

Article

The Longitudinal Effect of Digitally Administered Feedback on the Eco-Driving Behavior of Company Car Drivers

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Abstract: In the global fight against climate change, stimulating eco-driving could contribute to the reduction of CO₂ emissions. Company car drivers are a main target in this challenge as they represent a significant market share and are typically not motivated financially to drive more fuel efficiently (and thus more eco-friendly). As this target group has received little previous research attention, we examine whether digitally administered feedback and coaching systems can trigger such company car owners to drive eco-friendly. We do so by using respondents (employees of a financial services company (N = 327)) that voluntarily have a digital device ('dongle') installed in their company car, which monitors and records driving behavior-related variables. In a longitudinal real-life field study, we communicate eco-driving recommendations (e.g., avoid harsh braking, accelerate gently, etc.) to the respondent drivers via a digital (computer) interface. Over a 21-week time frame (one block of seven weeks before the intervention, seven weeks of intervention, and seven weeks after the intervention), we test whether eco-driving recommendations in combination with personalized, graphical 'eco-score index evolution' feedback increase eco-driving behavior. We also experimentally evaluate the impact of adding social comparison elements to the feedback (e.g., providing feedback on a person's eco-driving performance compared to that of the same car brand users). Structural Equation Modeling (in MPlus 8.4) is used to analyze data. Our results show that digitally administered personal performance feedback increases eco-driving behavior both during and after the feedback intervention. However, we do not observe increased effects when social comparison information is added to the feedback. As this latter element is surprising, we conclude with a reflection on possible explanations and suggest areas for future research. We contribute to the sustainable eco-driving literature by researching an understudied group: company car drivers. More specifically, we contribute by demonstrating the effectiveness of digitally administered personal performance feedback on eco-driving for this group and by observing and reflecting on the (in)effectiveness of feedback containing social comparison information.

Keywords: eco-driving; digital interfaces; feedback; social comparison; company cars



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1. Introduction

The urgency of finding strategies to protect the natural environment has become increasingly evident in the past decades [1,2]. A key environmental issue pertains to air pollution and its negative climate change effects. Air pollution is one of the greatest challenges for business and society [3] and has been identified as the single largest environmental health risk globally by the World Health Organization (WHO) [4]. Thus, it is not surprising that climate change as a result of human-caused greenhouse gas emissions is high on the policy and research agenda [5–8]. In the global fight against air pollution and its negative climate change effects, the large-scale adoption of eco-driving can be a contributor. Prior literature has stressed that eco-driving can reduce fuel consumption by 10%, on average

and over time, thereby reducing CO₂ emissions from driving by an equivalent percentage [9]. Eco-driving is defined as the implementation of ecologically beneficial driving techniques like keeping the speed down, efficient gear shifting, anticipatory, calm, and steady driving, and efficient braking [10]. Apart from reducing air pollution and greenhouse gas emissions, eco-driving has other beneficial effects, such as improving road safety and reducing fuel costs [9,11,12]. In the automotive market, company car drivers are an important target. They compose a significant part of the market in some geographical areas. For example, they account for 11% of all cars in the Netherlands and more than double that in Belgium [13]. Importantly, as many company car drivers (vs. private car drivers) can use fuel (payment) cards provided by their employer, they are not financially motivated to drive more fuel efficiently (and therefore eco-friendly).

More research is needed to better understand how societies can achieve large-scale adoption of eco-driving. This probably requires educational efforts and social norm reinforcement [9]. Digitally administered driving feedback systems may be helpful to contribute to this objective and speed up the process, but it remains unclear how feedback influences eco-driving in a setting where drivers have no financial stake in reducing their fuel consumption. It is also unknown to what extent adding social comparison elements may be helpful to obtain eco-driving-increasing effects. Whether, and if so, how feedback (provided by digitally administered systems) can trigger eco-driving in such a context is an understudied literature area. As to the ‘how’, assessing the extent to which specific social comparison elements (e.g., comparisons of eco-driving performance with that of same-car-brand users) are present is an area of research that can contribute to the existing literature. To address these knowledge gaps, this study focuses on company car drivers and examines the effect of digitally administered tips and feedback on eco-driving behavior (see Figure 1 for an overview). While doing so, we also test the effectiveness of different social comparison feedback set-ups (e.g., comparisons of eco-driving performance with that of same-car-brand users). We do this by using a pool of company car owners (whose fuel is paid for by the company) that take part in a real-life field study over the span of multiple weeks. With this approach, we aim to contribute to the literature in at least two important ways. First, we evaluate the effectiveness of providing digitally administered feedback on real-life longitudinal eco-driving performance in a field study. Second, we compare the effectiveness of different socially comparative framings, thus also contributing to the literature that studies the influence of social comparison on pro-environmental behavior.

All weeks:

- Avoid idling
- Avoid harsh braking
- Accelerate quietly
- Shift in a timely manner and drive in the highest gear possible
- Avoid using your car for short trips
- Drive with a constant and moderate speed
- Anticipate traffic conditions and look as far ahead as possible (avoid unnecessary acceleration or braking).

As from week 4 (randomly added over the weeks):

- Shift between 2000–2500 revolutions/min
 - Decelerate smoothly by releasing the accelerator in time while leaving the car in gear (this is called “coasting”)
 - If you are driving in traffic jam, leave as much space ahead of you as possible. This allows you to drive fluently
 - On flat, straight roads you can switch directly from first to third gear; accelerate quietly and avoid pushing the accelerator pedal more than halfway
 - Avoid maneuvers with a cold engine (park your car in the right direction...)
 - When taking an exit, change lanes on time and adapt your speed
-

Figure 1. Eco-driving tips and tricks offered to the experiment participants. Note: Adapted from various sources [14–19].

2. Embedding in Recent Literature on Eco-Driving

In the global effort to combat climate change, the promotion of eco-driving emerges as a strategic avenue to reduce CO₂ emissions. Fafoutellis, Mantouka, and Vlahogianni [20] offer a comprehensive overview, emphasizing eco-driving's multidimensional nature, encompassing driving behavior, route selection, and various choices influencing fuel consumption. This holistic perspective aligns with the broader sustainability goals of reducing the environmental footprint of individual vehicles. The critical analyses presented by Fafoutellis and colleagues [20] highlight the importance of a nuanced understanding of eco-driving practices, which is crucial for shaping policies that enhance both driver awareness and system performance in the pursuit of sustainable transportation. Collectively, these insights underscore eco-driving as a vital component of sustainable transportation, shedding light on diverse strategies and technological advancements that contribute to the broader agenda of reducing environmental impact. Within this landscape, the unique challenge posed by company car drivers (constituting a substantial market share) demands innovative solutions. Despite their significant impact on carbon emissions, company car drivers often lack financial incentives to adopt fuel-efficient and eco-friendly driving practices. The next section reviews literature examining the effectiveness of digitally administered feedback systems (in an eco-driving context), setting the stage for understanding the potential impact on eco-driving behavior.

Fafoutellis, Mantouka, and Vlahogianni [20] emphasize the importance of nuanced models for calculating fuel consumption and understanding the factors influencing them. Their work underscores the need for comprehensive insights into driving behaviors, laying a foundational understanding for evaluating the impact of digitally administered feedback systems on fuel efficiency. Coloma et al.'s [21] investigation into the environmental effects of eco-driving within courier delivery services sheds light on the challenges faced by professional drivers. Although the focus is on a different professional context, the study's findings suggest that time pressure and professional obligations may influence the effectiveness of eco-driving interventions. This prompts consideration of how such contextual challenges might impact the reception and efficacy of digitally administered feedback in professional driving settings. Günther, Kacperski, and Krems [22] delve into persuasive strategies for promoting eco-driving, specifically with battery electric vehicles (BEVs). While the study centers on BEV drivers, its findings on the impact of feedback, gamification, and financial rewards offer relevant insights for encouraging sustainable driving behaviors. The emphasis on real-world driving conditions aligns with the ecological validity sought in professional settings, mirroring the circumstances faced by company car drivers. Lin and Wang's [23] exploration of factors influencing drivers' intentions to practice eco-driving and their acceptance of eco-driving technology provides a theoretical framework. Integrating the Theory of Planned Behavior (TPB) and the Technology Acceptance Model (TAM), the study's insights guide the understanding of how digitally administered feedback may impact drivers' intentions and acceptance. This theoretical underpinning is instrumental in exploring the motivational factors shaping eco-driving behaviors. Allison and Stanton's [24], Sanguinetti et al. [25], and Picco et al. [26] emphasize feedback as a tool for reducing emissions from everyday driving behaviors. The focus on the maintenance of eco-driving behaviors provides a valuable perspective for evaluating the sustained impact of digitally administered feedback over time in professional driving settings.

3. Conceptual Development

Motivational research highlights the impact of extrinsic motivation (i.e., motivation by an external factor) [27]. Receiving financial benefits has been demonstrated to be a very strong extrinsic motivator in many situations [28,29]. In the context of our study (i.e., triggering people to eco-drive), one might be primarily motivated to engage in behavior that reduces CO₂ exhausts because of financial rewards (e.g., driving less or less aggressively to reduce fuel costs). In support of this, past pro-environmental behavior research has

identified cost-savings or other financial rewards as a strong extrinsic incentive and often the main motive to choose an eco-friendly option [30–32].

However, company car owners whose fuel is paid for by the company are not financially rewarded by an eco-friendly driving style. In such a context, it may be more valuable to consider the potential impact of other extrinsic motivators than personal cost savings or financial rewards [33]. One such extrinsic motivational mechanism could be to provide continuous personalized eco-driving feedback via a digital interface (e.g., a communicated custom eco-score that can increase or decrease). Implicitly, such continuous eco-score communication includes a trigger for improvement (i.e., increasing your eco-score achieved over time). Thus, we hypothesize:

Hypothesis 1 (H1). *Drivers who receive (personal comparison) eco-driving feedback (via continuous eco-score communication) will drive more ecologically as compared to drivers who do not receive feedback.*

While H1 focuses on personal comparison (cf. “competing” with oneself), we also want to test the impact of including an element of social comparison (cf. “competing” with others). Social comparison is defined as the tendency to self-evaluate by comparing ourselves to others [34]. In our study, this could be operationalized by providing feedback on a person’s eco-driving performance compared to that of the same car brand users, for example. Little research has focused on the impact of social comparison in an eco-driving context. An exception is the exploratory study by Brouwer et al. [35]. These authors evaluated different possibilities for feedback in a driving simulator, using two alternative ways of displaying eco-driving performance feedback with respect to goal orientation (for learning-oriented drivers and performance-oriented drivers). Among other things, they found that performance-related comparative feedback may be effective in stimulating eco-driving. We aim to further contribute to these findings. Other literature focusing on other pro-environmental and pro-health behaviors also shows that social comparison framing can have an impact. This phenomenon has been observed, for example, in stimulating energy savings, lowering water consumption, or stimulating physical exercise [34,36–42]. Thus, we expect the following:

Hypothesis 2 (H2). *Adding a social comparison component will increase the predicted effect in H1 (if any): eco-driving will increase when social comparison feedback is used (vs. personal comparison feedback).*

Multiple ways can be used to create a social comparison context. We start from two dimensions to create such a context: (1) comparisons can be situated at the within- (or intra-) vs. between- (or inter-) group level, and (2) groups can be defined based on symbolic characteristics (triggering normative (dis)similarities and resultant comparisons) vs. instrumental characteristics (triggering comparative (dis)similarities and resultant comparisons). We elaborate on the theoretical underpinnings of these dimensions and concepts in the next sections.

3.1. Within- (or Intra-) versus between- (or Inter-) Group Comparisons and Eco-Driving

Previous research shows that group identification is an important factor in creating distinctiveness between groups and similarity within groups [34,40,43]. Social comparison research suggests that both similarity and dissimilarity can be successful drivers of group comparison [34,42,44–46]. When similarity is the driver, comparison occurs primarily within groups. The more people feel similar to, or identify with, other members of their group, the more likely it is that these become their social comparison benchmarks. Prior literature denotes this as “intra-group” comparison (i.e., people comparing themselves to other members of the same group) and has demonstrated a positive impact on performance [34,42,45,46]. The effect of intra-group comparisons on promoting pro-environmental behavior has also been demonstrated [1]. For example, Goldstein, Cialdini,

and Griskevicius [46] and Schultz, Khazian, and Zaleski [47] observe this effect in the context of towel use in hotels. As another example, Schultz, Nolan, Cialdini, Goldstein, and Griskevicius [48] focus on household energy use and find that comparison with a neighborhood group can induce a change in pro-environmental behavior.

In contrast, when dissimilarity is the driver, comparison tends to happen primarily between groups. Prior literature denotes this as “inter-group” comparison (i.e., people comparing themselves between groups to members belonging to another group). The perceived difference or dissimilarity between one’s own group and another group has been demonstrated to trigger inter-group comparison. Inter-group comparison can enhance group performance [43,44,49,50]. Ferguson et al. [1] demonstrate that inter-group comparison can be used to increase willingness to perform pro-environmental behavior, for instance, when people are confronted with past and future generational group information in the context of actions to reduce climate change.

The above elements illustrate that there is evidence from previous research that both intra-group comparisons and inter-group comparisons can lead to “benchmarking”, which subsequently can drive pro-environmental behavior. Starting from these insights, we want to test the (additional) effect of intra- vs. inter-group comparison as a means to stimulate eco-driving. In this way, we also aim to address a call for research by Ferguson et al. [1] on the relative effectiveness of intra-group and inter-group comparisons in fostering sustainable behavior.

3.2. Eco-Driving and Normative (Dis)Similarity (via Symbolic Characteristics) vs. Comparative (Dis)Similarity (via Instrumental Characteristics)

Previous research on self-categorization distinguishes two ‘fit’ mechanisms for an individual to identify with a group: (a) normative and (b) comparative fit [34,40,43]. Normative fit (a) reflects socio-cultural relevance. More precisely, categorization has a social meaning. Car brands can offer such social meaning (cf. the eco-driving focus of this study). Research on brand communities has demonstrated that strong brands are able to create feelings of similarity among people using or buying the same brand [51]. Ekinci, Sirakaya-Turk, and Preciado [52] stress the social value of brands: “consumption objects such as brands evolve from having individual value (personal meaning) to becoming important objects in the social world, where they act as symbols with social meaning”. Brands are carriers of symbolic meaning and have been reported to be able to create feelings of similarity among people using or buying the same brand. On the other hand, they also allow one to differentiate from those not using or buying the brand [51–53]. Thus, brands have been identified as a potential source of symbolic similarity, whereby drivers identify with the brand and with other customers of the brand [54]. The Harley-Davidson customer community, consisting of aficionados sharing music preferences, clothing styles, etc., is a famous example [51]. We conclude that (car) brands can be used to test hypotheses starting from a ‘normative fit’ reasoning.

Comparative fit (b), on the other hand, reflects how relevant a certain classification is in a given situation [44,55,56]. For example, technical car specifications (such as engine size) are strongly associated with the context of eco-driving and fuel efficiency and can therefore form the basis for comparative fit. This may again provide an extrinsic motivational trigger via an intra-group mechanism (cf. *I am motivated to eco-drive better than other similar-engine cars*) or an inter-group comparison mechanism (cf. *when driving a car with a “small” engine, I am motivated to be among the very best eco-wise (as there are also cars with “bigger” engines that start with a disadvantage). On the other hand, when driving a “big” engine car, I may feel motivated to eco-wise outperform some “small” engine cars despite the initial disadvantage* [57]). Comparative fit will only be obtained if there is a sufficient correlation between the (dis)similarities of the groups and the context (to illustrate, categories/groups based on eco-driving relevant technical car specifications will have little effect when the focus is on political matters rather than pro-environmental behavior, for example).

The above theoretical underpinnings suggest that different types of social comparison contexts can potentially be used as an extrinsic motivator to promote eco-driving. It is unclear which social comparison approach is likely to be most effective (if there is an effect). In this study, we therefore test all the social comparison framings outlined. We do not propose specific hypotheses here but put forward a research question:

(RQ) If there is an extrinsic motivator effect of social comparison in stimulating eco-driving, is it more substantial (a) if it uses between-group vs. within-group comparisons or (b) comparisons based on normative (dis)similarity (via symbolic characteristics) vs. comparative (dis)similarity (via instrumental characteristics)?

4. Methods

4.1. Sample

In an effort to gather longitudinal eco-driving scores, employees at a financial services company willingly had a dongle installed in their cars to participate in a telematics test project. Out of the initial sample of 458 participants, sixteen were excluded due to technical issues. Additionally, twenty-four participants were assigned to a training session that prevented their involvement in the ongoing experiment. Two participants were excluded for being aware of the experimental setup, and six participants were omitted due to missing data (for the eco-driving scores under study). This leaves an eligible sample of $N = 410$ participants. A preliminary analysis of this sample showed that random assignment failed to result in comparable values for baseline eco-driving scores for one condition (between-brand social comparison, $n = 83$). We specified the pre-intervention eco-score as a latent factor with seven observed indicators (one per week), using the experimental condition as the grouping variable ($\chi^2(155) = 197.629$, $p = 0.012$, RMSEA = 0.064, CFI = 0.977, TLI = 0.982). Using the model constraints in Mplus 8.4, we computed the grand mean and tested the factor mean of each condition against this grand mean. The eco-score factor mean in condition 'inter-brand' deviated significantly from the overall mean: $M = 1.304$, $SE = 0.476$, $z = 2.737$, $p = 0.006$. Since this indicates that random assignment of participants to conditions did not successfully control for pre-intervention eco-scores, we omitted this condition from further analysis. None of the other conditions deviated significantly from the grand mean (all $p > 0.05$). We therefore excluded the data in this condition from further analysis, leaving us with an effective sample size of $N = 327$ (i.e., this sample was effectively used to evaluate the hypotheses and research questions we formulated). Every participant operates a lease car (company car), primarily utilized for commuting purposes. Due to GDPR restrictions, no demographic information was available. Car registration dates varied from 2014 to 2018. Respondents in the effective sample drove 12 different car brands, with kW (engine power) ranging from 54 to 160 kW ($M = 91.11$, $SD = 14.101$) and representing three fuel types: petrol, diesel, and hybrid cars.

4.2. Procedure

Data were collected in three blocks of seven weeks each: (a) a pre-intervention stage, (b) an intervention stage, and (c) a post-intervention stage. For each stage, the data consisted of seven weekly eco-driving scores (i.e., individual drivers' eco-driving scores totaled for the past week). Commencing in the first week of the intervention phase, all groups were provided with advice and strategies on driving in a more environmentally friendly manner (see Figure 1). The first seven tips and tricks in Figure 1 were shown every week. As of the fourth week, new tips and tricks were added (randomly over the weeks) to keep participants' interest. This was especially relevant for the control conditions that did not receive feedback but only tips and tricks. In addition, drivers in the non-social comparison feedback condition received individual personal comparison feedback about their driving behavior in the form of a weekly eco-score (but no social comparison feedback elements were provided). The three social comparison conditions additionally got socially comparative feedback (as detailed below).

4.3. Design

Participants were randomly assigned to the conditions shown in Table 1. We initially set up an experiment with six conditions, but one condition (inter-brand social comparison) unfortunately had to be dropped from the experiment due to a deviant baseline measurement (see above). For clarity, we will no longer refer to this condition in what follows. As shown in Table 1, we compare three social comparison conditions to one condition with personal comparison feedback and one control condition without feedback. At the onset of the experiment, every participant was sent an email containing general information, including details about the project schedule as well as condition-specific details regarding the eco-score for all feedback conditions and their respective social comparison conditions. Communication throughout the experiment was consistently delivered to all respondents weekly via email. It is important to note that these emails were received after the drive, with no real-time communication or feedback provided in the car. This post-drive setup was chosen at the request of the involved business partner. Over the course of seven weeks, participants in all conditions received weekly emails containing a range of validated eco-driving tips and tricks, e.g., drive at a constant, moderate speed; turn off the engine when idle; avoid harsh braking; etc. [14]. Furthermore, participants in the personal comparison feedback condition were provided with their individual eco-scores on a weekly basis, graphed over time with the addition of one data point each week. As for participants in the social comparison conditions (refer to Table 1), their weekly eco-scores were augmented with social comparison information. In each e-mail, all participants were reminded to which group they belonged in order to keep the salience of the social categorization high [55,58]. The wording and phrasing of the e-mail messages were based on best practices in past literature [46,59].

Table 1. Experimental conditions.

Social Comparison	N	Tips	Grouping	Feedback	dfb	dcomp	dinter	dbrand
Intra-brand	83	Yes	Brand (k = 12)	Within-group	1/4	1/3	0	1
Inter-tech	81	Yes	Technical (k = 12)	Between-group	1/4	1/3	1	0
Intra-tech	82	Yes	Technical (k = 12)	Within-group	1/4	1/3	−1	−1
Individual feedback	41	Yes	None (k = 1)	Individual eco-score	1/4	−1/2	0	0
Control: No feedback	40	Yes	None (k = 1)	None	−1	−1/2	0	0

Note: dfb = effect coded variable contrasting feedback vs. no feedback; dcomp = effect coded variable contrasting social comparison vs. no social comparison; dinter = effect coded variable contrasting the inter-tech with the intratech conditions; dbrand = effect coded variable contrasting intrabrand vs. intratech conditions. Respondents in the intra-brand, inter-tech, and intra-tech conditions were assigned to 12 groups per condition as the basis for the group-based comparative information (e.g., in the intra-brand condition, respondents received individual eco-scores compared to the mean of other same-brand drivers).

To be able to provide group-based feedback, participants in the social comparison conditions were assigned to groups. The way these groups were defined depended on the experimental conditions. The car brand served as a symbolic group characteristic. Thus, car brands were used as the basis for defining 12 brand groups in the intra-brand condition. Technical engine specifications were used as instrumental group characteristics. Engine power categories, nested within fuel type (petrol, diesel, and hybrid), were used to define 12 technical groups in the intra-tech condition and 12 matched groups in the inter-tech condition (see Table 1).

4.4. Measures

Eco-scores are derived from a weighted average of five sub-scores related to harsh braking, harsh acceleration, journey length (shorter journeys are less ecological), duration of driving at a speed above the optimally efficient speed, and duration of idling (please note that the specific operationalization is owned and copyrighted by the digital feedback system provider). These eco-scores were conveyed in the form of an index relative to a pre-

experimental baseline, which was measured from the moment the dongle was installed until the commencement of the experiment. Consequently, the eco-score index is computed as the average eco-score in the focal week minus the average eco-score in the pre-intervention phase. This resulting index can vary from -100 to 100 , with the baseline score defined as zero. In the social comparison conditions, participants were deemed to be performing better (or worse) than their counterparts if they had improved more (or less) compared to the baseline measurement. This information was also visually presented in a graph (refer to Figure 2 for an example of a BMW driver in the intra-brand condition). A red and green background was added to this graph in order to convey what behavior is (dis)approved to avoid respondents changing behavior in a negative direction, for instance, if the “comparison-others” are performing worse. The importance of avoiding the so-called “boomerang effect” is described by Chung and Rimal [59] and Dolan and Simon [60].

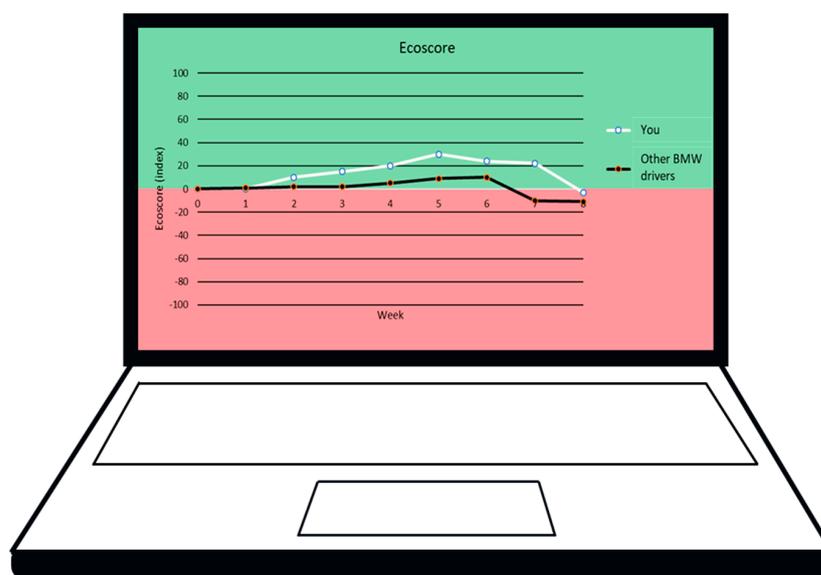


Figure 2. Personalized eco-score index plot in week 7 (for a BMW driver in the intra-brand condition).

5. Results

All analyses were run in Mplus 8.4 [61]. Time was represented in a multivariate way (that is, the 21 weekly eco-scores are treated as 21 distinct variables; descriptive statistics and correlations are provided in Appendix A, Table A1). This setup allows for flexible specification of residual terms. It also has the advantage that heteroscedasticity over time can be easily accounted for. We used the type = complex procedure, using the experimental group as the cluster variable, to account for the fact that drivers in the social comparison conditions received feedback that contained a common component for each group (e.g., all drivers in the BMW intra-brand group get feedback based on the same group mean; see Table 1). The non-social comparison conditions were each treated as a cluster as well (intra-class correlations for the eco-scores range from 0.021 to 0.086, in support of the need to account for the non-independence of the observations using this type of complex approach).

To test the effect of the intervention, we fit the Structural Equation Model shown in Figure 3 to the data. One latent eco-score factor is estimated for each of the three stages (the pre-intervention, the intervention, and the post-intervention stage). Thus, the model has three latent eco-score factors corresponding to the pre-, during, and post-intervention stages, each with seven observed indicators (one for each week). In each stage, the eco-scores for the seven weeks within the stage are used as the observed indicators of a latent eco-score factor. For parsimony, all indicators' intercepts are set to zero and loadings are set to one. However, based on preliminary data exploration, the residual variance at each time point is freely estimated to allow for heteroscedasticity. In addition, adjacent week scores

have a residual correlation to account for short-term carryover effects (this residual covariance term is constrained to be constant). The intervention and post-intervention factors are modeled as the dependent variables, with the experimental-effect-coded variables (see the four lower rows in Table 1 for the effect-coding we used) as the independent variables. The pre-intervention factor is included as the control variable with its regression weight fixed to one, so the factors of the intervention and post-intervention factors effectively represent the average change in eco-score relative to the pre-intervention eco-score [62]. The resulting model shows an acceptable fit to the data ($\chi^2_{MLR}(299) = 540.474$, CFI = 0.952, TLI = 0.953, RMSEA = 0.050). Unstandardized regression parameter estimates with bootstrapped confidence intervals are reported in Table 2. The results show that in general, eco-driving scores go up in the intervention (remember that higher scores indicate more eco-friendly driving) and remain above pre-intervention levels in the post-intervention stage (cf. intercept terms in Table 2). Providing personal comparison feedback by email results in significantly higher eco-driving scores during and after the intervention (cf. B feedback estimates in Table 2). However, adding a social comparison layer does not result in any additional effect, and there are no significant differences between the alternative social comparison conditions (i.e., there is no effect of social comparison, regardless of whether it is intra-tech, inter-brand, or inter-tech).

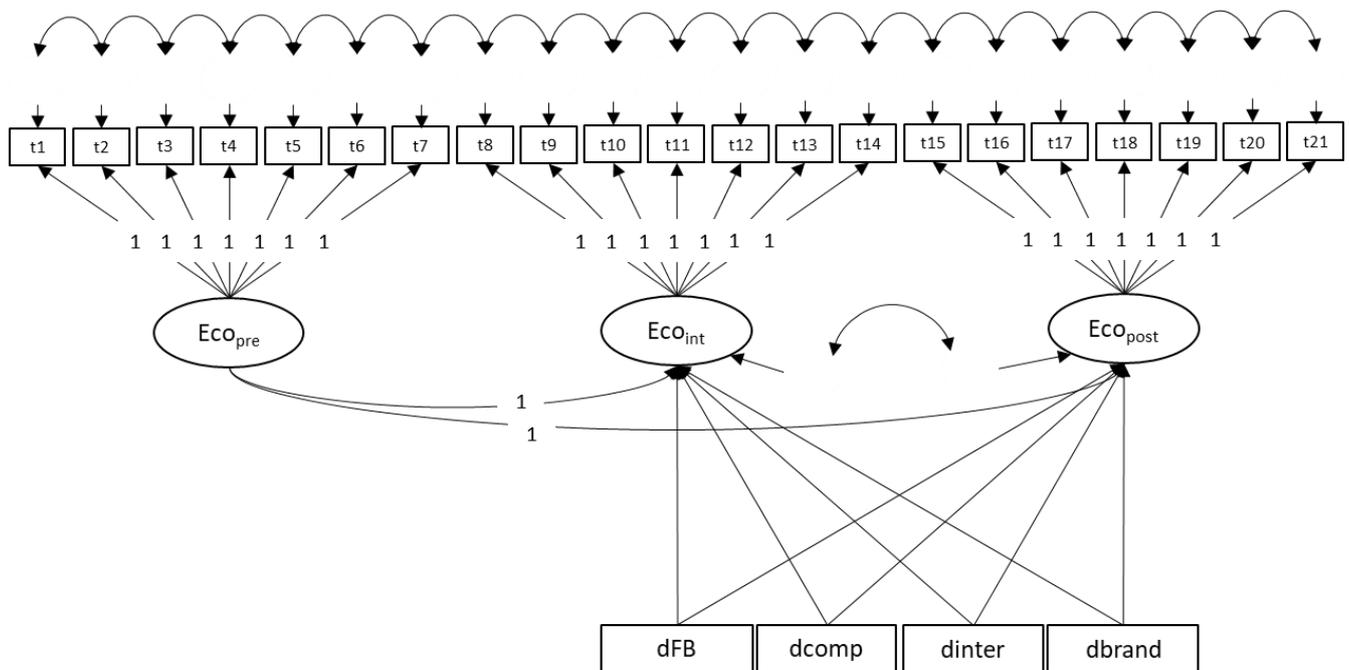


Figure 3. Structural Equation Model. Note: t_1 – t_{21} = eco-scores for weeks 1–21. Eco_{pre} , Eco_{int} , and Eco_{post} = eco-score factors for pre-intervention, intervention, and post-intervention stages. d_{fb} = effect coded variable contrasting feedback vs. no feedback; d_{comp} = effect coded variable contrasting social comparison vs. no social comparison; d_{inter} = effect coded variable contrasting the inter-tech with the intratech conditions; d_{brand} = effect coded variable contrasting intrabrand vs. intratech conditions. See Table 1 for specific coding values.

Table 2. Parameter estimates with bootstrapped 95% confidence intervals (n = 2000 bootstraps).

IV	Parameter	Intervention (DV = Eco_{int})			Post-Intervention (DV = Eco_{post})				
		Est.	LL	UL	Est.	LL	UL		
dFB	Intercept	0.574	0.274	0.889	*	1.077	0.752	1.367	*
	$B_{feedback}$	1.002	0.836	1.151	*	0.915	0.746	1.065	*

Table 2. Cont.

IV	Parameter	Intervention (DV = ECO _{int})			Post-Intervention (DV = ECO _{post})		
		Est.	LL	UL	Est.	LL	UL
dcomp	B _{competition}	0.002	−0.455	0.514	0.477	−0.022	0.972
dinter	B _{inter (vs. intra)}	−0.197	−0.795	0.394	−0.091	−0.642	0.491
dbrand	B _{brand (vs. tech)}	−0.027	−0.649	0.652	−0.089	−0.764	0.620

Note: IV = independent variable, as represented in Table 1 and Figure 3. DV = dependent variable (see Figure 3). Est. = estimate. LL/UL = lower and upper limits of the 95% confidence interval. * = $p < 0.05$.

6. Discussion

6.1. Main Observations

In the face of escalating environmental challenges (particularly the adverse effects of air pollution and climate change), the promotion of eco-driving has emerged as a strategic imperative for mitigating the impact of human-caused greenhouse gas emissions. This study, situated within the broader context of sustainable transportation, addresses a critical gap in the existing literature by focusing on company car drivers. Whereas some recent existing literature starts from the perspective of the type of vehicle (e.g., connected and automated vehicles [63], or battery electric vehicles [64]), this study starts from the perspective of a specific group of drivers: company car users. This is a significant yet often overlooked segment of the automotive market. The literature review underscores the importance of eco-driving as a multifaceted approach, encompassing driving behaviors, route selection, and choices influencing fuel consumption. Previous research has demonstrated that eco-driving not only reduces air pollution and greenhouse gas emissions but also enhances road safety and reduces fuel costs. However, company car drivers, who play a pivotal role in carbon emissions, are less incentivized to adopt eco-friendly practices due to the availability of employer-provided fuel cards.

Informed by this context, this study addresses the often-overlooked group of company car drivers as a key target for promoting eco-driving practices. This group is crucial in the global effort to mitigate climate change. Employing a digital feedback and coaching system, we conducted a longitudinal field study with 327 participants. We monitored their driving behavior through a ‘dongle’ installed in company cars. Our results, analyzed using Structural Equation Modeling, reveal that the provision of digitally administered personal performance feedback significantly enhances eco-driving behavior both during and after the intervention, as indicated by increased eco-driving scores (see Section 5). Surprisingly, the addition of social comparison elements to the feedback, such as comparisons with the same car brand users, did not yield further improvements. The study makes a notable contribution to the eco-driving literature by shedding light on the effectiveness of personalized feedback for company car drivers while also prompting a reflection on the unexpected ineffectiveness of social comparison information.

The main research goal was to investigate (1) whether personal comparison feedback could enhance drivers’ eco-driving scores and, if so, (2) whether adding a social comparison element would further boost feedback effectiveness. After a seven-week baseline measurement period, we experimentally assigned participants to a control condition (who only received tips and tricks on eco-driving; see Figure 1), an individual comparison feedback condition (who additionally received a weekly mail with their visually graphed eco-driving score over time), and three social comparison-oriented conditions who received a weekly mail with their visually graphed eco-driving score over time alongside a group-based average eco-driving score that served as a benchmark (see Figure 2 for an example). As hypothesized (H1), the main results indicate that providing personal comparison feedback by email on a weekly basis has a positive impact on the aggregate eco-driving score observed in our study. An interesting add-on observation is that the increase in average eco-scores during the seven-week intervention period also persisted in the seven-week

post-intervention period (compared to the seven-week baseline measurement period). Such an increase was not observed in the control condition and can therefore not be attributed to unintended external events or circumstances. Contrary to expectations, adding a social comparison layer to the feedback does not result in a significant additional effect. This is a different result than hypothesized (H2 is not supported). Below, we reflect on possible explanations for this unexpected observation. We also address related limitations and formulate areas for future research.

6.2. Reflections, Limitations, Applications, and Future Research Suggestions

The experimental set-up did not include gamification elements like leader boards. Previous research has demonstrated the impact of such elements [27,65–67]. In our study, these elements were deliberately left out to ensure a clean manipulation. However, they may be more important than initially expected for triggering social comparison effects. Possibly, the social comparison feedback format may have been insufficiently engaging to facilitate such a mechanism. This may be an element to consider in future research. Another reflection about the absence of a social comparison effect focuses on a possible mindset misfit. Intuitively, one might argue that a pro-social, environmentally beneficial mindset does not fit with a pro-self, social comparison-based competitive mindset. However, earlier research has suggested that pro-selves act more sustainably in a competitive setting than in a non-competitive setting, whereas pro-socials act sustainably, independent of competition; as a result, the net effect of social comparison-based competition should still be positive [68]. Still, future research could explore whether a more inclusive type of social comparison framing shows better results. A final thought centers around who the other party is in a social comparison frame. We experimented with a “peers” set-up (i.e., those driving the same car brand, those driving a similar engine car). However, Merrikhpour and Donmez [69] demonstrated that comparing one’s behavior with that of a “close or important other” can be very effective in steering eco-driving behavior. Close or important others are, for example, a person’s friends or family. Exploring in what way such a set-up could be translated to a digital interface context and next testing it could be a research avenue to further look into.

Despite these limitations, and in addition to the future research suggestions offered, we also want to stress some possible application domains of the research findings in hand. Specifically, we believe that there are hands-on learnings in the context of the development of feedback technologies for drivers that aim to encourage an eco-driving style. Specifically, we believe that developing digitally-administered feedback systems is valuable to motivate company car drivers (who have no financial incentive to drive in a more sustainable way) to adopt eco-driving. Inspiration is also offered (indicating what might work and what not) regarding motivational programs for fleet managers of company vehicles. Although the use of social comparison mechanisms (e.g., How do you perform compared to the average brand x car driver in eco-driving? How do you score in terms of eco-driving compared to those that drive a technically similar car?) feels intuitively promising, but our study does not demonstrate an increased effect on eco-driving behavior. Finally, applications in the domain of environmental protection policy and ecological education can also be derived from our study. For example, including gamification elements (missing in our study) may be a truly valuable element to include in real-life executions. Another context factor (not tested in our study) is to have a frame where a comparison is made with ‘close important ones’.

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Informed Consent Statement: The company's HR department obtained and stored the written informed consent of all participants in line with their internal policies and in line with the ethical guidelines mentioned under the Institutional Review Board Statement.

Data Availability Statement: The respondent-leasing-car number data collected and analyzed for this research project are considered proprietary data of the company the authors collaborated with. Due to General Data Protection Regulation (GDPR) imperatives and internal policy requirements, the collaborating company does not allow the data to be made publicly available. All references and other materials associated with the publication are openly shared and accessible to readers.

Conflicts of Interest: Author Pieter Vanpaemel was employed by the Vlerick Business School at the time of the research and is currently employed by the company Edgar and Cooper (which is not involved in the current research). All authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflict of interest.

Appendix A

Table A1. Mean, standard deviation, and correlations.

	M	SD	dfb	dcomp	dinter	dbrand	t1	t2	t3	T4	t5	t6	t7	t8	t9	t10	t11	t12	t13	t14	t15	t16	t17	t18	t19	t20	t21
dfb	0.10	0.41		0.61	−0.01	0.00	0.04	−0.01	−0.07	−0.03	0.01	0.03	0.04	0.00	0.11	0.08	0.06	0.07	0.07	0.03	0.01	0.05	0.10	−0.08	0.04	0.08	0.04
dcomp	0.12	0.36	0.61		−0.01	0.01	0.02	0.02	−0.07	0.02	0.06	−0.05	0.06	0.05	0.07	0.10	0.03	0.02	−0.04	−0.02	0.03	0.03	0.10	−0.12	0.04	0.05	0.05
dinter	0.00	0.71	−0.01	−0.01		0.50	0.05	0.05	0.05	0.05	0.01	0.11	−0.01	0.10	0.07	0.11	−0.02	0.01	0.03	0.05	0.03	−0.02	0.08	0.04	−0.03	0.02	0.07
dbrand	0.00	0.71	0.00	0.01	0.50		0.03	0.09	0.09	0.00	0.07	0.15	0.10	0.09	0.05	0.07	0.07	0.05	0.09	0.00	0.09	0.00	0.08	0.05	0.07	0.05	0.04
t1	59.66	8.77	0.04	0.02	0.05	0.03		0.71	0.66	0.62	0.63	0.61	0.59	0.63	0.65	0.59	0.63	0.66	0.65	0.60	0.57	0.41	0.43	0.53	0.65	0.58	0.60
t2	59.42	8.96	−0.01	0.02	0.05	0.09	0.71		0.65	0.64	0.65	0.63	0.61	0.61	0.64	0.52	0.63	0.67	0.62	0.56	0.59	0.44	0.46	0.50	0.57	0.53	0.62
t3	58.16	8.49	−0.07	−0.07	0.05	0.09	0.66	0.65		0.62	0.63	0.58	0.63	0.60	0.66	0.59	0.64	0.62	0.65	0.58	0.57	0.36	0.49	0.57	0.60	0.57	0.63
t4	58.64	8.83	−0.03	0.02	0.05	0.00	0.62	0.64	0.62		0.65	0.64	0.60	0.63	0.64	0.56	0.61	0.63	0.65	0.61	0.58	0.33	0.48	0.50	0.61	0.45	0.60
t5	59.16	8.57	0.01	0.06	0.01	0.07	0.63	0.65	0.63	0.65		0.70	0.67	0.60	0.67	0.60	0.69	0.69	0.63	0.64	0.61	0.32	0.47	0.43	0.59	0.49	0.61
t6	58.58	8.23	0.03	−0.05	0.11	0.15	0.61	0.63	0.58	0.64	0.70		0.65	0.62	0.69	0.62	0.66	0.68	0.67	0.64	0.63	0.30	0.48	0.50	0.62	0.52	0.58
t7	58.59	8.34	0.04	0.06	−0.01	0.10	0.59	0.61	0.63	0.60	0.67	0.65		0.61	0.65	0.59	0.64	0.64	0.66	0.62	0.59	0.32	0.45	0.41	0.61	0.47	0.57
t8	58.90	8.31	0.00	0.05	0.10	0.09	0.63	0.61	0.60	0.63	0.60	0.62	0.61		0.61	0.57	0.62	0.62	0.62	0.55	0.54	0.33	0.39	0.48	0.51	0.50	0.59
t9	58.72	8.47	0.11	0.07	0.07	0.05	0.65	0.64	0.66	0.64	0.67	0.69	0.65	0.61		0.65	0.69	0.69	0.67	0.64	0.63	0.38	0.55	0.52	0.56	0.50	0.61
t10	59.79	9.58	0.08	0.10	0.11	0.07	0.59	0.52	0.59	0.56	0.60	0.62	0.59	0.57	0.65		0.71	0.64	0.60	0.60	0.56	0.32	0.48	0.55	0.52	0.52	0.57
t11	59.95	8.42	0.06	0.03	−0.02	0.07	0.63	0.63	0.64	0.61	0.69	0.66	0.64	0.62	0.69	0.71		0.69	0.69	0.71	0.64	0.39	0.51	0.49	0.60	0.52	0.57
t12	59.91	8.65	0.07	0.02	0.01	0.05	0.66	0.67	0.62	0.63	0.69	0.68	0.64	0.62	0.69	0.64	0.69		0.72	0.67	0.71	0.38	0.46	0.50	0.59	0.56	0.63
t13	59.51	8.62	0.07	−0.04	0.03	0.09	0.65	0.62	0.65	0.65	0.63	0.67	0.66	0.62	0.67	0.60	0.71	0.72		0.67	0.64	0.42	0.53	0.49	0.62	0.52	0.60
t14	59.76	9.10	0.03	−0.02	0.05	0.00	0.60	0.56	0.58	0.61	0.64	0.64	0.62	0.55	0.64	0.60	0.64	0.67	0.67		0.65	0.30	0.46	0.40	0.57	0.50	0.56
t15	59.37	8.31	0.01	0.03	0.03	0.09	0.57	0.59	0.57	0.58	0.61	0.63	0.59	0.54	0.63	0.56	0.60	0.71	0.64	0.65		0.38	0.49	0.43	0.59	0.48	0.54
t16	59.66	8.78	0.05	0.03	−0.02	0.00	0.41	0.44	0.36	0.33	0.32	0.30	0.32	0.33	0.38	0.32	0.39	0.38	0.42	0.30	0.38		0.40	0.32	0.38	0.35	0.38
t17	60.70	8.45	0.10	0.10	0.08	0.08	0.43	0.46	0.49	0.48	0.47	0.48	0.45	0.39	0.55	0.48	0.51	0.46	0.53	0.46	0.49	0.40		0.48	0.49	0.46	0.44
t18	60.34	8.42	−0.08	−0.12	0.04	0.05	0.53	0.50	0.57	0.50	0.43	0.50	0.41	0.48	0.52	0.55	0.49	0.50	0.49	0.40	0.43	0.32	0.48		0.47	0.52	0.54
t19	60.19	8.70	0.04	0.04	−0.03	0.07	0.65	0.57	0.60	0.61	0.59	0.62	0.61	0.51	0.56	0.52	0.60	0.59	0.62	0.57	0.59	0.38	0.49	0.47		0.61	0.60
t20	60.05	8.20	0.08	0.05	0.02	0.05	0.58	0.53	0.57	0.45	0.49	0.52	0.47	0.50	0.50	0.52	0.52	0.56	0.52	0.50	0.48	0.35	0.46	0.52		0.61	0.62
t21	60.22	7.99	0.04	0.05	0.07	0.04	0.60	0.62	0.63	0.60	0.61	0.58	0.57	0.59	0.61	0.57	0.57	0.63	0.60	0.56	0.54	0.38	0.44	0.54	0.60		0.62

Note: t1 to t21 are weekly eco-scores. See Table 1 for other abbreviations. Correlations with absolute values exceeding 0.108 have $p < 0.05$.

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