficiency challenges before. It is our hope that our results will open an interesting avenue of research and application for eco-driving interventions (Sanguinetti *et al.* 2017), that it will broaden the range of contexts and challenges for which these frameworks have shown significant results on behaviour (Lahlou *et al.* 2015a; Yamin *et al.* 2019), and will also inform the operations of freight transport companies looking to improve fuel efficiency and reduce emissions.

Reductions in average monthly fuel consumption for the first and the total after three months (despite the changes in the second month measurements, which we will discuss below) are consistent with and of comparable magnitudes to previous social norm interventions that target other behaviours (John *et al.* 2014), and also with the interventions that use other methods to improve fuel ef-

iciency (Gosnell *et al.* 2016; Jeffreys *et al.* 2018; Lai 2015; Saboohi, Farzaneh 2009). Nevertheless, it should be taken into account that most of these interventions are applied in contexts with no existing initiatives to change behaviour or reduce fuel consumption already in place. And while more research is needed to test whether comparable effects can be reached in other contexts and using other intervention mechanisms (e.g., where social norms are not a relevant intervention option), our data shows that freight companies with similar challenges could expect considerable fuel savings and ROIs by applying these methods.

## 5.2. About the compared effects of the three interventions applied

However, despite these positive results, and contrary to our hypotheses (H1.3 and H2.1), we did not find evidence to support our assertion that one specific intervention would be more effective than others to reduce fuel consumption. Specifically, our data showed similar effect sizes for interventions based on GSI(R), to those based on EBO(R/I) (and even to the one that mixes both approaches in Case Study 2).

Of course, this might also be linked to the fact that in this particular context, drivers had no idea of how their own fuel consumption compared to the rest of the company before the intervention, and thus a simple card with this information could be as effective as seemingly more engaging methods. This goes against previous findings on the topic (Bergquist *et al.* 2019; Yamin *et al.* 2019), and is definitely one of the most interesting areas of research in the social norm intervention literature and practice today.

As for practitioners wanting to apply social norm interventions to improve fuel efficiency, this also suggests that if drivers don't have information about descriptive norms relating to this issue, giving simple and economical cards with personalized normative feedback can be as effective to reduce costs as more complicated interventions, which yields less risks and more returns on investment, of course.

But nevertheless, there is also an unmeasured effect here which relates to the perceptions of drivers about each intervention, and which we explored through our informal interactions and interviews with drivers after the studies were conducted. Because while the cards in GSI(R) were seen as a "useful, but ordinary" method, the videos and other mechanisms of the other two interventions caused much more passionate reactions and expressions of support that lasted for several weeks. Arguably, interventions based on the EBO(R/I) mechanisms seemed to be more memorable and caused a stronger impression in drivers (but still, interestingly, in our context this did not translate into quantifiable fuel savings).

## 5.3. About the duration of intervention effects

When exploring the sustainability in time that our interventions had (hypotheses H1.4 and H1.2), the results on both our studies show significant reductions in fuel con-

sumption for the first and third months after the intervention (including the total after month 3), but not for the second month. Actually, for all the treatment conditions, fuel consumption rises on the second month compared to the first. As we discussed previously, the literature on social norm interventions has documented how interventions that are applied on a single occasion quickly fade (Henry 2008; Henson *et al.* 2015). Nevertheless, in our case the same happened with the intervention in Case Study 2, in which we added recurring text messages to drivers and the *LightBox* device specifically to prevent this from happening (with no effect). This means our results didn't provide evidence to support any of our two hypotheses related to this issue: one-time interventions in Case Study 1 achieved savings on both months 1 and 3, and repeating certain intervention mechanisms in Case Study 2 did not manage to maintain effects for the second month.

Qualitative feedback collected from drivers after data analysis points to permitting and purging behavioural spillovers as documented by Dolan and Galizzi (2015). Drivers seem to have experienced a form of ego depletion: after having felt that they already did an effort to save fuel the first month, they decided to reduce their efforts for the second. Importantly, they link this reduced effort to the fact that there were no additional face-to-face interactions or surprising actions from the company, while the repeated messages and the *LightBox* devices had become ordinary and expected. Then, on the third month, they seemed to feel bad again for their low effort on the second month, which caused them to engage in a somewhat higher effort again (the moral cleansing spillover). The sustainability in time of the changes achieved by these methods is in our opinion one of the most critical issues for both research and practical applications. The specific intervention mechanisms that can achieve the enduring changes that both Installation Theory and social norm interventions aim for should be the focus of intensive research and empirical testing.

## 5.4. About telematics devices and DPAs

Telematics devices that measure and report DPAs are used by most major companies in the freight transport sector. Among other functions linked to their GPS capabilities, these devices are connected to vehicle computers or use separate sensors to measure parameters such as acceleration and speed. The device generates an alert each time drivers exceed pre-defined values in such parameters (in our case, number of sudden accelerations, sudden braking and speed excess events), which produce an auditory alert for the driver and are reported in real time to the company. This data is ordinarily used to inform company operations, define training, control and feedback needs (and prioritize individuals to undergo those processes), and even to inform hiring, compensation and termination decisions. In the company in our study, which is using one of the industry leaders worldwide in these type of telematics devices, the average number of DPAs that each

driver gets is one of the main criteria to assign drivers to re-training procedures (if they have many) or to give them different incentives (if they have none), as well as to make decisions about the continuity in their employment.

Nevertheless, at least according to our data, the relation between DPAs and fuel consumption, which arguably is one of the main outcomes that companies are aiming to influence, is not clear. Specifically, for all the months in our data, the correlation between fuel consumption and the recorded DPAs is weak (0.326 in the best case), or even negative (−0.328 in the worst and most cases). The most probable explanation for this is that the range of parameters used to log DPAs are not adequate to capture differences in fuel consumption levels, which is their ultimate goal. Moreover, this might also provide a possible explanation to why the *LightBox* intervention was less effective than the ones in Case Study 1. If sudden acceleration alerts are not correlated with fuel consumption levels, then the visual feedback emitted by the device could be ineffective to influence relevant actions.

### 5.5. Limitations and further research

As any field study, our research has limitations that must be taken into account when assessing our findings. The first, most obvious one stems from the fact that our experiments were applied in a real-world context under the complex operations of a national transportation company. This imposes several practical difficulties and limitations in setting up, applying and evaluating the experiment, including the variability in routes and cargo, the high rotation rate in the company, or changes in company procedures (like the change of the telemetric operator company in the middle of experiment one, which prevented us to analyse the relevant data). We believe, nevertheless, that these limitations are largely offset by the benefits of testing our treatments in real-world operation conditions, which is of course where we hope our findings will be useful as well.

Then, there is the design of the interventions themselves, which are different to how most psychological interventions are designed and applied. Because our objective was to test the real-world effectiveness of a particular intervention framework on a particular behavioural outcome, and not to isolate specific “psychological phenomena”, our interventions are complex and mix a variety of different mechanisms (cards, videos, promotional materials, face-to-face workshops and so on). Further research could certainly be done to try to isolate the effects of these mechanisms (e.g., is a certain message more effective than others, or is a card more effective than a video with the same information?), but an important point in our view is also how the combination of these mechanisms can improve results.

And finally, another important limitation in our studies is related to the behavioural outcome measures and other information we used. Because although average monthly fuel consumption is one of the most important

metrics used by transport companies to assess efficiency, as we discussed above it is also a synthesis of many behavioural and non-behavioural factors. Just in terms of driving behaviours, it is the aggregate of many actions repeated thousands of times. Furthermore, the configuration of the experiment in real-world conditions meant that collecting measures that could have acted as moderators for the results obtained would have been very difficult, if not impossible (such as distances, slope, traffic lights, weather or traffic conditions, for example). Nevertheless, the configuration of our experiment (applied over a period of 4...5 months among 211 drivers and trucks, with an approximate total of 11 million km travelled in total), as well as the random assignment of participants to control and treatment groups are meant to provide some plausible control for pre-existing characteristics and external influences in psychological field experiments (Gerber, Green 2011). Because of these issues, further research should strive to obtain more detailed and direct data (as long as it is possible in real-world field conditions) about driving behaviours and other potential moderators of interest. Through the telemetric devices that many companies today use, the technology to do this and at least some of the behavioural data is already available (it is just a matter of calibration and of using the data).

### Conclusions

In this paper, we present the results of a field study that tested the effects on fuel efficiency and driving behaviour of three interventions based on Installation Theory and social norms. Interventions were tested among professional truck drivers in Colombia with data from the regular operation of a national freight transport company. Our results show that the Installation Theory framework is a useful method to identify promising intervention areas to improve fuel efficiency in road transport: here it pointed at a new layer of behavioural channelling that could be used, social norms, and to a system of making it present to the driver in driving conditions (in-situ flip-flop symbolic reminder in the truck cockpit). They also show (with some qualifications), that this framework and social norm interventions can have significant effects on fuel efficiency in real-world operations, even when strong training, incentive, control and feedback measures are already in place.

Our hope is that our research broadens the available evidence on eco-driving, Installation Theory and social norm interventions in the literature, and suggest new research areas around how focusing on local physical, psychological and social determinants of behaviour (including social norms), can be an effective alternative to promote more sustainable behaviours related to driving and other areas. In addition, for policymakers and transport companies, we hope our findings can provide a proof of concept of the benefits they can obtain by taking seriously driving behaviour and applying the Installation Theory framework to it.

Because while the transport industry is expected to shift towards electric and autonomous vehicles in the next few decades, in the meantime reducing costs associated with fuel consumption and accidents, as well as harmful emissions and noise, should be a priority of policy makers and sustainable business strategies. And also, some of these insights will definitely prove useful as well for hybrid, electric and autonomous vehicles to improve safety, efficiency and human-robot interaction outcomes (as research in this area already show).

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## Author contributions

Paulius Yamin and Saadi Lahlou conceived the study and were responsible for the design and development of the experiments.

Paulius Yamin and Santiago Ortega were responsible for the experiment coordination and application, and for the production intervention materials.

Viktor Skrickij was responsible for the analysis of experimental data.

Paulius Yamin wrote the first draft of the paper and was responsible for data interpretation, while Saadi Lahlou reviewed and edited the first draft.

Finally, all authors reviewed and provided comments to the final draft.

## Disclosure statement

Authors declare that they do not have any competing financial, professional, or personal interests.

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