# PROMOTING GREEN DRIVER BEHAVIOR

## DETERMINANTS OF AND MOTIVATIONAL INTERVENTIONS FOR (FUTURE) PRO-ENVIRONMENTAL DRIVER BEHAVIORS

Dissertation

Jule Kramer

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# Promoting Green Driver Behavior

## Determinants of and Motivational Interventions for (Future) Pro-Environmental Driver Behaviors

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# Statement

The following empirical studies included in Chapters 6 to 10 of this thesis have already been published or are submitted:

**Study I (Chapter 6):**

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Jule Kramer developed the study concept and study design under the supervision of Prof. Dr. Tibor Petzoldt. Jule Kramer performed the data analysis, drafted the manuscript, and implemented revisions.

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All publications are exclusively used in the present dissertation and are not planned to be used in other dissertations.

# Contents

Acknowledgement ... 1

Statement ... 4

Contents ... 6

List of tables and figures ... 9

Abstract ... 12

1 General introduction ... 17

2 Pro-environmental behavior and eco-driving ... 21

2.1 Definition of pro-environmental behavior ... 21

2.2 Definition of eco-driving ... 22

2.2.1 Strategic decisions ... 23

2.2.2 Tactical decisions ... 24

2.2.3 Operational decisions ... 25

3 Impact factors – Drivers and barriers of pro-environmental (driver) behavior change ... 28

3.1 Psychological factors ... 29

3.1.1 Self-determined (autonomous) motivation and self-concordance ... 33

3.2 Contextual factors (behavioral costs) ... 40

3.3 Relationship between psychological and contextual factors ... 42

3.3.1 Campbell Paradigm ... 42

3.3.2 Low-Cost Hypothesis ... 43

3.3.3 A-B-C Model ... 44

3.3.4 Effort Hypothesis ... 45

3.3.5 Summary ... 46

4 Behavioral interventions for pro-environmental (driver) behavior change ... 49

4.1 Effectiveness of behavioral interventions ... 50

4.2 Strategies for implementing effective behavioral interventions ... 52

5 Summary and research questions ... 57

5.1 Do autonomous and self-concordant motivations predict pro-environmental driver decisions and behavior (studies 1, 2)? ..... 57

5.2 What is the relationship between behavioral costs and psychological factors/interventions for pro-environmental driver decisions and behavior (studies 2, 3)? . 59

5.3 Which interventions are effective for promoting pro-environmental driver decisions and behavior (studies 3, 4, 5)? ..... 60

6 Study 1: The role of self-concordance for self-reported strategic, tactical, and operational eco-driving ..... 62

6.1 Introduction ..... 62

6.2 Method ..... 68

6.3 Results ..... 75

6.4 Discussion ..... 81

7 Study 2: Behavioral costs moderate the relationship between environmental motivations and eco-driving ..... 89

7.1 Introduction ..... 89

7.2 Study 2.1 ..... 94

7.2.1 Method ..... 95

7.2.2 Results ..... 100

7.3 Study 2.2 ..... 105

7.3.1 Method ..... 105

7.3.2 Results ..... 108

7.4 Discussion ..... 112

8 Study 3: A matter of behavioral cost: Contextual factors and behavioral interventions interactively influence pro-environmental charging decisions ..... 117

8.1 Introduction ..... 117

8.2 Method ..... 126

8.3 Results ..... 135

8.4 Discussion ..... 144

9 Study 4: Environmental, altruistic, or monetary benefits? A longitudinal online experiment on how framed behavioral consequences affect self-reported eco-driving of German vehicle owners ... 149
9.1 Introduction ... 149
9.2 Method ... 160
9.3 Results ... 169
9.4 Discussion ... 174
10 Study 5: Carbon savings, fun, and money: The effectiveness of multiple motives for eco-driving and green charging with electric vehicles in Germany ... 181
10.1 Introduction ... 181
10.2 Method ... 190
10.3 Results ... 206
10.4 Discussion ... 211
11 General discussion ... 217
11.1 Summary of empirical research findings ... 217
11.2 Discussion of research questions ... 219
11.3 Implications of research findings ... 227
11.4 Open questions and outlook ... 233
11.5 Conclusion ... 240
References ... 242
Appendix ... 295
A. Full intervention material of study 4 ... 295
B. Questionnaire material of study 4 ... 302
C. Eco-driving behaviors and intervention material of study 5 ... 303
Consent ... 304

# List of tables and figures


Table 1. *Overview of strategic, tactical, and operational eco-driving behaviors* ............ 27

Table 2. *Concepts of the Self-Concordance Model (see Sheldon & Kasser, 1995)* .......... 39

Table 3. *Descriptive statistics and zero-order correlations of the main variables (study 1)* ........................................................................................................ 74

Table 4. *Factor loadings of the latent eco-driving construct (study 1)* ............................ 76

Table 5. *Knowledge of eco-driving behaviors (multiple answers possible; study 1)* ........ 80

Table 6. *Eco-driving behaviors investigated in study 2* .................................................... 91

Table 7. *Eco-driving behaviors of study 2.1* .................................................................... 97

Table 8. *Descriptive statistics and zero-order correlations of the main variables (study 2.1)* ........................................................................................................ 98

Table 9. *Mean values for reported eco-driving beahviors of different behavioral costs for participants with low and high self-determination (study 2.1)* ......................... 104

Table 10. *Multivariate linear regression results predicting reported eco-driving behavior from self-determined motivation (study 2.1)* .................................................... 104

Table 11. *Eco-driving behaviors of study 2.2* .................................................................. 107

Table 12. *Descriptive statistics of the main variables (study 2.2)* ................................... 110

Table 13. *Mean values for reported eco-driving behaviors of different behavioral costs for participants with low and high self-determination (study 2.2)* ......................... 111

Table 14. *Multivariate linear regression results predicting reported eco-driving behavior from self-determined motivation (study 2.2)* .................................................... 111

Table 15. *Characteristics of the smart compared to the conventional charging station (study 3)* ........................................................................................................ 130

Table 16. *Relative frequencies (i.e., means) of smart charging decisions for the intervention conditions and the control group dependent on the contextual factors of the smart compared to the conventional charging station as well as across all conditions (study 3)* ........................................................................ 137

Table 17. *Results of mixed-effects logistic regression models testing the interaction between experimental conditions and contextual factors (both dummy coded) predicting smart charging choice without (Model 1) and with control variables (Model 2) (study 3)* ........................................................................................ 139

Table 18. *The eco-driving behaviors presented to participants (study 4)* ........................ 151

Table 19. *Differences between dropout after time and remaining sample at T2 (study 4)*162

Table 20. *Number of participants in the dropout and remaining sample by experimental groups (study 4)* ........ 163
Table 21. *Intervention material (study 4)* ........ 165
Table 22. *Descriptive statistics for worthiness of savings, eco-driving intention, and reported eco-driving behavior in all experimental conditions (study 4)* ........ 168
Table 23. *Results of one-way ANOVA with user-defined contrasts predicting worthiness of eco-driving savings (study 4)* ........ 171
Table 24. *Results of one-way ANOVA with user-defined contrasts predicting eco-driving intention (study 4)* ........ 172
Table 25. *Results of linear mixed-effects model with user-defined contrasts predicting reported eco-driving behavior (study 4)* ........ 173
Table 26. *Dependent variables, experimental groups, and hypotheses (study 5)* ........ 192
Table 27. *Descriptive statistics and zero-order correlations of the main variables (study 5)* ........ 205
Table 28. *Means (or rather relative frequencies for binary variables) and standard deviations (in brackets) of independent and dependent variables for the intervention and the control group (study 5)* ........ 207
Table 29. *Means and standard deviations for energy consumption when eco functions were on vs. off (study 5)* ........ 208
Table 30. *Parameter estimates of logistic regression predicting green charging (study 5)* ........ 209
Table 31. *Parameter estimates of hurdle regression predicting amount of requested eco-driving tips (study 5)* ........ 210

Table C1. *Eco-driving tips with intervention information that was displayed in the prototypical smartphone application (for descriptions of the in-vehicle eco functions, see section 10.2; study 5)* ........ 303

*Figure 1.* The Self-Determination Theory (based on Deci & Ryan, 2000). ........ 36
*Figure 2.* An exemplary goal system according to the Self-Concordance Model (based on Sheldon & Kasser, 1995). ........ 38
*Figure 3.* Simplified predictions of the Campbell Paradigm (Kaiser, 2021; own illustration). ........ 43

*Figure 4.* Simplified predictions of the Low-Cost Hypothesis (Diekmann & Preisendörfer, 2003; own illustration). ........ 44
*Figure 5.* Simplified predictions of the A-B-C Model (Guagnano et al., 1995; own illustration). ........ 45
*Figure 6.* Simplified predictions of the Effort Hypothesis (Schultz & Oskamp, 1996; own illustration). ........ 46
*Figure 7.* The hypothesized motivational model of eco-driving behaviors (study 1). ........ 67
*Figure 8.* Tested motivational model of eco-driving behaviors (study 1). ........ 78
*Figure 9.* Simple slopes plot for the regression of self-determined motivations on reported eco-driving behavior (higher values indicate stronger reported eco-driving behavior; scale ranged from 1 to 7) at three levels of individually perceived behavioral costs of eco-driving (low = 1 *SD* below the mean; high = 1 *SD* above the mean) for study 2.1. ........ 102
*Figure 10.* Default settings for searching a charging station in the study's hypothetical shopping center scenario (study 3). ........ 131
*Figure 11.* Presented charging station lists in the prototypical smartphone app with different smart charging characteristic variations for the (a) framing group, (b) social norm group, (c) gamification group, and (d) control group (study 3). ........ 132
*Figure 12.* Bar plots predicting smart charging station choice with binomial 95% confidence intervals. (a) Prediction of smart charging station choice by walking distance of the smart compared to the conventional charging station and the experimental conditions. (b) Prediction of smart charging station choice by price saving of the smart compared to the conventional charging station and the experimental conditions (study 3). ........ 143
*Figure 13.* Study design, procedure, and collected variables (study 4). ........ 159
*Figure 14.* Default settings for searching a charging station in the smartphone app (study 5). ........ 197
*Figure 15.* Presented charging station lists in the prototypical smartphone app for (a) the intervention group and (b) the control group (study 5). ........ 198
*Figure 16.* Exemplary eco-driving tips (i.e., tip 1 and 7) in the prototypical smartphone app for (a) + (b) the intervention group and (c) + (d) the control group (study 5). 199

# Abstract

The ongoing climate change and its dramatic consequences for nature threaten the life of all humans and other species on earth (IPCC, 2022a). Although new technologies and political measures have an important influence on the containment of human-produced greenhouse gas emissions (e.g., $CO_2$ emissions), which are the main cause of climate change (IPCC, 2022b), people must also change and adapt their behavior in the long term in order to counteract climate change (Klöckner, 2013). Such behavioral changes are particularly important in the transport sector, which is responsible for about a quarter of all energy-related $CO_2$ emissions (IEA, 2020). Road transport vehicles account for a significant share of these emissions (IPCC, 2022b), which is why behavioral changes by *drivers* are crucial now and in future years. These changes include strategic (e.g., buy low-emission vehicles), tactical (e.g., charge electric vehicles with renewable electricity), and operational (e.g., avoid speeding) *eco-driving* behaviors that reduce fuel and energy consumption of road transport vehicles (Sivak & Schoettle, 2012).

Multiple studies have already addressed the question of which determinants can predict eco-driving behavior and which interventions can effectively motivate pro-environmental driver behavior change. Although these studies have identified important determinants, these often only explain parts of the behavior or cannot directly predict it (e.g., Lauper et al., 2015, 2016; Ünal et al., 2018). Therefore, the research of previously neglected factors is needed to extend and deepen the understanding of eco-driving (Steg & Vlek, 2009). Furthermore, studies need to investigate the interrelationship between different determinants, which has also been neglected in the past (Li et al., 2019). Therefore, one goal of this dissertation was to identify important determinants (and their interrelationship) of pro-environmental driver behaviors (studies 1, 2, 3).

In addition to the lacking research on multiple eco-driving determinants, research on interventions to promote eco-driving has shown mixed and inconclusive effects. For example, educational information and financial incentives have shown insufficient or diminishing effects on pro-environmental driver behavior (Af Wåhlberg, 2007; Beusen et al., 2009; Degraeuwe & Beusen, 2013; Schall & Mohnen, 2017; Zeiske et al., 2021). Lindenberg and Steg (2007) suggest two strategies to stimulate pro-environmental behavior successfully. The researchers suggest that interventions to promote pro-environmental behavior should either a) strengthen the normative goal (i.e., to act appropriately) and/or b) make the normative goal compatible with the hedonic (i.e., to have fun) and/or gain (i.e., to improve resources such as money) goal.

Interventions that follow these strategies were effective in influencing pro-environmental behavior (e.g., Günther et al., 2020; Steinhorst et al., 2015; Steinhorst & Klöckner, 2018; Steinhorst & Matthies, 2016). However, the effectiveness of these interventions on pro-environmental *driver* behaviors is not clear to date. Furthermore, there is a lack in research on how the effectiveness of interventions is affected by different situational conditions (e.g., contextual factors). Therefore, another goal of this dissertation was to identify effective interventions that motivate pro-environmental driver behavior change, but also to analyze how these interventions depend on the presence of other (contextual) factors (i.e., behavioral difficulty; studies 3, 4, 5).

In detail, study 1 investigated the motivational predictors of eco-driving based on the theory of self-concordance (i.e., the consistency between a behavior/goal with the person's pre-existing values and interests). For this, data of 539 German drivers of a cross-sectional online survey was analyzed. The findings show that self-reported eco-driving was significantly predicted by sustained effort towards eco-driving, which in turn was predicted by self-concordance. Therefore, individuals pursuing eco-driving out of strong interest or deep personal beliefs (i.e., autonomous motivation) as opposed to external forces or internal pressure (i.e., controlled motivation) reported greater effort towards this behavior. Furthermore, biospheric striving coherence, i.e., the coherence between biopsheric values (i.e., values addressing the well-being of the environment/biosphere) and eco-driving, significantly predicted effort towards eco-driving. In sum, the results of study 1 suggest that autonomous rather than controlled motives and coherence between behavior and intrinsic rather than extrinsic values are relevant predictors of eco-driving.

In addition to low autonomous motivations, behavioral costs (i.e., physical effort, time losses, etc.) might also play a decisive role in explaining why many individuals do not eco-drive in their daily lives. However, high autonomous motivations could counteract the barrier of behavioral costs. To gain insights into the relationship between autonomous motivations and behavioral costs for eco-driving, in study 2, data of two online surveys was analyzed ($N_{Study2.1}$ = 207, $N_{Study2.2}$ = 539). The analyses indicate that high autonomous motivations for eco-driving were more effective in promoting eco-driving behavior than low motivations if individuals perceive eco-driving as both low- or high-cost. Furthermore, the results indicate that high autonomous motivations predicted eco-driving behaviors better when these behaviors are associated with moderate or high than with very low behavioral costs. Therefore, eco-driving interventions should focus on how autonomous motivations can be influenced.

However, changing (perceived) behavioral costs of eco-driving may also be a promising intervention technique.

In study 3, it was investigated if the effectiveness of behavioral interventions (aimed at changing pro-environmental behavior) also depends on the presence of behavioral costs. Because the sales rate of electric vehicles (EVs) is steadily increasing, in the future, a huge demand of electricity is needed, which needs to be produced $CO_2$-neutral to make EVs a green alternative. To address this issue, smart charging shifts the charging process to optimal day/night times when (renewable) electricity is available and energy consumption is low. Especially when charging in public, smart charging may produce external behavioral costs (e.g., charging delays) that should be offset by personal and highlighted environmental benefits. Hence, study 3 examined the interactive influence of contextual factors (i.e., charging delay, walking distance, price saving) and behavioral interventions on pro-environmental smart charging decisions in an online experiment ($N = 286$). The results showed that the interventions influenced the decision to choose the smart charging station over a convenient non-sustainable alternative when behavioral costs were small to moderate. In situations with no or only negligible extra costs, participants did not need additional persuasion, whereas in high-cost situations, behavioral interventions were insufficient to influence pro-environmental behavior.

To extend these insights, study 4 aimed at investigating if several (low- and moderate-cost) eco-driving behaviors with internal combustion engine vehicles (i.e., the currently predominant vehicle type) could be motivated by symbolically and/or monetarily framed benefits (i.e., framing interventions). Framing interventions that emphasize behavioral consequences are gaining prominence for promoting pro-environmental behaviors like eco-driving. Hence, to investigate if and how eco-driving tips with highlighted behavioral consequences promote eco-driving motivations and behaviors in everyday life, a longitudinal online experiment was conducted. For this, German vehicle owners ($N = 402$) filled out two online surveys over the course of one month ($N_{T1} = 281$; $N_{T2} = 228$). As part of the first survey, participants were randomly assigned to a framing group, in which either $CO_2$ (environmental framing), pollutant (altruistic framing), or monetary savings (monetary framing) of eco-driving were highlighted, or the control group. It was examined whether the framed tips increased short-term eco-driving motivation and intention as well as medium-term eco-driving behavior change. Participants rated the savings of environmental and altruistic framing (i.e., $CO_2$/pollutant savings) as worthier than the monetary savings. However, individuals who were exposed to framed eco-driving information independent of framing content reported an increase of eco-driving behavior, compared to the control group. Therefore, symbolic *and* structural benefits motivated self-reported eco-driving behaviors that are associated with low to moderate behavioral costs.

Because psychological *and* contextual factors could predict eco-driving behaviors in the previous studies, study 5 set out to explore if a combined intervention addressing multiple motives could influence actual behavior change of the behaviors that were measured only by self-report in the previous studies. Because eco-driving behaviors may come with behavioral costs, they need to be offset by motivating behavioral interventions (see studies 2, 3). Therefore, in an experimental driving study with 94 German drivers on the company site of a vehicle manufacturer and on public roads in the south of Germany, it was investigated how combined interventions affect pro-environmental charging and eco-driving behavior with an electric vehicle. Participants were randomly assigned to the intervention or the control group. The findings suggest that a combined intervention with informational cues (i.e., $CO_2$ emission savings) as well as gamified (i.e., competitive task) and monetary incentives did not significantly motivate individuals to choose a charging station that provides renewable electricity. However, the intervention did motivate individuals to seek eco-driving information. Being interested in eco-driving behaviors helped to improve energy consumption during a real-world drive. Hence, interventions providing behavioral information and addressing multiple motives are a promising approach to motivate future electric vehicle owners to behave pro-environmentally.

To summarize, the present dissertation contributes valuable empirical results that broaden and deepen the understanding of various strategic, tactical, and operational eco-driving behaviors (e.g., charging an EV with renewable electricity, driving at moderate speed). First, the findings indicate that autonomous motivations and behavioral costs are important determinants of eco-driving behaviors. The results further indicate that these two factors have interactive instead of additive effects on pro-environmental driver behaviors. Therefore, both factors should be taken into account (interactively) within theoretical frameworks that aim at explaining pro-environmental driver behaviors. Thirdly, the findings provide important implications for the development of effective interventions that promote eco-driving behaviors of (electric and internal combustion engine vehicle) drivers. Based on the present results, such interventions should address autonomous motivations *and* be tailored to the contextual factors (i.e., behavioral difficulty) of the behavior that is aimed at being changed or tailored to the situation in which the behavior arises. Informational interventions that inform individuals why and how to behave pro-environmentally and stimulate autonomous motivations provide promising results for low- and moderate-cost behaviors (see studies 3, 4, 5). However, for high-

cost behaviors, informational interventions are not sufficient but should be combined with hard measures instead, e.g., structural changes or financial incentives (see study 3). Future studies should take these findings into account when analyzing and developing interventions for pro-environmental behaviors in general and eco-driving behaviors in particular.

# 1 General introduction

*All we have to do is to wake up and change.*
Greta Thunberg (2019)

The findings of the latest report of the Intergovernmental Panel on Climate Change (IPCC) should eliminate the last remaining skepticism and downplaying of the phenomenon that currently threatens the earth most strongly. It again makes clear that human-made greenhouse gas emissions are the cause of current and future global warming (IPCC, 2022a). According to this report, humans and their actions are the main cause of the actual increase in extreme weather events (such as extreme heat, floods, tsunamis and the like), which are likely to become more frequent and severe in the future. Although many people may still be convinced that climate change is a distant problem to them, both temporally and geographically, the report also states that about half the people living on earth reside in an area that is highly vulnerable to climate change (IPCC, 2022a). However, not only is the destruction of habitat for humans and other species a serious risk now and in the future, but (physical and psychological) health problems associated with the effects of climate change, as well as water and food shortages are among the many climate change risks identified in the IPCC report. Global warming, which may exceed 1.5 degrees Celsius in 2030 and therefore 10 years earlier than predicted in 2018, is particularly driven by $CO_2$ emissions (IPCC, 2021, 2022a). Consequently, it is necessary to mitigate $CO_2$ emissions caused by humans and their behavior (IPCC, 2022b).

In 2019, 23% of global energy-related $CO_2$ emissions were attributable to the transport sector. Road vehicles caused 70% of direct transport emissions (IPCC, 2022b). These alarming numbers lead to the question of how we can reduce the emissions caused by road vehicles. While the International Energy Agency (IEA) makes clear that policies need to be implemented and scaled up, and new technologies should be introduced (IEA, n.d. b), behavioral changes by transport users (e.g., public transport usage, reduction of short vehicle rides) and the acceptance of new technologies (e.g., electric vehicles) are also necessary to radically reduce $CO_2$ emissions of the transport sector (Barkenbus, 2010). Indeed, the response to the global COVID-19 pandemic (e.g., reduced mobility behavior) has shown that behavioral changes by individuals can reduce transport-related greenhouse gas emissions effectively (Anke et al., 2021; Aruga et al., 2021; Gensheimer et al., 2021; Habib & Anik, 2021; IEA, n.d. b; Schulte-Fischedick et al., 2021).

The most promising solution to achieve large-scale $CO_2$ reductions in the road transport sector is probably the widespread introduction of light-duty battery electric vehicles (BEVs). BEVs have lower life-cycle greenhouse gas emissions than the currently predominant internal combustion engine vehicles (ICEVs), when they are charged with low-carbon electricity (IPCC, 2022b). However, since renewables cannot respond quickly to high electricity demand (which may occur with many BEVs needed to be charged at the same time) and are more variable in supply than current fossil fuels, *smart* storage and distribution of renewable electricity as well as *energy-saving* driver activities and decisions seem necessary to realize the full potential of BEVs (Daina et al., 2017; Eider et al., 2017; Eurelectric, 2015; Jäger et al., 2019; Pettersson, 2013; Richardson, 2013).

However, there is still a long way to go before only BEVs will be on the road, which will, in the European Union (EU), probably not be until 2050 or later (European Commission, 2020b). Accordingly, the goal in the near future, while the majority of individuals are still driving ICEVs, should be to promote *fuel-saving* activities by drivers too (Alam & McNabola, 2014; Barkenbus, 2010; Keyvanfar et al., 2018; Sivak & Schoettle, 2012). Therefore, in order to achieve both near and future $CO_2$ reductions of the road transport sector, it is necessary to promote pro-environmental driver decisions and behaviors of people driving an ICEV or a BEV (or a hybrid-powered vehicle for which a mixture of the driving principles outlined in this dissertation apply). According to Sivak and Schoettle (2012), pro-environmental decisions in the driving context include strategic, tactical, and operational decisions. Therefore, transport decisions not related to driving a vehicle (e.g., avoid driving, use public transport), decisions before driving (e.g., combine vehicle trips), and decisions during driving (e.g., avoid extreme speeds) are all part of a pro-environmental driver style commonly referred to in the literature as *eco-driving*.

Although according to a recent Eurobarometer survey, 94% of all EU citizens state that environmental protection is important to them (European Commission, 2020a), only few people show high-impact behaviors (e.g., low-carbon travelling, reduced vehicle usage) in everyday life to reduce their own $CO_2$ footprint (European Commission, 2020a). Research in environmental psychology that addressed the question why this is the case began as early as 1970 (Altman, 1976) and experienced a great resurgence after the turn of the century (Stern, 2000). Although this research has made considerable progress in the field of eco-driving in the last years (Bolderdijk, Steg, et al., 2013; Dogan et al., 2014; Lauper et al., 2015, 2016; Ünal et al., 2018), it has neglected some impact factors (e.g., motivations, contextual factors) that may explain why people struggle to make high-effort pro-environmental transport decisions and maintain an eco-driving style in their daily lives (Pampel et al., 2018).

Likewise, although a wide variety of interventions such as training courses or monetary incentives have been designed to promote eco-driving, these interventions showed only small and, more importantly, diminishing effects on pro-environmental driver behavior in the past (Af Wåhlberg, 2007; Beusen et al., 2009; Degraeuwe & Beusen, 2013; Schall et al., 2016; Schall & Mohnen, 2017). Therefore, it remains not entirely clear why people often do not make pro-environmental mobility choices or rather do not eco-drive. Only by understanding and knowing the key determinants of eco-driving, effective interventions can be developed. Such interventions have the power to motivate many people to change their driving behavior, which has the potential to result in essential emission savings.

Consequently, this thesis aims at contributing to the identification of important determinants of eco-driving and, in detail, to clarify the so far neglected role of motivation and contextual factors (e.g., physical effort, time loss, monetary savings). Furthermore, the aim of the present research is to investigate the effectiveness of behavioral interventions derived from existing theoretical assumptions and the identified eco-driving determinants. Only by involving peoples' concerns and needs, it will be possible to make a rapid transition to climate-friendly transport. Therefore, this thesis seeks to understand which psychological (e.g., environmental motivation) and structural factors (e.g., monetary benefits) promote or hinder pro-environmental driving decisions and how these can be addressed by effective interventions.

Chapter 2 of this thesis defines and clarifies pro-environmental behavior in general and eco-driving in particular. Furthermore, the different types and behaviors of eco-driving will be presented. Chapter 3 will provide an overview of currently discussed determinants of pro-environmental (driver) behavior. Furthermore, this chapter gives an overview of relevant, but so far neglected determinants (and their relationship) of eco-driving. Chapter 4 provides an overview of the current state of research on interventions for promoting eco-driving. This chapter also discusses how interventions should be designed and used to motivate (eco-driving) behavior change effectively. Chapter 5 summarizes the introduction and defines the research questions of this dissertation that are addressed by the then following empirical studies. The study presented in chapter 6 examines the influence of different motivations on strategic, tactical, and operational eco-driving behaviors. Chapter 7 contains an empirical study that considers the interplay of motivational and contextual factors for various eco-driving behaviors. Chapter 8 extends these insights by examining the interplay between different psychological interventions and behavioral costs for a tactical eco-driving decision (i.e., charging a BEV).

Chapter 9 of this dissertation deepens the understanding of the effectiveness of interventions by examining the influence of interventions on tactical and operational eco-driving behaviors in the context of a longitudinal online survey. The empirical part of this dissertation concludes with chapter 10, which examines the influence of a combined intervention addressing multiple motives on objectively measured eco-driving behaviors, which were previously collected via self-report. The final chapter of the dissertation discusses the results of each study and provides theoretical and practical implications. Furthermore, this chapter closes with open research questions and an outlook to future research.

# 2 Pro-environmental behavior and eco-driving

## 2.1 Definition of pro-environmental behavior

It is obvious that all people on earth wish to satisfy their basic needs. The problem, however, is that many people also want to satisfy their seemingly endless needs and desires for pleasure and flexibility. This behavior contributes to the depletion of the earth's resources, endangering the lives of future generations and all living things on earth (Lehman & Geller, 2004). Therefore, even though many people probably hope that technological advances and national and international policy developments will counteract these problems in the near future, individual behavior changes are also necessary to address climate change mitigation in the upcoming years (Klöckner, 2013).

Pro-environmental behavior defines "behavior that harms the environment as little as possible, or even benefits the environment" (Steg & Vlek, 2009, p. 309). In the private domain, pro-environmental behavior relates to the "purchase, use, and disposal of personal and household products that have environmental impact" (Stern, 2000, p. 409). This means that people cannot pursue all their inexhaustible desires and needs but must limit them in order to protect life on earth in the long term (Brown & Kasser, 2005). This has led researchers to view pro-environmental behavior as a social dilemma because individuals are required to suppress short-term egoistic tendencies (e.g., fly on vacation) in order to act in the interest of the community but also in the interest of the long-term health of the earth and its species (Harland et al., 1999; Nordlund & Garvill, 2003).

Several studies show that pro-environmental behavior in the private domain can have a significant direct impact on climate protection. For example, several researchers conclude that about 70% of all greenhouse gas emissions are attributable to the consumption of private households, while food, housing, and mobility are responsible for the highest share (Hertwich & Peters, 2009; Tukker & Jansen, 2006). Dietz et al. (2009) suggest that implementing a few (low-effort) behavioral changes (e.g., eco-driving, carpooling, purchase efficient water heaters or more fuel-efficient vehicles) could reduce carbon dioxide emissions of private households by about 20%. In fact, according to the researchers, these behaviors would *not* significantly reduce the comfort of people either. This is particularly important because it is unlikely that many people will engage in pro-environmental behaviors if these behaviors are sacrificial and require a lot of time and effort (Brown & Kasser, 2005).

Overall, pro-environmental decisions in the private domain are important for countering climate change (Klöckner, 2013). Especially for the transport sector, there is great emission savings potential, which is why pro-environmental behavior change in the mobility context should be tackled by psychological and environmental research. For this, it is important to analyze pro-environmental behavior change holistically. Hence, it is not only essential to a) analyze pro-environmental behaviors with a large environmental impact but also to b) study which determinants cause this behavior, c) develop interventions to change the behavior or the determinants of a behavior, and d) investigate the effectiveness of these interventions (Abrahamse & Matthies, 2018; Steg & Vlek, 2009). The present thesis aims at addressing these points for pro-environmental driver decisions and behavior, i.e., eco-driving.

## 2.2 Definition of eco-driving

Due to improved technology and enhanced know-how in the last years, the average fuel and energy consumption of new light-duty passenger vehicles has been falling continuously. Nevertheless, traffic-related emissions remain at a high level, which is probably due to the increased mobility and travel needs of people and due to the constant increase of large vehicles on the road (IEA, n.d. a). Consequently, behavioral changes in the transport sector are necessary in order to achieve climate protection goals (Lehman & Geller, 2004; Poortinga et al., 2004).

Although it would certainly be most effective for climate change mitigation if all people refrained from owning and driving vehicles (Strömberg et al., 2015), this approach is unrealistic because personal ownership of motorized vehicles has become essential for an adventurous life, flexibility, and commuting to work (Poortinga et al., 2004; Stanton & Allison, 2020). The rate of vehicle ownership among U.S. households remains over 90% (U.S. Government, 2020), while the European Environment Agency (EEA) reports that the EU counts over 500 passenger vehicles per 1,000 inhabitants (EEA, 2019). This is not surprising since, according to research findings, vehicle use offers significant benefits to people, such as speed, availability, fun, convenience and safety, as well as privacy and independence (Schoenau & Müller, 2017; Steg, 2005). Therefore, it is practically impossible to completely eliminate private vehicle use. Instead, it is more achievable to motivate pro-environmental driver choices and the adoption of pro-environmental driving behaviors. Such eco-friendly activities in the mobility context are important because they have an impact on the environment, which is superior to the impact that many other behaviors in the private user domain have (Jones & Kammen, 2011; Lacroix, 2018; Wynes & Nicholas, 2017).

Eco-driving describes all strategic, tactical, and operational driver behaviors and decisions that reduce the fuel or energy consumption (Sivak & Schoettle, 2012). Eco-driving behaviors, which are also referred to as smart driving behaviors, have a decisive impact on the environment and can reduce fuel consumption by up to 5 or rather 45% dependent on which behaviors are implemented by drivers (Alam & McNabola, 2014; Barkenbus, 2010; Boriboonsomsin et al., 2010; Sivak & Schoettle, 2012; Zarkadoula et al., 2007).

If we assume that as of today, every vehicle driver in the U.S. would save 10% of fuel consumption, more than 13 billion gallons of gasoline could be saved after one year, which would equate to about 114 billion kilograms of saved $CO_2$ emissions[1]. In the EU, this driver behavior could save 222 million gallons of gasoline, which would save about 2 billion kilograms of $CO_2$ emissions[2]. This thought experiment illustrates that an enormous amount of emission savings could be achieved even when not everyone but at least a majority of ICEV drivers adopted a pro-environmental driving style.

Likewise, eco-driving with a BEV generates energy saving potentials, which can be as high as 30% (Bingham et al., 2012; Helmbrecht et al., 2013a). Researchers state that the driver's influence when driving a BEV is even higher than it is when driving an ICEV, which is why eco-driving with a BEV is of special significance in the future (McIlroy et al., 2014; Neumann et al., 2015; Walsh et al., 2010). Below, the strategic, tactical, and operational behaviors that a driver can implement to reduce the vehicle's fuel or energy consumption are defined and listed (see Table 1 for an overview of eco-driving behaviors based on Fontaras et al., 2017; Günther et al., 2017; Huang et al., 2018; Martin et al., 2012; Sanguinetti et al., 2017, 2020; Sivak & Schoettle, 2012; Strömberg et al., 2015).

### 2.2.1 Strategic decisions

Sivak and Schoettle (2012) define strategic eco-driving decisions as all behaviors associated with owning or purchasing a vehicle that do not concern the actual activity of driving. For example, this includes the decision not to drive the vehicle but to choose public transportation instead (Strömberg et al., 2015). Furthermore, the selection of vehicle size and type (e.g., BEV, ICEV) can be considered as a strategic decision. In addition, maintaining an

[1] Based on the assumption that the yearly U.S. consumption of gasoline is 134.83 billion gallons (U.S. Energy Information Administration, 2022) and one gallon gasoline produces 2.4 kg $CO_2$ emissions (EPA, 2005).
[2] Based on the assumption that the yearly European consumption of gasoline is 70 million tones (Eurostat, 2022) and one gallon gasoline produces 2.4 kg $CO_2$ emissions (EPA, 2005).

optimal tire pressure can be viewed as a strategic behavior (Alam & McNabola, 2014; Sivak & Schoettle, 2012). Many researchers do not consider strategic behaviors when studying eco-driving (e.g., Delhomme et al., 2013; Dogan et al., 2011; Pampel et al., 2015, 2018). This is understandable because strategic decisions do not concern *driving* activities. Therefore, strategic decisions are also not considered in various driving models that have been developed in the past (see, for example, Hollnagel et al., 2005; Michon, 1985). However, these kinds of decisions are associated with great savings potentials and are within the conscious control of the driver (i.e., possibly easier to change than automated driving tasks), which is why these behaviors should not be neglected (Sivak & Schoettle, 2012). For example, not maintaining the vehicle emission control system can attribute to up to 40% of vehicle emissions (An & Ross, 1996). Table 1 provides an overview of multiple strategic decisions that have been categorized as eco-driving behaviors for traditional and battery-powered vehicles by researchers in the past.

### 2.2.2 Tactical decisions

According to Sivak and Schoettle (2012), tactical decisions do not concern driving activities too but rather address the pre-driving decisions that need to be made when people have decided to travel by vehicle. Thus, tactical decisions include, for example, the selection of the driving route (e.g., with regard to road gradient, traffic) or the loading of the vehicle. For instance, the U.S. Environmental Protection Agency (EPA) states that carrying a load of about 45kg in the vehicle can increase fuel consumption by 2% dependent of the vehicle size and the time of travel (EPA, n.d.). Furthermore, the selection of energy-efficient driving routes may result in a reduction of fuel consumption by 15 to 40% (Sivak & Schoettle, 2012). A study in Sweden found that 46% of the route options selected by drivers were not the most optimal choices regarding fuel efficiency. However, a fuel-optimized navigation system could reduce fuel consumption by up to 8.2% (Ericsson et al., 2006).

The refueling or charging behavior can also be considered as a tactical behavior. Therefore, smart charging, which is examined in more detail in this dissertation, can also be perceived as a tactical decision. In order not to overload the power grid in the future due to the high number of BEVs on the road and also to integrate volatile green energy from renewable sources into the power grid, smart charging is a crucial solution for BEVs. Smart charging delays or adjusts the charging process of BEVs aiming at reaching specific optimization goals (e.g., avoid peak loads; García-Villalobos et al., 2014). For this, charging takes place at times when the power grid is stable or green (Huber et al., 2019, 2020). However, smart charging not only stabilizes the power grid and supports the integration of renewable electricity but also includes benefits for the user because of possible price advantages due to charging at times of low electricity demand (Schmalfuß et al., 2015). Smart charging is one of the most important tactical decisions with a BEV in the future, which is why this behavior receives special attention in this dissertation.

Because tactical eco-driving decisions relate to the driving activity itself, these decisions occur in classical driving models and are ironically referred to as behaviors on the strategic level in these models. Michon (1985) refers to the strategic level of the driving task as the one that includes activities such as planning or navigation; therefore, this level involves deliberate and time-consuming decision-making. Table 1 displays an overview of the tactical decisions with a BEV and an ICEV that were identified and classified in past research.

### 2.2.3 Operational decisions

Lastly, operational eco-driving decisions relate to the driving task. Accordingly, operational decisions include actual driving behaviors, such as anticipatory driving or smooth acceleration/braking, and closing windows at high speeds (see Table 1). These driving behaviors can in fact have great emission reduction potential, which may be even higher than those of maintenance practices (Alam & McNabola, 2014). Most researchers in environmental research consider these behaviors when studying the determinants, interventions, and effects of eco-driving (e.g., Beusen et al., 2009; Zarkadoula et al., 2007). Obviously, these behaviors fit most closely with the term eco-driving. Michon's (1985) driving model enact operational behaviors at the maneuver or control level. Accordingly, these behaviors may be under the driver's conscious control (e.g., minimizing the use of consumers) or represent largely automated behaviors that may be difficult to change due to deeply rooted driving habits (e.g., shifting gears).

Especially for operational behaviors, there are differences between driving an ICEV and a BEV. Of course, some operational decisions apply to both types of vehicles (e.g., avoid high speeds); however, there are also changes in the driving task with BEVs, such as the elimination of gear changes or the addition of recuperation (McIlroy et al., 2014). Thus, "eco" driver assistance systems promoting eco-driving, which are common in new passenger cars, seem to be gaining relevance especially with BEVs to support drivers with pro-environmental driving behaviors with a new vehicle type. In fact, several studies showed that "eco" assistance systems could result in high fuel reductions with a BEV (or ICEV; Boriboonsomsin et al., 2010; Kim et al., 2015; Staubach et al., 2014; Stillwater & Kurani, 2013). Such devices use engine or GPS (real-time) data to calculate the fuel consumption and are able to give appropriate tips and feedback to drivers assisting them with fuel reduction activities during driving (Alam & McNabola, 2014; Ando et al., 2010; Beusen et al., 2009). Table 1 provides an overview of operational eco-driving behaviors with an ICEV and a BEV.

Table 1

*Overview of strategic, tactical, and operational eco-driving behaviors*

| Strategic decision | Tactical decision | Operational decision |
|---|---|---|
| Avoid driving | Ridesharing | Shift up early (*only ICEV*) |
| Drive less | Choose energy-efficient routes (e.g., regarding congestion, grade profile, road type) | Drive at low engine speed (*only ICEV*) |
| Use alternative travel means | Do not carry weight | Avoid high speeds/avoid overtaking |
| Take vehicle in for service | Improve aerodynamics | Accelerate smoothly |
| Vehicle maintenance activities (e.g., oil changing, tire pressure checking) | Trip-chaining | Maintain steady speed or use cruise control |
| Park vehicle in garage/shadow | | Decelerate smoothly |
| Switch tires seasonally | | Drive anticipatorily/keep distance to vehicle in front |
| Avoid car ownership | | Let vehicle sail when possible |
| Buy low-emission vehicles (e.g., electric vehicles) | | Minimize idling/use start-stop system (*only ICEV*) |
| Use proper fuel grade or renewable electricity | | Minimize use of consumers |
| | | Use eco mode of vehicle |
| | | Use air conditioning at high speeds and open windows at low speeds |
| | | Use regenerative breaking |

*Note*. For references, see Fontaras et al. (2017), Günther et al., (2017), Huang et al. (2018), Martin et al. (2012), Sanguinetti et al. (2017, 2020), Sivak & Schoettle (2012), and Strömberg et al. (2015).

# 3 Impact factors – Drivers and barriers of pro-environmental (driver) behavior change

In order to change human pro-environmental behavior, it is necessary to understand which factors significantly influence this behavior (Klöckner, 2013). People often do not behave pro-environmentally because these behaviors usually involve high costs, whether they are monetary or physical in nature (Steg & Vlek, 2009; Stern, 2000). Purchasing renewable electricity, for instance, is often more expensive than purchasing electricity from fossil sources. In addition, electric vehicles are currently still significantly more expensive than those with internal combustion engines are. Furthermore, traveling by train often involves more effort and uncertainty as well as a loss of time than traveling by vehicle or airplane. Accordingly, external factors frequently hinder pro-environmental behavior, which are examined in more detail in chapter 3.2.

However, although high behavioral costs often discourage pro-environmental (driver) behaviors (Diekmann & Preisendörfer, 2003), it appears that many people nevertheless behave pro-environmentally in everyday life. For example, many people travel by train even though they could afford traveling by plane, which would be much more time-effective in most cases. Furthermore, many people already buy BEVs, even if they still have the option to buy much cheaper ICEVs. Likewise, many people choose to purchase renewable electricity for their household even though purchasing the significantly cheaper “grey” electricity from fossil sources would allow to follow daily tasks and needs in the exact same way. This suggests that other factors such as environmental/normative concerns and environmental motivations may influence pro-environmental behavior too (De Groot & Steg, 2008; De Young, 1996; Guagnano et al., 1995; Steg et al., 2016; Schultz & Zelezny, 1999). These factors are referred to as psychological factors in this dissertation and are discussed below.

To date, it is not extensively studied which factors influence pro-environmental driver decisions. Although, of course, the determinants of pro-environmental behaviors in general are well researched, it is likely that the impact factors differ for various pro-environmental behaviors (Poortinga et al., 2004). Therefore, it is the goal of this dissertation to examine the influence of impact factors that have been neglected in previous eco-driving research. For this, it is assumed that psychological and contextual factors, which have also been referred to as internal and external factors (Kollmuss & Agyeman, 2002), personal and social factors (Gifford & Nilsson, 2014), or intrapersonal and contextual factors (Steg & Vlek, 2009), are most important for eco-driving.

## 3.1 Psychological factors

Environmental psychology research, both in the past and more recently, has focused predominantly on the psychological determinants of pro-environmental behaviors, such as environmental attitudes (Hawcroft & Milfont, 2010; Van Liere & Dunlap, 1980), general and specific knowledge (Maloney & Ward, 1973; Ünal et al., 2018), moral and personal norms (Guagnano et al., 1995; Hunecke et al., 2001; Stern, 2000), behavioral intentions (Bamberg & Schmidt, 2003; Lauper et al., 2015), and values (De Groot & Steg, 2010; Jakovcevic & Steg, 2013; Perlaviciute & Steg, 2015). This is also reflected in the theories that have been used to explain pro-environmental behavior. Some researchers refer to Schwartz's (1977) Norm-Activation Model (NAM), which was developed as early as 1977 to explain prosocial behavior. Thus, this theory was originally applied to explain altruism and helping behavior. However, several researchers used this theory to explain pro-environmental behavior too (Black et al., 1985; Guagnano et al., 1994; Harland et al., 2007). Thøgersen (1996) clarifies that pro-environmental behavior is morally motivated, which is why the NAM is suitable for many pro-environmental behaviors according to his view. The basic assumption of the NAM is that individuals behave in a prosocial manner when they feel morally obligated to do so. Schwartz (1977) describes this moral obligation as a *personal norm* that is only activated when two conditions are met. First, the individual must be aware of the behavioral consequences of the behavior (*awareness of consequences*, AC), and second, the individual must accept responsibility for showing the behavior (*ascription of responsibility*, AR). Researchers who are convinced that pro-environmental behavior is influenced by moral commitment showed that this model could indeed successfully predict many pro-environmental behaviors, such as energy saving (Black et al., 1985), recycling (Guagnano et al., 1995), or choosing a sustainable travel mode (Hunecke et al., 2001).

However, some researchers criticize the use of this model, mainly because the authors of the NAM have not properly elaborated the structure of the theory and thus, different variations of this theory appear in research (Klöckner, 2013). Due to this, many researchers use an extension of the NAM, namely Stern's (2000) integrative Value-Belief-Norm (VBN) theory, to predict pro-environmental behavior (e.g., Poortinga et al., 2004). This theory extends the assumptions of the NAM, proposing a causal chain for the antecedents of personal norms (Poortinga et al., 2004). As proposed in the NAM, the VBN theory assumes that *personal norms* directly influence pro-environmental behavior, but that the antecedent of personal norms is the *ascription of responsibility*, which in turn is influenced by the *awareness of consequences*.

However, the awareness of consequences is not the start of the causal chain but is in turn influenced by the *ecological worldview* as measured by the New Ecological Paradigm (NEP; Dunlap et al., 2000). This worldview describes the belief that humans are significantly endangering the environment and depleting valuable resources. Furthermore, this worldview incorporates the belief that humans should not dominate and control nature (Dunlap et al., 2000). The VBN theory assumes that this belief is predicted by *personal values* (Stern, 2000).

Values describe overarching goals in people's lives that serve as their leading principles (Schwartz, 1992). Values are believed to influence how people think and act and are considered to be relatively stable over a lifetime (Feather, 1995; Steg, Bolderdijk, et al., 2014). In the VBN theory, the ecological worldview is predicted by various values, mostly referred to as *self-enhancement* and *self-transcendence* values (Schwartz, 1994). According to Schwartz (1994), these values are higher value orientations in a universal value system. Self-transcendence values incorporate values such as universalism and benevolence (Schwartz, 1994) and represent *altruistic* and *biospheric* values of new value theories (De Groot & Steg, 2007, 2008; Stern, 2000; Stern & Dietz, 1994). Altruistic values concern the well-being of other people while biospheric values describe the well-being of nature and the environment (De Groot & Steg, 2007, 2008). Research shows that these values both directly and indirectly influence a range of pro-environmental behaviors (De Groot et al., 2007; De Groot & Steg, 2010; Jakovcevic & Steg, 2013; Perlaviciute & Steg, 2014; Steg, Bolderdijk, et al., 2014; Steg, Perlaviciute, et al., 2014; Steg & De Groot, 2012), which is why they are positively related to an individual's ecological worldview according to the VBN theory (Stern, 2000).

On the other hand, Schwartz's (1994) value system includes self-enhancement values, which relate to self-centered goals (e.g., power, money, hedonism). More recent value theories for pro-environmental behaviors label these kind of values *egoistic* and *hedonic* values, which refer to the improvement of one's own resources, such as money or status or rather the improvement of one's mood (De Groot & Steg, 2007, 2008). It has been argued that these values are negatively associated with the ecological worldview (Stern, 2000), which is also reflected in numerous research findings showing that these values negatively correlate with pro-environmental attitudes and behavior (De Groot & Steg, 2010; Nordlund & Garvill, 2002; Steg & De Groot, 2012; Thøgersen & Ölander, 2002).

Both the distinction between self-enhancement and self-transcendence values and the distinction between egoistic, hedonic, altruistic, and biospheric values have been validated in different countries and cultures in the past (De Groot & Steg, 2007; Schultz & Zelezny, 1999). Values are therefore considered to play an important role in the VBN theory and have received strong research attention (Boomsma & Steg, 2014; Jakovcevic & Steg, 2013; Perlaviciute & Steg, 2015; Van der Werff et al., 2014). Furthermore, a number of research reports show that the VBN theory explains various pro-environmental behaviors successfully, such as energy saving (Poortinga et al., 2004; Shi et al., 2019), recycling (Izagirre-Olaizola et al., 2015), or sustainable vehicle use (Nordlund & Garvill, 2003).

Although both theories remain popular among researchers until today to explain pro-environmental behavior, the application of the theories is not lacking criticism. For example, Steg and Vlek (2009) point out that while these theories are useful in explaining low-effort behaviors, they tend to perform poorly in predicting high-cost pro-environmental behaviors. Furthermore, it must be questioned whether normative and moral environmental concerns and values alone are sufficient to explain pro-environmental behaviors (Kollmuss & Agyeman, 2002). Indeed, meta-analyses show that personal norm, the most important predictor of behavior in the NAM and VBN theory, explains only up to 30% of the variance in self-reported recycling behavior (Do Valle et al., 2005). Furthermore, Hines et al. (1987) found that based on six studies, the correlation between moral obligation and behavior is .33 (Bamberg & Schmidt, 2003).

Because of this, another theory, namely Ajzen' s (1991) Theory of Planned Behavior (TPB), which is an extension of the Theory of Reasoned Action (Ajzen & Fishbein, 1980), is often applied to explain pro-environmental behavior. The theory considers pro-environmental behavior as rationally and hedonistically motivated (Lauper et al., 2015; Sniehotta et al., 2014). Therefore, individuals rationally choose a behavior based on a cognitive cost-benefit analysis that results in initiating a behavior when reward/joy outweighs the costs of a behavior (Antimova et al., 2012). The TPB theory assumes *behavioral intention* as a direct predictor of behavior. Intention is in turn predicted by *attitudes*, *subjective norms*, and *perceived behavioral control*. Attitudes represent the sum of all beliefs about a behavior, which include all (positive and negative) evaluations of the behavior. Subjective norms reflect the perceived expectations that other important people have about performing the behavior, i.e., what other people would or would not approve of. Perceived behavioral control, in turn, which can also directly influence behavior (i.e., dependent on the *actual* behavioral control; Sniehotta et al., 2014), refers to people's abilities and skills to perform the behavior and thus, defines the perceived ease or difficulty of a behavior (Lindenberg & Steg, 2007). The TPB theory is very popular among researchers for explaining pro-environmental behaviors and has proven to be effective in predicting a range of these behaviors, such as sustainable transportation choice (Bamberg & Schmidt, 2003; Harland et al., 1999), electric vehicle use or purchase intentions (Lee et al., 2023; Shanmugavel & Balakrishnan, 2023), eco-driving (Lauper et al., 2015), household recycling (Mannetti et al., 2004), the purchase of green products, and water and meat consumption (Harland et al., 1999).

However, the TPB theory has also received much criticism in the past. For example, it has been criticized because of its lacking consideration of moral beliefs (Klöckner & Blöbaum, 2010) and for its inability to withstand experimental tests (Sniehotta et al., 2014). It is also criticized because of its parsimonious structure that may not include all relevant predictors of pro-environmental behavior, which is supported by meta-analytical results showing that about 50% of the variance in behavior can be explained by the factors of the TPB theory (Bamberg & Schmidt, 2003). Furthermore, it is questioned whether the assumptions about the mediation are correct, since, for example, attitudes can also directly predict behavior (Hines et al., 1987; Sniehotta et al., 2014). Overall, it is certainly not plausible that a theory as parsimonious as the TPB takes into account all factors that influence behavior (Sniehotta et al., 2014). For example, researchers believe that habits or contextual factors are also important determinants of pro-environmental behavior, which was supported by extended theoretical models that have proven to be effective in explaining pro-environmental behaviors (Klöckner, 2013).

To summarize, although all the mentioned theories have been successful in explaining parts of pro-environmental behaviors and therefore, serve their raison d'être, recent comments have accumulated that these theories fail to consider many other crucial determinants of pro-environmental behaviors (Sniehotta et al., 2014). Further, it is argued that the most important behavioral determinants in these theories often do *not* directly influence behavior (see intention-behavior gap; Sheeran & Webb, 2016). For example, Lauper et al. (2015) found that eco-driving intentions explained only small parts of variance in eco-driving behavior. Instead, motivational factors such as planning how to implement the intention (i.e., implementation intentions) were found to be more important to predict eco-driving. Furthermore, studies found that although individuals often form successful intentions to implement pro-environmental behaviors in the future, the reported or actual behavior is not changed (Steinhorst & Klöckner, 2018). Therefore, some researchers conclude that the gap between intentions and behavior (Sheeran & Webb, 2016) is probably due to individuals' lack of motivation to perform the behavior in everyday life (Franke et al., 2017). Indeed, motivations have proven to predict a number of effortful and not inherently fun behaviors that must be sustained over time, such as sports (Ntoumanis et al., 2014; Pelletier et al., 2001 Smith et al., 2007) or academic learning (Sheldon & Elliot, 1998).

Eco-driving motivation describes the goal to start and maintain a fuel- or energy-efficient driving style (Franke et al., 2017) and most likely represents an important predictor of eco-driving (Cristea et al., 2012; Lauper et al., 2015). However, the problem is that eco-driving motivation is often represented by measuring the intention to eco-drive (Franke et al., 2017). Contrary to the TPB, however, it is possible that not the intention alone but, additionally, the reason that underlies the intention formulation (e.g., because environmental protection is important) is decisive for actually showing eco-driving behavior. Ryan and Deci (2000) propose to consider motivation not as a single construct but rather as including different types of motivational representations. Hence, the authors distinguish between helpful motivations that foster long-term behaviors and rather “unhelpful” motivations that cannot motivate (sustainable) behavioral effort. Although the motivational reason might explain why individuals eco-drive or not, the influence of (multiple) motivations on pro-environmental driver decisions has been rather neglected in past eco-driving research. Therefore, the aim of the present dissertation is to shed light on motivational theories for the prediction of eco-driving.

### 3.1.1 Self-determined (autonomous) motivation and self-concordance

People pursue various goals in their lives (i.e., goal strivings), which can be challenging for different reasons. For example, the goal to travel the world is usually pleasant and joyful but not affordable for everybody. The goal to protect the earth and nature may be fulfilling but can often be uncomfortable and exhausting. Personal goals influence and determine behavior and choices (Locke & Latham, 2006) and promote meaning, which impacts human well-being (Diener et al., 1999). However, people often struggle to maintain their goal strivings and/or are not satisfied and happy with them. According to some researchers (Ryan & Deci, 2000; Sheldon & Elliot, 1999; Sheldon & Kasser, 1995), the fact that people often fail to pursue goals sustainably is due to errors in the *conative process*. The conative process considers the process of goal selection, goal pursuit, and goal achievement (Sheldon & Elliot, 1999). Although goals are often appropriately selected, people often fail to pursue those in the long-term because of the “wrong” motivation or the lack of motivation (Sheldon & Kasser, 1995). In detail, it is assumed that goals are more likely to be motivating and maintained in the long-term when they align with individuals’ values and interests than when they are motivated by pressure and punishment (Sheldon & Kasser, 1995). Therefore, it seems that the motivation quality of (challenging) goals and actions (like eco-driving) is essential (Deci & Ryan, 2000).

The Self-Determination Theory (Deci & Ryan, 2000) considers motivation as a key factor of behavior but furthermore defines motivation quality rather than motivation quantity as the decisive factor for long-lasting behavior change. Hence, according to this theory, the reason that underlies the respective goal striving is an important factor of behavioral initiation and maintenance. The theory distinguishes between six forms of behavioral regulations, representing three different motivations, i.e., intrinsic motivation, extrinsic motivation, and amotivation, that can be more or less self-determined. The amount of self-determination determines the position of the motivation on a self-determination continuum (see Fig. 1).

Intrinsic regulation represents the most self-determined form of motivation (i.e., intrinsic motivation) and describes a behavioral regulation that is determined by pure pleasure and satisfaction that is due to the activity itself. Hence, intrinsic motivation is understood as the most valuable motivational form because people are driven by pure joy and pleasure that comes with simply doing the activity. The following four regulation forms represent extrinsic motivations that describe behaviors performed because of instrumental reasons (i.e., being motivated in order to achieve something). Integrated regulation means that a form of behavior is performed because it is part of one's identity and self-expression. People who are motivated by identified reasons also act for internal reasons and show a certain form of behavior when it is important to them and has inherent value because their behavior serves the achievement of higher-order meaningful goals and values (e.g., environmental protection). Although only intrinsic regulation is considered a purely intrinsic form of motivation while identified and integrated motivation are considered extrinsic forms of motivation (see Fig. 1), these three behavioral regulations are considered autonomous motivations because people act for internal reasons and identify their actions as self-determined and free-willed (i.e., self-integrated; Deci & Ryan, 2000).

In contrast, the following two forms of (extrinsic) motivation are considered externally determined or regulated. Introjected motivation means that individuals perform an activity because they experience internal pressure to do it and behave in a certain way out of guilt and shame. Therefore, although introjected reasons come from within one's self, the internalization tends to be ineffective because internal sanctions drive behavior and the behavior is not integrated within one's self. External motivation means that individuals perform an activity due to external controls, incentives, or punishment, i.e., reasons that lie outside their selves. Non-regulation representing amotivation is the least self-determined motivation form and refers to the absence of any motivation for a behavior (see Fig. 1; Deci & Ryan, 2000).

Research has shown that it is primarily intrinsically and self-determined or autonomously regulated people who initiate and maintain (challenging) behaviors over the long term as opposed to introjected, externally, or non-regulated people (Lavergne et al., 2010; Osbaldiston & Sheldon, 2003; Pelletier et al., 1998; Sheldon & Kasser, 1995). Self-determined forms of motivation are also associated with more behavioral persistence and psychological health and well-being in contrast to controlled motivations or amotivation (Deci & Ryan, 2008). Furthermore, in contrast to controlled motivations, autonomous motivations are associated with a range of pro-environmental behaviors, such as pro-environmental vehicle choice (De Groot & Steg, 2010) and recycling (Green-Demers et al., 1997). Further, autonomous motivations promote the use of self-control; thereby, making long-lasting behaviors more likely (Berkman, 2016). Thus, the degree of self-determination is a good predictor of the initiation, maintenance, and intensification of low- and high-effort behaviors (Green-Demers et al., 1997).

The theory also hypothesizes that people internalize more self-determined motivations for a behavior when three basic needs are met; i.e., autonomy, competence, and relatedness (Deci & Ryan, 2000). Internalization describes the process when regulations by external controls (e.g., incentives) are shifted to regulations by internal processes (e.g., environmental beliefs; Ryan & Deci, 2000). Autonomy refers to a sense of free choice, volition, and self-determination. Competence describes the belief that one can control outcomes, and relatedness concerns the experience of supportive social relationships. When these three needs are supported by social contexts, people experience autonomous reasons for behaving in a certain way. In contrast, controlling contexts that do not meet these needs but are characterized by coercion, pressure, or external cues can undermine autonomous motivations and thereby inhibit long-term behavioral changes (Ryan & Deci, 2000).

The theory is based on the assumption that people by nature want to grow and find meaning in life, i.e., want to fulfill their basic needs, and thus, internalize and integrate even less interesting and highly effortful activities (like pro-environmental behaviors) when the social context supports this internalization. If this happens, researchers suggest that not only is the maintenance of intrinsic motivation possible, but it is also facilitated to internalize extrinsic motivations and achieve aspirations and long-term life goals (Deci & Ryan, 2000). Thus, autonomous motivations or social contexts that satisfy autonomy, competence, and relatedness are particularly beneficial for (pro-environmental) behavior change, which is why interventions should aim at promoting these motivations or create such contexts.

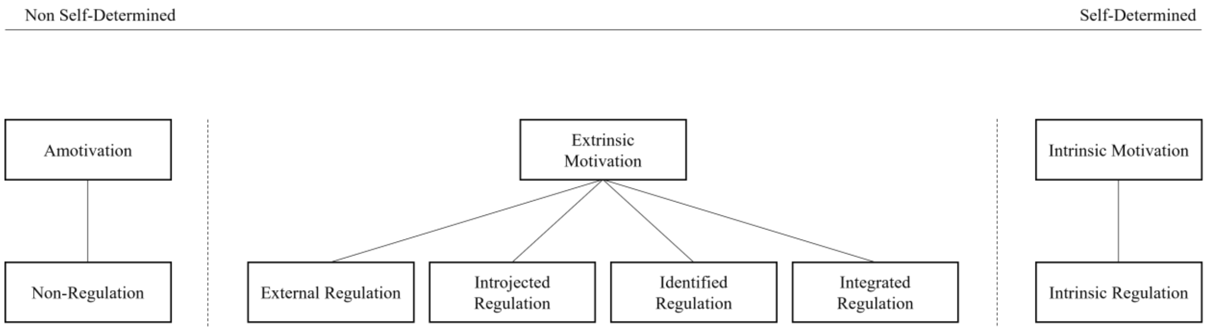



*Figure 1.* The Self-Determination Theory (based on Deci & Ryan, 2000).

Similar assumptions follow from the Self-Concordance Model (Sheldon & Elliot, 1999; Sheldon & Kasser, 1995), which is an extension of the Self-Determination Theory and states that congruence and coherence of personal goal systems are crucial for goals being self-integrated and thus, pursued successfully in the long-term. The Self-Concordance Model considers all processes of goal striving after goal selection (i.e., the process of goal pursuit and the process after goal achievement; Sheldon & Elliot, 1999). The model assumes that people act in terms of personal goal systems, in which various goals are anchored (see, for example, Fig. 2). These goal systems are hierarchical, in which higher-level goals tend to be more global (e.g., "be a good person") and lower-level goals describe more specific goal strivings or behaviors (e.g., "be nice to people").

The first process of the Self-Concordance Model is called the inception-to-attainment process. During this process, the authors of the Self-Concordance Model propose that goal self-concordance needs to be achieved for further successful goal pursuit (Sheldon & Elliot, 1999). For this, a selected goal striving should cohere with other goals on different goal levels and be congruent with higher-order important organismic needs (i.e., autonomy, relatedness, growth). Hence, according to the authors, for people to pursue goal strivings successfully, coherence and congruence of several goals within the goal system are crucial. Goal coherence means that goals should be both coherent with each other at the same level (i.e., *horizontal coherence*) and consistent with higher-order goals (i.e., *vertical coherence*). Thus, the goal of a pro-environmental lifestyle can be pursued successfully when multiple lower-level goal strivings are consistent with each other (e.g., "buy organic food" and "choose public transport") and have positive connections to higher-level goals that bring out possible selves (e.g., "become an eco-friendly person"; see Fig. 2). For example, according to the theory, eco-driving can be pursued particularly well when people want to reduce their carbon footprint *and* reduce traffic noise (i.e., horizontal coherence). Further, eco-driving can be pursued successfully when this goal striving helps to achieve higher-order goals, such as *protect nature,* or bring out possible selves, such as *being an eco-friendly person* (i.e., vertical coherence; Sheldon & Elliot, 1999).

Next to goal coherence, goal congruence is also an important determinant of successful goal pursuit according to the model. According to the authors of the model, congruence between a certain form of behavior and internal parts of a person (i.e., the organismic self) is divided into two different aspects. First, as described in the Self-Determination Theory, it is important that people pursue behaviors for autonomous rather than controlled reasons. The extent to which people pursue personal goals for autonomous (i.e., intrinsic or identified reasons) as opposed to controlled reasons (i.e., introjected or external reasons) is what the authors of the Self-Concordance Model refer to as *striving self-determination*. The model states that goals pursued for autonomous reasons are likely to be consistent with one's own interests and values and thus, are self-concordant. Second, congruence is also determined by the content of higher-order goals that drive lower-order personal strivings. In detail, the authors of the Self-Concordance Model differentiate between intrinsic and extrinsic higher-order goals. Intrinsic goals describe goals and values that are intrinsically satisfying and meaningful while extrinsic goals are oriented towards external gains and status improvements. Behaviors that are coherent with intrinsic goals are more desirable because they fulfill higher-order organismic needs (such as autonomy or relatedness) and are more integrated within the self than behaviors that are coherent with extrinsic goals. Thus, vertical coherence between goals is particularly predictive of behavior when lower-level goals are coherent with intrinsic goals (i.e., *intrinsic vertical coherence*) instead of extrinsic goals (i.e., *extrinsic vertical coherence;* Sheldon & Kasser, 1995).

In line with this, Vansteenkiste et al. (2004) found that individuals were more motivated to learn about and (sustainably) perform recycling activities when this behavior was framed in terms of intrinsic (e.g., community benefits) in contrast to extrinsic (e.g., monetary benefits) higher-order goals. On the other hand, Unsworth and McNeil (2017) found that interventions linking pro-environmental behaviors to higher-order goals that are important to people influenced the implementation of these behaviors even if these higher-order goals were unrelated to intrinsic values (e.g., climate change mitigation) but focused on egoistic aspects instead (e.g., money). Consequently, it is not yet clear if pro-environmental behaviors should be related to higher-order organismic needs such as personal growth or if it can also be helpful when these behaviors are linked to more egoistic tendencies, like money savings or status improvements. Certainly, this is dependent on the pro-environmental behavior under study and thus, needs to be examined on a domain-specific basis to understand which interventions might be most successful to influence behavior in a sustainable way (i.e., Are interventions that link eco-driving behavior to intrinsic and/or extrinsic higher-order goals successful in influencing this behavior?).

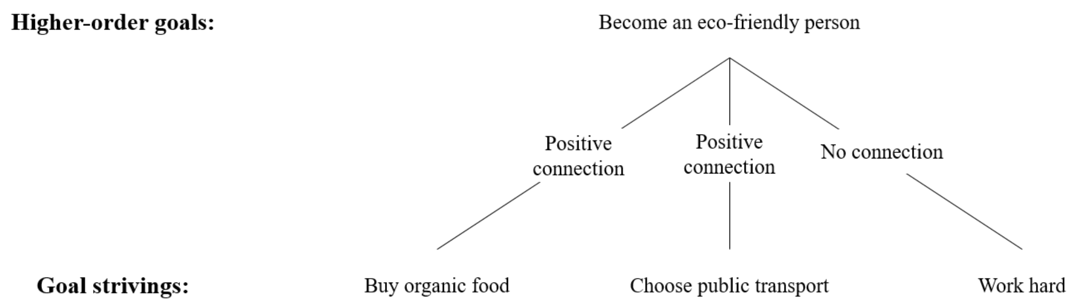



*Figure 2.* An exemplary goal system according to the Self-Concordance Model (based on Sheldon & Kasser, 1995).

In summary, successful long-term behavioral maintenance is, according to the Self-Concordance Model, dependent on two factors: coherence and congruence. In a personal goal system, coherence determines the connection between goals at the same and different levels, and congruence is determined by the content of higher-order goals (i.e., being intrinsic or extrinsic) as well as the extent to which individuals strive for autonomous instead of controlled reasons. Thus, for successful long-term goal pursuit, two aspects should be present, a) consistency among different goals in a personal goal system and b) congruence of goals with organismic needs, such as growth, community, or autonomy (see, for an overview of the concepts, Table 2; Sheldon & Kasser, 1995).

However, until now, research lacks studies investigating the validity of this model for pro-environmental behaviors. Hence, although the assumptions of the model are well researched in some behavioral domains like academic learning (e.g., Oaten & Cheng, 2006; Sheldon & Houser-Marko, 2001) or physical activity (e.g., Smith et al., 2007, 2011), they are only insufficiently investigated with regard to pro-environmental behaviors so far. Furthermore, the few currently existing studies investigating the model's assumptions for pro-environmental behaviors revealed inconsistent conclusions (Unsworth & McNeill, 2017; Vansteenkiste et al., 2004). Therefore, it is imperative to examine these assumptions for additional pro-environmental behaviors (such as eco-driving) to deepen the insights concerning the applicability of the theory in the environmental (transport) domain and to extend the current understanding of possible determinants of pro-environmental (driver) behaviors. The second process of the Self-Concordance Model, the attainment-to-well-being process, i.e., the process after goal achievement, will not be discussed in detail, since this would go beyond the objectives of the present dissertation (for a process description, see Sheldon & Kasser, 1995).

Table 2

*Concepts of the Self-Concordance Model (see Sheldon & Kasser, 1995)*

| **Concept** | **Definition** |
|---|---|
| Goal strivings | Enduring personal goals of individuals |
| Striving self-determination | Extent to which goal strivings are pursued for autonomous instead of controlled reasons |
| Horizontal coherence | Extent to which goal strivings are consistent with each other |
| Vertical coherence | Extent to which goal strivings help to achieve higher-order goals (i.e., bring out possible selves) |
| Intrinsic vertical coherence | Extent to which goal strivings help to achieve higher-order intrinsic goals, such as growth or autonomy |
| Extrinsic vertical coherence | Extent to which goal strivings help to achieve higher-order extrinsic goals, such as financial success or status improvement |

A number of research findings support that autonomous and self-determined goals are more likely to be achieved than controlled and non-self-determined goals (Osbaldiston & Sheldon, 2003; Tabernero & Hernández, 2011; Unsworth & McNeill, 2017). For example, Koestner et al. (2002) found that there was a positive relationship between autonomous goal motivation and monthly progress on New Year's resolutions. Sheldon and Elliot (1998) as well as Sheldon and Houser-Marko (2001) showed that autonomous reasons for pursuing academic goals positively predicted goal attainment as well as well-being. Furthermore, self-determined motivations are related to higher engagement in pro-environmental behaviors (Lavergne et al., 2010; Pelletier et al., 1998; Tabernero & Hernández, 2011), a broad range of pro-environmental behaviors (Villacorta et al., 2003), and more persistence in pursuing difficult and uncomfortable pro-environmental behaviors (Green-Demers et al., 1997). For instance, Osbaldiston and Sheldon (2003) showed that study participants were more likely to achieve self-selected pro-environmental goals if they internalized them or expected to enjoy them than participants who pursued goals because they felt internal or external pressure. Autonomous motivations were further more likely to lead to an “upward spiral” that resulted in the behavior being intended to shown again after the study ended (Sheldon & Houser-Marko, 2001). Furthermore, studies showed that goals that are coherent with higher-order (intrinsic *and* extrinsic) goals are likely to be followed sustainably (Unsworth & McNeill, 2017; Vansteenkiste et al., 2004). For example, making pro-environmental behaviors coherent with higher-order goals like environmental protection (Schwartz et al., 2015), health protection (Asensio & Delmas, 2015), or monetary savings (Dogan et al., 2014) was effective in predicting pro-environmental intention and action.

Overall, both theories, i.e., the Self-Determination Theory and the Self-Concordance Model, assume that, provided people pursue a pro-environmental goal striving, they will effectively pursue it (in the long-term) if they find the behavior pleasurable or if the behavior is personally important to them (i.e., autonomously motivated) and concordant with higher-order values and motives (such as protecting nature so that future generations can live on it). However, it is yet unclear how these factors influence eco-driving and which coherent higher-order goals (i.e., intrinsic and/or extrinsic goals) are most likely to affect eco-driving behavior. Therefore, the present thesis aims at closing this research gap in order to gain a deeper understanding of the impact factors of eco-driving and derive effective eco-driving interventions.

## 3.2 Contextual factors (behavioral costs)

Although considering motivations to explain pro-environmental behavior is certainly warranted, it is also necessary to consider determinants other than psychological factors to address past criticism that mainly psychological determinants were investigated as antecedents of pro-environmental behavior (Linder et al., 2021). Previous research found that positive environmental attitudes did not or did not always predict pro-environmental behavior (e.g., *attitude-behavior-gap,* Kollmuss & Agyeman, 2002). This discrepancy between cognitive factors and pro-environmental behavior has been known for several years, and yet, the reasons responsible for this gap remain poorly understood and rarely studied empirically. Although motivations will certainly help us better understand pro-environmental behavior, it seems unlikely that motivations alone can predict pro-environmental behaviors in various situations successfully. Indeed, while high motivations are important for individuals to translate their intentions into practice, high contextual barriers (e.g., lack of personal resources) may still hinder costly behaviors (Kaiser et al., 2021). The popularity of the TPB for explaining pro-environmental behavior is probably also because it incorporates rational considerations (i.e., perceived behavioral control) into its theoretical assumptions (Steg & Vlek, 2009). Certainly, it is correct to assume that not only moral but also rational considerations influence pro-environmental behavior. Indeed, as previously reported, it is likely that some pro-environmental behaviors are so effortful (e.g., require a lot of time) that even high attitudes and motivations are not sufficient to promote pro-environmental behavior (Diekmann & Preisendörfer, 2003). This is why researchers suggested that contextual factors are important predictors of pro-environmental behaviors too (Guagnano et al., 1995; Kaiser et al., 2021; Steg & Vlek, 2009).

For instance, it has been found that recyclers tend to use recycling facilities especially when they feel that recycling is convenient and they are familiar with the facilities (Sidique et al., 2010). Poortinga et al. (2013) found that it is easier for individuals to avoid using plastic bags in contexts where it is necessary to pay for these bags. Furthermore, it was found that public transport is preferred over vehicles when travel time of public transport decreases (Van Vugt et al., 1996) and financial incentives are present (Hunecke et al., 2001). Supporting these findings, meta-analyses found that contextual factors such as minimizing travel time seem to be important determinants of sustainable vehicle use (Gardner & Abraham, 2007).

Therefore, costs in terms of time and money or high physical effort appear to be barriers to many pro-environmental behaviors (Kaiser et al., 2021). Hence, the costliness of a behavior conditioned by external and contextual factors may be the key reason why normative beliefs incompletely predict multiple pro-environmental behaviors (Steg & Vlek, 2009). Behavioral costs, which are defined as barriers associated with behaviors (money, effort, convenience, time, social disapproval, etc.) that require personal resources to be overcome (Kaiser et al., 2021), can be hypothesized as important determinants of pro-environmental behavior. Many researchers suggest that the consideration of behavioral costs as an additional predictor of pro-environmental behavior may contribute to the explanation of the gap between psychological factors and pro-environmental behavior (Turaga et al., 2010).

Therefore, it can be assumed that the integration of both psychological (e.g., autonomous motivations, striving coherent values) and contextual factors (e.g., behavioral costs) is important for understanding eco-driving behavior. The question, however, that has not been well understood yet or adequately studied, is how behavioral costs and psychological factors interact in predicting pro-environmental (driver) behavior. Although there are multiple assumptions about how the two factors interplay (or not), empirical research has not yet created a unified picture. The existing theories about the interaction between these two factors agree on the fact that higher environmental attitudes are superior to lower attitudes in positively predicting pro-environmental behavior and lower behavioral costs are superior to higher behavioral costs in positively predicting pro-environmental behavior (Diekmann & Preisendörfer, 2003; Guagnano et al., 1995; Kaiser, 2021; Schultz & Oskamp, 1996). However, the theories differ with regard to the assumptions about the interaction between these factors (see chapter 3.3).

## 3.3 Relationship between psychological and contextual factors

### 3.3.1 Campbell Paradigm

The Campbell Paradigm can be considered a behavior model explaining behavior causally by behavioral costs and personal goal commitment and was introduced to understand pro-environmental behavior change by Kaiser (2021). The paradigm proposes that contextual and psychological factors additively affect pro-environmental behavior. Therefore, Kaiser (2021) assumes that environmental attitudes must be considered relative to behavioral costs when predicting pro-environmental behavior, assuming that high attitudes must compensate high behavioral costs. This means that attitudes affect behavioral engagement linearly, independent of behavioral costs. At the same time, behavioral costs also influence behavior linearly, independent of the individual attitude level (see Fig. 3). In detail, higher attitudes predict higher pro-environmental behavior independent of behavioral costs and lower behavioral costs predict higher pro-environmental behavior independent of environmental attitudes. Thus, the paradigm rules out an interaction effect between psychological and contextual factors. Instead, it predicts that individuals with different environmental attitudes respond to high and low behavioral costs in the same way. This assumption is supported by results of Hunecke et al. (2001) who found that contextual factors (i.e., price) and personal norms showed additive effects on transport mode choice (i.e., subway use). Thus, the Campbell Paradigm describes pro-environmental behavior as a compensatory function of psychological factors and behavioral costs.

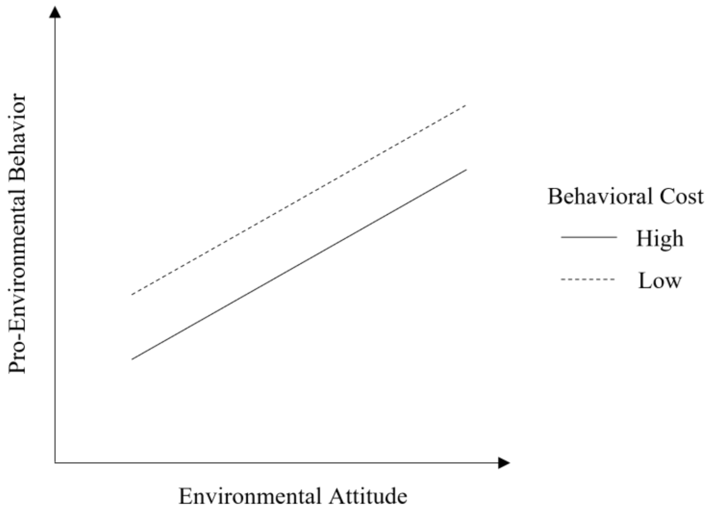



*Figure 3.* Simplified predictions of the Campbell Paradigm (Kaiser, 2021; own illustration).

### 3.3.2 Low-Cost Hypothesis

In contrast to the Campbell Paradigm, the Low-Cost Hypothesis (LCH; Diekmann & Preisendörfer, 2003) proposes an interactive relationship between contextual and intrapsychic factors for pro-environmental behavior. Thus, according to the authors, the influence of psychological factors on pro-environmental behavior depends on behavioral costs. Specifically, this hypothesis states that attitudes and environmental concerns predict pro-environmental behaviors when behavioral costs are low. In contrast, environmental concerns and attitudes lose predictive strength for pro-environmental behaviors when high costs arise (see Fig. 4). These assumptions are supported by recently published results by Wyss et al. (2022), which showed that pro-environmental attitudes predicted pro-environmental decisions when the personal costs of a decision (i.e., monetary costs) were low in contrast to high.

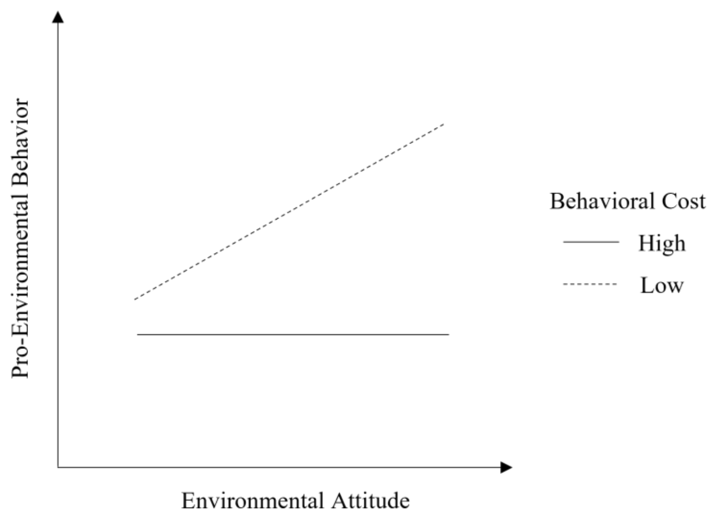



*Figure 4.* Simplified predictions of the Low-Cost Hypothesis (Diekmann & Preisendörfer, 2003; own illustration).

### 3.3.3 A-B-C Model

Guagnano et al. (1995) formulated the A-B-C Model in response to research results showing that personal norms influenced recycling behavior at moderate personal costs but not at very low personal costs. This model also proposes interactive effects between contextual and psychological factors. In detail, the authors assume a specific relationship between attitudes (A), behavior (B), and situational conditions or behavioral costs (C) that manifests that attitudes are most predictive of pro-environmental behavior at moderate behavioral costs. Analogous to the LCH, psychological factors are not expected to have a strong influence at high behavioral costs. In contrast to the LCH, however, no strong influence of attitudes on pro-environmental behaviors is expected at low behavioral costs either, but instead at behavioral costs of medium intensity (see Fig. 5). These assumptions are supported by recently published results by Keizer et al. (2019) who found that transport measures intended to reduce vehicle use are predicted by personal norms when the measures are associated with moderate but not with low or high personal costs to individuals.

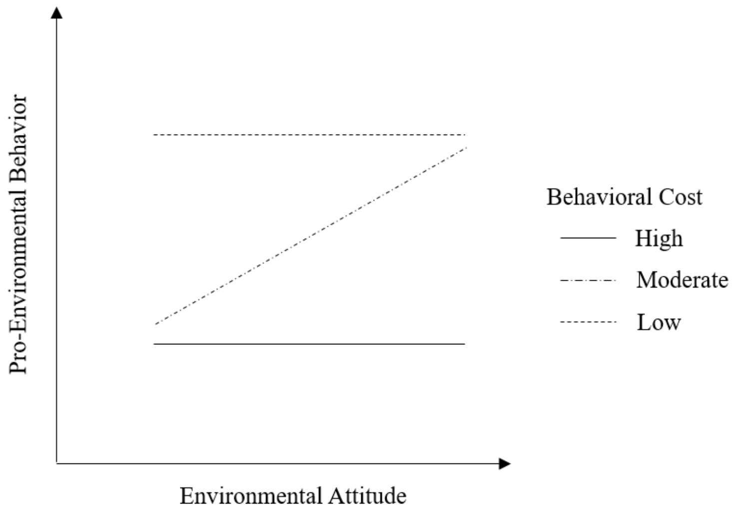



*Figure 5.* Simplified predictions of the A-B-C Model (Guagnano et al., 1995; own illustration).

### 3.3.4 Effort Hypothesis

The Effort Hypothesis (EH) formulated by Schultz and Oskamp (1996) assumes a linear positive interaction between intrapsychic and contextual factors. Accordingly, based on empirical findings on recycling behavior, the researchers assume that as behavioral difficulty, i.e., behavioral effort, increases, the relationship between attitudes and pro-environmental behavior becomes stronger too. Thus, pro-environmental behaviors need to be challenging for attitudes or environmental concerns to be behaviorally relevant. In line with the A-B-C Model, the hypothesis states that at low behavioral costs, high environmental attitudes are not necessary but gain relevance as behavioral costs increase (see Fig. 6). These results are supported by Green-Demers et al. (1997) who found that environmental attitudes became more predictive the more challenging the investigated pro-environmental behaviors were (e.g., read books or magazines about the environment). Furthermore, the results of Heath and Gifford (2002) support the assumptions of the EH by finding that moral and environmental attitudes influenced the intention to take the bus instead of the vehicle only when financial price reductions were not present. Hence, when the behavior is facilitated by monetary benefits, environmental concerns are not necessary to influence low-cost pro-environmental transport choices.

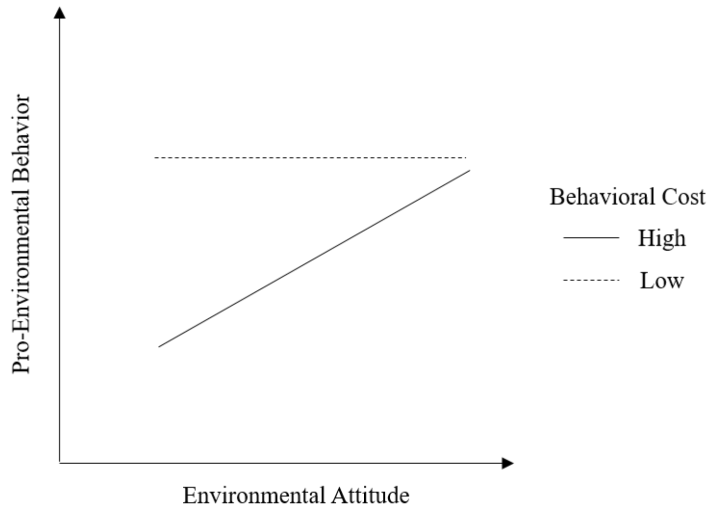



*Figure 6.* Simplified predictions of the Effort Hypothesis (Schultz & Oskamp, 1996; own illustration).

### 3.3.5 Summary

Overall, there are competing theories and assumptions about the relationship between psychological and contextual factors in the literature so far, which is why the validity of these assumptions needs to be tested for several pro-environmental behaviors. This is also necessary since most of the theories have been modelled based on research results on recycling behavior, which is generally considered a low-cost pro-environmental behavior by researchers and individuals (Osbaldiston & Schott, 2012; Steg, 2023). Therefore, it is necessary to investigate which theories are successful in predicting rather high-cost pro-environmental behaviors, such as high-effort driver behaviors.

It is important to point out that the assumptions of the A-B-C Model and the Effort Hypothesis are probably quite similar, since attitudes are unlikely to influence pro-environmental behavior associated with *very* high behavioral costs. This is supported by the fact that the two assumptions were formulated in response to research results of the same recycling behaviors. It is certainly only logical to assume that highly effortful behaviors such as a 45-minute walking effort to a bus stop represents a form of behavior for which even the strongest environmental attitudes may not be sufficient. Therefore, it can be assumed that both theories allow similar hypotheses regarding the relationship between psychological and contextual factors. In detail, it can be assumed that both theories predict that high attitudes are more relevant for effortful behaviors than for low-cost behaviors but loose predictive power when behavioral costs become extremely high.

The costliness of a certain form of behavior may not only explain the gap between attitudes and behavior but may also serve as an explanation why interventions often fail to change pro-environmental behaviors. In fact, previous research shows that informational and motivational interventions (e.g., appeals, knowledge-enhancing interventions) have no or only small effects on several pro-environmental behaviors (Abrahamse et al., 2005; Abrahamse & Matthies, 2018; Lange & Dewitte, 2023; Sloot et al., 2021). Because these interventions are designed to promote favorable psychological determinants of pro-environmental behaviors like environmental concerns and attitudes, the conclusion that the effect of such interventions may be hindered by high behavioral costs is only logical. Hence, it is likely that, as is the case for cognitive factors like environmental concerns, the efficacy of interventions designed to elicit cognitive factors depends on contextual factors.

For example, it can be assumed that informational interventions about how to behave pro-environmentally is not sufficient to influence rather costly behaviors like driving energy- or fuel-efficiently, but may be more helpful for low-cost behaviors like recycling. This assumption would follow from the LCH, according to which informational interventions promoting environmental attitudes and motivations should be effective for low-cost behaviors (Diekmann & Preisendörfer, 2003). In contrast, according to the hypothesis, informational interventions should not be helpful for high-cost behaviors, but structural interventions that change the behavioral costs of a behavior (i.e., contextual factors such as the price) could be more promising. This assumption would also follow from the A-B-C Model. However, assuming that environmental attitudes primarily influence moderate-cost behaviors (Guagnano et al., 1995), informational interventions that elicit environmental attitudes and motivations could be effective primarily for such moderate-cost behaviors. In contrast, according to the A-B-C Model, informational interventions should be less predictive of low-cost behaviors because most people will show this behavior anyway independent of high attitudes or motivations. The Campbell Paradigm, on the other hand, would suggest no interplay between informational interventions and behavioral costs (Kaiser, 2021). Hence, informational interventions should be effective independent of behavioral costs. In the same way, structural interventions changing contextual factors should be effective independent of environmental attitudes. These descriptions illustrate that the effectiveness of interventions may depend on the costliness of the behavior. Hence, assuming that the A-B-C Model or the LCH describes the relationship between environmental attitudes and behavioral costs correctly and eco-driving can be considered a rather high-cost behavior, these theories could explain why informational interventions on how to eco-drive (e.g., training courses) may not be helpful to motivate sustainable driving behavior change (Af Wåhlberg, 2007; Wu et al., 2018).

In conclusion, previous research misses to include contextual factors as determinants of various pro-environmental behaviors and to consider the influence of behavioral costs when testing interventions for pro-environmental behaviors. Although there are theories on the relationship between contextual and psychological factors for pro-environmental behaviors, their explanatory power with regard to high-cost pro-environmental behaviors (e.g., eco-driving) seems unclear so far. Furthermore, research lacks to consider psychological *and* contextual factors when designing effective interventions for pro-environmental (driver) behaviors. Therefore, it is the aim of this dissertation to investigate how both factors affect pro-environmental driver decisions and how the effectiveness of interventions for eco-driving depends on contextual factors.

# 4 Behavioral interventions for pro-environmental (driver) behavior change

To achieve strongly needed reductions of environmental harmful greenhouse gas emissions, it is not enough if just a few people behave pro-environmentally. Instead, large-scale behavioral changes of many people are crucial to mitigate the progression of climate change (Abrahamse & Matthies, 2018; Barkenbus, 2010). Therefore, the development of effective interventions is a key task of environmental psychology to motivate people to adopt and maintain pro-environmental behaviors. This step also follows from identifying the key determinants of pro-environmental behaviors (Steg & Vlek, 2009). Environmental interventions aim at inducing pro-environmental behavior changes. These can change either the behavior itself or behavioral determinants (Steg & Vlek, 2009). Although the latter enables to understand why an intervention is successful or not, many determinants of pro-environmental behavior that have been assumed to influence behavior (e.g., attitudes), in fact, did not predict pro-environmental behavior sufficiently (see above). Thus, interventions should change actual behavior. Intervention strategies can be classified according to whether they address/change psychological/cognitive factors or contexts (i.e., informational vs. structural interventions; Abrahamse & Matthies, 2018; Steg & Vlek, 2009), precede or follow a behavior (i.e., antecedent or consequence interventions; Steg & Vlek, 2009), and reduce cognitive effort (i.e., nudging interventions; Thaler & Sunstein, 2009) or require attention.

Informational interventions or strategies aim at influencing knowledge, values, norms, motivations, or perceptions without changing the external context of a behavior (e.g., educational driving courses). Structural interventions or strategies, on the other hand, aim at changing the external context, changing, for example, the availability, cost, or benefits of behaving pro-environmentally (e.g., raising fuel prices). According to the term, antecedent strategies refer to changing factors that precede the behavior while consequence strategies address the consequences of a behavior. In more detail, antecedent strategies aim at increasing (problem) awareness and information as well as announce consequences of the behavior. Consequence strategies inform individuals about the actual consequences of the behavior or use reward, punishment, or other feedback to motivate future pro-environmental behavior (Steg & Vlek, 2009).

Lastly, intervention strategies can be implemented as choice architecture interventions or rather *nudging* interventions, which aim at reducing the cognitive effort of information processing (Schubert, 2016). Nudging interventions make use of small and subtle changes in the choice infrastructure enabling effortless decision-making and behavior change (Thaler & Sunstein, 2009). These interventions can be applied easily, quickly, and inexpensively and can result in effective behavioral changes (Mertens et al., 2022). For example, communicating social norms (i.e., the behavior of others or the approval of a behavior by others) with choice options can motivate individuals to act conformably to others (De Groot et al., 2013). Furthermore, small $CO_2$ information cues that are added to flight choices can influence pro-environmental behavior of air passengers (Carroll et al., 2022). Thus, reduced cognitive effort due to nudging or choice architecture interventions can facilitate pro-environmental decisions and behavior. These interventions are particularly easy to implement when individuals have to decide between two or multiple choices (e.g., turning on an in-vehicle driving system; Kutzner et al., 2021; Vetter & Kutzner, 2016).

Several studies and meta-analyses examined the effectiveness of various environmental interventions in the past with mixed empirical success (Abrahamse et al., 2005; Dogan et al., 2014; Hunecke et al., 2001; Kormos et al., 2015; Noppers et al., 2014; Osbaldiston & Schott, 2012; Schwartz et al., 2015; Sloot et al., 2019, 2021; Steinhorst & Matthies, 2016; Van den Broek et al., 2017). While it is clear that different interventions are effective for different pro-environmental behaviors (e.g., informational interventions may influence recycling but not purchase decisions), past studies (Af Wåhlberg, 2007; Bolderdijk, Steg, et al., 2013; Degraeuwe & Beusen, 2013; Dogan et al., 2014) did not provide a conclusive picture of how eco-driving can be influenced successfully.

## 4.1 Effectiveness of behavioral interventions

Interventions that have been studied to promote pro-environmental driver behavior have mostly focused either on egoistic behavioral tendencies or on informational and educational aspects (Af Wåhlberg, 2007; Beusen et al., 2009; Lai, 2015; Schall et al., 2016; Schall & Mohnen, 2017). Although these intervention strategies have been very popular, critical voices have been accumulating that claim the inadequacy of these approaches for influencing long-term behavior change successfully (Abrahamse et al., 2005; Bolderdijk & Steg, 2015; Lindenberg & Steg, 2007).

Based on homo-economicus models and the assumption that consumers are predominantly motivated by economic interests, some researchers assume that individuals strive to maximize their personal benefit and make rational decisions (Turaga et al., 2010). This means that individuals will only act in favor of the environment if they will personally benefit from these actions (Penn, 2003). These assumptions may serve as an explanation why policymakers often use taxes and subsidies or similar monetary benefits or penalties to motivate consumers to behave pro-environmentally (Bolderdijk & Steg, 2015). Indeed, such policies are effective in influencing the initiation of pro-environmental behaviors, such as the purchase of electric vehicles (Deuten et al., 2020). Furthermore, Bolderdijk et al. (2011) showed that a financial discount on insurance fees was effective in discouraging speeding behavior among novice drivers. However, when the discount was removed, novice drivers' speeding behavior returned to baseline levels. Furthermore, Zeiske et al. (2021) showed in a recent study that a three-week public transport free pass could reduce car use and increase public transport use in the short term but not in the long term (i.e., after the financial incentive was removed). Thus, studies showed that financial benefits can make pro-environmental behavior attractive in the short term, but behavior returns to baseline levels in the long term, especially after the motivator is removed. Furthermore, Schall and Mohnen (2017) found that economic incentives could not soften deeply rooted driving habits. Harvey et al. (2013) further concluded from their study that saving money is no sufficient motivator to increase the voluntary usage of ecological in-vehicle feedback devices.

Bolderdijk and Steg (2015) report that rewards create external reasons for showing a form of behavior, which changes the decision frame from an ethical or moral to a business frame. Hence, incentives can undermine normative or moral considerations and activate cognitive cost-benefit analyses resulting in pro-environmental decisions only being made when it is “worthy” (Dogan et al., 2014; Heyman & Ariely, 2004; Thøgersen & Crompton, 2009). Hence, for (high-cost) pro-environmental behaviors associated with only little financial benefits (e.g., eco-driving is effortful but associated with only little monetary benefits on the fuel receipt), monetary rewards may not be beneficial because they are not perceived as rewarding enough to justify the high behavioral effort (Bolderdijk & Steg, 2015). However, large incentives might also not be a good solution because they disrupt the process of self-persuasion. This may result in individuals attributing the behavior to external reasons, which is why these incentives are only effective as long as they are present and cannot promote spillover effects (i.e., showing a pro-environmental behavior transfers to behaving pro-environmentally in other domains; Bolderdijk & Steg, 2015). In addition, the use of small incentives may not be helpful because people do not want to be perceived as stingy, uncaring, or egoistic but rather demonstrate themselves as a moral, caring, or “green” person (Bolderdijk & Steg, 2015). The authors of the Self-Determination Theory (Ryan & Deci, 2000) and the Self-Concordance Model (Sheldon & Elliot, 1999) also do not recommend extrinsic incentives because they may disrupt the process of internalization and promote controlled rather than autonomous motivations. All in all, financial benefits or external pressure seem to be helpful for initiating but not for sustaining pro-environmental behaviors like eco-driving.

Another intervention strategy that many researchers examine for pro-environmental behaviors is educational outreach and knowledge building (Af Wåhlberg, 2007; Boomsma & Steg, 2014; Howell, 2014; McConky et al., 2018; Taube et al., 2021; Zarkadoula et al., 2007). This informational antecedent strategy is based on the assumption that individuals do not know how to behave pro-environmentally, which is why they need detailed information. However, it has been shown in various studies that knowledge alone is not sufficient to motivate pro-environmental driver behavior (Af Wåhlberg, 2007). For example, at first, Beusen et al. (2009) found that an eco-driving training course reduced fuel consumption by 5.8% and that this effect persisted over the long term. However, a reanalysis of the data showed that it was actually the ambient temperature and not the driving behavior changes that were decisive for the reduced consumption (Degraeuwe & Beusen, 2013). Schall et al. (2016) also found no effect of a purely theoretical driver training on fuel consumption. In fact, several researchers raise the question of whether such courses and trainings are necessary, because individuals know how to drive pro-environmentally because they do so when asked but not in everyday life (Pampel et al., 2015, 2017). These findings have led to the argument that purely information-based strategies cannot influence pro-environmental behavior changes because these strategies do not take into account motivational tendencies, which may be the main driver of behavior changes in the transport domain (Bolderdijk et al., 2018; Franke et al., 2017).

To sum up, although both information-based and monetary-based intervention strategies are very popular and frequently used for pro-environmental driver behavior not only in research but also in politics (Bolderdijk & Steg, 2015), their effectiveness remains questionable for (long-term) eco-driving behavior change (Af Wåhlberg, 2007; Dogan et al., 2014). Therefore, research still needs to identify how individuals can be motivated to eco-drive (in the long term). Based on theoretical considerations, the next chapter will discuss how this can be achieved effectively.

## 4.2 Strategies for implementing effective behavioral interventions

Researchers advise that the development and use of environmental interventions should be guided by theory (Abrahamse & Matthies, 2018). In environmental psychology, the Goal-Framing Theory (GFT; Lindenberg & Steg, 2007) has proven to be a helpful theoretical basis for intervention development (Ebermann & Brauer, 2016; Westin et al., 2020). This theory assumes that goals frame and guide how individuals process and react to information. According to the authors of the GFT, different goals can be activated in certain situations (i.e., being the focal goal frames), which determine behavior and/or cognition. For example, watching a movie about poor people can activate normative and altruistic goals and motivate generous donations. Hence, after activating a goal (e.g., the normative goal to help people), a behavior is selected that is congruent with this goal (e.g., make donations; Lindenberg & Steg, 2007).

Based on several theories and predictors that have historically been crucial for pro-environmental behavior, the authors of the GFT distinguish between normative (i.e., to act appropriately; see NAM, VBN), hedonic (i.e., to have fun, improve one's mood; e.g., Smith et al., 1994) and egoistic (i.e., to improve one's resources; see TPB) goal frames that can be focal (i.e., activated) in different situations and contexts. Although there is always a dominant goal frame (e.g., to protect nature), other goal frames may be present in the background and may (e.g., save money) or may not (e.g., have fun) be compatible with the focal goal promoting or hindering (pro-environmental) behavior. For example, buying a BEV may be motivated by normative beliefs (e.g., contribute to environmental protection) and hedonic aspects (e.g., enjoy technological characteristics of BEVs like fast acceleration) but may not be in line with gain goals (e.g., to save money), because BEVs are usually rather costly. In contrast, eco-driving may be motivated by normative (e.g., to protect nature for future generations) and gain (e.g., fuel reductions are associated with monetary savings) goal frames but may not be compatible with the hedonic goal frame, which is oriented towards mood improvements (e.g., speeding is fun). Hence, for individuals it may be most beneficial to purchase inexpensive ICEVs and use them to commute to work every day. In the long run, however, to protect the community and nature, it may be more beneficial to use public transport, eco-drive, or buy BEVs.

In summary, as already indicated in previous chapters and in line with the GFT, pro-environmental behavior results from multiple motives that can be compatible or not. Accordingly, normative concerns, hedonic aspects, behavioral and external costs (e.g., inconvenience, money) may be crucial for motivating long-term maintenance of pro-environmental behaviors. From these insights, the authors of the GFT derive specific suggestions for designing effective behavioral interventions. In detail, they propose two strategies for developing effective interventions, which are a) to *strengthen the normative goal frame* and b) to *make the gain and/or hedonic goal frame compatible with the normative goal frame*.

Since the authors of the GFT are convinced that the normative goal frame (i.e., to act appropriately and in line with the expectations of other people) is most important for initiating and maintaining (various) pro-environmental behaviors, this goal frame should always be the focus while developing environmental interventions. As the hedonic goal frame will activate the goal to improve the own mood and the gain goal frame activates the goal to improve personal profit, both goal frames may be instable sources of long-term pro-environmental behavior change. This follows from the fact that pro-environmental behaviors are often effortful (e.g., travelling by train) or costly (e.g., buying BEVs; Lindenberg & Steg, 2007). Hence, it is obvious that the normative goal frame is most compatible with pro-environmental behavior, because acting pro-environmentally is a moral and ethical thing to do (Thøgersen, 1996). This is supported by various studies showing that normative values and beliefs predicted pro-environmental behaviors most strongly (De Groot & Steg, 2010; Steg et al., 2016; Ünal et al., 2018; Van der Werff et al., 2013). Therefore, Lindenberg and Steg (2007) advise that interventions should make the normative goal frame dominant and feedback appropriate behaviors to individuals (such as "act pro-environmentally").

For this strategy to work, the authors suggest that people need to know how to act pro-environmentally (e.g., travel by train instead of by vehicle) and be aware of the environmental impact of the behavior (e.g., the amount of $CO_2$ emission savings that can be achieved by showing a behavior). For example, environmental labeling (Thøgersen, 2000), comparative feedback (Schultz et al., 2007), or persuasive environmental information (Steinhorst & Klöckner, 2018) can be successful strategies to strengthen the normative goal frame and thus, motivate pro-environmental behavior. Hence, according to the authors, the normative goal frame should be strengthened to such an extent that competing gain or hedonic goals are pushed into the background (Lindenberg & Steg, 2007).

This intervention strategy may also be derived from the motivation theories reported in chapter 3.1.1. According to these, autonomous motivations are most likely to predict pro-environmental behaviors (Ryan & Deci, 2000; Sheldon & Elliot, 1999). Assuming that these motivations are crucial for pro-environmental behavior, interventions should motivate people to behave pro-environmentally because it is an important thing to do or because it serves higher-order meaningful goals (e.g., nature/health protection). Indeed, framing interventions that provide eco-driving tips and connect these with important higher-order goals are effective in promoting eco-driving intention (Dogan et al., 2014). Furthermore, providing information about other peoples' behavior and giving persuasive environmental (e.g., $CO_2$ emission) information about bottled water consumption enhanced pro-environmental intentions (Van der

Linden, 2013). Additionally, persuasive messaging highlighting the environmental and health benefits of electricity production (e.g., pollutants production, childhood asthma, and cancer) motivated energy saving behavior in households (Asensio & Delmas, 2015).

Hence, activating higher-order intrinsic or normative goals addressing the motive to do "the right thing" are effective in influencing several pro-environmental behaviors including eco-driving. To conclude, based on the reported theories, it is advisable that persuasive informational interventions increasing knowledge (e.g., "refraining from clothes dryer usage can reduce 300 kg of $CO_2$ emissions per year"), strengthening environmental (i.e., identified or integrated) motivations (e.g., "try to collect many green points"), highlighting social norms (e.g., "65% of your neighbors recycle"), or addressing personal meaningful values (e.g., "protect the nature") should be designed for pro-environmental behaviors (Kramer & Petzoldt, 2022b; 2023a; Schultz et al., 2007; Steinhorst & Klöckner, 2018; Van der Linden, 2013).

The second strategy, which the GFT proposes, is to make the hedonic and gain goal frame compatible with the normative goal frame. This strategy becomes important when behavioral costs arise, such as when pro-environmental behaviors are no fun (e.g., driving is more convenient than taking the train) and/or expensive (e.g., purchasing renewable electricity is costly; Lindenberg & Steg, 2007). Since a strengthened normative goal frame may not be sufficient in such (high-cost) situations, it is advisable to use interventions that make background goals less incompatible or even compatible with normative goals (Lindenberg & Steg, 2007).

For example, to stimulate monetarily or physically costly pro-environmental behaviors, additionally to strengthening the normative goal frame, contextual factors could be changed that make the behavior more rewarding (e.g., provide monetary incentives) or convenient (e.g., increase product/facility availability). Indeed, studies showed that when gain goal frames were made compatible with high-cost pro-environmental behavior (e.g., reward interventions for eco-driving), individuals were motivated to behave pro-environmentally (Günther et al., 2020). On the other hand, in situations where individuals are particularly sensitive for mood improvements (e.g., when planning a vacation), interventions should - additionally to strengthen the normative goal frame - appeal to individuals' hedonic emotions. In fact, interventions that made hedonic goals ("to have fun") compatible with normative goals ("to protect the environment"; e.g., via gamified smartphone apps) could motivate individuals to behave pro-environmentally (Vaezipour et al., 2016). Furthermore, research indicated that pro-environmental behavior is also motivated successfully, if hedonic, gain, *and* normative goal frames are made compatible via interventions (Ebermann & Brauer, 2016).

It is important to note, however, that the normative goal frame should always be the focus of the intervention strategy while the hedonic and egoistic advantages should be in the background (Lindenberg & Steg, 2007). This is important, because only normative goals can internalize behavior successfully and be stable sources of long-term behavioral maintenance. Indeed, providing external reasons for the behavior will not be successful to induce long-term pro-environmental behavior change because of the disadvantages of external (financial) incentives reported in the previous chapter. Hedonic goals, on the other hand, can induce intrinsic motivation; therefore, they are particularly desirable for sustainable behavior change according to the Self-Determination Theory (Ryan & Deci, 2000). The problem, however, is that most pro-environmental behaviors usually do not inherently generate pleasure and flow because they tend to involve behavioral costs (Lindenberg & Steg, 2007). Even though, intervention strategies that induce intrinsic motivations can promote pro-environmental behavior at first, study findings show that these interventions often cannot promote behavioral engagement in the long term (Abrahamse et al., 2005). Hence, using interventions promoting intrinsic motivation of behaviors that are not inherently fun cannot influence sustainable behavior change. Consequently, researchers suggest that interventions should address hedonic goals in combination with normative goals (Lindenberg & Steg, 2007).

To conclude, based on the GFT and the assumptions of the Self-Determination and Self-Concordance Theory, one of the two strategies presented in this chapter should be followed when developing environmental interventions. Therefore, researchers should either a) strengthen normative goals when behavioral costs of pro-environmental behaviors are rather low or moderate *or* b) make gain and hedonic goals compatible with dominant normative goals when behavioral costs are rather high (Lindenberg & Steg, 2007). In line with this, interventions should induce autonomous motivations and activate coherence between lower-order goal strivings (e.g., eco-driving) and higher-order (intrinsic) goals (e.g., protect the health of the community). This will generate stable long-term behavior changes because of internalized and self-integrated environmental motivations and beliefs (Deci & Ryan, 2000).

# 5 Summary and research questions

The previous chapters of this thesis indicated the importance of pro-environmental driver changes (i.e., eco-driving) for high-impact emission mitigation in the transport sector. As chapter 3 displays, past studies have focused intensively on identifying the most important impact factors of pro-environmental behaviors including eco-driving. Although these studies have greatly improved the understanding of these behaviors to date, several impact factors are still neglected in research. It is also apparent that although some factors have already been identified as insufficient early on (e.g., attitude; Kollmuss & Agyeman, 2002), they still can be found in recent studies (Gansser & Reich, 2023; Kesenheimer & Greitemeyer, 2021; Prati et al., 2017). Therefore, it is the aim of this thesis to understand which (previously neglected) factors are important for the implementation of pro-environmental driver behavior. Furthermore, as interventions for pro-environmental behaviors that were investigated in the past indicated inconclusive and mixed results (see chapter 4), this thesis aims at analyzing which interventions can be used to promote this kind of behavior. To this end, a series of online and offline studies of cross-sectional and longitudinal designs were conducted by asking people to show a certain behavior either theoretically, in everyday life, or in the laboratory. These studies are intended to answer the following research questions that have been neglected in past research or cannot be answered conclusively based on the results that have been found.

## 5.1 Do autonomous and self-concordant motivations predict pro-environmental driver decisions and behavior (studies 1, 2)?

One of the major aims of this dissertation was to clarify the role of motivation for eco-driving. This seems to be important because several previous studies found that individuals have the intention to eco-drive but usually do not put this intention into practice (Pampel et al., 2018). According to the assumptions of some researchers, it is likely that this is due to the lack of motivation (Franke et al., 2017). In addition, it is possible that inefficient (i.e., controlled) motivations drive behavior, which cannot influence long-term maintenance of the behavior (Ryan & Deci, 2000). For example, although short-term effects of monetary or informational interventions were found, these effects diminished over time (Af Wåhlberg, 2007; Bolderdijk et al., 2011; Degraeuwe & Beusen, 2013). The Self-Determination Theory (Ryan & Deci, 2000) and the Self-Concordance Model (Sheldon & Elliot, 1999) may explain these effects because they assume that there are favorable (i.e., autonomous) and unfavorable (i.e., controlled) motivations that determine the maintenance of strenuous pro-environmental behaviors.

Although studies found that self-determined motivations influenced pro-environmental behaviors (Barszcz et al., 2022; De Groot & Steg, 2010; Lavergne et al., 2010; Nguyen et al., 2022), their popularity in terms of a broad extension to other pro-environmental behaviors has remained limited. The assumptions of the Self-Concordance Model for pro-environmental behaviors, on the other hand, have only been investigated in one study (Unsworth & McNeill, 2017) based on best knowledge. However, no study has examined the effects of the determinants of these theories on eco-driving so far. Thus, to gain a deep understanding regarding the role of favorable motivations for eco-driving, the results of two studies were examined.

Study 1 aimed at testing a motivational model derived from the assumptions of the Self-Determination and Self-Concordance Theory in the context of a cross-sectional online survey. The study investigated not only the influence of striving self-determination but also the effect of striving coherence with regard to four different value types. Hence, it was examined if eco-driving is perceived as coherent with biospheric (addressing the importance of protecting nature), altruistic (addressing the importance of helping others), hedonic (addressing mood improvements), and egoistic (addressing personal benefits) values and if this perceived coherence could influence behavior. The large-scale study was designed to answer the open research question of whether autonomous and self-determined motivations can predict strategic, tactical, and operational eco-driving. For this, a total of 536 participants responded to an online study and a total of 25 individual eco-driving behaviors were included in the study. Autonomous and self-concordant motivations were expected to predict eco-driving effort, which in turn was expected to predict strategic, tactical, and operational eco-driving.

Study 2 was designed to investigate interaction effects between self-determined motivations and behavioral costs on eco-driving (see below). However, the results of this study also have implications for the role of (autonomous) motivations for eco-driving alone. Overall, the study aims at deepening the understanding of the role of motivations not only for sustainable driving behaviors per se, but also for pro-environmental mobility choices.

## 5.2 What is the relationship between behavioral costs and psychological factors/interventions for pro-environmental driver decisions and behavior (studies 2, 3)?

Although motivations are important for putting eco-driving intentions into practice, it is unlikely to assume that high motivations alone are sufficient to engage in a set of eco-driving behaviors. Instead, it is more likely to assume that the implementation of behaviors also depends on their behavioral costs (Kaiser, 2021; Steg & Vlek, 2009). Pro-environmental behaviors are often associated with high behavioral costs (e.g., loss of time) that sometimes cannot be overcome even by highly motivated individuals (Diekmann & Preisendörfer, 2003). Building on this assumption, a number of researchers have formulated theories about the relationship between pro-environmental concerns and behavioral costs based on scientific evidence (see chapter 3.3). These theories have competing assumptions and, to date, do not create a unified picture on how psychological beliefs *and* behavioral costs predict different pro-environmental behaviors. Critically, these theories have been examined primarily with respect to low-cost behaviors like recycling (Guagnano et al., 1995; Schultz & Oskamp, 1996). Furthermore, although the theories have been around for a long time, experimental tests of the assumptions are scarce. Indeed, to date, based on best knowledge, no study examined the influence of both factors, i.e., behavioral costs and psychological beliefs, on eco-driving.

This dissertation aims at filling this research gap and finding answers to the research question if and how behavioral costs (whether subjective or objective) interact with self-determined motivations when predicting various eco-driving behaviors. It will also examine whether the effectiveness of psychological interventions that address motivations and attitudes also depend on behavioral costs. Thus, conducting two studies, it is analyzed if behavioral costs influence the predictive power of psychological determinants and the effectiveness of interventions for various tactical and operational eco-driving behaviors.

Study 2 examined the interaction between self-determined motivations and behavioral costs on driver decisions by analyzing the results of two online surveys (see studies 1, 3). In detail, study 2 was intended to address the question of whether perceived behavioral costs and self-determined motivations show interaction effects regarding tactical and operational eco-driving behaviors or not. Moreover, study 2 aimed at investigating which eco-driving behaviors (i.e., low-, moderate-, or high-cost behaviors) can be most strongly predicted by these motivations.

In addition, because interventions can also be hypothesized to depend on behavioral costs of a behavior (see chapter 3.3.5), study 3 examined the extent to which behavioral costs of a hypothetical charging decision with a BEV influenced the effectiveness of various psychological interventions. A total of 286 drivers participated in this study and made hypothetical charging decisions in a randomized experiment. The manipulation of three factors with three different cost characteristics allowed investigating if the effectiveness of psychological interventions depends on behavioral costs. The analyses of these two studies allow important conclusions for the theories presented in chapter 3.3 and thus, deepen the understanding of why individuals do not consequently make pro-environmental transport decisions in everyday life.

## 5.3 Which interventions are effective for promoting pro-environmental driver decisions and behavior (studies 3, 4, 5)?

One research question that is particularly important, because it has urgently needed practical consequences, is the following: Which strategies and interventions will lead people to eco-drive? The development of appropriate interventions can be particularly successful if the key determinants of the behavior have been identified (Steg & Vlek, 2009). Therefore, to create a holistic picture, three studies investigated which interventions can motivate various eco-driving behaviors.

As already reported above, study 3 examined the effectiveness of three different intervention strategies, that have been used in the past for motivating pro-environmental behaviors, on a hypothetical charging decision with a BEV. Study 4, on the other hand, examined the effect of an informational intervention on driver behavior with an ICEV. This longitudinal online survey examined whether eco-driving information with highlighted positive consequences (i.e., environmental, altruistic, or monetary consequences) can influence self-reported everyday-life eco-driving intentions and behaviors in the short- and medium-term.

Due to mixed results of these two studies, the final study (i.e., study 5) used a combined approach, addressing normative, hedonic, *and* gain goals, to influence pro-environmental charging decisions and energy-efficient driving behaviors with a BEV in an experimental driving study. Using three combined intervention designs, it was examined whether a combined approach can effectively influence pro-environmental driver behaviors and might be superior to using only one strategy. In all studies, it was hypothesized that the interventions used, which considered one of the strategies proposed by the GFT (see chapter 4.2; Lindenberg & Steg, 2007), were helpful in influencing eco-driving.

The different approaches and designs contribute to an in-depth understanding of which eco-driving interventions can be effective. This will help to use eco-driving interventions in practice and serve as a basis for future intervention development. Unfortunately, previous studies have often failed to find effects of interventions (Sloot et al., 2021; Steinhorst & Klöckner, 2018). Thus, the results of this dissertation will contribute to developing and using eco-driving interventions in the future more effectively.

# 6 Study 1: The role of self-concordance for self-reported strategic, tactical, and operational eco-driving

## 6.1 Introduction

The transport sector is one of the main human sources of massive greenhouse gas emissions around the world and responsible for almost a quarter of all $CO_2$ emissions worldwide (IEA, 2021). Greenhouse gas emissions caused by the transport sector have more than doubled since 1970 and, despite technological advances, are growing faster than any other energy sector (Sims et al., 2014). Therefore, a mobility change seems inevitable for the achievement of climate protection goals in the future.

To achieve this, it is not enough to wait for innovations and new technologies that are introduced only gradually, but to mobilize individuals to change their behavior towards less $CO_2$ emitting activities in the long term (Barkenbus, 2010; Steg & Vlek, 2009). For this, high-impact behaviors in the private sector are particularly relevant, including eco-driving (Sivak & Schoettle, 2012). Strategic decisions, which concern the selection and maintenance of the vehicle, become especially important due to new, stricter $CO_2$ regulations that make fleet conversions for all car companies indispensable (Barkenbus, 2010; Keyvanfar et al., 2018). However, contrary to what is conveyed occasionally in the media (Volkswagen, 2020), it is not true that alternative drive technologies make other eco-driving behaviors irrelevant. Instead, tactical and operational decisions have to be considered even when driving low-emission vehicles, because energy saving activities remain highly important to counteract resource exploitation in the long term.

Despite a steady growth of research articles in recent years on both determinants (Lauper et al., 2015; Ünal et al., 2018) as well as educational and motivational interventions (Beloufa et al., 2014; Günther et al., 2020; Sanguinetti et al., 2020; Wu et al., 2018), researchers found that most people do not eco-drive in real life or maintain eco-driving behavior over time (Pampel et al., 2015, 2018). Furthermore, as reported, intervention studies reported inconsistent and contradictory eco-driving effects, while motivational determinants of eco-driving are not well understood yet (Barkenbus, 2010). Based on this, the overall aim of this study was to test a motivational model based on self-concordance (i.e., the consistency between a behavior or goal with deep values or pre-existing identities; Sheldon & Elliot, 1999) theory to derive implications for successful eco-driving interventions fostering voluntary behavior change in the long term.

**Eco-driving as high-impact behavior – What are the motivational drivers?**

Dietz et al. (2009) identified several behaviors that could significantly reduce U.S. household emissions if implemented at the national level. These behaviors include purchasing fuel-efficient vehicles and low rolling resistance tires, routine vehicle maintenance, driving behavior, and carpooling as well as trip-chaining. Barkenbus (2010) reported that efficient driving behavior reduces fuel consumption by up to 10%. However, Sivak and Schoettle (2012) reported that maintenance practices, route choice and vehicle loading, as well as efficient driving reduce fuel consumption by up to 45%. Thus, the inclusion of behavior that is not directly relevant to driving behavior has enormous additional saving potential.

Despite the positive effects of eco-driving on the environment and the finding, that many people consider implementing eco-driving behaviors as easy (Delhomme et al., 2013), a study by Nègre and Delhomme (2017) found that only 11% of participants reported being an eco-driver. One possible explanation seems to be that people struggle putting the intention to eco-drive into practice. Indeed, while some researchers found no correlation between intention and eco-driving behavior (Schoenau & Müller, 2017), Lauper et al. (2015) reported that the relationship is mediated via implementation intentions. Understanding the motivational drivers of eco-driving can help to explain why only some individuals implement eco-driving intentions in real life and to derive implications for future successful eco-driving interventions.

In addition, motivational determinants of eco-driving should be investigated due to contradictory results and decaying effects of eco-driving interventions found by previous studies for which an explanation is still lacking. Various researchers reported that although training interventions show direct effects on behavior, the effects diminish over time and people return to their original driving habits (Af Wåhlberg, 2007; Beusen et al., 2009; Degraeuwe & Beusen, 2013; Huang et al., 2018; Pampel et al., 2017; Schall et al., 2016). Therefore, knowledge seems no sufficient factor to change strong driving habits. As a result, many researchers and policy makers focus on monetary motivators. In the transport sector, a variety of such financial rewards and penalties can be observed, including congestion charges (Atkinson et al., 2009), taxes, and price reforms (Anas & Lindsey, 2011; Bolderdijk & Steg, 2015; Keyvanfar et al., 2018). However, while some researchers found positive effects of financial incentives on eco-driving (Kacperski & Kutzner, 2020; Lai, 2015), other researchers reported that monetary incentives only motivate drivers as long as they are apparent (Bolderdijk et al., 2011) or that the small monetary benefits of eco-driving are not perceived as being worth the effort (Dogan et al., 2014). Studies on pro-environmental behaviors including eco-driving found that highlighting environmental (e.g., $CO_2$ emission reductions) instead of monetary benefits motivate individuals more strongly to engage in eco-driving behaviors (Bolderdijk, Steg, et al., 2013; Dogan et al., 2014).

However, Lindenberg and Steg (2007) argue that not all people will implement pro-environmental behavior out of environmental concerns. Strengthening the gain goal will be especially effective when the behavior is costly (e.g., in terms of money, effort, time) while the normative goal frame will be dominant when the behavior is rather easy to implement (Lindenberg & Steg, 2007). As strategic, tactical, and operational eco-driving is composed of behaviors that are costly (e.g., vehicle selection), moderate costly (e.g., route selection), and rather low-cost (e.g., anticipating traffic flow), financial *and* environmental benefits might be considered worthy by individuals. In fact, Unsworth and McNeill (2017) have shown that connecting a pro-environmental behavior with financial goals can promote this behavior as much as linking it with normative goals. In their study, the authors tested the assumptions of the Self-Concordance Model which are rather underrepresented in the current literature. In sum, analyzing motivational determinants of this model is helpful for multiple reasons: 1) to understand why some people do not eco-drive although they intend to do so, 2) to understand the reasons for failed intervention effects in the past, and 3) to derive implications for more successful eco-driving interventions in the future.

**Self-Concordance Model**

As reported in chapter 3.1.1., the Self-Concordance Model assumes that people can pursue a goal, which is a personal striving in life (Emmons, 1992), for one or more of four types of reasons, i.e., extrinsic, introjected, identified, and intrinsic motivation. While an extrinsically motivated person would eco-drive because it saves money, an introjectedly motivated person would eco-drive to avoid unpleasant feelings, which are not externally triggered but arise due to internal thoughts (e.g., having a guilty conscience towards own children). Both forms represent non-self-concordant or controlled forms of motivation that are not integrated in the self (Sheldon & Elliot, 1998, 1999).

On the other hand, an identified motivated person would eco-drive because of strong environmental values and beliefs, while an intrinsically motivated person would eco-drive because fuel-efficient driving is perceived to be more comfortable. These two types of motivations represent autonomous or self-concordant reasons that represent the individual's true interests and inner values (Sheldon & Elliot, 1998, 1999). As reported in chapter 3.1.1, the extent to which people strive for a goal for autonomous rather than controlled reasons is termed striving self-determination, which is, in this study, empirically measured in form of an index (autonomous motivation – controlled motivation).

In an online survey, De Groot and Steg (2010) found that autonomous motivations and values are important for pro-environmental vehicle choice. Although the authors showed the dominance of values in contrast to self-determined motivations, values are also important in the Self-Concordance Model. Besides striving self-determination, the model includes the concept of striving coherence, which describes whether higher-order goals, values, or identities are concordant with lower-order goals, such as commuting behavior (Sheldon & Kasser, 1995; Unsworth & McNeill, 2017). Hence, according to Sheldon and Kasser (1995), a goal is striving coherent based on two processes: the importance of higher-order values (e.g., environmental protection) and the helpfulness of a behavior (e.g., eco-driving) to achieve these higher-order values.

The current literature on pro-environmental behavior dominantly examined the impact of biospheric, altruistic, egoistic, and hedonic values. Studies have shown that these values positively (e.g., biospheric values) and negatively (e.g., egoistic values) correlate with pro-environmental behaviors (De Groot & Steg, 2010; Shi et al., 2019; Ünal et al., 2018). As reported above, Unsworth and McNeill (2017) expanded these findings on the impact of values and first integrated the concept of striving coherence in a series of studies. They found that strong striving coherence not only predicts pro-environmental intentions but also causally relates to them. The researchers found that not only connecting pro-environmental behavior with normative values (e.g., environmental protection, social responsibility) predicted the behavior but that establishing links to higher-order gain goals (e.g., saving money) also influenced sustainable energy use and commuting behavior. Although these are promising results indicating that people without environmental concerns can be motivated to act pro-environmentally by motivating striving coherence, the study has some shortcomings. First, the authors did not separately investigate striving coherence of different value types (i.e., coherence with gain *vs*. environmental goals). Secondly, the authors point out that in many identified and classified *financial* goals, people emphasized rather less selfish but *altruistic* motives. Third, the authors report only small effects and find mixed effects on pro-environmental behavior.

In summary, to derive successful eco-driving interventions, it needs to be investigated if normative considerations (i.e., internal reasons and environmental/altruistic motives) are superior to gain beliefs (i.e., external reasons and gain motives) within the domain of eco-driving. Thus, based on the Self-Concordance Model, the present study tested the effect of self-concordance (i.e., striving self-determination and striving coherence) on eco-driving behavior via effort (see Fig. 7).

Effort describes how hard a person tries and mobilizes personal resources and energy in order to achieve a goal or behave in a certain way (e.g., maintain/start to eco-drive; Sheldon & Elliot, 1998). Various studies found that effort is not only a theoretically important mediator between self-concordant goals and goal attainment (Sheldon & Elliot, 1999) but also an empirically proven one (Gaudreau et al., 2012; Sheldon & Elliot, 1998; Smith et al., 2007). Even if not all eco-driving behaviors are effortful in the classical sense (e.g., driving slowly), individuals need to mobilize personal resources and energy to engage in eco-driving behaviors and maintain them. This includes, for example, overcoming automated habits or always remembering the eco-driving rules in order to stick to these "easy" behaviors (Green-Demers et al., 1997). Studies investigating the effect of striving self-determination or striving coherence on eco-driving are currently lacking. Instead, researchers rather *assume* that these concepts are important when designing eco-driving interventions (An, 2020; Anagnostopoulou et al., 2016; Vaezipour et al., 2016, 2017).

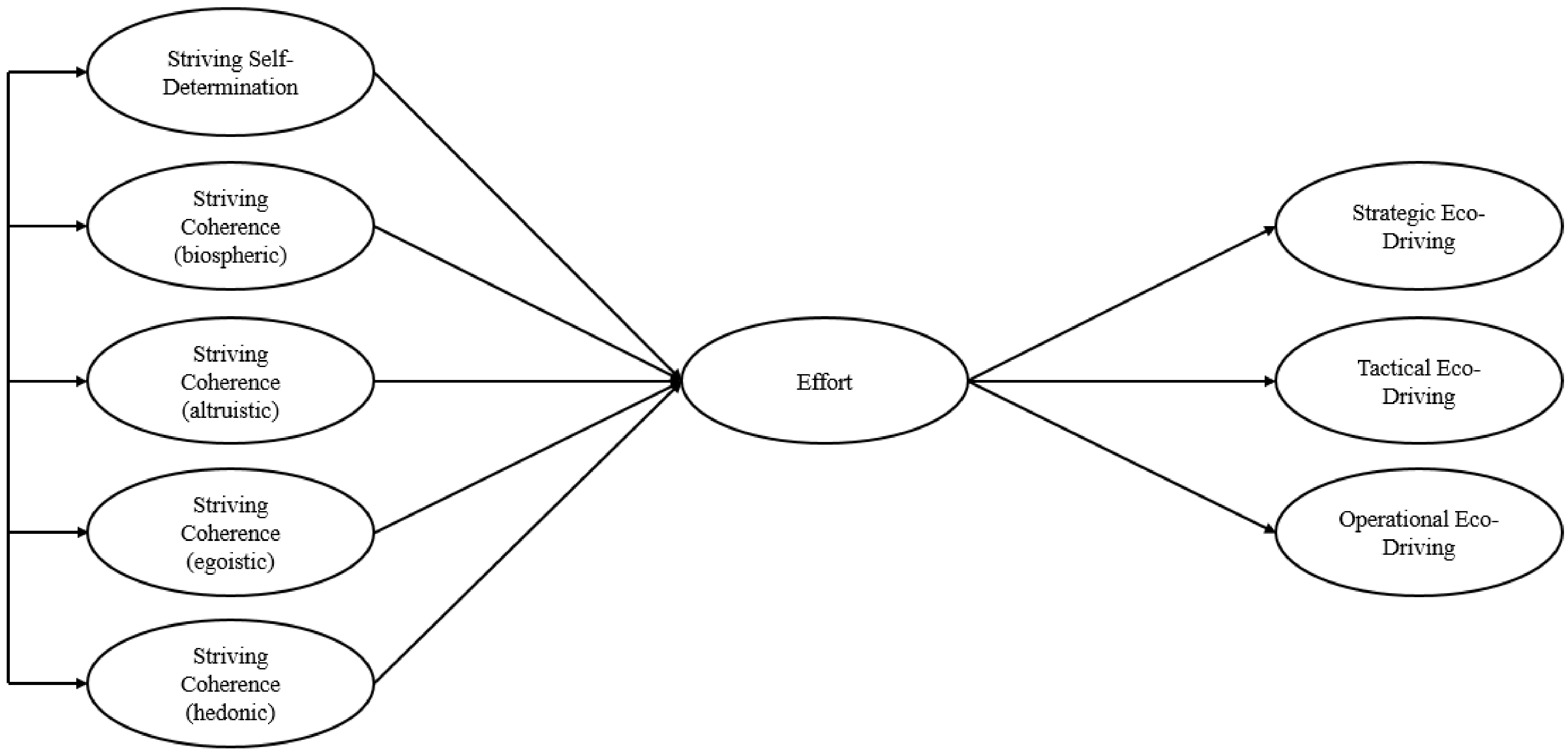



*Figure 7.* The hypothesized motivational model of eco-driving behaviors (study 1).

**The present study**

The aim of the present study was to test the motivational process that triggers self-reported eco-driving behavior (see Fig. 7). More specifically, it was analyzed whether the extent to which people pursue autonomous rather than controlled motives for eco-driving and the perceived coherence between eco-driving and higher-order values predict eco-driving behavior mediated via effort. It was assumed that striving self-determination positively predicts eco-driving effort based on theory and previous findings of autonomous motivations on pro-environmental strivings (Green-Demers et al., 1997; Osbaldiston & Sheldon, 2003). Furthermore, positive relations between striving coherence and effort towards eco-driving (Unsworth & McNeill, 2017) were expected but the effects for biospheric, altruistic, egoistic, and hedonic values were analyzed separately to test if normative (i.e., biospheric/altruistic) striving coherence is a stronger predictor of eco-driving effort than egoistic and hedonic striving coherence (De Groot & Steg, 2010). Furthermore, eco-driving knowledge was investigated qualitatively assuming that it may have little influence on showing eco-driving behavior but is surely a necessary pre-condition (Abrahamse et al., 2005, 2007; Barkenbus, 2010; Bolderdijk, Gorsira, et al., 2013; Nègre & Delhomme, 2017). Furthermore, previous results regarding eco-driving knowledge were aimed at being replicated (see Lauper et al., 2016; McIlroy & Stanton, 2017).

## 6.2 Method

**Participants and procedure**

For the present study, a 20-minute online questionnaire was developed with the questionnaire tool Tivian (Tivian XI GmbH, 2021) to test the hypothesized motivational model. For this, personal links were sent out via e-mail inquiry to participants who have registered in the participant database of Mercedes-Benz Group AG in October 2020. The contacted participants are people living in Germany who voluntarily registered in the participant database because of an interest to participate in customer studies of Mercedes-Benz Group AG. The participants were required to be car drivers (i.e., own a vehicle) and drive regularly (annual mileage ≥ 3000 km). The study was conducted during the ongoing COVID-19 pandemic in Germany. The infection levels during the study period were, compared to earlier months in 2020, at a low level (Robert Koch Institut, 2020) but slowly increased again. Certainly, this unique situation restricted the mobility behavior of German car owners (Anke et al., 2021). However, since it is assumed that this was the case for most people to that time, the present results are still comparable. Participants were informed that their participation was voluntary and that their responses were anonymized. The RD Ethical Advisory Board of Mercedes-Benz Group AG approved the research.

Overall, 587 participants responded to the questionnaire in full. Subjects who had an average score of less than three points when answering three questions on goal striving regarding eco-driving on a scale from 1 (*totally disagree*) to 7 (*totally agree*) were excluded from the data analysis as eco-driving goal pursuit was an important theoretical assumption underlying this research ($n$ = 27). Furthermore, subjects who reported an average annual mileage of less than 3000 km were excluded, because it was assumed that these participants drove too little to be able to show visible effects of eco-driving; therefore, they did not belong to the desired target group ($n$ = 21).

In total, data from 539 participants (253 women, 284 men, 2 non-binary) were included in the analysis. The mean age was 44.94 years ($SD$ = 16.07, Range = 18–79). Rating the highest degree of education, two percent had completed the mandatory nine school years, 20% obtained an extended school-leaving certificate (including high school diploma), 27% had a vocational degree, 48% indicated to be university graduates, and 2% had a doctoral degree. The mean of the average annual mileage was 18,196.25 km ($SD$ = 12,712.12; reported annual mileages > 100,000 km/year were included as NA, because such high mileages were considered unrealistic). Participants held a valid driver's license for an average of 26.73 years ($SD$ = 15.63, Range = 1–60) and had vehicles with different types of drives (gasoline (58%), diesel (36%), gas (1%), hybrid (2%), electric (2%), and fuel cell (1%)). In comparison to the German population, the present study sample contained a larger proportion of males, had a higher level of education but a similar average age (Destatis, n.d.). Furthermore, the sample had a higher annual mileage than the German average (Kraftfahr-Bundesamt, 2019). An a-priori power analysis was not conducted because the assumed relationships were not tested before; therefore, there was no knowledge about possible effect sizes. However, as correlation coefficients stabilize with at least $N$ = 250 (Schönbrodt & Perugini, 2013), this was the minimum desired sample size for the present study.

Following the link sent to the participants, participants had first to accept the consent form. Then, they entered the questionnaire and were first asked about sociodemographic data and their knowledge of eco-driving before they received a detailed definition about the strategic, tactical, and operational decisions of eco-driving (Sivak & Schoettle, 2012). After that, they answered the scales in the order as described below (see Measures). Table 3 depicts the reliability estimates and descriptive statistics of the survey's variables. The questionnaire included some additional items on eco-driving attitude, information level of eco-driving, and causality orientations, which were not relevant for the present study; therefore, they are not reported here. After answering the questionnaire completely, participants could receive a monetary compensation of €5 by clicking on a link redirecting them to an external page where they could log in to their profile of the participant database and confirm participation. This ensured the anonymity of data, as the answers to the questionnaire could not be linked to the confirmation of participation in the access-restricted database.

**Measures**

*Knowledge.* Knowledge of eco-driving behaviors was measured using an open answer format (i.e., a text field), asking participants to report all behaviors that reduce the fuel or energy consumption of a vehicle. Participants were explicitly asked to also think of behaviors that are not directly related to the driving activity.

*Striving self-determination.* Striving self-determination was measured using the scale developed by Sheldon and Kasser (1995) assessing the motivational reason of participants for pursuing personal goals. Participants rated their motivational reasons for pursuing eco-driving with regard to four different reasons; external motivation ("…because somebody else wants me to do it or because I get something out of it."), introjected motivation ("…because I would feel ashamed, guilty, or anxious if I did not."), identified motivation ("…because I really believe it is an important goal to have."), and intrinsic motivation ("…because of the fun and enjoyment that it provides me."). They rated their agreement with each of these items on a 7-point Likert scale (1 = *not at all for this reason* to 7 = *completely for this reason*). A striving self-determination index was calculated for every participant summing the identified and intrinsic score and subtracting the introjected and external score (Judge et al., 2005; Sheldon & Elliot, 1999; Sheldon & Kasser, 1995). Therefore, answers could range from -12 to 12. Due to time constraints, only one item per motivational reason was used, which is why a reliability score could not be calculated. However, using multiple goal strivings in their study, Sheldon and Kasser (1995) reported an internal consistency of $\alpha = .89$. Various studies reported similar reliability coefficients over the years applying the same measure (Judge et al., 2005; Sheldon et al., 2004; Sheldon & Elliot, 1999).

*Striving coherence.* The measurement of striving coherence was based on Unsworth and McNeill (2017), which was based on Sheldon and Kasser (1995). Therefore, participants first rated the importance of 16 values (De Groot & Steg, 2007, 2008; Steg, Perlaviciute, et al., 2014). These values reflected egoistic (e.g., "Authority: the right to lead or command"), altruistic (e.g., "Equality: equal opportunity for all"), biospheric (e.g., "Preventing pollution:

protecting natural resources"), and hedonic (e.g., "Pleasure: joy, gratification of desires") goals. Participants rated the importance of values on a 7-point Likert scale (1 = *not at all important* to 7 = *very important*). Next, to determine striving coherence, participants reported how much eco-driving would help them to achieve each of the higher-order life values. Participants rated the subjective helpfulness on a 7-point Likert scale (1 = *not at all helpful* to 7 = *very helpful*). The weighted striving coherence scores for the different value types was calculated by multiplying the importance scores with the helpfulness scores for every value (i.e., importance of social justice * helpfulness of eco-driving to achieve social justice +…). Because this resulted in an *index* of striving coherence, internal reliability could not be calculated. However, this measurement was used and validated in previous studies (Sheldon & Kasser, 1995; Unsworth & McNeill, 2017) and correlation coefficients showed positive relationships between normative striving coherence and striving self-determination ($r_{biosperic}$ = .23, $r_{altruistic}$ = .12) indicating convergent validity. Furthermore, separately calculated internal consistencies of the value and the helpfulness scale revealed acceptable values (see Table 3; Nunnally, 1978).

*Effort.* Three items developed based on the Self-Concordance Model measured effort in terms of eco-driving (e.g., "I do my best to act in accordance with my goals regarding eco-driving"; Sheldon & Elliot, 1998, 1999). Participants rated their agreement on a 7-point Likert scale (1 = *totally disagree* to 7 = *totally agree*). The reliability of the scale was high (see Table 3). Higher values on this scale reflect greater effort towards eco-driving behaviors.

*Strategic, tactical, and operational eco-driving.* An extensive eco-driving scale was developed based on previous research connecting the corresponding behaviors with their positive impact on the environment (Martin et al., 2012; Sanguinetti et al., 2017; Sivak & Schoettle, 2012; Strömberg et al., 2015). The scale consisted of 25 items representing eight strategic (e.g., "I avoid short vehicle rides."), five tactical (e.g., "I do not carry unnecessary weight in my vehicle.") and 12 operational (e.g., "I anticipate the traffic flow and keep distance to the vehicle in front.") decisions regarding eco-driving (Sivak & Schoettle, 2012; Strömberg et al., 2015). Participants rated their agreement with each item on a 7-point Likert scale (1 = *totally disagree* to 7 = *totally agree*). Participants were allowed to click the answer alternative "*not possible*" due to different drive types and vehicle equipment of the contacted participants. An average score for every subscale was calculated. Higher values represented stronger eco-driving behavior. The internal consistency of the subscales was acceptable considering the early stage of scale development (see Table 3; Nunnally, 1967). Lower values were considered acceptable because items were also validated within a confirmatory factor analysis. Furthermore, items with low factor loadings and inter-item correlations were removed (Streiner, 2003; see Table 4 for the final eco-driving behaviors).

**Statistical analyses**

The following analyses were conducted by means of structural equation modelling using the lavaan package (Rosseel, 2012) in R (R Core Team, 2020). Structural equation modelling (SEM) enables the analysis of causal structures and allows the simultaneous investigation of relationships between various variables based on theoretical assumptions (Steinmetz, 2015). In addition, structural equation modelling investigates relationships between latent concepts accounting for the measurement error (Hair Jr. et al., 2019). The simultaneous observation of several relationships lead to the superiority of structural equation modelling over simpler regression analyses in the present case.

For analyzing the newly developed eco-driving scale, a confirmatory factor analysis (CFA) using the robust WLSMV (weighted least squares with mean and variance adjustments) estimator for ordered categorical data and pairwise deleted missing data was applied. Pairwise deleting missing data seemed justifiable as there were non-substantial missing data patterns (13.0%) and MCAR (missing completely at random) assumption seemed to hold (after visual inspection and applying the TestMCARNormality function from the MissMech package; Jamshidian et al., 2014).

Maximum likelihood estimation with robust estimators was applied for analyzing the validity of the motivational model. Missing data was replaced by applying full information maximum likelihood procedure. The $\chi^2$-value, the comparative fit index (CFI), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR) are reported to evaluate the model fit. However, since the $\chi^2$-value is sensitive to large sample sizes (Hair et al., 2019), it was not expected to be non-significant, which would imply a good model fit. Instead, an acceptable model fit was assumed if the CFI is greater than .90 (Bentler, 1992), the RMSEA is between .05 and .08 (Brown & Cudeck, 1989) and SRMR is $\leq .08$ (Hu & Bentler, 1998). Although CFI > .90 is a controversial cut-off value, it is commonly considered acceptable in practice if fit indices are acceptable overall (McDonald & Ho, 2002).

Knowledge effects were examined qualitatively. Based on empirical and theoretical literature and based on the answers itself, valid answers were assigned to categories reported in Table 5. The first author of this dissertation coded all answers. Two independent researchers who had no knowledge of the research project coded 20% of randomly selected answers determining inter-rater reliability. Cohen's Kappa between rater 1 and rater 2 was .79 and between rater 1 and rater 3 was .80 indicating a moderate to strong agreement (McHugh, 2012).

Prior to the analysis, the data was scanned for outliers, missing data, and assumptions of multivariate data analysis. Two multivariate outliers were identified applying Mahalanobis distance with $p < .001$, which were removed from the data set. Furthermore, one participant who answered no item on striving coherence was excluded. All variables and the eco-driving items were inspected on skewness and kurtosis and three eco-driving items were excluded ("I take my vehicle in for service on a regular basis.", "I avoid objects on my vehicle that affect drag (e.g., cargo box) unless they are in use.", "I change the tires on my vehicle seasonally.") because of skewness values exceeding two and kurtosis values exceeding seven (Curran et al., 1996). Checking the main variables of the analysis in more detail, no violation of linearity, homoscedasticity, and multicollinearity was found (see Table 3). Displaying the histograms of the included variables indicated that the variables of the survey were normally distributed. In sum, three cases were excluded resulting in 536 cases for data analysis.

Table 3

*Descriptive statistics and zero-order correlations of the main variables (study 1)*

| Variable | α | *M* | *SD* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Striving Self-Determination | - | 5.89 | 3.44 | | | | | | | | | |
| 2. Striving Coherence (biospheric) | .87 (.88) | 138.48 | 40.28 | **.23** | | | | | | | | |
| 3. Striving Coherence (altruistic) | .77 (.85) | 88.13 | 44.97 | **.12** | **.44** | | | | | | | |
| 4. Striving Coherence (hedonic) | .78 (.84) | 66.23 | 31.30 | .05 | **.21** | **.42** | | | | | | |
| 5. Striving Coherence (egoistic) | .72 (.77) | 62.85 | 34.87 | -.02 | **.15** | **.46** | **.44** | | | | | |
| 6. Effort | .88 | 5.05 | 1.33 | **.42** | **.42** | **.29** | **.24** | **.15** | | | | |
| 7. Knowledge | - | 3.54 | 2.32 | .08 | .05 | -.05 | -.08 | -.06 | .04 | | | |
| 8. Strategic Eco-Driving[a] | .58 | 4.87 | 1.18 | **.33** | **.35** | **.30** | **.13** | **.13** | **.53** | .08 | | |
| 9. Tactical Eco-Driving[a] | .56 | 4.86 | 1.24 | **.19** | **.29** | **.24** | .07 | **.15** | **.39** | .06 | **.49** | |
| 10. Operational Eco-Driving[a] | .82 | 5.37 | 1.01 | **.33** | **.26** | **.14** | .08 | .08 | **.57** | **.11** | **.57** | **.51** |

*Note*. Significant correlations, $p < .05$, are presented in bold. For striving coherence, Cronbach's α of the value scale and the helpfulness scale (in brackets) are reported.

[a]Data refer to the shortened scale after CFA.

## 6.3 Results

Table 3 displays the descriptive statistics and zero-order correlations of all variables after data exclusion. People reported high eco-driving behavior and effort. Furthermore, they identified strongest coherence between biospheric values and eco-driving. Participants perceived the lowest coherence between eco-driving and egoistic values. Furthermore, participants were rather autonomously motivated than controlled motivated to eco-drive. As expected, correlation coefficients indicate that all predictors correlate with effort towards eco-driving. The correlation between striving self-determination/biospheric striving coherence and effort shows medium effect sizes, while the correlation between effort and eco-driving behaviors indicates medium to large effect sizes (Cohen, 1992). The fact that striving self-determination and striving coherence for different value types showed significant and insignificant relations indicate that both variables are related with each other but also differ to some degree.

**CFA eco-driving scale**

A CFA on eco-driving items was performed and modified to support the theoretical 3-factor structure of eco-driving (strategic, tactical, operational decisions) assumed by Sivak and Schoettle (2012). Initially, entering all items except for those excluded resulted in only a poor fit of the data, $\chi^2(206) = 793.94$, $p < .001$; CFI = .90; RMSEA = .073 (90% confidence interval of RMSEA = .068 to .078); SRMR = .070. Inspecting low factor loadings, correlations among items, and the modification indices, the model fit was stepwise improved by excluding two items (“I park my vehicle in the garage whenever possible.”; “I switch off the engine during longer stops or use my vehicle’s automatic start/stop system.”) with low factor loadings (< .40) and small correlations with other items (< .20). Furthermore, modification indices suggested adding covariances between variables similar in content that were included in the model (e. g., “I make sure to drive at low engine speed.”; “I shift up early (between 2000 and 25000 rpm).”). This resulted in an acceptable model fit, $\chi^2(162) = 482.66$, $p < .001$; CFI = .94; RMSEA = .061 (90% confidence interval of RMSEA = .055 to .067); SRMR = .058. Table 4 displays the item factor loadings of the analysis.

Table 4

*Factor loadings of the latent eco-driving construct (study 1)*

| Item | Strategic | Tactical | Operational |
|---|---|---|---|
| When buying a vehicle, I make sure to buy a low-emission vehicle. | .50 | | |
| When choosing tires for my vehicle, I make sure that the tires are fuel-efficient. | .48 | | |
| I regularly check the tire pressure of my vehicle. | .37 | | |
| I avoid short vehicle rides. | .57 | | |
| I consider alternative means of transport (e.g., public transport) before I start a journey. | .47 | | |
| I do not carry unnecessary weight in my vehicle. | | .59 | |
| I plan travel routes conscientiously (e.g., regarding traffic volume, road type, road gradient). | | .57 | |
| I participate in carpooling. | | .36 | |
| Instead of driving several short trips, I combine trips whenever possible. | | .68 | |
| I anticipate the traffic flow and keep distance to the vehicle in front. | | | .61 |
| I drive at a constant speed or with cruise control whenever possible. | | | .64 |
| I avoid driving at high speeds. | | | .71 |
| I accelerate gently (pedal not more than half depressed). | | | .77 |
| I use the momentum of the vehicle and let the vehicle roll out as far as possible. | | | .59 |
| I switch up early (between 2000 and 2500 rpm). | | | .61 |
| I minimize the use of electric consumers in the vehicle (e.g., air conditioning, seat heating, interior lighting). | | | .56 |
| If necessary, I open the window at low speeds (e.g., in the city) and turn on the air conditioning at higher speeds (e.g., on the highway) instead. | | | .35 |
| I make sure to drive at low engine speed. | | | .70 |
| I avoid breaking hard. | | | .68 |
| I use the eco-mode of my vehicle. | | | .60 |

*Note*. All factor loadings are significant at $p < .001$.

**Motivational model predicting eco-driving**

First, the measurement model was tested by conducting confirmatory factor analysis. Striving coherence values were divided with 100 equalizing them with the size of the other variables. Testing how good the model measures the latent constructs all latent variables were included. The loading for the first indicator of each latent variable was fixed to 1.0 for identification purposes. Covariances between eco-driving items similar in content were included again. The measurement error could not be estimated for the variables with only one indicator (i.e., striving self-determination, striving coherence). Hence, following suggestions by Steinmetz (2015), the measurement error of those variables was fixed to 10% of the indicator variance. The analysis revealed that the hypothesized model fit the data well, $\chi^2(368) = 639.79$, $p < .001$; CFI = .93; RMSEA = .039 (90% confidence interval of RMSEA = .034 to .044); SRMR = .045.

Next, the structural model was tested, which showed a satisfactory fit, $\chi^2(328) = 613.67$, $p < .001$; CFI = .93; RMSEA = .043 (90% confidence interval of RMSEA = .038 to .048); SRMR = .048. Standardized regression coefficients and explained variances are reported in Fig. 8. As expected, eco-driving effort strongly predicted self-reported strategic, tactical, and operational eco-driving decisions. Effort explained most variance of strategic eco-driving decisions (59%). Effort strongly predicted all eco-driving decisions with large effect sizes. As hypothesized, striving self-determination significantly predicted eco-driving effort. However contrary to the assumptions, only biospheric and hedonic striving coherence significantly predicted eco-driving effort, whereas altruistic and egoistic striving coherence showed no significant effect. All indicators together accounted for 39% of variance in effort. Striving self-determination and biospheric striving coherence showed similar high beta weights; therefore, they were both significant predictors of effort with medium effect sizes. Hedonic striving coherence also predicted eco-driving effort but showed a rather small effect.

Within exploratory analyses, an additional model including all direct paths simultaneously was tested to evaluate direct effects of striving self-determination and striving coherence on eco-driving behaviors. The exploratory nature of this analysis resulted in adjusting the significance level to $p < .01$ (Lauper et al., 2016). However, the analysis revealed only significant effects of biospheric and hedonic striving coherence on tactical eco-driving decisions.

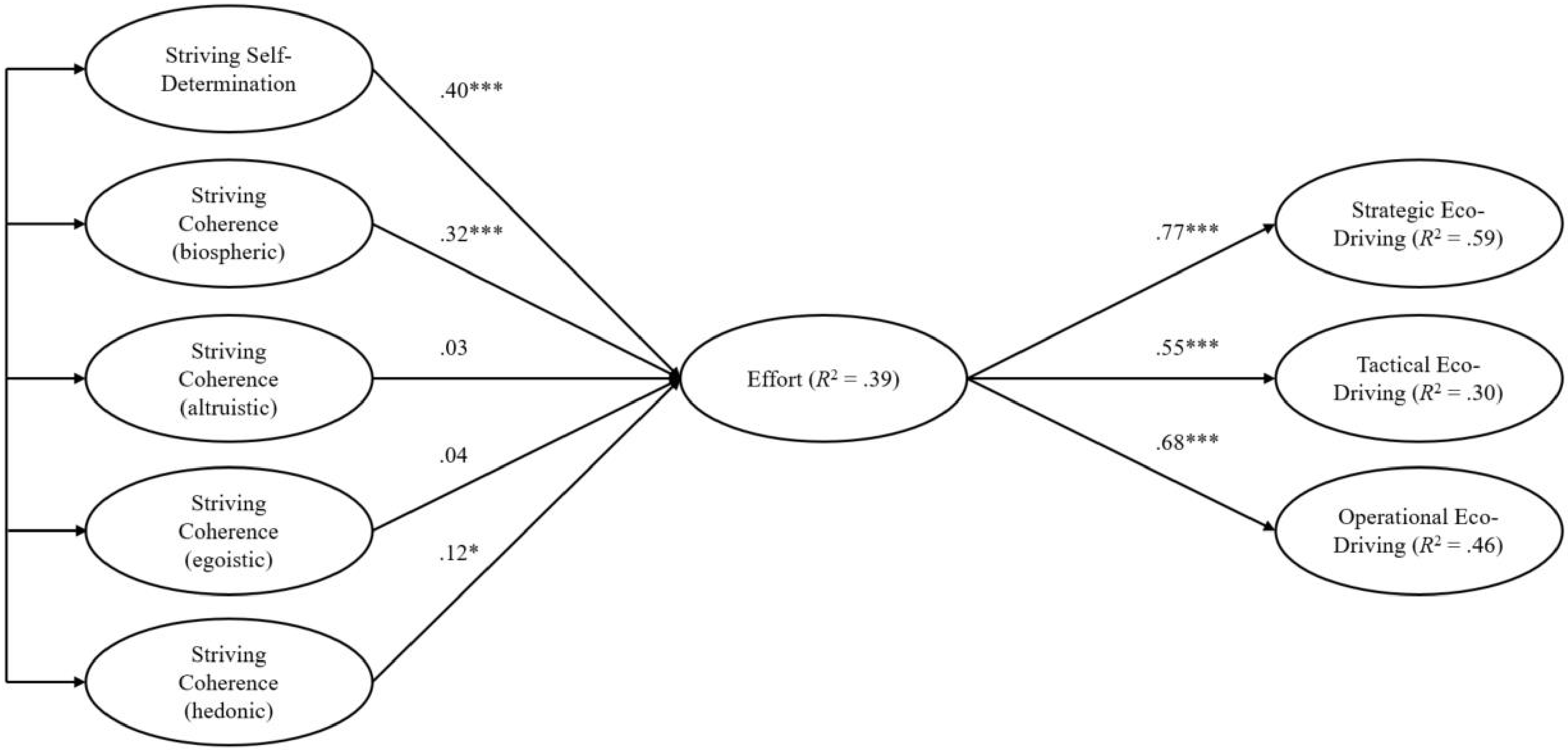



*Figure 8.* Tested motivational model of eco-driving behaviors (study 1).

*Note.* Standardized regression coefficients and explained variances ($R^2$) of endogenous variables are displayed (indicators and residual variances are omitted for figure simplicity).

* $p < .05$. *** $p < .001$.

### Qualitative analysis of knowledge about eco-driving

Only 28 participants provided zero (i.e., left the answer section blank) or only invalid eco-driving behaviors indicating that 95% of participants provided at least one valid eco-driving behavior. Overall, participants gave 1899 valid behaviors. Seventy-seven individuals provided only one tip (14.4%). Most participants (189 participants) gave two or three valid behaviors (35.3%), 150 participants (28.0%) entered four or five valid tips and 92 participants provided more than five eco-driving behaviors (17.2%). Table 5 displays the frequencies of eco-driving behaviors sorted by decision type. Anticipatory driving and keeping distance to other vehicles was the most commonly reported eco-driving behavior with 240 participants offering this tip (44.8%). The purchase of low-emission vehicles (29.5%) and the minimization of electrical consumers follow by far (28.5%). Few participants provided the behaviors of parking the vehicle in the garage (4; 0.01%), using the right engine oil (6; 0.01%), and seasonally changing the tires (9; 0.02%). The participants gave the most tips in the category of operational decisions, which are certainly most closely associated with the term eco-driving. 31% of participants reported behaviors from one, 36% from two, and 28% from all three categories.

Table 5

*Knowledge of eco-driving behaviors (multiple answers possible; study 1)*

| Eco-Driving | Category | Frequency | %[a] |
|---|---|---|---|
| Strategic Decisions | Low-emission vehicle | 158 | 29 |
| | Fuel-efficient tires | 59 | 11 |
| | Tire pressure check | 136 | 25 |
| | *Use correct engine oil* | 7 | 1 |
| | *Vehicle maintenance* | 32 | 6 |
| | *Seasonal tire change* | 9 | 2 |
| | *Park vehicle in garage* | 4 | 1 |
| | Avoid short trips | 43 | 8 |
| | Consider alternative means of transport | 52 | 10 |
| Tactical Decisions | Not carry unnecessary weight | 144 | 27 |
| | *Improve aerodynamics* | 57 | 11 |
| | Choose most energy-efficient route | 52 | 10 |
| | Carpooling | 32 | 6 |
| | Trip-chaining | 10 | 2 |
| Operational Decisions | Anticipatory driving | 240 | 45 |
| | Constant speed/cruise control | 68 | 13 |
| | Avoid high speeds | 95 | 18 |
| | Gentle acceleration | 67 | 13 |
| | Let vehicle roll out/sailing | 85 | 16 |
| | Gentle braking/use overrun cutoff | 41 | 8 |
| | Keep low engine speed | 73 | 14 |
| | Shift up early | 77 | 14 |
| | *Switch off engine at stops/automatic start-stop* | 83 | 15 |
| | Minimize use of electrical consumers | 153 | 29 |
| | Close windows at high speeds | 26 | 5 |
| | Use eco-mode | 55 | 10 |
| | *Do not warm up the engine* | 11 | 2 |
| | *Use recuperation* | 30 | 6 |

*Note*. Items not covered in the final eco-driving scale are displayed in italics.

[a]Proportion of total sample ($N = 536$)

## 6.4 Discussion

The goal of study 1 was to investigate a motivational model based on the Self-Concordance Model predicting self-reported eco-driving regarding strategic, tactical, and operational decisions (Sivak & Schoettle, 2012). The analyses were calculated based on a data set from 536 German vehicle drivers that drive regularly.

As expected, the results showed that effort is a strong predictor of the three different eco-driving decisions which were confirmed in a confirmatory factor analysis. This supports previous research showing the effect of effort on behavior requiring self-control (Sheldon & Elliot, 1999; Smith et al., 2007, 2011). Furthermore, the present research also showed that effort is not only a theoretically plausible mediator between self-concordance and behavior, but also an empirically significant one.

The analyses further revealed that striving self-determination is a significant predictor of effort. This is in line with previous findings showing that autonomous motivation significantly predicts pro-environmental behavior and is superior over controlling motives (De Groot & Steg, 2010; Lavergne et al., 2010; Osbaldiston & Sheldon, 2003). This is not only true for pro-environmental behaviors in general but also for pro-environmental mobility behavior, which can often be effortful and costly. Hence, people are more likely to engage in eco-driving behavior when they think it is an important thing to do, or because it is fun than when they think they would personally benefit from it, or because the current situation requires it.

Regarding the relationship between striving coherence and eco-driving, a significant relationship between biospheric striving coherence and eco-driving but no effect of egoistic striving coherence was found. Hence, the present results support theoretical assumptions of researchers that normative value orientations are superior to gain beliefs in the domain of pro-environmental behavior (Lindenberg & Steg, 2007; Steg et al., 2016; Ünal et al., 2018). Therefore, participants not only perceive coherence between biospheric values and eco-driving but the perceived helpfulness of eco-driving to achieve higher-order biospheric values is a strong predictor of eco-driving, whereas individuals perceive little coherence between egoistic motives and eco-driving that is further no sufficient predictor of eco-driving. Therefore, the present results extend the literature on the influence of biospheric value orientations (Lauper et al., 2016; Ünal et al., 2018) by showing that the perceived coherence between biospheric values and eco-driving can influence behavior via increased effort. With regard to eco-driving interventions, this is an important finding as there are strategies to foster striving coherence (see Unsworth & McNeill, 2017) while values are rather rigid and difficult to change.

Consistent with the results on value orientations (Ünal et al., 2018) but unexpectedly, no effect of altruistic coherence on effort was found. The mean differences in biospheric and altruistic striving coherence support that individuals perceived more coherence between biospheric values and eco-driving than between altruistic values and eco-driving (Steg et al., 2016). There are two interesting points in here, which will be discussed in the following.

First, based on the results, it is not clear whether people are motivated to save the earth (i.e., regardless of people's lives on it) or rather to save humanity on earth (i.e., saving the earth as a means to the end of saving humanity) when prioritizing biospheric values. Most interventions focus on strengthening the goal to save the planet because it is the home of us people. Future studies should investigate if most people are motivated because of this reason or if some people also focus on saving the earth because it is the habitat of other species or just for the sake of nature. Clearly, this would be a biospherically motivated reason. However, to what extent the preservation of human life on earth can be seen as a biospheric (saving the earth), altruistic (protecting the lives of others/future generations), or egoistic (humans as the center of the biosphere) motivation is a point for discussion that should receive more attention in future research.

Second, it is interesting that people did not identify a strong link between altruistic values and eco-driving although there are multiple altruistic benefits of eco-driving. In fact, not driving environmentally friendly has easily identifiable impacts on other people (e.g., increased air pollution in urban areas that threaten the health of individuals living there) but also impacts on other people that are more difficult to identify (e.g., migration). Therefore, more research should be conducted on how to make these impacts more accessible to people and whether they have sufficient motivating power to trigger pro-environmental behavior changes. This is also important considering the fact that there may be people who do not see themselves as an ecological but as a social person.

A new but theoretically plausible result is that hedonic striving coherence predicted effort towards eco-driving. This is consistent with autonomous forms of motivation having an impact on eco-driving effort. Thus, some people perceive coherence between hedonic values and eco-driving that motivates them to engage in this behavior. Indeed, some eco-driving behaviors are associated with fun (e.g., recuperation, carpooling, free routes, relaxed driving). Nevertheless, only weak effects of hedonic coherence were found. While these effects are compelling, they should be interpreted cautiously and, above all, replicated in future research also because hedonic values are so far underrepresented in the literature.

Overall, the present results underline the importance of autonomous motivations and biospheric beliefs for eco-driving. Accordingly, the commitment to eco-drive that is not integrated in the self but rather arises from external or internal pressure (i.e., controlled motivation) is not a sufficient motivator of long-term sustainable mobility behavior. Furthermore, the present results support the findings that the coherence between a behavior and intrinsic (i.e., biospheric) values is a stronger predictor of sustained pro-environmental effort than the coherence between extrinsic (i.e., egoistic) values and the behavior (Sheldon & Kasser, 1995; Vansteenkiste et al., 2004).

It is interesting that the present results are not in line with the findings of Unsworth and McNeill (2017), who found that the coherence between pro-environmental behavior and a wide variety of motives, including monetary ones, influenced pro-environmental behavior. However, in contrast to the present study, Unsworth and McNeill (2017) did not separately examine the influence of striving coherence for different value types (i.e., biospheric, altruistic, egoistic, hedonic). Furthermore, it could be that the investigated dependent variable caused the different effects. While Unsworth and McNeill (2017) examined the effect of self-concordance on sustainable energy use, the present study examined effects on eco-driving. It may be that the associated monetary consequences have a greater impact on energy use than on eco-driving, which should be analyzed in future studies. Overall, the present research extends the research of the impact of self-concordance on pro-environmental behaviors by showing that striving coherence is an important predictor of pro-environmental effort and behavior but the effect is particularly strong when the behavior is coherent with biospheric values. Nevertheless, as this is the first study that found these results, further studies need to replicate them.

Finally, the results of this study support the importance of a motivational model based on the Self-Concordance Model applied to pro-environmental strategic, tactical, and operational driver decisions (i.e., eco-driving; Sivak & Schoettle, 2012). The concept of striving coherence has not been tested before regarding eco-driving and seems to be as relevant in the field of habitual private mobility as in the domain of other habitual behaviors. Furthermore, previous studies that tested the determinants of eco-driving have focused primarily on operational eco-driving decisions and have largely neglected non-driving related behaviors that have an additional impact on $CO_2$ emission reduction.

Lastly, in accordance with Strömberg et al. (2015) as well as Nègre and Delhomme (2017), the analyses of this study revealed that only few participants (5.2%) had no knowledge of eco-driving behaviors. Furthermore, this study indicates that the most frequently reported behaviors are also those with the strongest effect on fuel or energy efficiency, which replicates and extends findings by McIlroy and Stanton (2017). Nevertheless, there are many eco-driving behaviors that few people are aware of, making it clear that informational strategies are still important but should be combined with motivational strategies in the future.

**Practical implications for effective eco-driving interventions**

Based on this research, implications for future interventions are derived that should foster long-term behavior change regarding eco-driving. Furthermore, explanations for failed intervention attempts in the past are derived. However, it is important to further study eco-driving regarding strategic, tactical, and operational decisions because first, larger technological innovations take time and are not extensively implemented overnight. Second, even with technical innovations, eco-driving will remain important due to the progression of climate change and the insufficient knowledge of many eco-driving decisions by a majority of people.

From the present results, it is concluded that individuals view eco-driving as a means of environmental protection and not as a means of improving one's own resources. However, high intentions and motivations alone will not be sufficient to significantly reduce the environmental impact of mobility behavior (Schoenau & Müller, 2017). Instead, appropriate interventions must be developed that reinforce biospheric values and autonomous motivations, such as highlighting $CO_2$ savings, implementing the opportunity to collect "green" points, or making pictures salient that show the environmental impact of a behavior (Steinhorst & Klöckner, 2018; Van den Broek et al., 2017; Wang & Yao, 2020). Hence, environmental advantages of eco-driving need to be activated and framed in situations when people can show that behavior. Several researchers suggest that feedback can be framed with different information leading to the activation of different kinds of values (Cheng et al., 2011; Lindenberg & Steg, 2007; Pelletier et al., 2011; Pelletier & Sharp, 2008). This strategy also known as message framing helps to overcome habitual behavior (Carfora et al., 2019). Message framing has been effective in promoting operational and tactical eco-driving intentions emphasizing the environmental but not the monetary benefits of this behavior (Bolderdijk, Steg, et al., 2013; Dogan et al., 2014).

The present results provide an explanation why emphasizing environmental (i.e., $CO_2$ savings) rather than economic benefits (i.e., monetary savings) may be more motivating for future eco-driving interventions. Highlighting environmental benefits strengthen the perceived coherence of biospheric values and eco-driving as well as autonomous motivations (especially identified motivation) that motivate individuals to eco-drive. In contrast, highlighting the coherence between egoistic motives and eco-driving by monetary benefits (e.g., fuel savings) will not sufficiently motivate people to perform eco-driving. This is supported by results of

Dogan et al. (2014) who showed that the small monetary savings of eco-driving are not considered worth the effort of implementing eco-driving behaviors. Although future studies are needed to test if monetary incentives could have different impacts on eco-driving at the three decision levels (e.g., assuming that a sufficiently high one-off reward may have an impact on cost-intensive strategic eco-driving decisions), highlighting environmental benefits could be a cost-effective and easy-to-implement intervention that motivates people to eco-drive. In contrast, external incentives may undermine environmental intrinsic motivation hindering long-term behavior change and positive spillover effects (Bolderdijk & Steg, 2015; Deci, Ryan, et al., 1999; Evans et al., 2013; Steg, Bolderdijk, et al., 2014; Steinhorst & Klöckner, 2018) and may be only short-lived, i.e., motivate people only as long as they are in place (Bolderdijk et al., 2011). At the same time, unwanted rebound effects may occur (Fehr & Falk, 2002).

Many researchers emphasize that driving behavior is highly automated (Nègre & Delhomme, 2017; Pampel et al., 2018) and that the pro-environmental goal of driving fuel-efficiently is neglected during stressful periods when other goals take precedence (e.g., maintaining safety, arriving in time; Dogan et al., 2011). Based on these findings, it becomes clear that high pro-environmental motivations may not be sufficient to consistently maintain eco-driving behaviors in real life. Therefore, continuous in-car feedback that reinforces eco-friendly motivations and biospheric values may be effective in maintaining drivers' mental eco-driving models helping them to remember the environmental goal of fuel- or energy-efficient driving. Future studies should test if delayed feedback may be helpful too, because it benefits from not being distracting while driving.

Because of the results of this study showing that both intrinsic motivation and the coherence between hedonic values and eco-driving predicted eco-driving effort, future researchers should continue to investigate the effectiveness of gamification (i.e., the use of "game design elements in non-game contexts"; Deterding et al., 2011, p.9) and its mediating variables on eco-driving. It can be hypothesized that this intervention strategy can be effective for eco-driving because it strengthens intrinsic motivation and hedonic feelings (i.e., fun, pleasure) of drivers, which should be tested in future studies. Some studies found that gamified elements (such as stars, points, leaderboards, etc.) influenced fuel or energy efficiency while driving (Corcoba Magaña & Muñoz-Organero, 2015; Günther et al., 2020). Similarly, studies found that gamified elements assist in learning eco-driving skills (e.g., Hrimech et al., 2016). However, the mechanisms of gamification are still unclear. When analyzing gamification or similar motivational strategies, future studies should, however, consider the following aspects.

First, theoretical research suggests that rewards and incentives lead to a perceived external locus of causality making external factors necessary for initiating and maintaining behavior (Deci, Ryan, et al., 1999; Deci & Moller, 2014; Deci & Ryan, 1987). In addition, theory suggests that for strengthening perceived competence, it is more successful to promote cooperation than competition. Cooperation has shown to be more effective in promoting autonomy whereas competition is more likely to be perceived as a controlling context (An, 2020; Deci et al., 1981). Furthermore, feedback communicated through digital applications on the smartphone or in-car should allow positive (Sheldon & Filak, 2008; Van de Velde et al., 2010) and informative non-controlling feedback (An, 2020; Deci, Koestner, et al., 1999; Mouratidis et al., 2010). Furthermore, it is important to recognize and feedback good performance providing competence and a belief in the ability to implement the behavior (Deci et al., 1996; Deci, Ryan, et al., 1999). This seems to be particularly important for driving behavior. Therefore, researchers designing and evaluating (gamified) in-car assistant systems should consider these aspects to create strategies that show long-lasting effects on eco-driving behavior. Furthermore, future studies should investigate whether gamified learning can also be helpful for adopting the new eco-driving rules of modern propulsion technology (i.e., hybrid/electric cars), which are probably still unknown by many people.

In sum, it can be concluded that while informational strategies and monetary incentives can be an approach to promote short-term pro-environmental behavior, the ambiguous effects of past interventions as well as the present results suggest that these interventions should be combined with other strategies emphasizing intrinsic, moral, and normative advantages. In order to counter climate change, it is essential that a majority of people implement long-term pro-environmental behavior in a wide variety of domains. To achieve this, multiple strategies should be combined that are tailored to the specific behavior and the person (and the preferred values), with particular emphasis on the fun and the environmental relevance of the behavior.

**Limitations**

One limitation of the present study is that it had a cross-sectional design; therefore, it cannot draw any causal conclusions about the investigated relations and may contain method variance bias (Podsakoff et al., 2003). Although other studies have already found causal effects between self-concordance and pro-environmental behavior (Unsworth & McNeill, 2017), the present results should be replicated and validated in controlled laboratory studies or in longitudinal studies separating independent and dependent variables over time (Lauper et al., 2015).

Another limitation of the study is that actual eco-driving behavior was not measured. Therefore, objective behavioral measures should be applied in future studies to replicate the effects of self-reported behavior, which may be also limited because of possible social desirability effects.

Additionally, although the present sample is sufficiently diverse with regard to different age groups and genders, it is not representative of all car drivers. However, since the present study mainly examined correlative relationships and did not compare mean scores, a non-representative sample is of less impact (Walter et al., 2019).

Another limitation of the study is that the ongoing COVID-19 pandemic may have limited the mobility behavior of the participants, which may have affected their response behavior on the eco-driving items (e.g., regarding public transport or carpooling). However, participants reported their general behavior, which may have reduced the bias.

Moreover, it is clear that there are additional behavioral drivers that were not included in the survey (e.g., motives, self-control, social norms). Hence, future studies should examine additional determinants of eco-driving to gain a more comprehensive insight into the underlying drivers of eco-driving in order to make interventions more effective.

Finally, the present research developed and used the eco-driving scale for the first time; therefore, it is essential that future studies replicate its structure and reliability. It could have been a problem that the car drivers were not aware of the impact of all eco-driving behaviors included in the scale. However, as most of the eco-driving items were found in the eco-driving behaviors reported by participants, it can be concluded that most people are aware about the impact of multiple eco-driving behaviors. The comprehensive consideration of eco-driving behaviors should encourage researchers to consider not only driving behavior itself, but also strategic and tactical decisions of eco-driving in the future. Although operational decisions will not change completely but slightly with the introduction of new propulsion techniques, strategic and tactical decisions will remain the same in the future.

## Conclusion

Transport emissions are a dramatic and ongoing problem for climate change. Because this crisis cannot wait for structural changes that are introduced only gradually (Barkenbus, 2010), changes in human behavior are essential. The present results suggest that people who pursue eco-driving for motives that are autonomous rather than controlled and perceive coherence between biospheric values and eco-driving show more effort to achieve this behavior; therefore, they are more likely to do so. Based on these outcomes, future studies should shift their research focus from purely informative interventions and monetary incentives towards meaningful informational and feedback interventions that emphasize the valuable contribution of the specific behavior to the environment and life on earth and allow the perception of connections between the behavior and personal valuable biospheric motives.

# 7 Study 2: Behavioral costs moderate the relationship between environmental motivations and eco-driving

## 7.1 Introduction

Scientists never tire of emphasizing that for human-caused climate change (to which $CO_2$ emissions of the transport sector significantly contribute) there is no time left to be inactive. Hence, adapting high-impact pro-environmental behaviors is more relevant than ever, which includes transport-related behaviors, such as eco-driving (Sivak & Schoettle, 2012). Although high-impact transportation measures are already in place - such as the increased development and introduction of alternative drive types - conventional combustion vehicles will continue to dominate the road for a long time to come. Accordingly, it is necessary that people adopt and consistently practice an environmentally friendly driving style. However, although various eco-driving campaigns have been developed in recent years (Barkenbus, 2010) and many people know how to eco-drive (see study 1), only few people drive fuel-efficiently in their daily lives (Pampel et al., 2017). To better understand why this is the case and how to achieve long-term behavior change, in the present study, the (interactive) influence of motivational *and* contextual factors was investigated. Furthermore, it was analyzed if the influence of motivational factors varies depending on the level of perceived behavioral effort of eco-driving behaviors.

**What drives eco-driving?**

As indicated, fuel savings potentials of up to 45% are achievable, which shows that eco-driving can significantly reduce $CO_2$ emissions of the transport sector (Af Wåhlberg, 2007; Barkenbus, 2010; Sivak & Schoettle, 2012). Eco-driving behaviors include, among others, anticipatory driving, avoiding extreme speeds, and planning energy-efficient routes (see Table 6 for used eco-driving behaviors in study 2; Barkenbus, 2010; Dogan et al., 2014; Huang et al., 2018; Kramer & Petzoldt, 2022a; Nègre & Delhomme, 2017; Sanguinetti et al., 2017; Sivak & Schoettle, 2012; Strömberg et al., 2015). The benefits of eco-driving extend beyond fuel savings and emissions reductions and also include noise reduction and safety benefits (Alam & McNabola, 2014; Barkenbus, 2010; Lauper et al., 2015; Nègre & Delhomme, 2017). Additionally, contrary to what many individuals probably assume, eco-driving does not necessarily increase travel time (Barth & Boriboonsomsin, 2009).

Despite these benefits, Pampel et al. (2015) found that the study participant's "normal" driving style differed from their eco-driving style, indicating that although individuals know how to eco-drive, they do not show this behavior in everyday life when driving "normally". This finding is consistent with a number of studies reporting that individuals do not necessarily lack eco-driving knowledge and skills (McIlroy & Stanton, 2017; Nègre & Delhomme, 2017; Strömberg et al., 2015). The fact that people struggle to maintain eco-driving behaviors in everyday life is also supported by studies that examined effects of training interventions. These studies found that although such interventions showed initial effects on driving behavior and fuel consumption, the effects disappeared after a while hardly showing any savings potentials in the long term (Beusen et al., 2009; Degraeuwe & Beusen, 2013; Zarkadoula et al., 2007). For instance, Af Wåhlberg (2007) found that an eco-driving training reduced fuel consumption by 6%; however; the reduction effect decreased to 2% twelve months after the intervention.

Hence, instead of informational factors, researchers believe that motivational factors are critical to pro-environmental behavior (Bolderdijk et al., 2018). Indeed, a number of studies found that normative values (Steg, Bolderdijk, et al., 2014; Ünal et al., 2018) as well as self-determined (study 1; De Groot & Steg, 2010) and environmental intrinsic motivations (Steinhorst & Klöckner, 2018) positively influenced pro-environmental behavior and eco-driving. Likewise, interventions strengthening autonomous motivations could also encourage individuals to engage in pro-environmental behaviors including mobility behaviors such as eco-driving (Bolderdijk, Steg, et al., 2013; Dogan et al., 2014; Schwartz et al., 2015; Spence et al., 2014).

Table 6

*Eco-driving behaviors investigated in study 2*

| Category | Eco-driving behavior |
|---|---|
| Strategic decision | Purchase low-emission vehicle |
| | Purchase fuel-efficient tires |
| | Check tire pressure regularly and ensure that tires are not underinflated |
| | Change tires seasonally |
| | Park vehicle in garage |
| | Take vehicle to service regularly |
| | Avoid short vehicle rides |
| | Consider alternative means of transport (e.g., public transport) |
| Tactical decision | Improve aerodynamics of vehicle (e.g., remove roof luggage box) |
| | Choose energy-efficient travel routes |
| | Do not carry unnecessary weight in the vehicle |
| | Carpooling |
| | Trip-chaining |
| Operational decision | Anticipatory driving |
| | Avoid very high speeds |
| | Drive at constant speed or with cruise control |
| | Accelerate gently |
| | Use momentum and let vehicle roll out |
| | Shift up early |
| | Open windows at low speeds and use air conditioning at high speeds |
| | Drive at low engine speed |
| | Avoid breaking hard |
| | Reduce electrical consumer use (e.g., heating, air conditioning) |
| | Turn off engine at stops/ use start-stop system |
| | Use eco-mode of vehicle |

**The predictive role of self-determined motivation**

Previous research has shown that self-determined or autonomous motivations in contrast to controlled motivations positively predicted various effortful behaviors, such as physical activities (Calvo et al., 2010; Vlachopoulos et al., 2000), academic learning (Taylor et al., 2014), and pro-environmental behavior (Green-Demers et al., 1997; Lavergne et al., 2010). In study 1 of this dissertation, it was found that self-determined eco-driving motivations and prioritizing goals coherent with eco-driving (e.g., values about the importance of preserving the biosphere) significantly predicted eco-driving effort, which in turn predicted reported eco-driving behavior. In sum, self-determined motivations appear to be key not only to pro-environmental behaviors in general but also to eco-driving in particular. However, whether motivations alone are sufficient to motivate pro-environmental behavior in real life seems questionable especially for behaviors that involve high personal costs (Steg & Vlek, 2009).

**Is high motivation enough?**

It is obvious that pro-environmental behavior is often associated with high behavioral costs and with little fun, which prevents many people from behaving pro-environmentally in their daily lives (Lindenberg & Steg, 2007). For example, convenience (e.g., turning on the seat heating in winter) or enjoyment (e.g., driving fast) may prevent people from eco-driving (Günther et al., 2017; Kaiser et al., 2021). Furthermore, high effort seems to be necessary to maintain eco-driving skills and suppress learned driving habits (Pampel et al., 2018). In summary, various external behavioral barriers may hinder (even highly motivated) individuals to eco-drive. Hence, researchers advise that both psychological and contextual factors need to be considered when predicting pro-environmental behaviors (see chapter 3.2). However, it is yet unclear how these factors interact (or not; see chapter 3.3).

To recapitulate, Kaiser (2021) assumes that environmental attitudes and behavioral costs represent compensatory (i.e., statistically additive) factors in explaining pro-environmental behaviors according to the Campbell Paradigm (see chapter 3.3.1). In contrast, the Low-Cost Hypothesis (LCH; see chapter 3.3.2) assumes that environmental attitudes influence pro-environmental behavior primarily in situations with low behavioral costs, whereas environmental attitudes significantly loose predictive power when behavioral costs increase (Diekmann & Preisendörfer, 2003). Guagnano et al. (1995) provide another theoretical assumption and hypothesize that psychological and external factors show an inverted U-formed relationship when predicting pro-environmental behavior (see A-B-C Model; chapter 3.3.3). Hence, the researchers assume that when behavioral costs are high even strong environmental attitudes are not sufficient to overcome high behavioral barriers, whereas in low-costs situations most people will choose the environmental alternative irrespective of environmental attitudes.

Accordingly, there are several assumptions in the current literature about why environmental attitudes and motivations inconsistently affect pro-environmental behavior. Although most researchers agree that this is because of the lacking consideration of behavioral costs (Steg & Vlek, 2009), the assumptions about the relationship between behavioral costs and environmental attitudes differ (see chapter 3.3). Furthermore, it seems unclear if psychological factors are most decisive for low-, moderate- or high-cost pro-environmental behaviors. Especially for pro-environmental behaviors that are associated with high behavioral costs (which mostly have a high impact on climate change mitigation too), it seems essential to identify which determinants influence the implementation of these behaviors. Furthermore, this is also necessary to make interventions for pro-environmental behavior change (more) effective.

Eco-driving can be associated with low (e.g., do not carry weight in the vehicle), moderate (e.g., avoid high speeds), or high (e.g., avoid car use) behavioral costs. Although it has already been established that self-determined motivations can successfully predict eco-driving behaviors (see study 1), the role of behavioral costs is unclear so far. However, understanding if and how strongly pro-environmental behaviors are influenced by environmental motivations *and* behavioral costs enables the targeted implementation and use of interventions. To date, no study has examined how psychological *and* contextual factors (interactively) affect eco-driving, which may explain why some eco-driving interventions have not been successful in influencing long-term behavior change (Af Wåhlberg, 2007; Beusen et al., 2009; Degraeuwe & Beusen, 2013).

Therefore, the present study aims at investigating the influence of both factors to derive helpful suggestions for future intervention development. Based on the outlined theoretical assumptions, it may be that motivational and contextual factors represent additive (i.e., in line with the Campbell Paradigm) or interactive variables and influence low- (i.e., in line with the LCH) or rather moderate-cost (i.e., in line with the A-B-C Model) eco-driving behaviors best.

**Study aim**

The aim of the present study was to investigate the relationship between behavioral costs and self-determined motivations for eco-driving and gain insights into whether self-determined motivations predict eco-driving behaviors involving different levels of behavioral costs (i.e., low, moderate, high) differently or not. For this, the results of two online surveys were analyzed.

Based on the theoretical and empirical research of past research, two research questions were formulated to get a deeper insight into the determinants of (different behaviors of) eco-driving.

*1) Do behavioral costs moderate the effect of self-determined motivations on eco-driving behaviors (i.e., is there an interaction effect or are there two additive effects of behavioral costs and self-determined motivations on eco-driving; see study 2.1)?*
*2) Do self-determined motivations for eco-driving predict low-, moderate-, and high-cost eco-driving behaviors with similar strength or is there a difference in the predictive power (see studies 2.1 and 2.2)?*

The first study that was analyzed to answer both questions was a longitudinal intervention survey (see study 4). Participants in this survey were asked to implement eight eco-driving behaviors in everyday life during the study period (i.e., for three months) following an intervention at baseline. The variables of interest for the present study were assessed during the midpoint of the survey.

The data of the second study came from a cross-sectional online survey investigating the predictive power of a motivational model for eco-driving (see study 1). This study examined 25 eco-driving behaviors. The analysis of this study only addressed the second research question.

## 7.2 Study 2.1

The study was conducted as part of a larger intervention study to examine framing effects on eco-driving behavior. In this longitudinal study (see study 4), participants were assigned to different intervention groups, which challenged participants to implement eight eco-driving tips in real life during the study period, or to the control group. Participants were asked to implement those tips during the study period, which is why only participants with an annual mileage of more than 3000 kilometers were contacted to ensure that only drivers who drive regularly participated in the study. For the present analyses, participants from the control group who were not asked to practice eco-driving behaviors during the study period were excluded (i.e., because they did not strive to eco-drive). The intervention groups did not differ significantly in terms of reported eco-driving behaviors. Therefore, the assignment to the experimental groups can be neglected for the present study.

### 7.2.1 Method

**Procedure**

The study consisted of two survey periods. Participants who completed the preceding online questionnaire went through all survey periods, in November (T1) and December 2020 (T2), whereby the variables of the first survey were of no interest for the present study (except for sociodemographic data). For each survey assessment, participants received an online questionnaire by e-mail and had one week to complete it.

Individuals from the participants pool of a large German vehicle manufacturer who expressed interest in participating in the study were contacted. An internal committee approved the study with regard to ethical aspects. The participants were able to receive €30 upon completion of all questionnaires. For the present study, only the variables collected in the online questionnaire at T2 were relevant. This questionnaire was accessible via a link, took approximately 10 to 15 minutes to complete, and was developed using the questionnaire tool Tivian (Tivian XI GmbH, 2022). Participants answered questions on several scales related to eco-driving (e.g., attitude, intention, behavior) and personality traits/attitudes (e.g., driving motives, self-determination, values). They gave consent and were informed that the participation is voluntary and data is anonymized. Below, the variables relevant to the present study are reported.

**Measures**

*Self-determination for eco-driving.* The scale measuring self-determination (SD) was adopted from Pelletier et al. (1998) who developed and validated the "Motivation Towards the Environment Scale" (MTES). Instead of asking participants why they do things for the environment, participants were asked to rate 23 statements indicating the reason why they eco-drove in the past four weeks (i.e., since the intervention started). Overall, the scale consists of six subscales of four items (except for introjected motivation, for which there are three items) representing six motivation types. The motivation types consist of (ranging from most self-determined to least self-determined) intrinsic motivation (IM; e.g., "… because I feel pleasure in improving the quality of the environment."), integrated motivation (INTE; e.g., "… because taking care of the environment is an integral part of my personality."), identified motivation (IDEN; e.g., "… because it is a sensible thing to do."), introjected motivation (INTRO; e.g., "… because I would feel guilty if I did not."), external motivation (EXT; e.g., "… because I received a reward/benefit for doing it."), and amotivation (AMO; e.g., "I wonder why; the situation is not improving."). The internal reliability of the subscales was acceptable (see Table

8). Participants had to rate their agreement with these items on a 7-point Likert scale (1 = *strongly disagree* to 7 = *strongly agree*). Self-determination indices were calculated for every participant by weighting autonomous forms of self-determination and subtracting weighted controlled forms of self-determination from this value (i.e., SD = (IM + INTE + IDEN) – (INTRO – EXT – AMO)). The index reflects the extent to which individuals eco-drive for self-determined (i.e., autonomous) rather than controlled reasons. Higher scores reflect that individuals prioritize self-determined over controlled motivations, whereas lower scores reflect that individuals are more likely to act for controlled than for self-determined reasons.

*Perceived behavioral cost of eco-driving.* Participants rated the perceived behavioral costs of implementing the eight eco-driving behaviors described in the eco-driving tips (e.g., choosing an energy-efficient route; see Table 7 for the full list of eco-driving behaviors) in the past four weeks on a 7-point Likert scale (1 = *not at all difficult* to 7 = *extremely difficult*). The internal consistency of the scale was acceptable (see Table 8).

*Reported eco-driving behavior.* Participants had to report if they implemented the eco-driving behaviors described in the tips in the past four weeks (e.g., "I avoided very high speeds."; see Table 7 for a full list of the eco-driving behaviors). Participants were encouraged to implement these eco-driving behaviors at T1. The behaviors were selected due to their ease of implementation and due to their calculable influence on fuel consumption (which was presented in the intervention for motivating reasons). Participants indicated their level of agreement to the statements on a 7-point Likert scale (1 = *strongly disagree* to 7 = *strongly agree*; higher values indicated stronger eco-driving behavior). All items were averaged. The internal consistency of the scale was acceptable (see Table 8).

Table 7

*Eco-driving behaviors of study 2.1*

| Eco-driving behaviors |
| --- |
| Avoid hard braking and acceleration and strong speed fluctuations and let the vehicle roll out |
| Avoid objects that increase the air resistance of the vehicle (e.g., roof luggage box), especially when they are not in use |
| Avoid very high speeds |
| Plan and drive most energy-efficient travel route |
| Avoid the use of electrical consumers (e.g., air conditioning, seat heating) in the vehicle |
| Turn off the engine during stops or use the vehicle's automatic start-stop system |
| Do not carry unnecessary weight in the vehicle |
| Check the vehicle's tire pressure regularly and ensure not to drive with underinflated tires |

Table 8

*Descriptive statistics and zero-order correlations of the main variables (study 2.1)*

| Variable | α | *M* | *SD* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Intrinsic motivation | .95 | 5.32 | 1.62 | | | | | | | | |
| 2. Integrated motivation | .89 | 5.25 | 1.45 | **.90** | | | | | | | |
| 3. Identified motivation | .87 | 5.74 | 1.28 | **.84** | **.87** | | | | | | |
| 4. Introjected motivation | .80 | 3.62 | 1.72 | **.59** | **.61** | **.56** | | | | | |
| 5. External motivation | .53 | 1.82 | 0.90 | .14 | .14 | .12 | **.33** | | | | |
| 6. Amotivation | .83 | 1.84 | 1.08 | *-.22* | **-.25** | **-.27** | .00 | **.38** | | | |
| 7. Self-determination index | - | 9.03 | 4.07 | **.76** | **.77** | **.77** | .14 | **-.33** | **-.61** | | |
| 8. Perceived behavioral cost | .68 | 2.62 | 0.95 | **-.33** | **-.41** | **-.44** | **-.29** | .09 | **.35** | **-.41** | |
| 9. Reported eco-driving | .63 | 5.21 | 0.92 | **.51** | **.60** | **.60** | **.42** | .09 | *-.18* | **.47** | **-.61** |

*Note*. Significant correlations with $p < .001$ are shown in bold. Significant correlations with $p < .01$ are shown in italics.

**Participants**

At T2, 214 participants from the intervention conditions completed the online questionnaire. Because participants received questions on eco-driving behaviors with an internal combustion engine (ICE), only participants driving those kinds of vehicles were contacted and participants who indicated in the questionnaire that they did not drive a vehicle with an ICE were excluded ($n = 6$). Furthermore, participants who answered the questionnaire in less than 5 minutes were excluded because it was assumed that the questionnaire could not be answered conscientious enough in this short time ($n = 1$). In the end, data of 207 participants were included in the data analyses. The mean age was 43.51 years ($SD = 14.70$; Range = 18-69). The proportion of participating men and women was balanced (male = 55%). Participants held a valid driver's license for an average of 25.40 years. Furthermore, they reported an average annual mileage of 15,000 kilometers (median).

**Statistical analysis**

All statistical analyses were calculated in R (R Core Team, 2020). For testing if there was an interaction effect between perceived behavioral costs and self-determination on eco-driving (i.e., for investigating the first research question), a multiple regression analysis was calculated. The variables *self-determination for eco-driving* and *perceived behavioral costs* were included as independent variables and *reported eco-driving behavior* was included as dependent variable. The interaction effect between self-determination and perceived behavioral costs was analyzed, which is why the variables were centered. For all effects, the *t*-value with associated *p*-value, and the β-value with associated 95% confidence interval (*95% CI*) is reported. To interpret the interaction effect, a simple slopes analysis was conducted and the simple slopes graph plotting reported eco-driving behavior against self-determination for low (1 *SD* below the mean of behavioral cost), moderate (at the mean of behavioral cost), and high (1 *SD* above the mean of behavioral cost) perceived behavioral costs of eco-driving was analyzed. Testing assumptions of regressions showed no violations of multicollinearity, linearity, normality, or homoscedasticity.

For the second research question analyzing if self-determined motivations predict different costly eco-driving behaviors (i.e., low-, moderate-, and high-cost behaviors) with different strength, a multivariate linear regression was calculated. Diekmann and Preisendörfer (2003) reported that behavioral cost intensity can be measured indirectly by assessing the frequency of behaviors in the aggregate. The authors state that a behavior, which is shown by a majority of people, will most likely be less costly than a behavior, which is shown by only a minority of people. Although this will not be true for every person, the assumption holds, according to the authors, in the aggregate (Diekmann & Preisendörfer, 2003).

Following this reasoning, in the present study, low-cost behaviors were defined as behaviors that have a mean score that is 1 *SD* above the mean of reported eco-driving behavior (> 6.12). Since only one behavior met this criterion (i.e., "I avoided objects that increase the drag of my vehicle (e.g., roof luggage box), especially when they were not in use.", $M = 6.70$), another eco-driving behavior that narrowly missed this criterion was categorized as low-cost ("I did not carry unnecessary weight in my vehicle.", $M = 6.02$). High-cost behaviors were defined as behaviors having a mean value 1 *SD* below the mean of reported eco-driving behavior (< 4.29). Two behaviors met this criterion ("I have minimized the use of electrical consumers (e.g., air conditioning, heated seats) in the vehicle.", $M = 4.02$; "When planning routes, I chose the most energy-efficient travel route.", $M = 4.06$). The remaining behaviors were categorized as moderate-costly based on their mean scores in terms of reported eco-driving behavior ("I avoided hard braking and acceleration as well as strong speed fluctuations and let the vehicle sail.", $M = 5.66$; "I avoided very high speeds.", $M = 5.39$; "I turned off the engine at stops or used my vehicle's automatic start-stop system.", $M = 4.77$; "I checked my vehicle's tire pressure regularly and made sure not to drive with underinflated tires.", $M = 5.01$). The values of the corresponding behaviors were averaged for all participants.

*Low-, moderate-, and high-cost eco-driving behaviors* were integrated as dependent variables and *self-determined motivation* was integrated as independent variable in the multivariate linear regression. The amount of explained variance ($R^2$) was compared for all three regressions. Based on Austin and Hux (2002) and Payton et al. (2003), 84% confidence intervals (*84% CI*) were calculated for the three different $R^2$ values and it was concluded that these values are significantly different when the *CI*s do not overlap. According to Austin and Hux (2002), using *84% CIs* is a more adequate procedure of a significance test at $\alpha = .05$ than using *95% CIs* when standard errors are approximately equal, which was the case in the present study. For all three regressions the $F$-value with associated $p$-value is reported. Testing multivariate regression analysis assumptions showed no violations of linearity, normality, or homoscedasticity.

### 7.2.2 Results

**Moderation effect of behavioral costs and self-determined motivations**

*Descriptive statistics*. Descriptive statistics in Table 8 indicate that individuals reported rather high self-determined motivations for eco-driving. In contrast, they rated the non-self-determined motivations for eco-driving rather low, which was also the case for amotivation. Participants rated the behavioral costs of eco-driving low to medium. Individuals reported a rather strong implementation of eco-driving behaviors during the study period. With regard to the correlations, it can be seen that self-determined forms of motivation are highly correlated with each other. In contrast, controlled forms of motivation correlate with self-determined motivations rather lowly while amotivation shows negative correlations. As expected, self-determination correlates highly with autonomous forms of motivation and only slightly or negatively with controlled motivations and amotivation. The higher the self-determination for eco-driving, the lower individuals evaluated the behavioral costs of eco-driving behaviors. In addition, self-determination and autonomous motivations were positively correlated with reported eco-driving behaviors. Perceived behavioral cost of eco-driving was negatively correlated with reported eco-driving.

*Multiple regression analysis*. The regression model predicting eco-driving behavior by self-determination and behavioral costs as well as their interaction was statistically significant, $F(3, 202) = 53.40, p < .001$. Self-determination was a strong predictor of eco-driving, indicating that people with stronger self-determined motivations reported stronger eco-driving behavior, $\beta = .29$, $t(202) = 4.56$, $p < .001$, *95% CI* = [0.039, 0.092]. Furthermore, behavioral cost negatively predicted reported eco-driving behavior, indicating that the higher the perceived behavioral costs of eco-driving, the lower the reported eco-driving behavior, $\beta = -.55$, $t(202) = -9.22$, $p < .001$, *95% CI* = [-0.650, -0.421]. Additionally, there was a significant interaction effect between self-determined motivations and behavioral costs, $\beta = -.16$, $t(202) = -7.74$, $p = .007$, *95% CI* = [-0.051, -0.008]. Therefore, the relationship between self-determined motivations for eco-driving and eco-driving differs for different levels of behavioral costs. The simple slopes analysis facilitates the interpretation of the interaction effect. Fig. 9 displays the mean of reported eco-driving behavior as a function of self-determined motivations grouped for low, moderate, and high behavioral costs. It can be seen, that for people with low self-determined motivations, reported eco-driving behavior is low independent of the behavioral costs. In contrast, if individuals have high self-determined motivations, they reported stronger eco-driving behavior irrespective of perceived behavioral costs. However, looking at the slopes of the regression lines, it can be seen that the relationship between self-determination and eco-driving is positive but stronger for low and moderate perceived behavioral costs than for high perceived behavioral costs. The *t*-tests analyzing if the simple slopes depicted in Fig. 9 were significantly different from zero indicated that all slopes for low, moderate, and high behavioral costs were significantly different from zero, $t > 2.54$, $p < .012$.

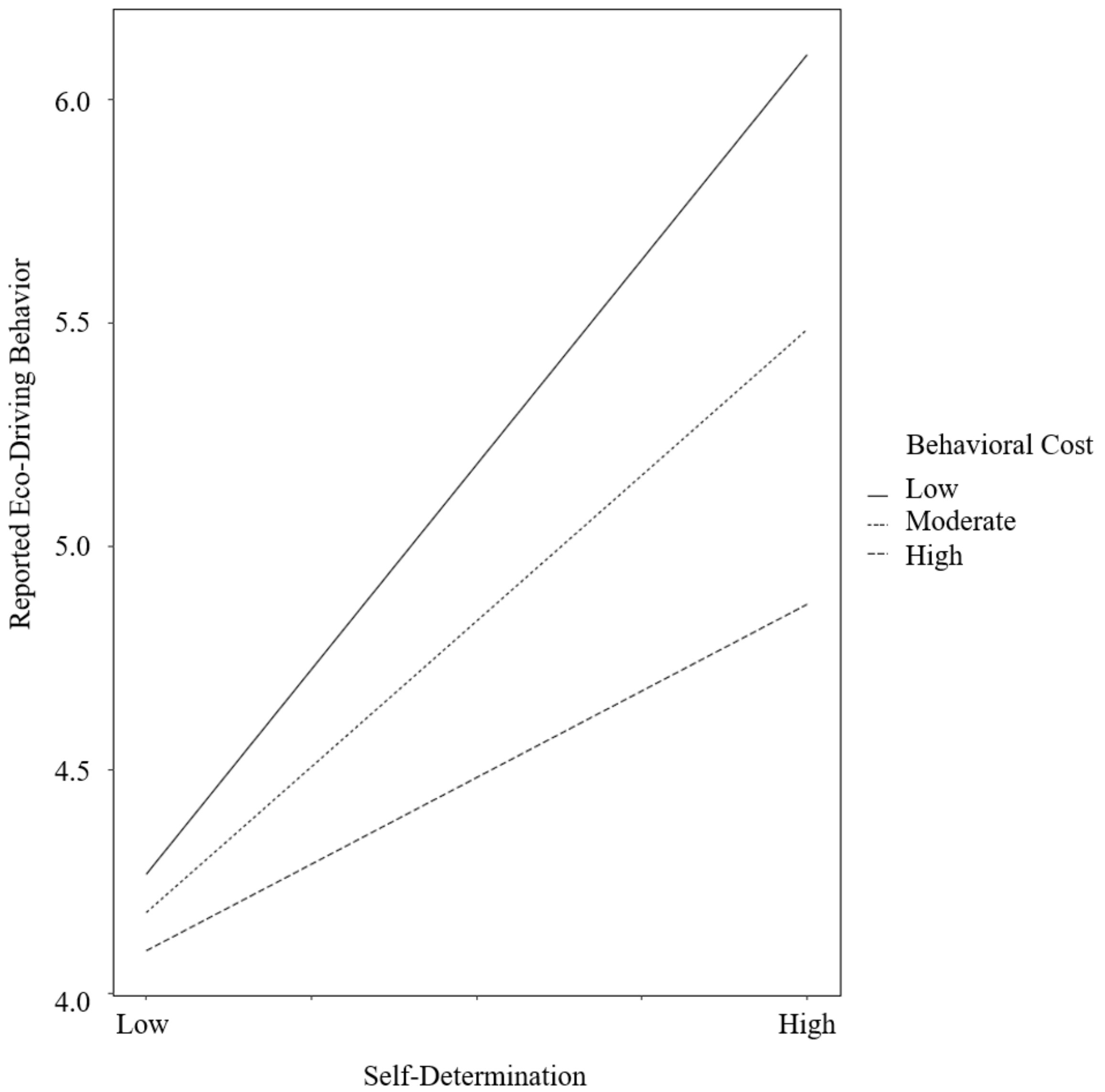



*Figure 9*. Simple slopes plot for the regression of self-determined motivations on reported eco-driving behavior (higher values indicate stronger reported eco-driving behavior; scale ranged from 1 to 7) at three levels of individually perceived behavioral costs of eco-driving (low = 1 *SD* below the mean; high = 1 *SD* above the mean) for study 2.1.

*Note*. All slopes were significantly different from zero ($p < .012$).

**The role of self-determined motivations for eco-driving behaviors with different behavioral costs**

*Descriptive statistics*. Descriptive statistics in Table 9 indicate that people with high in contrast to low self-determination (categorized based on a median split) reported more frequent eco-driving behavior independent of the amount of behavioral cost (which was classified based on average behavioral frequency). However, interestingly, the difference for reported behavior between individuals with low and high self-determination for eco-driving increases as the behavior becomes more costly. Thus, particularly large differences in the implementation of eco-driving behaviors between individuals with low and high self-determined motivations emerge at moderate- and high-cost behaviors, while the difference is only marginal for low-cost behaviors.

*Multivariate linear regression analysis*. The multivariate linear regression predicting low-, moderate-, and high-cost behaviors from self-determined motivations was statistically significant, $F(3, 202) = 19.24$, $p < .001$. Table 10 indicates that self-determined motivations significantly predicted moderate- and high-cost but not low-cost eco-driving behaviors. Hence, individuals with low and high self-determination did not significantly differ with regard to the eco-driving behaviors that are frequently implemented; thus, regarding the behaviors that are characterized as low-cost. However, the results suggest that high self-determined individuals showed moderate- and high-cost eco-driving behaviors significantly more often than less self-determined individuals did. Because the *84% CI*s for low-cost and moderate-cost or rather high-cost eco-driving did not overlap, it is justified to assume that self-determination was more predictive of moderate- and high-cost behaviors than of low-cost behaviors. However, the *CI*s for moderate- and high-cost behaviors did overlap, which is why self-determined motivations were similarly predictive of these two behaviors.

Table 9

*Mean values for reported eco-driving behaviors of different behavioral costs for participants with low and high self-determination (study 2.1)*

| | Low-cost eco-driving | Moderate-cost eco-driving | High-cost eco-driving |
|---|---|---|---|
| Low self-determination | 6.24 | 4.91 | 3.39 |
| High self-determination | 6.48 | 5.52 | 4.67 |
| Mean | 6.36 | 5.21 | 4.04 |

*Note*. Low and high self-determination were categorized using a median split. Behavioral costs of eco-driving were classified based on behavioral frequency. Low-cost eco-driving behaviors were 1 *SD* above the mean of reported eco-driving behavior and high-cost eco-driving were 1 *SD* below the mean. Moderate-cost eco-driving included behaviors with eco-driving behavior values between these limits.

Table 10

*Multivariate linear regression results predicting reported eco-driving from self-determined motivation (study 2.1)*

| Dependent variable | *F* | *p* | $R^2$ | *Adj.* $R^2$ | *84% CI* |
|---|---|---|---|---|---|
| Low-cost eco-driving | 2.50 | .116 | .01 | .01 | [-0.009, 0.033] |
| Moderate-cost eco-driving | 36.98 | .000*** | .15 | .15 | [0.090, 0.217] |
| High-cost eco-driving | 40.47 | .000*** | .17 | .16 | [0.100, 0.231] |

*Note*. Behavioral costs of eco-driving were classified based on behavioral frequency. Low-cost eco-driving behaviors were 1 *SD* above the mean of reported eco-driving behavior and high-cost eco-driving behaviors were 1 *SD* below the mean. Moderate-cost eco-driving included behaviors with eco-driving behavior values between these limits.

*** $p < .001$.

## 7.3 Study 2.2

A limitation of study 2.1 was that very few eco-driving behaviors were under study. Furthermore, the eight behaviors tended to involve rather low or moderate instead of very high behavioral costs (see Table 9). However, high-cost behaviors such as public transportation usage or carpooling have a very high impact on transport-related $CO_2$ emissions, which is why many individuals should implement these behaviors in future years. Therefore, for study 2.2, data from a cross-sectional online survey (see study 1) that considered a wide range of eco-driving behaviors was analyzed. The analysis of this survey also served to replicate the results from study 2.1 addressing the second research question.

### 7.3.1 Method

**Participants and procedure**

The online survey consisted of a 20-minute online questionnaire programmed with Tivian (Tivian XI GmbH, 2022) examining a motivational model for predicting eco-driving (see chapter 6). For this, as reported earlier, individuals who regularly drive their vehicles were invited (> 3000 km a year). The individuals were recruited from a participants pool of a large German vehicle manufacturer, who were interested in participating in the study. The study was approved by an internal ethics committee. Participants received €5 for their participation. After clicking on the link to the questionnaire, participants first answered sociodemographic questions. Then, they answered a number of different questions, from which only some were relevant to the present study (see Measures).

Overall, 587 people participated in the study. However, people who indicated that they do not strive to implement a pro-environmental driving style in their daily lives were excluded because individuals were asked about their motivation for eco-driving (i.e., individuals that had a mean score < 3 when answering three questions on goal striving regarding eco-driving on a scale from 1 to 7 were excluded from the analysis; $n = 27$). Furthermore, individuals who drove less than 3000 km per year were excluded, so that only those who have the chance of implementing eco-driving regularly in everyday life participated in the study ($n = 21$).

In the end, data from 539 individuals (47% female) were entered in the analysis. The mean age was 44.94 ($SD = 16.07$, Range = 19-79). Individuals reported an annual mileage of approximately 15.000 km (median). Participants held their driver's license for an average of 26.63 years.

**Measures**

*Self-determination for eco-driving*. Because of time constraints, a more streamlined scale compared to the one in study 2.1 was used. The used scale was developed by Sheldon and Kasser (1995) to measure self-determined motivations for goal strivings. This scale assesses the motivational reason for striving for a certain goal (i.e., in this case eco-driving). The scale consists of four items assessing different motivations to eco-drive; external motivation ("… because somebody else wants me to do it or because I get something out of it."), introjected motivation ("… because I would feel ashamed, guilty, or anxious if I did not."), identified motivation ("… because I really believe it is an important goal to have."), and intrinsic motivation ("… because of the fun and enjoyment that it provides me."). On a 7-point Likert scale participants rated their level of agreement with the items (1 = *not at all for this reason* to 7 = *completely for this reason*). Based on earlier procedures to calculate a self-determination index (Judge et al., 2005; Sheldon & Elliot, 1999; Sheldon & Kasser, 1995), the identified and intrinsic score were summed and subtracted from the introjected and external score. Because of time constraints, only one item per striving reason was used, which is why a reliability score could not be calculated. However, the measure has been validated in past studies (Judge et al., 2005; Sheldon et al., 2004; Sheldon & Elliot, 1999).

*Reported eco-driving behavior*. A newly developed eco-driving scale was used, which was based on previous research that identified and clustered various eco-driving behaviors (Martin et al., 2012; Sanguinetti et al., 2017; Sivak & Schoettle, 2012; Strömberg et al., 2015). Overall, the measurement consists of 25 items measuring eight strategic (e.g., "I avoid short vehicle rides."), five tactical (e.g., "I do not carry unnecessary weight in my vehicle."), and 12 operational (e.g., "I anticipate the traffic flow and keep distance to the vehicle in front.") eco-driving behaviors (see Table 11). Participants rated their agreement with these items on a 7-point Likert scale (1 = *totally disagree* to 7 = *totally agree*). Because participants most likely drove different drive types and had different vehicle equipment, they could click the answer alternative "*not possible*".

Table 11

*Eco-driving behaviors of study 2.2*

| **Eco-driving behaviors** |
|---|
| *Strategic decisions* |
| Make sure to buy a low-emission vehicle |
| Make sure to buy fuel-efficient tires |
| Take vehicle in for service regularly |
| Change tires seasonally |
| Check vehicle’s tire pressure regularly |
| Park vehicle in garage whenever possible |
| Avoid short vehicle rides |
| Consider alternative means of transport (e.g., public transport) before starting a journey |
| *Tactical decisions* |
| Do not carry unnecessary weight in the vehicle |
| Plan travel routes conscientiously (e.g., regarding traffic volume, road type, road gradient) |
| Participate in carpooling |
| Combine trips whenever possible instead of driving several short trips |
| *Operational decisions* |
| Anticipate traffic flow and keep distance to vehicle in front |
| Drive at constant speed or with cruise control whenever possible |
| Avoid driving at high speeds |
| Avoid objects that increase aerodynamic drag unless they are in use (e.g., cargo box) |
| Accelerate gently (pedal not more than half depressed) |
| Use momentum of vehicle and let the vehicle roll out as far as possible |
| Shift up early (between 2000 and 2500 rpm) |
| Minimize use of electrical consumers in the vehicle (e.g., air conditioning, seat heating, interior lighting) |
| Switch off engine during stops or use vehicle’s automatic start-stop system |
| If necessary, open windows at low speeds (e.g., in the city) and turn on air conditioning at higher speeds (e.g., on the highway) instead |
| Make sure to drive at low engine speed |
| Avoid breaking hard |
| Use eco-mode of the vehicle |

**Statistical analysis**

For analyzing the second research question, a multivariate linear regression was computed. Similarly as in study 2.1, the categorization of the costliness of the eco-driving behaviors was based on their frequency. Accordingly, low-cost behaviors had a mean score that was 1 *SD* above the mean of reported eco-driving behavior (> 6.15). High-cost behaviors had a mean value 1 *SD* below the mean of reported eco-driving behavior (< 4.52). The remaining behaviors were categorized as moderately costly based on their mean scores in terms of reported eco-driving behavior. Table 12 displays which eco-driving behaviors were categorized as low-, moderate-, or high-cost.

The behavior score was averaged for all participants. *Low-, moderate-, and high-cost behaviors* were integrated as dependent variables and *self-determined motivation* as independent variable in the multivariate linear regression. As in study 2.1, the amount of explained variance ($R^2$) was compared for all three regression analyses. For the three different $R^2$ values, 84% confidence intervals (*84% CI*) were calculated. It was concluded that the $R^2$ values are significantly different when the *CI*s do not overlap. For all three regressions, the *F*-value with associated *p*-value is reported. The test of multivariate regression analysis assumptions showed no violations of linearity, normality, or homoscedasticity.

### 7.3.2 Results

*Descriptive statistics*. The descriptive statistics in Table 12 show that individuals generally reported autonomous rather than controlled motivations for eco-driving as the average self-determination index is rather high. Furthermore, it can be seen that similar behaviors were categorized as low-, moderate-, and high-cost as in study 2.1. However, in this study, choosing energy-efficient routes was categorized as a moderate-cost instead of a high-cost behavior while avoiding carrying a lot of weight in the vehicle was categorized as a moderate-cost behavior rather than a low-cost behavior. The least frequently implemented behaviors were carpooling and considering alternative means of transport, which indicates that especially those behaviors that make a high contribution to environmental protection seem to be rarely implemented in everyday life. Furthermore, as in study 2.1, minimizing electrical consumer use was considered very costly. Conducting the study in winter may have contributed to this finding. Improving aerodynamics of the vehicle was the most frequently implemented behavior in study 2.2.

Table 13 shows that the agreement for the behaviors decreases as they become more costly for both individuals with low and high self-determined motivations (categorized based on a median split). However, it is also noticeable that the difference between self-determined and less self-determined individuals for reported behavior is marginal for low-cost behaviors and becomes larger for moderate- and high-cost behaviors.

*Multivariate linear regression results*. Testing the multivariate linear regression predicting low-, moderate-, and high-cost behaviors from self-determined motivations was statistically significant, $F(3, 535) = 25.36, p < .001$. As can be seen in Table 14, self-determined motivations significantly predicted low-, moderate- and high-cost eco-driving behaviors. However, the *84% CI*s for low-cost and moderate-cost or rather high-cost eco-driving did not overlap, which is why self-determination was more predictive of moderate- and high-cost behaviors than of low-cost behaviors. The *CI*s for moderate- and high-cost behaviors did overlap, which is why self-determined motivations were similarly predictive of these two behaviors.

Table 12

*Descriptive statistics of the main variables (study 2.2)*

| Variable | *M* | *SD* |
|---|---|---|
| **1. Self-Determination** | 5.88 | 3.44 |
| **2. Low-cost eco-driving** | 6.39 | 0.75 |
| Take vehicle to service regularly | 6.49 | 1.22 |
| Change tires seasonally | 6.36 | 1.66 |
| Improve aerodynamics of vehicle | 6.57 | 1.12 |
| Avoid breaking hard | 6.17 | 1.17 |
| **3. Moderate-cost eco-driving** | 5.44 | 0.86 |
| Purchase low-emission vehicle | 5.13 | 1.71 |
| Purchase fuel-efficient tires | 4.66 | 1.99 |
| Check tire pressure regularly and ensure they are not underinflated | 5.57 | 1.72 |
| Park vehicle in garage | 5.96 | 1.90 |
| Do not carry unnecessary weight in the vehicle | 5.78 | 1.51 |
| Avoid short vehicle rides | 5.05 | 2.00 |
| Trip-chaining | 5.54 | 1.65 |
| Anticipatory driving | 6.14 | 1.13 |
| Choose energy-efficient routes | 4.70 | 1.91 |
| Drive at constant speed/with cruise control | 5.82 | 1.51 |
| Accelerate gently | 5.25 | 1.66 |
| Use momentum/let vehicle roll our | 5.95 | 1.39 |
| Shift up early | 5.77 | 1.47 |
| Turn off engine at stops/use start-stop system | 5.65 | 2.02 |
| Open windows at low speeds/use air conditioning at high speeds | 4.58 | 2.18 |
| Drive at low engine speed | 5.98 | 1.47 |
| Use eco-mode | 5.35 | 2.10 |
| **4. High-cost eco-driving** | 3.90 | 1.47 |
| Consider alternative means of transport | 3.86 | 2.16 |
| Carpooling | 3.00 | 2.17 |
| Avoid very high speeds | 4.27 | 2.04 |
| Reduce electrical consumer use | 4.20 | 2.08 |

Table 13

*Mean values for reported eco-driving behaviors of different behavioral costs for participants with low and high self-determination (study 2.2)*

| | Low-cost eco-driving | Moderate-cost eco-driving | High-cost eco-driving |
|---|---|---|---|
| Low self-determination | 6.34 | 5.22 | 3.61 |
| High self-determination | 6.46 | 5.70 | 4.25 |

*Note*. Low and high self-determination were categorized using a median split. Behavioral costs of eco-driving were classified based on behavioral frequency. Low-cost eco-driving behaviors were 1 *SD* above the mean of reported eco-driving behavior and high-cost eco-driving were 1 *SD* below the mean. Moderate-cost eco-driving included behaviors with eco-driving behavior values between these limits.

Table 14

*Multivariate linear regression results predicting reported eco-driving from self-determined motivation (study 2.2)*

| Dependent variable | *F* | *p* | $R^2$ | *Adj.* $R^2$ | *84% CI* |
|---|---|---|---|---|---|
| Low-cost eco-driving | 11.20 | .001*** | .02 | .02 | [0.004, 0.037] |
| Moderate-cost eco-driving | 73.69 | .000*** | .12 | .12 | [0.084, 0.157] |
| High-cost eco-driving | 40.09 | .000*** | .07 | .07 | [0.040, 0.099] |

*Note*. Behavioral costs of eco-driving were classified based on behavioral frequency. Low-cost eco-driving behaviors were 1 *SD* above the mean of reported eco-driving behavior and high-cost eco-driving were 1 *SD* below the mean. Moderate-cost eco-driving included behaviors with eco-driving behavior values between these limits.

*** $p < .001$.

## 7.4 Discussion

The aim of the present study was to investigate how behavioral costs and self-determined motivations influence eco-driving behavior and whether self-determined motivations predict behaviors of different behavioral costs with the same or different strength. The research questions formulated to gain insights about these relationships were tested using data of two online surveys. Data from the first study was collected in a larger-scale longitudinal intervention survey with 202 drivers (see study 4). Data from the second study came from a cross-sectional online survey with 539 drivers (see study 1).

**Predicting eco-driving from self-determined motivations and perceived behavioral costs**

Replicating previous research findings of this dissertation (see study 1), self-determined motivations positively predicted eco-driving while perceived behavioral costs of eco-driving negatively predicted eco-driving behavior. Interestingly, a negative interaction effect between self-determined motivations and perceived behavioral costs was found, indicating that the relationship between self-determined motivation and eco-driving depends on the level of perceived eco-driving costs. The interaction effect is not consistent with the predictions of the Campbell Paradigm (Kaiser, 2021). The Campbell Paradigm would have predicted additive effects of behavioral costs and psychological factors for eco-driving, according to which the implementation of eco-driving behaviors would decrease with increasing behavioral costs for non-self-determined individuals and self-determined individuals to the same extent (Kaiser, 2021). Instead, it was found that the effect of self-determination on eco-driving is weaker for high perceived behavioral costs than for low or moderate behavioral costs. In addition, the negative interaction effect indicates that the negative effect of behavioral costs on eco-driving decreases when self-determination increases.

In summary, the results provide evidence that high eco-driving motivations can buffer the negative effect of behavioral costs on pro-environmental transport behavior and gain influence when individuals consider the behaviors as costly. Furthermore, perceiving eco-driving as low-cost *and* having high self-determined motivations for eco-driving seem to be most promising for engaging in eco-driving behaviors. Therefore, contextual and psychological/personal factors should not be considered separately but instead interactively (Steg & Vlek, 2009). This seems imperative not only to better understand the lacking or inconsistent influence of environmental attitudes on pro-environmental behavior (Kollmuss & Agyeman, 2002), but also for studying the effectiveness of environmental interventions that should not address motivations or contextual factors alone, but rather use combined strategies that address both aspects.

**The role of self-determined motivations for eco-driving behaviors of varying behavioral costs**

In both studies, consistent with the results from Delhomme et al. (2013), rather low values for the perceived behavioral costs of eco-driving were found, indicating that none of the eco-driving behaviors were considered as extremely costly. The analyses of both studies revealed that self-determined motivations for eco-driving strongly predicted those behaviors that are classified as moderate- or high-cost. In contrast, self-determined motivations predicted low-cost behaviors less well. Accordingly, the present results show no support for the LCH, which assumes that psychological factors are most important for low-cost rather than high-cost behaviors (Diekmann & Preisendörfer, 2003). However, the results are also not entirely consistent with the A-B-C Model, which predicts that psychological factors are primarily predictive of moderate- rather than of low- or high-cost behaviors (Guagnano et al., 1995).

However, the high agreement values for the behaviors that are defined as high-cost in the present studies could mean that the range of behavioral costs was not sufficiently covered by the conducted studies. In detail, it may be that *very* high-cost behaviors were not included in the present studies and that the low-cost behaviors could have been of only negligible cost (Diekmann & Preisendörfer, 2009). This means that the possibility that individuals perceived the classified high-cost behaviors as rather moderately costly and the classified low-cost behaviors as rather "low-low-costly" (Diekmann & Preisendörfer, 2009) cannot be ruled out. Hence, future results should include a broader range of eco-driving behaviors to extend the present results and provide conclusive theoretical support.

**Recommendations for effective eco-driving interventions**

Based on the results, it can be concluded that, to convince many individuals to implement eco-driving behaviors that are perceived as costly, pro-environmental interventions should support self-determined motivations. Self-Determination Theory assumes that even personally uninteresting activities such as eco-driving can be internalized (i.e., autonomously motivated) if three basic needs are met: Autonomy, competence, and relatedness. Autonomy describes maintaining control over one's own behavior and associated outcomes. Competence describes mastering new tasks and learning new skills. Relatedness addresses the sense of belonging and connectedness with others (Deci & Ryan, 1985; Vaezipour et al., 2016).

To promote autonomy, it is argued that instead of using controlling interventions (e.g., highlighting monetary benefits or monitoring behavior), autonomy-supporting interventions should be implemented to foster long-term pro-environmental behavior change (Vansteenkiste et al., 2004). Vansteenkiste et al. (2004) found that individuals pursued pro-environmental goals more successfully when they felt free to decide to learn more about recycling instead of when they felt pressure to do so. This effect was even stronger when individuals experienced the congruence between recycling and higher-order intrinsic (in contrast to extrinsic) goals (e.g., community, health, personal growth). Furthermore, autonomous motivation mediated the effect of autonomy support and intrinsic goals on pro-environmental behavior. Hence, it is important that interventions support autonomy (e.g., the freedom to choose) and create links between a desirable pro-environmental behavior and higher-order growth-relevant and meaningful instead of money- or image-relevant goals (Sheldon & Kasser, 1995). Indeed, past studies have shown that highlighting environmental or community benefits of eco-driving (e.g., $CO_2$ savings) could significantly influence effortful eco-driving behaviors (Dogan et al., 2014). For example, communicating positive impacts of driving behaviors or decisions in user-centered in-vehicle feedback systems (e.g., the positive impact of a behavior on the environment) can help individuals to perceive environmental or community benefits of their behavior, fostering long-term driving behavior change. In fact, previous results support that categorizing one's behavior as environmentally friendly can support environmental consciousness (Cornelissen et al., 2008) or promote autonomous motivation for the behavior (Van der Werff et al., 2013).

In addition to autonomy, competence should also be supported, for example, via tailored and informative feedback about the user's decisions or behavior (Abrahamse et al., 2007; An, 2020; Berkovsky et al., 2012; Deci, Ryan, et al., 1999). Feedback should be communicated in a positive, non-controlling manner and provide challenges for the driver to overcome (Deci et al., 1996; Sheldon & Filak, 2008; Van de Velde et al., 2010). Likewise, solutions or recommendations in certain situations should be provided and a reasonable rationale for the behavior should be given (Pelletier & Sharp, 2008; Van de Velde et al., 2010).

Additionally, relatedness should best be supported through cooperative (rather than competitive) eco-driving challenges (An, 2020; Deci et al., 1981). Moreover, showing the discrepancy between an existing and desired (shared) goal can promote relatedness and autonomous motivation (An, 2020). Several researchers also agree that gamification can promote the three basic needs of autonomy, competence, and relatedness (An, 2020; Mekler et al., 2013; Sheldon & Filak, 2008). Autonomy can be fostered, for example, by using profiles or avatars, while competence can be reinforced by earning points and levels, or displaying leaderboards. Relatedness can be supported through shared goals or chats with friends and other users (Aparicio et al., 2012). Research studies show that gamification is indeed helpful to promote various eco-driving behaviors (Corcoba Magaña & Muñoz-Organero, 2015; Günther et al., 2020).

Although these measures can certainly convince many people to eco-drive, high (self-determined) motivation alone is not enough to maintain eco-driving in stressful situations or over the long term (Dogan et al., 2011). According to the present results, individuals most likely show high eco-driving behavior when they have high self-determined motivations as well as when they perceive the behavioral costs of eco-driving as low. Hence, it is advisable to change behavioral costs of eco-driving too. On the one hand, this could be done via hard measures. For example, speed limits might be helpful to take pressure off drivers to conform to the speed or behavior of others and therefore, may remove barriers for not showing eco-driving (Fleiter et al., 2012; Leandro, 2012). Furthermore, driver assistance systems (e.g., systems that recommend behavior or automatically reduce fuel or energy consumption) as well as the automation of driving can facilitate the implementation of eco-driving (Fors et al., 2015; Van der Voort et al., 2001). Cost-effective and easy-to-implement interventions may be helpful to persuade drivers to turn on these kind of driving systems (e.g., Kutzner et al., 2021). On the other hand, it could be helpful to change the perception of behavioral costs. Hence, it is possible that individuals perceive giving up the car as less costly if they experience doing it. For example, a car-free day in the city could show people that not using the vehicle is possible (e.g., availability of public transport) and comes with multiple benefits (e.g., reduced noise emission). Future studies should examine if this experience changes vehicle use intentions and could create new driving habits.

**Limitations**

A limiting factor of the study is that the categorization of behavioral costs may represent a validity problem. In the past literature, diverse methods have been used to measure behavioral costs. These range from measuring the frequency of behaviors to assessments by authors or experts and subjective assessments by participants (Best & Kneip, 2011; Diekmann & Preisendörfer, 2003, 2009; Guagnano et al., 1995; Taube et al., 2018). However, the most common method is the frequency method, which was used in the present studies. It is plausible to assume that those behaviors that are rarely implemented are also more costly to perform. However, it may also be that individuals are rarely in the situation to perform the behavior and therefore report low scores. For the calculation of the interaction effect, the subjective assessment by participants was used. This seems to be an appropriate tool when surveying many subjects, since, on average, those behaviors are classified as low- or high-cost that are easy or difficult for most. Nevertheless, not everyone is likely to agree with this classification. For example, turning off the engine at stops appears to be easier for individuals with an automatic start-stop system than for those who must turn off the engine manually. Overall, no method for measuring behavioral costs seems to be free of disadvantages. Nevertheless, the usage of frequency scores or a subjective assessment by participants seem to provide valid results when collecting data of many individuals (Diekmann & Preisendörfer, 2003), which was the case in the present studies ($N_{Study2.1} = 202$, $N_{Study2.2} = 539$).

Furthermore, the use of self-reports in the present studies can be viewed critically. Since pro-environmental behavior statements are socially sensitive reports for some individuals (Andersson & Von Borgstede, 2010), responses could be biased by social desirability. However, there are studies that show that self-reports are an appropriate method for capturing pro-environmental behavior (Fuj et al., 1985) and that social desirability is of negligible impact for pro-environmental attitude and behavior measures (Milfont, 2009).

**Conclusion**

Greenhouse gas emissions of the transport sector have been rising enormously for years, despite technological innovations. Since the introduction of electrified transport systems is lethargic and will not be implemented on a large scale for many years, high-impact actions like eco-driving behaviors, i.e., the implementation of a driving style that has a positive effect on $CO_2$ emission mitigation, are needed. Despite the innumerable advantages of eco-driving (e.g., monetary savings, noise reduction, safety), few people demonstrate this behavior in everyday-life (Pampel et al., 2015). In the present studies, it was found that individuals perceive eco-driving behaviors as involving a different amount of behavioral costs and that self-determined motivations can buffer the negative effect of moderate and high behavioral costs on reported eco-driving behavior. Hence, based on the present results, future interventions should not address either motivational *or* contextual factors to promote pro-environmental driver behavior, but should a) make the behavior easier *and* b) promote self-determined motivations (i.e., the enjoyment of the activity or the identification of why the behavior is important for oneself or the environment/community).

# 8 Study 3: A matter of behavioral cost: Contextual factors and behavioral interventions interactively influence pro-environmental charging decisions

## 8.1 Introduction

Transport-related greenhouse gas emissions and energy use have been rising steadily for years. Without far-reaching countermeasures, researchers predict that this trend will continue in future years (IEA, 2009). Consequently, the European Commission presented its "Sustainable and Smart Mobility Strategy" targeting the green and digital transformation of the transport sector in 2020. With this strategy, the Commission aims to reduce transport-related emissions by 90% until 2050. To achieve this, nearly all vehicles need to be zero-emission by 2050 (European Commission, 2020b).

It is obvious that these measures will lead to a strong increase in demand for electric vehicles (EVs) in the next years (Eurelectric, 2015). This goes hand in hand with the electrification strategy of most of the major vehicle manufacturers (OEMs). However, the additional electricity demand for charging these vehicles will place an enormous burden on the power grid (especially in times of simultaneous charging), which can cause problems with power generation and distribution (Daina et al., 2017; Eider et al., 2017; Eurelectric, 2015; Huber et al., 2019; Jäger et al., 2019). Furthermore, to be a real green alternative, it is important that EVs are charged with renewable (i.e., green) electricity so that transport-related greenhouse gas emissions are not simply shifted from fuel to electricity generation (Buekers et al., 2014; Degirmenci & Breitner, 2017; Franke et al., 2018).

However, renewable energy sources are highly variable in supply and cannot respond quickly to user demand (Daina et al., 2017; Pettersson, 2013; Richardson, 2013). Hence, to fully realize the potential of electric vehicles, many researchers and practitioners believe that smart charging needs to be introduced to avoid excessive and expensive peak demands (Huber et al., 2019, 2021; Kristoffersen et al., 2011; Pettersson, 2013; Richardson, 2013). Smart charging schedules charging operations based on optimal technical and economic conditions (García-Villalobos et al., 2014). By allowing to delay and adjust the charging process, smart charging further promotes the integration of renewable energies into the power grid (Richardson, 2013). However, without user acceptance, the approach fails to deliver the described benefits. Since smart charging tends to provide little benefit to the user itself but the community and the environment instead, it is necessary to investigate how the acceptance of this approach can be supported and corresponding behavior facilitated (Franke et al., 2018; Huber et al., 2019). For this, this study will shed light on the role of contextual and informational factors that influence the decision to choose a public smart charging station.

**Smart charging**

Many researchers believe that monitoring, controlling, and limiting the charging process of EVs can help optimize energy consumption and charging costs in the future (Franco et al., 2020; Huber et al., 2019, 2020). To date, a uniformly used term and definition of smart charging is still lacking. In this study, it is referred to the International Agency of Renewable Energy (IRENA, 2019), which describes smart charging as follows: “Smart charging means adapting the charging cycle of EVs to both the conditions of the power system and the needs of the vehicle users. This facilitates the integration of EVs while meeting mobility needs.” (p.2).

Conventional (uncontrolled) charging, which is currently the prevailing approach, starts the charging process as soon as the vehicle is connected to the charging station. Smart charging instead shifts and delays the charging process to achieve different optimization goals (e.g., avoid peak loads; Huber et al., 2020; Richardson, 2013; Schmalfuß et al., 2015). This is especially necessary during periods of high electricity demand (e.g., in the evenings; Huber et al., 2019) or when excessive energy from renewable sources is available (e.g., solar energy during midday; Eurelectric, 2015). In such cases, smart charging allows to shift the start of the charging process to optimal day (e.g., when renewable energy is available) and night (e.g., when energy demand is low) times (Eurelectric, 2015; Richardson, 2013).

However, it is obvious that the implementation of smart charging can only succeed if users accept it and communicate their mobility needs to a smart system, which is a critical factor due to the high planning effort and flexibility required from the user (Franke et al., 2018). In the present study, flexibility is understood as temporal flexibility, i.e., the time span by which the vehicle can be charged to a desired amount of energy (e.g., from arrival at 20 p.m. to departure at 6 a.m.; Huber et al., 2019).

Some studies on how to convince users of smart charging have been limited to charging at home (e.g., Schmalfuβ et al., 2015). Even though charging will probably take place mostly at home in the future, smart charging will also be necessary at public stations where the mentioned behavioral costs (e.g., required flexibility) may be even higher (e.g., at work, shopping centers; Huber et al., 2019, 2020; Kacperski & Kutzner, 2020). Hence, potential disadvantages of smart charging (e.g., reduced flexibility due to charging delays) need to be addressed by intervention strategies highlighting the benefits for the user.

Will and Schuller (2016) conclude from their study with early adopters of EVs that the key motivations for participating in smart charging are the integration of renewable energy and the contribution to grid stability. Schmalfuβ et al. (2015) emphasized that financial incentives should compensate for high planning effort and reduced flexibility. Thus, while most researchers agree that we need to understand the effect of behavioral barriers (e.g., charging delay, detours to smart charging stations) or facilitators (e.g., price savings), there remains little research on how to do this effectively. The present work starts to close this gap by analyzing the interactive effect of contextual factors and behavioral interventions.

**Contextual factors**

To recapitulate, although several studies found that normative concerns and environmental values could predict pro-environmental behaviors (e.g., study 1; Liu et al., 2017; Paul et al., 2016), researchers (e.g., Perlaviciute & Steg, 2014; Steg & Vlek, 2009) emphasized that not only psychological but also contextual factors (e.g., availability of products) influence pro-environmental behavior. Hence, in some cases, external costs (i.e., in terms of money, time, and effort) may hinder (e.g., in high-cost situations) or facilitate (e.g., in low-cost situations) pro-environmental behavior. For instance, high prices for organic fruit or insufficient public transport connections prevent people from behaving pro-environmentally. Indeed, studies have shown that the availability of recycling facilities increases recycling behavior (Guagnano et al., 1995), and price reductions positively influence subway use (Hunecke et al., 2001) and the decision to purchase green energy (Arkesteijn & Oerlemans, 2005).

Similarly, smart charging may come with external behavioral costs as well as opportunities to facilitate the behavior. These limiting and facilitating factors need to be studied more intensively to understand and influence future smart charging user behavior. For example, Kacperski and Kutzner (2020) studied how users behave when a smart charging station with available green energy forces a driving detour that results in a loss of time. Indeed, it is likely that smart charging stations a) will not be widespread immediately or b) those with available green energy will not be along the way or directly near an actual destination. Therefore, it is assumed that smart charging stations may in some cases require a detour, resulting in either a longer driving distance (e.g., when charging the vehicle while waiting) or a longer *walking distance* to an actual destination (e.g., when charging the vehicle while visiting a shopping center). Walking distances will play an important role especially if people want to charge their vehicle while doing another activity (e.g., exercising, shopping, working). Hence, if a destination such as a shopping center does not offer smart charging stations with green energy, but there are parking lots further away that do offer these charging stations, individuals have to decide whether acting pro-environmentally outweighs the loss of time as well as the extra walking effort. In this study, it is assumed that longer walking distances represent a behavioral barrier that could result in fewer people opting for a smart charging station if there are convenient non-sustainable alternatives.

Next to this behavioral cost, *charging delay* seems to be another barrier of smart charging that could negatively affect behavior because of reduced flexibility. A long charging delay may have only little impact if one charges overnight at home and does not need the vehicle until the next day. However, when charging at public charging stations, a charging delay may have a negative impact. For instance, if one wants to leave earlier than originally planned (e.g., because of a spontaneous appointment/spending less time shopping than originally thought), it is possible that the vehicle has not yet been charged to the desired state of charge, which can lead to user dissatisfaction. Therefore, in this study, a charging delay is considered as a behavioral barrier due to limited flexibility.

Despite these behavioral costs, which, if they are severe, could potentially negatively affect smart charging decisions, external benefits in form of monetary incentives are also discussed in the context of smart charging (Eider et al., 2017; Geske & Schumann, 2018). Consistently, potential customers and users are also in favor of ensuring a monetary counter value for the disadvantages of smart charging (Schmalfuß et al., 2015). Thus, a *price saving* for a smart compared to a conventional charging station is a behavioral facilitator for smart charging because individuals financially benefit from a price advantage. Thus, there are some contextual factors that may hinder (e.g., long walking distances or detours, severe charging delays) or facilitate (e.g., monetary incentives) the decision in favor of a smart instead of a conventional charging station. To date, studies that examine the effect of behavioral costs and benefits associated with these factors on smart charging decisions are lacking. However, to convince many users to accept possible disadvantages of smart charging, intervention techniques that highlight the benefits of smart charging for the community or the environment are needed (Franke et al., 2018).

**Behavioral interventions**

Researchers are convinced that user-centered designs for smart charging are needed because the technical benefits of smart charging are unlikely to be motivating for the user (Huber et al., 2020). In the past, researchers have used various behavioral interventions to nudge individuals towards desirable behaviors. For instance, such interventions are often used to convince users to live healthy, engage in pro-environmental behaviors, or purchase a certain product (Berkovsky et al., 2012; Landais et al., 2020).

Behavioral interventions also include choice architecture interventions, which use small or subtle changes in a choice environment to influence the user to choose a desired alternative (e.g., a product in an online store; Landais et al., 2020). Researchers have studied a number of such interventions in the past (e.g., default settings, information about others' people behavior), and their effects on behavior change have been meta-analytically supported (e.g., Mertens et al., 2022). In the following, three behavioral interventions that have proven to be effective for strenuous pro-environmental behaviors are proposed (Avineri & Waygood, 2013; Dogan et al., 2014; Kacperski & Kutzner, 2020; Ro et al., 2017; Steinhorst & Klöckner, 2018).

**Goal framing**

Recently, researchers have investigated the effect of framing on diverse pro-environmental behaviors, such as household energy consumption (Schwartz et al., 2015; Steinhorst & Klöckner, 2018) or making pro-environmental transport choices (Gaker et al., 2011; Schrills et al., 2020). This method is based on the assumption that people react differently to factually equivalent but differently framed messages (Avineri & Waygood, 2013). Levin et al. (1998) distinguished between risky choice framing (options differ in their subjective degree of risk), attribute framing (options differ in their subjective attractiveness of certain attributes), and goal framing (options differ in their subjective desirability of their consequences). In the present study, goal framing is used as a behavioral intervention. Goal framing is implemented by making consequences or goals that are already inherent in a certain behavior salient. For example, most people know that eco-driving saves fuel and in turn reduces an individual's $CO_2$ impact. However, highlighting these consequences (e.g., reporting it in the vehicle's dashboard) can have a positive impact on behavior because it actively reminds people of the positive consequences. Thus, in line with Steinhorst and Klöckner (2018), in the present study, framing refers to highlighted environmental consequences (e.g., $CO_2$ savings) of a behavior.

For instance, Dogan et al. (2014) found that highlighting $CO_2$ savings of energy-efficient driving behaviors (e.g., avoid speeding) significantly influenced the intention to adopt an energy-efficient driving style. In another study, Kacperski and Kutzner (2020) found that symbolic goal framing (i.e., highlighting $CO_2$ savings) successfully influenced the decision to take a route that was considered as "green" due to the available excessive renewable electricity of a smart charging station.

**Social norm**

Another popular behavioral intervention technique is to provide a social norm information. Social norms are the perceptions about the accepted/approved behaviors in the society (Cialdini & Trost, 1998). Although people are not always aware of the effect of social norms, they indeed influence human behavior (e.g., Nolan et al., 2008), if, according to the Focus Theory of Normative Conduct, they are highlighted during the decision-making process (Cialdini et al., 1990). Cialdini et al. (1990) distinguished between descriptive norms, which are the individuals' perception of what others usually do in a situation, and injunctive norms, which are the individuals' perception of what is usually approved or disapproved in a situation.

The effect of social norms has been demonstrated in numerous environmental contexts, such as household energy saving (Allcott & Rogers, 2014; Nolan et al., 2008; Schultz et al., 2007; Wong-Parodi et al., 2019) or water bottle consumption (Van der Linden, 2013). Goldstein et al. (2008) showed that descriptive norms about reusing towels in hotels (i.e., the information that the majority of the other hotel guests reuse their towels) could significantly increase reuse rates. This effect was even stronger when subjects were given the information that people who were sharing the same physical environment (i.e., people who were in the same hotel room before) were reusing their towels. Researchers agree that descriptive norms can be particularly successful when using a public good (such as electricity) because they can trigger feelings of guilt and shame that motivate action and contribution (Miller & Prentice, 2016).

**Gamification**

Because people like to play and compare (Hsu & Lu, 2004), numerous studies used the concept of gamification in various behavioral fields, such as education (Christy & Fox, 2014; Hamari et al., 2016), health (Hamari & Koivisto, 2015), and pro-environmental behavior (Ke et al., 2019; Morganti et al., 2017; Ro et al., 2017; Vaezipour et al., 2016). Gamification is defined as the "use of game design elements in non-game contexts" (Deterding et al., 2011, p. 9). Thus, points and badges are often awarded for certain desirable behaviors or leaderboards are presented (Beck et al., 2019; Hamari et al., 2018) to elicit positive emotions (Huber & Hilty, 2015), ensure an enjoyable experience (Hamari et al., 2018), and have a motivating effect on individuals (Diewald et al., 2015).

A recent report by Douglas and Brauer (2021) presented a number of gamified smartphone applications for promoting energy reduction and transportation behavior, for which such applications will play an increasingly important role. For example, the authors highlight the so-called Cool Choices application, which aims at motivating players to save energy by earning points and competing with others (Ro et al., 2017). Indeed, studies support the effectiveness of such energy-saving apps by showing that they have a positive effect in everyday life even in the long term (e.g., *Powersaver Game*, *Reduce your Juice*, Fijnheer et al., 2019; Mulcahy et al., 2020). Likewise, gamified apps for transportation behavior showed promising results in promoting sustainable travel choices or carpooling (e.g., *Mordor Sharper*, *GoEco!*, Cellina et al., 2019; Olszewski et al., 2018). Furthermore, Corcoba Magaña and Muñoz-Organero (2015) showed that earning points for fuel-efficient driving behaviors could significantly affect fuel consumption. In a similar vein, Günther et al. (2020) concluded from a longitudinal field study that gamification in the form of a leaderboard could promote energy-efficient driving with an EV.

**Interaction between contextual and psychological factors**

Most researchers agree that to understand why people act (or act not) pro-environmentally in certain situations, psychological as well as contextual factors have to be considered (Perlaviciute & Steg, 2014; Steg & Vlek, 2009). For instance, environmental concerns will only result in more sustainable charging decisions if stations are available at suitable locations. Similarly, available green charging alternatives will only be used if individuals are aware of their environmental benefits. Although there is agreement that both psychological and contextual factors should be considered for pro-environmental behavior, there are divergent opinions on the relationship between these two factors.

However as outlined previously (see chapter 3.3), it does not seem conclusive how contextual and psychological factors interplay. What is striking about the studies that have examined the interactive influence of both factors in the past is that the categorization of low- and high-cost situations often diverges. While there is large agreement on the categorization of low-cost behaviors (e. g., curbside recycling is usually categorized as a low-cost behavior), the categorization of moderate- or high-cost behaviors tends to diverge (e.g., drop-off recycling). This issue led to different conclusions in past studies (see Andersson & Von Borgstede, 2010; Guagnano et al., 1995). Looking closer at the categorization of costs, it seems that low-cost situations require at least some extra effort compared to not acting pro-environmentally (e.g., recycling in itself requires some effort even if it is picked up) and moderate-cost situations require a moderate extra effort (e.g., as recycling tends to be a low-cost behavior, drop-off recycling seems to be moderate costly).

Based on these latter empirical observations, it is assumed that in those situations with small to moderate extra effort, pro-environmental attitudes and motivations will drive pro-environmental choices (in line with the assumptions of the LCH and A-B-C Model). However, in situations where pro-environmental choices involve no extra effort or even an advantage compared to a non-sustainable alternative, pro-environmental attitudes may not be necessary, because most people will behave pro-environmentally. In contrast, when behavioral costs are high, pro-environmental attitudes and motivations will not be sufficient (in line with the LCH and A-B-C Model).

In the present study, the assumed interaction effects were not investigated in terms of psychological factors but in terms of behavioral interventions that should induce psychological factors (e.g., environmental attitudes). Since in the future a majority of people should be motivated to choose pro-environmental alternatives to counteract the progression of climate change, such interventions seem to become increasingly important. Behavioral interventions are expected to induce changes in attitudes, motivations, perceptions, cognitions, and norms (Steg & Vlek, 2009). In the environmental domain, they have proven to activate environmental motivations and attitudes successfully that in turn predicted pro-environmental behavior (Steinhorst & Klöckner, 2018) and thus, are expected to interact with contextual factors the same way as psychological factors do.

**The present study**

The aim of the present study was to investigate the interaction effect between contextual factors and behavioral interventions for the decision in favor of a public smart charging station with $CO_2$-neutral electricity (i.e., the pro-environmental alternative) in contrast to a conventional charging station with non-$CO_2$-neutral electricity. For this purpose, a prototypical smartphone-based app visualization was developed that always offered two public charging stations (i.e., a smart and a conventional charging station) to participants in an online experiment. Participants had to choose one of the charging stations in several runs within a hypothetical scenario.

For the contextual factors, the walking distance (distance to a hypothetical destination), price saving, and charging delay of the smart charging station was varied while the characteristics of the conventional charging station remained the same. All factors had three different factor levels increasing (i.e., in terms of walking distance and charging delay) or decreasing (i.e., in terms of price saving) the costs of deciding in favor of the smart charging station (see Table 15). By examining charging decisions in multiple situations involving a different amount of behavioral cost (i.e., no extra effort, small to moderate extra effort, high extra effort), it is aimed to gain a deeper understanding of the interplay between contextual factors and behavioral interventions.

Based on the reported assumptions, it is hypothesized that a walking distance from a charging parking lot to an actual destination is a behavioral barrier that, if it is high (e.g., > 15 minutes), will not be accepted even if the behavioral interventions are persuading (i.e., activate high environmental attitudes). However, it is hypothesized that in cases with moderate or small behavioral costs (e.g., 6 or 11 walking minutes), interventions that emphasize the positive benefits of a behavior may convince people; therefore, they accept the costs and behave pro-environmentally. A charging delay also appears to be a behavioral barrier due to reduced flexibility, which if it is high (i.e., charging completed just before planned departure), is perceived as too inconvenient so that even interventions may not be sufficiently motivating. In contrast, a small to moderate charging delay appears to be a behavioral barrier whose effect could be mitigated by appropriate interventions, whereas no motivational interventions are needed for no charging delay (i.e., because of no extra costs compared to a conventional alternative). In contrast, a price saving for a smart compared to a conventional charging station seems to make the behavior rather convenient; therefore, most individuals will choose the smart charging station independent of additional persuading information. However, how different price savings (e.g., low vs. high) play out seems unclear and will be analyzed in the study. No price saving could be considered as involving either no or low behavioral costs. Since one does not gain anything with no price advantage, but one also does not lose anything, it intuitively seems to represent a situation with no additional costs. However, since smart charging stations, due to their nature (i.e., that charging may be delayed), are often associated with disadvantages in contrast to conventional charging stations, no price advantage can also be considered a somewhat costly situation, in which interventions could convince individuals to choose the smart charging station.

For the behavioral interventions, goal framing (i.e., highlighted $CO_2$ emission information), a descriptive norm (i.e., information about the behavior of others), and gamification (i.e., the opportunity to collect points) were used in a between-subjects design. The contextual factors and the described interventions were implemented by adapting the user interface of the prototypical app.

The present study is the first that examines the effect of both contextual factors and behavioral interventions on a pro-environmental smart charging decision. This seems to be particularly important in the present case, as personal effort (e. g., reduced flexibility), price benefits, and environmental concerns (affected by the source of electricity) might significantly influence the decision to use a public charging station. In the analyses, several control variables were included, such as gender, EV experience, purchase of renewable electricity for own household, and ecological awareness.

## 8.2 Method

### Design

The study was conducted as an online experiment programmed with Tivian (Tivian XI GmbH, 2021) in the period from April 22 to May 06, 2021. In the present case, an online study seemed most suitable due to the global COVID-19 pandemic and due to the possibility to recruit a high number of participants. Participants were recruited via a company-owned participants panel of a large German vehicle manufacturer. All members of the panel reside in Germany.

Participants were contacted via non-binding e-mail request. If they were interested in taking part in the online study, they could click on a link opening a questionnaire, which took a maximum of 30 min to complete. Participants from the region of Stuttgart and the surrounding areas were contacted as a scenario was used, which required some knowledge of the area. Participants were informed that their answers were anonymized. If participants answered the questionnaire completely, they were eligible for an allowance of €5. The study was reviewed regarding ethical aspects and approved as part of an internal process.

### Hypothetical scenario and "SmartCharge" app

The participants were asked to imagine a hypothetical scenario in which they were owners of a fast-charging battery electric vehicle and were visiting acquaintances in Ulm (a city in the south of Germany, about 100 km away from Stuttgart). The participants were told that smart charging stations were already widely available in this fictitious scenario and that an app "SmartCharge" has been developed that displays both smart and conventional charging stations. Previous research has shown that smartphone applications are suitable for communicating mobility needs in a smart charging scenario (Huber et al., 2020; Kacperski & Kutzner, 2020). Participants were told that they wanted to go to a shopping center and explore the city of Ulm for about 3 h before driving home again. As the vehicle only had 21% battery power left, they needed to look for a charging station near the shopping center in the app. The initial information was set by default and the same for all participants. Participants were told that it was a sunny day and they arrived at the shopping center at around 09:00 a.m. and wanted to search for a charging station on a radius of 1.1 km around the shopping center. For driving home, they were told to need a total of 30% battery power, which is why the safety buffer was 10%. Previous research has shown that allowing participants to select a charging level that is charged as quickly as possible and is not delayed (i.e., a safety buffer) contributes to the acceptance of smart charging (Schmalfuß et al., 2015). To make the situation more realistic, fictitious charging stations were put at fictitious locations. Participants were told that when they clicked on “Search” they saw a screen with all charging stations located near to the shopping center. In the online experiment, this information was presented as a visual representation showing an app interface on a smartphone (see Fig. 10).

**Contextual factors**

Within the second screen of the displayed app, contextual factors and behavioral interventions were implemented. Participants saw two charging stations (a conventional and a smart charging station) as well as a third charging station to ensure the presentation of a scrollable list; however, this charging station was not entirely visible. As contextual factors, the walking distance from the charging stations to the actual destination (i.e., the shopping center), the price for charging at the two different stations, and the duration (or rather delay) of charging (i.e., the time when charging is completed) were implemented.

The first charging station in the list was a conventional charging station, whose contextual factors remained the same across all runs and was always presented first. This charging station was located directly at the shopping center (1 minute walking distance), charged the vehicle immediately upon arrival (charging completed after 34 minutes), and charging there cost 20 euros. The charging station charged the vehicles with electricity from the German electricity mix, which is not $CO_2$-neutral; therefore, charging there was considered as the non-sustainable alternative (see Fig. 11).

Below this charging station, the smart charging station was displayed, whose characteristics with regard to walking distance, price saving, and charging delay varied in all runs (see Table 15). With regard to charging delay, the differences were not set at equal intervals (which was the case for walking distance and price saving) because the different delay situations should be perceived as involving no, low/moderate, or high behavioral costs. Therefore, the first factor level was chosen in a way that it did not differ from the conventional station. The second factor level should be perceived as moderate costly because the vehicle completed charging after one and a half hours. Hence, flexibility is only moderately affected, since it is likely to spend 1.5 h in a shopping center. The last factor level was chosen so that the vehicle completed charging just before the scheduled departure. This situation should be perceived as highly costly as it is likely to finish shopping earlier, since the initial departure time was only roughly estimated.

In every scenario, the smart charging station charged the vehicle with electricity from 100% renewable energies ($CO_2$-neutral energy). Based on the source of electricity, this smart charging station was considered as the pro-environmental alternative. All factors (i.e., walking distance, price saving, charging delay) had three factor levels (see Table 15), which resulted in 27 combinations in a balanced design, which were randomly presented to all participants.

**Behavioral interventions**

In the goal framing condition, participants were shown how much $CO_2$ is produced during electricity generation for the desired amount of energy. To make this information evaluable and accessible to participants (Hsee & Zhang, 2010; Kacperski & Kutzner, 2020), participants additionally saw the information of how many cups of coffee one could make to produce the same amount of $CO_2$ (UCL, 2021). The electricity from the smart charging station produced 0 kg of $CO_2$ and the electricity from the conventional charging station 19 kg of $CO_2$[3].

In the social norm condition, participants were given the fictitious information about how many people charged their vehicle at the charging stations before. In every scenario, more people charged their vehicle at the smart than at the conventional charging station (ratio 2:1). In the case of the smart charging station, it was also stated how much $CO_2$ could be saved by the people who charged at this station, with a value varying by around 20 kg.

In the gamification condition, participants were informed that by choosing the smart charging station, they could collect green points, which, if collected in sufficient numbers, would allow them to receive discounts at selected charging stations. In this condition, the first four scenarios were presented to the participants in a non-randomized manner, so that personalized feedback could be given to participants on how many points they had already collected as an additional motivating factor. To motivate participants to select the smart charging station particularly in cases with high flexibility demand, participants were able to collect a different number of points per scenario depending on the charging delay (1 point for no delay, 2 points for 47 minutes delay, and 3 points for 125 minutes delay).

The control group did not receive any additional information and the smart charging station was not displayed in green color as it was in the three intervention conditions. The

[3] The $CO_2$ emission information was calculated based on current data on $CO_2$ production per kwH of the German electricity mix (Umweltbundesamt, 2020) and the assumption that charging from 21% to 80% state of charge requires 47,2 kwH.

visualizations of the app were designed with Microsoft PowerPoint. The entire scenario was fictitious with the given information kept as realistic as possible (see Fig. 11).

**Measures**

Several control variables were included that were measured after the choice task. Some scales were not the subject of the present study, which is why they are not reported here. Participants were asked about their usage experience with EVs on a binary scale (1 = *yes*, 2 = *no*). Similarly, subjects were asked if they currently purchase renewable (green) electricity for their household on a binary scale (green energy purchase; 1 = *yes*, 2 = *no*).

Furthermore, participants' ecological awareness was measured using the scale developed and validated by Schlüter and Weyer (2019). The scale measures people's awareness of ecological issues (e.g., "Currently, most people behave with little environmental awareness") on a 7-point Likert scale (1 = *strongly disagree* to 7 = *strongly agree*). One item was omitted due to a possible reaction to it with high reactance ("Environmental precautions should be enforced even if they cause job losses."). The scale showed an acceptable reliability ($\alpha = 0.79$). Two items had to be recoded so that higher scores indicated higher ecological awareness. The items were presented in a randomized order.

Table 15

*Characteristics of the smart compared to the conventional charging station (study 3)*

| | Smart Charging Station | Conventional Charging Station |
|---|---|---|
| **Walking Distance** | | |
| +5min | 6min | 1min |
| +10min | 11min | 1min |
| +15min | 16min | 1min |
| **Price Difference** | | |
| 0% | 20€ | 20€ |
| -5% | 19€ | 20€ |
| -10% | 18€ | 20€ |
| **Charging Delay** | | |
| +0min | 09:34 a.m. | 09:34 a.m. |
| +47min | 10:21 a.m. | 09:34 a.m. |
| +125min | 11:39 a.m. | 09:34 a.m. |

*Note*. Every intervention group and the control group saw all possible combinations of these characteristics (27 in total).

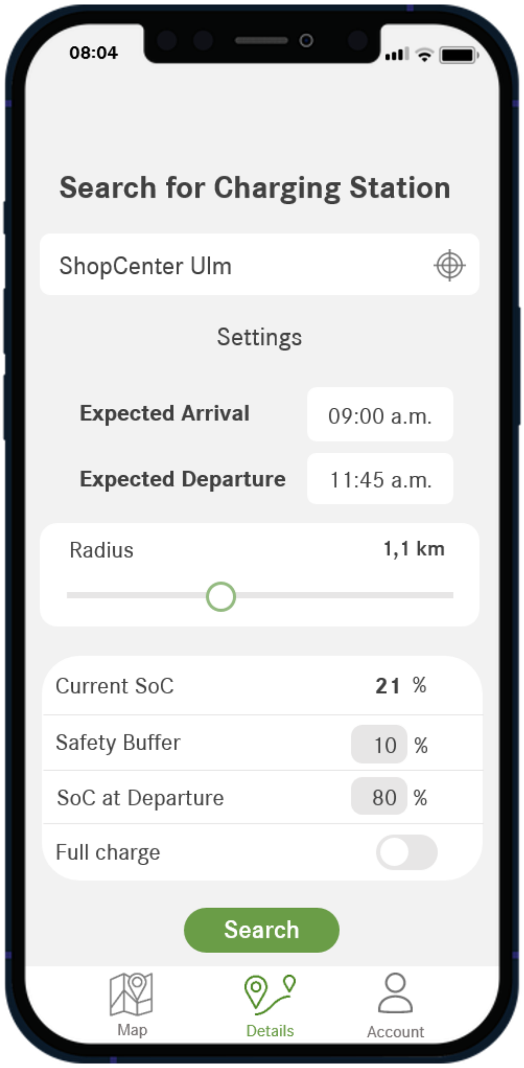
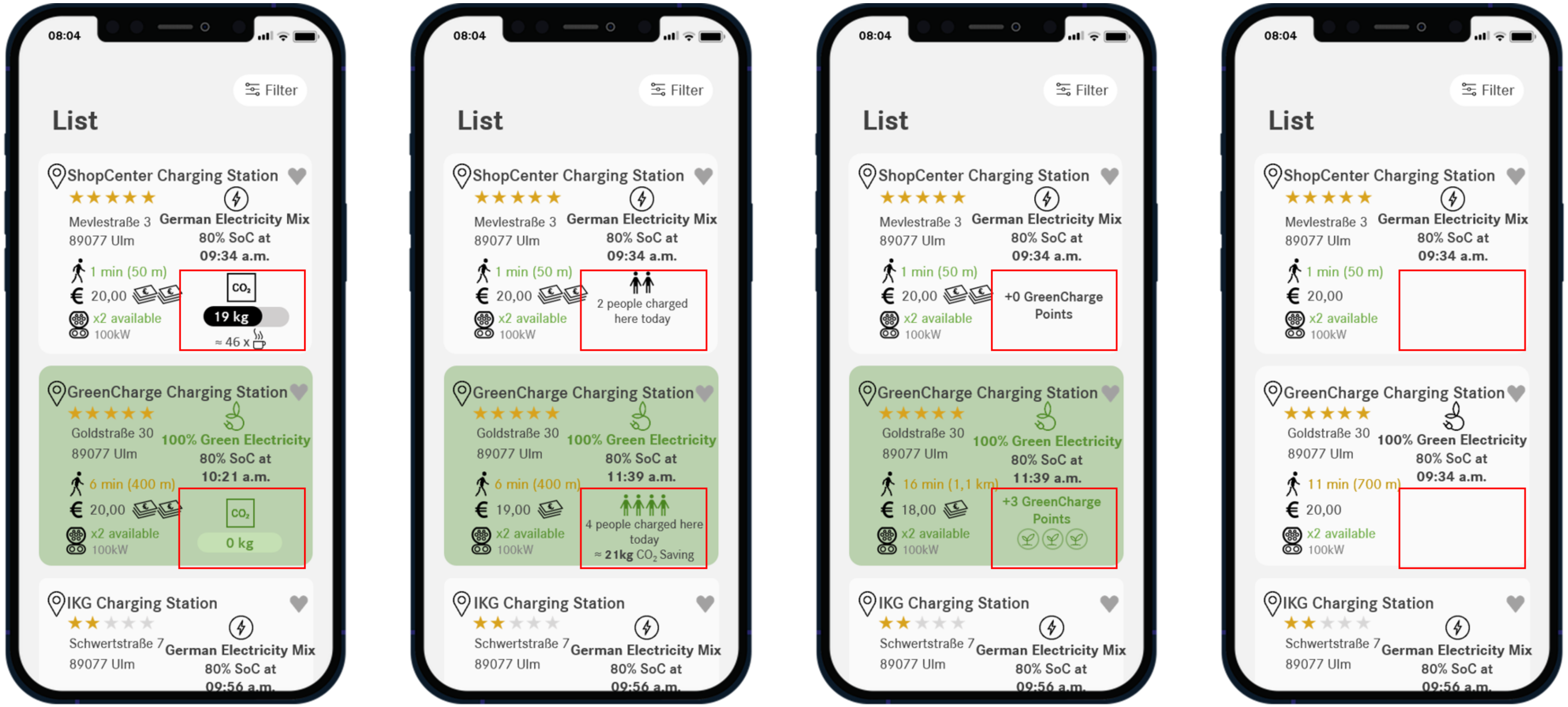



*Figure 10.* Default settings for searching a charging station in the study's hypothetical shopping center scenario (study 3).

*Note.* SoC = State of Charge.




(a) (b) (c) (d)

*Figure 11.* Presented charging station lists in the prototypical smartphone app with different smart charging characteristic variations for the (a) framing group, (b) social norm group, (c) gamification group, and (d) control group (study 3).

**Procedure**

After clicking on the questionnaire link, participants gave their consent. At the beginning of the online experiment, participants answered sociodemographic questions before they were given a detailed definition of smart charging. This was followed by a manipulation control question and the explanation of the smartphone application. All participants saw 27 visualizations of the app with different variations of walking distance, price saving, and charging delay of the smart charging station in a fully balanced design. In all 27 choices, participants had to choose one of the two presented charging alternatives based on the fictitious scenario (binary decision). Participants were randomly assigned to one of the three intervention conditions or the control group (between-subjects design). The presentations of the app were followed by several measures. Finally, participants were informed about the purpose of the study and if they were interested in the allowance, they were redirected to an external page by clicking on a link where they could confirm participation.

**Participants**

Based on a similar study examining behavioral interventions for smart charging choices that found a medium to large effect of the intervention (*OR* = 3.24; Kacperski & Kutzner, 2020), a medium effect was assumed for the sample calculation. An a-priori power analysis with G*Power (Faul et al., 2007) indicated that to detect a medium effect (*OR* = 2.5, power = .80, $\alpha = 0.05$), 200 participants were needed, which is why this was the minimum sample size that was aimed to be reached. Overall, 334 participants completed the online questionnaire. To ensure that only individuals who understood the concept of smart charging were included in the analysis, a manipulation check was included after the definition of smart charging. All participants who answered this question incorrectly were excluded, assuming that they had not correctly understood the concept or had not read the definition ($n = 28$). Moreover, participants who completed the questionnaire in less than 10 min were excluded, assuming that the questionnaire could not be read carefully and not answered conscientiously enough in this short time ($n = 20$).

After data exclusion, data from 286 participants (163 men, 123 women) were included in the analysis. The mean age was 45.70 years (*SD* = 14.42, Range = 20–78). The participants held a valid driver's license for an average of 27.52 years and drove approximately 16,500 km per year. There was a selection criterion for the sample, which was to include at least 40% drivers with electric vehicles. Hence, 21% were driving a hybrid electric vehicle and 21.7% of all participants were driving a battery electric vehicle.

**Statistical analysis**

Due to the repeated-measures design, a mixed-effects logistic regression was calculated using the glmer command (binomial family) of the lme4 package (Bates, Mächler, et al., 2015) in R (R Core Team, 2020). In total, 7720 data points for the 27 binary decisions (1 = smart charging station, 0 = conventional charging station) of all participants ($N$ = 286) were entered in the analysis (i.e., 2 missing data points, which is a negligible amount).

First, the maximal random effects structure of the model was identified and tested based on the recommendations of many researchers (Barr et al., 2013; Gomes, 2022; Meteyard & Davies, 2020). To control for by-subject variation due to multiple responses from the individuals, a random intercept for the subjects was included. Furthermore, random slopes for all contextual within-subjects factors were included (i.e., walking distance, price saving, charging delay). Various researchers argue that even with a small number of factor levels (i.e., less than 5–10 factor levels), the maximal random effects structure should be fitted and only in the case of singular fits or convergence issues, switching to simplified models is justified (Bates, Kliegl, et al., 2015; Matuschek et al., 2017; Meteyard & Davies, 2020). Since the model with this maximal random effects structure indicated a singular fit and a closer analysis revealed perfect correlations for two random slopes (walking distance and price saving), it was decided to exclude these random slopes from the model since they probably did not improve the model fit (Meteyard & Davies, 2020). Furthermore, a visualization of the slopes indicated some variance between individuals for charging delay, which is why it seemed justified that only the random slope for delay was retained in the model. In addition, calculating a principal component analysis with the rePCA function as proposed by Bates, Kliegl, et al. (2015) revealed that including only one random slope explained most of the variance. Indeed, excluding the random slopes for walking distance and price saving resulted in no singular fit issues anymore.

In the next step, the identified random effects model (i.e., containing a random intercept for participants and a random slope for delay) was extended by the fixed effects for the variables of interest. For this purpose, the experimental condition with the four between-subjects factor levels (i.e., control group, framing, social norm, gamification) and the three contextual factors (i.e., walking distance, price saving, charging delay) with the three within-subjects factor levels as main effects and the interaction between every contextual factor and the experimental condition were included. For the experimental condition, dummy coding was used while the control group was defined as the reference group. The same was done for the factor levels of the contextual factors for which the first factor level was defined as the reference level. To determine the significance of the fixed effects, the *z*-value with associated *p*-value as well as the odds ratio (*OR*) with the 95% confidence interval (*95% CI*) for the model with the identified random effects structure and the mentioned fixed effects are reported.

A second model was computed for which the control variables ecological awareness, gender, EV experience, and green energy purchase were integrated additionally. To determine whether the model with the control variables represented a better fit for the data, not only the summary statistics of this model but also the results of a likelihood ratio test are reported (i.e., $\chi2$ -value and *p*-value).

## 8.3 Results

### Descriptive statistics

Descriptive statistics in Table 16 indicate that with higher walking distance, the decision in favor of the smart charging station decreased in all experimental conditions. However, the descriptive statistics also show that participants in the intervention conditions were more likely to choose the smart charging station than the subjects in the control group when the additional walking time switched from 5 to 10 or 15 minutes. Furthermore, descriptive statistics show that with higher price savings, the decision for the smart charging station increased in all conditions. However, it is also visible that the difference from none to a 5% or 10% price saving was smaller in the intervention conditions than in the control group. In addition, with increasing charging delays, the decision in favor of the smart charging station decreased. However, the effect was smaller than for the factor walking distance. Although, the differences between the intervention conditions and the control group for the different factor levels are smaller for the charging delay, they still exist in some cases showing that a charging delay did affect the smart charging decision of participants in the intervention conditions slightly less (see Table 16).

With regard to the control variables, it was found that respondents reported a rather high ecological awareness (EA, $M = 5.15$, $SD = 0.95$). Using a median split, it was found that people who reported an ecological awareness that was above the median were more likely to choose the smart charging station than those who reported an ecological awareness that was below the median ($M_{highEA} = 0.51$, $M_{lowEA} = 0.43$). Men and women differed only slightly in their preference for the smart charging station; women chose the smart charging station slightly more often ($M_{female} = 0.49$, $M_{male} = 0.45$). People with no EV experience were also more likely to choose the smart charging station than those with EV experience, although again the difference was only slight ($M_{withEVexperience} = 0.46$, $M_{withoutEVexperience} = 0.50$). Similarly, there was little difference in terms of purchasing green energy (GE); individuals already sourcing green energy at home chose the smart charging station slightly more often ($M_{GE} = 0.49$, $M_{noGE} = 0.44$).

Table 16

*Relative frequencies (i.e., means) of smart charging decisions for the intervention conditions and the control group dependent on the contextual factors of the smart compared to the conventional charging station as well as across all conditions (study 3)*

| | | Condition | | | | **Across all conditions (*n*=286)** |
|---|---|---|---|---|---|---|
| | | Control Group (*n*=71) | Framing (*n*=62) | Social Norm (*n*=80) | Gamification (*n*=73) | |
| | | *M* | *M* | *M* | *M* | *M* |
| Walking Distance | +5min | 0.73 | 0.75 | 0.73 | 0.76 | 0.74 |
| | +10min | 0.40 | 0.45 | 0.48 | 0.50 | 0.46 |
| | +15min | 0.17 | 0.23 | 0.21 | 0.22 | 0.21 |
| Price Saving | 0% | 0.31 | 0.39 | 0.40 | 0.39 | 0.37 |
| | -5% | 0.46 | 0.49 | 0.47 | 0.51 | 0.48 |
| | -10% | 0.53 | 0.56 | 0.54 | 0.58 | 0.55 |
| Charging Delay | +0min | 0.49 | 0.55 | 0.55 | 0.57 | 0.54 |
| | +47min | 0.46 | 0.49 | 0.48 | 0.50 | 0.48 |
| | +125min | 0.34 | 0.39 | 0.37 | 0.42 | 0.38 |
| **Across all conditions** | | 0.43 | 0.48 | 0.47 | 0.49 | |

**Hypothesis testing**

The results of the final identified mixed-effects logistic regression models without and with control variables indicated that comparable effects for both models were found (see Model 1 and Model 2 in Table 17). A model comparison using a likelihood ratio test showed that the model with the control variables described the data better than the model without the control variables, $\chi^2(4) = 23.25, p < .001$. Therefore, in the following, the results of Model 2 are reported in detail. Table 17 shows that there was no main effect of the experimental conditions. Therefore, the smart charging station decisions did not differ significantly between the intervention groups and the control group. However, significant main effects for the contextual factors were found. Accordingly, individuals were significantly less likely to opt for the smart charging station when the additional walking distance changes from 5 to 10 or to 15 minutes. In contrast, individuals were significantly more likely to choose the smart charging station if it offers a price saving (of 5% or 10%) compared to the conventional charging station. Only a charging delay of 125 minutes had a significant effect on the charging decision showing that individuals chose the smart charging station less frequently with this delay. A charging delay of 47 minutes compared to the conventional station did not have a significant effect. Furthermore, Table 17 indicates that there was a significant main effect for ecological awareness, whereas the other effects of the control variables were not significant. Hence, subjects with higher ecological awareness chose the smart charging station significantly more often than subjects with lower ecological awareness.

However, what is most interesting are the interaction effects between the experimental conditions and the contextual factors, which show that there are some significant effects especially for the factor price saving. With respect to walking distance, two interactions emerge. As displayed in Table 17, the difference from 5 to 10 additional minutes of walking was smaller for participants from the social norm and gamification intervention than for participants from the control group. Both effects showed a small to medium effect size (Chen et al., 2010). However, the intervention conditions and the control group did not differ with respect to the difference from 5 to 15 additional minutes of walking (see Fig. 12). In addition, the analysis revealed that the increase from 0% to 5% price saving was smaller for participants from the intervention conditions than for participants from the control group. Similarly, the difference from 0% to 10% price saving was significantly smaller for participants from the social norm and the gamification condition than for participants from the control group (see Fig. 12). No interaction between the experimental conditions and charging delay could be found (see Table 17).

Table 17

*Results of mixed-effects logistic regression models testing the interaction between experimental conditions and contextual factors (both dummy coded) predicting smart charging choice without (Model 1) and with control variables (Model 2) (study 3)*

| Predictors | Model 1 | | | | Model 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | *z* | *p* | *OR* | *95% CI* | *z* | *p* | *OR* | *95% CI* |
| (Intercept) | 3.55 | .000*** | 4.82 | [2.021, 11.509] | 3.25 | .001** | 6.79 | [2.137, 21.549] |
| Framing | 1.60 | .110 | 2.86 | [0.789, 10.389] | 1.81 | .071 | 3.23 | [0.904, 11.567] |
| Social Norm | 1.51 | .131 | 2.53 | [0.759, 8.466] | 1.73 | .084 | 2.88 | [0.868, 9.532] |
| Gamification | 1.07 | .283 | 1.95 | [0.576, 6.613] | 1.14 | .256 | 2.01 | [0.602, 6.741] |
| Walking Distance$_{+10min}$ | -14.79 | .000*** | 0.04 | [0.026, 0.060] | -14.80 | .000*** | 0.04 | [0.025, 0.060] |
| Walking Distance$_{+15min}$ | -20.02 | .000*** | 0.00 | [0.002, 0.005] | -20.04 | .000*** | 0.00 | [0.002, 0.005] |
| Price Saving$_{-5\%}$ | 8.51 | .000*** | 5.76 | [3.849, 8.624] | 8.52 | .000*** | 5.78 | [3.861, 8.660] |
| Price Saving$_{-10\%}$ | 11.77 | .000*** | 12.96 | [8.458, 19.861] | 11.77 | .000*** | 13.02 | [8.495, 19.966] |
| Charging Delay$_{+47min}$ | -1.86 | .063 | 0.63 | [0.392, 1.024] | -1.86 | .063 | 0.63 | [0.393, 1.025] |
| Charging Delay$_{+125min}$ | -4.79 | .000*** | 0.15 | [0.072, 0.332] | -4.78 | .000*** | 0.15 | [0.070, 0.329] |
| Gender | | | | | -0.95 | .340 | 0.64 | [0.256, 1.601] |
| EV Experience | | | | | 0.35 | .726 | 1.21 | [0.411, 3.587] |
| Green Electricity Purchase | | | | | -1.27 | .203 | 0.58 | [0.252, 1.339] |

Table 17 (continued)

| Predictors | Model 1 | | | | Model 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | *z* | *p* | *OR* | *95% CI* | *z* | *p* | *OR* | *95% CI* |
| Ecological Awareness | | | | | 4.15 | .000*** | 2.36 | [1.573, 3.545] |
| Framing* Walking Distance$_{+10min}$ | 0.41 | .679 | 1.14 | [0.612, 2.126] | 0.44 | .662 | 1.15 | [0.617, 2.139] |
| Framing* Walking Distance$_{+15min}$ | 0.31 | .755 | 1.14 | [0.504, 2.570] | 0.33 | .743 | 1.15 | [0.508, 2.585] |
| Social Norm* Walking Distance$_{+10min}$ | 2.38 | .017* | 1.99 | [1.129, 3.511] | 2.42 | .015* | 2.01 | [1.144, 3.550] |
| Social Norm* Walking Distance$_{+15min}$ | 0.90 | .366 | 1.41 | [0.667, 2.997] | 0.96 | .339 | 1.44 | [0.681, 3.053] |
| Gamification* Walking Distance$_{+10min}$ | 2.54 | .011* | 2.09 | [1.183, 3.697] | 2.54 | .011* | 2.09 | [1.183, 3.697] |
| Gamification* Walking Distance$_{+15min}$ | 1.71 | .087 | 1.91 | [0.910, 4.025] | 1.71 | .087 | 1.92 | [0.911, 4.029] |
| Framing* Price Saving$_{-5\%}$ | -1.96 | .050 | 0.56 | [0.313, 1.001] | -1.97 | .049* | 0.56 | [0.312, 0.999] |
| Framing* Price Saving$_{-10\%}$ | -1.86 | .063 | 0.56 | [0.306, 1.032] | -1.87 | .062 | 0.56 | [0.305, 1.029] |
| Social Norm* Price Saving$_{-5\%}$ | -3.28 | .001** | 0.41 | [0.237, 0.695] | -3.30 | .001*** | 0.40 | [0.236, 0.692] |
| Social Norm* Price Saving-10% | -3.01 | .003** | 0.42 | [0.240, 0.740] | -3.04 | .002** | 0.42 | [0.238, 0.733] |

Table 17 (continued)

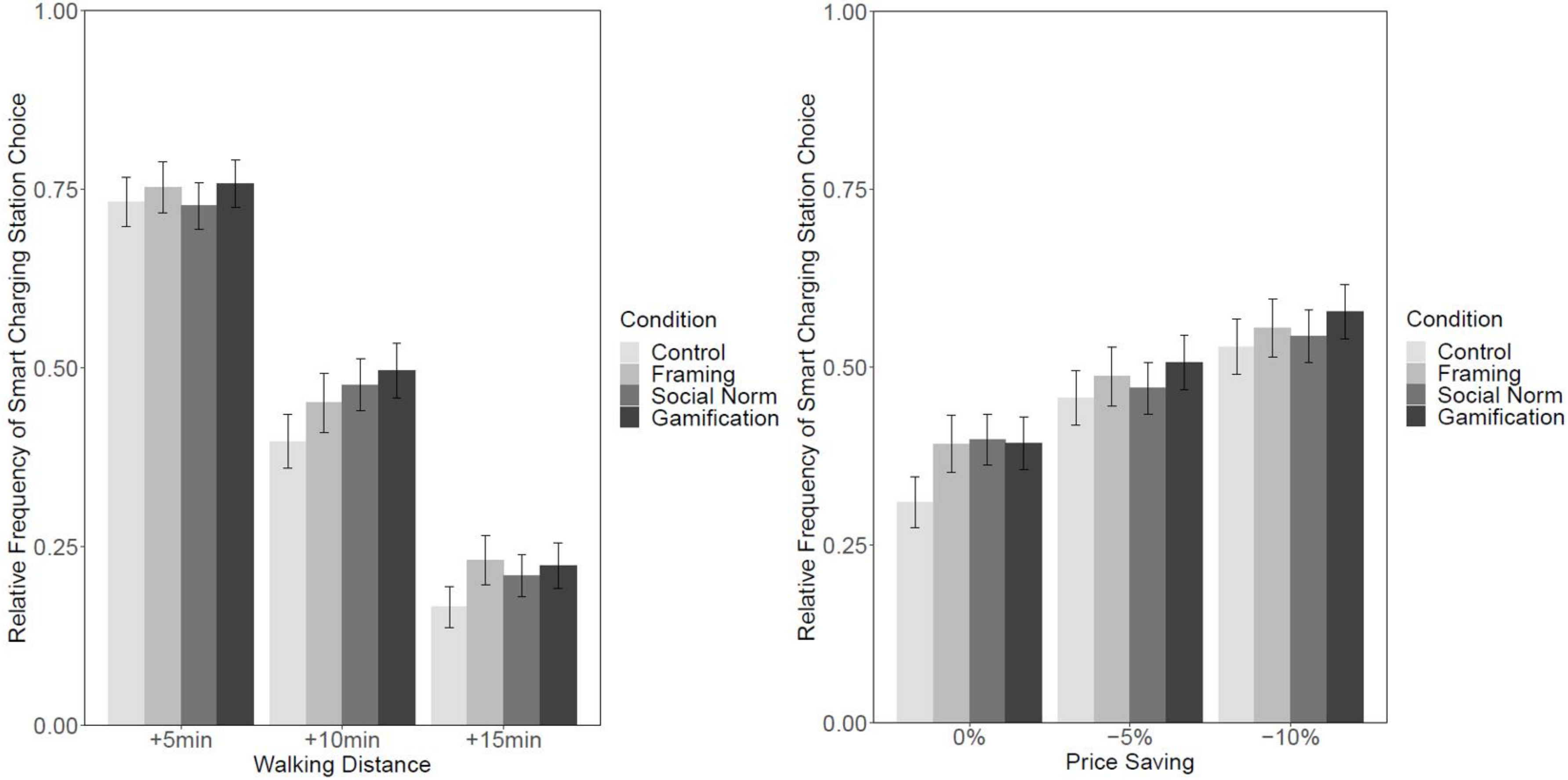
| Predictors | Model 1 | | | | Model 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | *z* | *p* | *OR* | *95% CI* | *z* | *p* | *OR* | *95% CI* |
| Gamification* Price Saving$_{-5\%}$ | -1.97 | .049* | 0.58 | [0.339, 0.999] | -1.97 | .049* | 0.58 | [0.338, 0.998] |
| Gamification* Price Saving$_{-10\%}$ | -2.08 | .038* | 0.55 | [0.312, 0.967] | -2.08 | .038* | 0.55 | [0.311, 0.967] |
| Framing* Charging Delay$_{+47min}$ | -0.43 | .670 | 0.86 | [0.419, 1.749] | -0.51 | .611 | 0.83 | [0.408, 1.693] |
| Framing* Charging Delay$_{+125min}$ | -0.16 | .875 | 0.91 | [0.297, 2.812] | -0.18 | .860 | 0.90 | [0.290, 2.813] |
| Social Norm* Charging Delay$_{+47min}$ | -0.93 | .353 | 0.73 | [0.376, 1.418] | -0.97 | .332 | 0.72 | [0.372, 1.396] |
| Social Norm* Charging Delay$_{+125min}$ | -0.44 | .657 | 0.79 | [0.276, 2.252] | -0.42 | .672 | 0.80 | [0.275, 2.297] |
| Gamification* Charging Delay$_{+47min}$ | -0.77 | .442 | 0.77 | [0.395, 1.499] | -0.82 | .413 | 0.76 | [0.390, 1.472] |
| Gamification *Charging Delay$_{+125min}$ | 0.34 | .732 | 1.20 | [0.418, 3.459] | 0.33 | .740 | 1.20 | [0.412, 3.488] |
| **Random Effects** | | | | | | | | |
| $\tau_{00}^2$ | 10.60$_{participants}$ | | | | 10.18$_{participants}$ | | | |
| $\tau_{11}^2$ | 1.52$_{+47min}$ | | | | 1.49$_{+47min}$ | | | |

Table 17 (continued)

| Predictors | Model 1 | | | | Model 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | *z* | *p* | *OR* | *95% CI* | *z* | *p* | *OR* | *95% CI* |
| | $7.08_{+125min}$ | | | | $7.27_{+125min}$ | | | |
| $\rho_{01}$ | $-.02_{+47min}$ | | | | $-.15_{+47min}$ | | | |
| | $-.29_{+125min}$ | | | | $-.32_{+125min}$ | | | |
| $ICC_{adjusted}$ | .78 | | | | .77 | | | |
| *N* | $286_{participants}$ | | | | $286_{participants}$ | | | |
| Observations | 7720 | | | | 7720 | | | |
| AIC | 5676.20 | | | | 5661.00 | | | |

*Note*. The control group was set as the reference level for the conditions. The factor level of the contextual factors walking distance, price saving, and charging delay that does not appear in this table was set as the reference level. *OR* = Odds Ratio.

* $p < .05$. ** $p < .01$. *** $p < .001$.




(a) (b)

*Figure 12*. Bar plots predicting smart charging station choice with binomial 95% confidence intervals. (a) Prediction of smart charging station choice by walking distance of the smart compared to the conventional charging station and the experimental conditions. (b) Prediction of smart charging station choice by price saving of the smart compared to the conventional charging station and the experimental conditions (study 3).

## 8.4 Discussion

In the present study, it was investigated whether cost-effective interventions (i.e., framing, social norm, gamification) and contextual factors interactively influenced the decision in favor of a public smart charging station. For this, an online experiment was conducted and the visualization of an app was developed that offered two charging stations, a pro-environmental smart charging station and a non-sustainable conventional alternative, which differed or did not differ in various contextual relevant factors.

The results showed that higher behavioral costs discouraged individuals from choosing the smart charging station when a more convenient conventional charging station was available. However, if behavioral costs were very low, the majority of participants choose the pro-environmental smart charging station. Psychological interventions with persuasive content did not show a main effect on the smart charging decision, but gained importance when behavioral costs changed. Therefore, the interventions buffered the negative effect of behavioral costs when these were moderate or small. However, the results were not entirely consistent with the initial expectations.

In detail, with respect to walking distance, it was found that when behavioral costs of the smart charging station were low (i.e., +5 walking minutes compared to a conventional charging station), the vast majority opted for the smart in contrast to the conventional charging station regardless of whether one was shown additional motivating information or not. However, the results also showed that when behavioral costs increased slightly (+10 walking minutes), more participants who were presented with compelling information opted for the smart charging station compared to those who saw no additional information. When behavioral costs increased even more (i.e., +15 minutes of walking), there was no interactive effect assuming that costs were too high so that even environmental motivations triggered by behavioral interventions had no effect on behavior.

Similar results regarding price saving were found. A change from no price saving to a low price saving (i.e., −5%) compared to a non-sustainable alternative had a smaller effect on participants who saw additional persuasive information (i.e., framed $CO_2$ benefits, information what others were doing, gamified interface) than for those who were not given any additional information. Hence, in contrast to individuals from the control group, participants from the intervention groups opted for the smart charging station more often even though individual benefits were not present. The change to a higher price saving (i.e., −10%) was smaller for participants from the social norm and gamification condition than for participants from the control group.

With regard to charging delay, no interactive effects between behavioral interventions and contextual factors of the charging decision were found. This might be the case because, first, a moderate charging delay was not considered as a really high barrier as evidenced by the fact that a charging delay of almost 50 minutes had no main effect on the smart charging decision. Second, a charging delay of 125 minutes might have been considered too costly for interventions to have an impact.

To sum up, it appears that for situations with small to moderate behavioral costs (no price advantage, 10-min walking distance), behavioral interventions may provide a motivational boost and nudge individuals towards the pro-environmental alternative. In situations in which pro-environmental options do not require additional costs or provide external benefits, most people choose the pro-environmental option independent of additional motivators. Similarly, this seems to be the case in situations where pro-environmental options require only a negligible extra effort compared to a non-sustainable alternative. In contrast, if the extra costs are very high, behavioral interventions are insufficient to motivate individuals to choose the pro-environmental option.

It is not assumed that the observed interaction effects were driven by ceiling or floor effects, because Fig. 12 indicates that even when the pro-environmental option involved high-costs, some participants decided in favor of the smart charging station (presumably participants with strong environmental motivations), whereas in low-cost situations, still some participants chose the non-sustainable alternative. This was evident for all of the contextual factors, i.e., walking distance, price saving, and charging delay. Of course, with more extreme levels for the contextual factors of smart charging (e.g., 30 minutes walking distance, charging completed after pre-defined departure, price disadvantage), probably no one will opt for the smart charging station anymore. However, it is only reasonable to assume that a (small) price advantage for smart charging should be offered and that charging should be completed within the time window previously defined by the user. In addition, smart charging stations should be near locations where individuals park vehicles for long periods (e.g., near work, shopping centers). Therefore, it is assumed that the selected factor levels were realistic and did not drive the interaction effect.

The present results may provide an explanation for inconclusive results of behavioral interventions in different pro-environmental domains in past studies. Indeed, in the transport domain, where behavioral changes are considered highly costly, interventions were often shown not to influence behavior in the long term or not at all (Degraeuwe & Beusen, 2013; Pampel et al., 2017). This was also evident in energy saving behavior. For example, in a study by Steinhorst and Klöckner (2018), it was shown that framing could influence motivation and intention, but there was no effect on behavior. Here, too, it can be assumed that the implementation of the energy-saving tips given in the study was considered too costly and effortful, which is why even a high level of intrinsic motivation was not sufficient to influence behavior. On the other hand, behavioral interventions were effective for behaviors that require only moderate effort, such as avoiding waste or plastic (Aguiar-Castillo et al., 2019; De Groot et al., 2013).

In the analysis, an effect of ecological awareness on the smart charging decision was found. This result is consistent with a large body of research that found that environmental beliefs could predict pro-environmental behavior in diverse domains (for an overview, see Steg et al., 2016). Hence, people who are convinced that environmental protection is important are more likely to behave pro-environmentally. In fact, many researchers argue that convincing the unmotivated is a key issue that needs to be addressed in future intervention research (Sass et al., 2018).

**Limitations**

The representativeness of the sample is one limiting factor of the present study. Although the study is balanced in terms of gender and age, the sample reported rather high ecological awareness. In general, other authors also reported that ecological awareness tends to be high in Germany (Bohner & Schlüter, 2014), which limits the generalizability of the study's findings to other countries and cultures.

Furthermore, the external validity of the results is limited because the study was conducted as an online survey in which the decisions for the charging stations were not made in real-life but in a hypothetical scenario. Therefore, the decisions could be biased due to social desirability or the lack of consequences of the decisions on one's real life (e. g., one's real time or money budget).

Additionally, this study certainly did not integrate all aspects that may influence the decision to use a smart charging station. For example, it is possible that other personality traits (e.g., personal norms) as well as cultural background and ideological views (Costa & Kahn, 2013) may influence the decision to use a smart charging station, which should be considered in future studies.

Beyond that, the categorization of behavioral costs might pose a limitation. Indeed, it is difficult to decide if behavioral costs are considered low, moderate, or high by most of the people (Diekmann & Preisendörfer, 2009). This may be one reason why different studies draw different theoretical conclusions. For instance, Diekmann and Preisendörfer (2009) notice that in some studies, behavioral costs were not "low" as claimed by the authors but rather "low-low". In the present study, it is also possible that the additional 5 minutes of walking effort or a moderate charging delay present "low-low-cost" instead of low-cost situations. Based on this assumption, the results may support either the LCH (assuming that a 10-min extra walking effort or no price advantage represent low-cost situations) or the A-B-C model (assuming that a 10-min extra walking effort or no price advantage represent moderate-cost situations) or a mixture of both dependent on how behavioral costs are interpreted by individuals. Therefore, it is necessary that for testing and validating the different theoretical assumptions outlined in section 3.3, researchers should study the same costly pro-environmental behaviors, since it will always be difficult to compare the level of costs for different behaviors. Furthermore, study participants might have interpreted behavioral costs differently. For instance, sport enthusiasts might view the extra walking distance as an option to do some extra exercise. Likewise, individuals might interpret the additional charging delay as an option to spend more time shopping. However, since the main effects of the contextual factors showed the expected effects in the statistical analysis, it is assumed that the present categorization of behavioral costs was consistent with the interpretation of most participants.

**Implications and conclusion**

The results of the study support the assumption that personal motivations and contextual factors of pro-environmental behavior influence behavior (Perlaviciute & Steg, 2014; Steg & Vlek, 2009). This assumption is extended by showing that interventions that may elicit these motivations also interact with contextual factors. Thus, theoretical approaches should not focus on either contextual or psychological factors but should consider both factors and their interactive effects. Similarly, it is argued that the context of behavior must be considered when examining the influence of pro-environmental interventions.

Hence, for practical purposes, it is suggested that for moderate-cost behaviors, cost-effective and easy-to-implement strategies can trigger a motivational boost that influences behavior. For very costly behaviors, contextual factors should be changed (e.g., adapting infrastructure) to make the behavior easier and interventions should be used additionally. In contrast, if the behavior is more likely to involve no or only small behavioral costs (e.g., switching off lights), most people will be convinced to show the behavior (nevertheless, using cost-effective interventions may help to persuade even more people). Caution is needed with (new) low-cost pro-environmental behaviors whose environmental benefits are not obvious or clear to all. For such behaviors, informative approaches seem to be necessary even though the behavior is rather low-cost.

In the present study, a manipulated social norm information was provided to the participants, which led to significant results. However, it needs to be pointed out that this information may not be helpful for new pro-environmental behaviors (like smart charging), for which only a minority tends to opt in right at the beginning due to lack of knowledge. In this case, it may be more successful to use an injunctive (i.e., the information that a behavior is (dis-)approved by others) or a dynamic (i.e., the information that an increasing number of people start to behave in a certain way) norm (Cialdini et al., 2006; Loschelder et al., 2019).

To conclude, in the present study, behavioral interventions influenced pro-environmental smart charging behavior especially in situations with small to moderate costs. As a result, practitioners and researchers should consider interactions between contextual and psychological factors when developing and deploying interventions to promote pro-environmental behavior.

# 9 Study 4: Environmental, altruistic, or monetary benefits? A longitudinal online experiment on how framed behavioral consequences affect self-reported eco-driving of German vehicle owners

## 9.1 Introduction

Current research indicates that climate change is progressing faster than expected (ARM Research Facility, 2021). For this reason, the EU has already announced ambitious goals to counter climate change effectively in the upcoming years (European Commission, n.d.). These goals also affect the transport sector, which is the second largest source of $CO_2$ emissions worldwide (IEA, 2020). The challenges for the car companies and mobility providers are evident: Technological innovations and appealing creative mobility solutions must be pursued more rigorously. However, this alone will not be enough; the majority of people must be ready to change their mobility behavior in order to generate visible effects for our biosphere (Barkenbus, 2010; Steg & Vlek, 2009). This includes adopting a fuel- or energy-efficient driving behavior, i.e., eco-driving.

Although eco-driving can significantly reduce $CO_2$ and pollutant emissions of the transport sector (Alam & McNabola, 2014), most people do not eco-drive (Pampel et al., 2015). This is why various persuasive eco-driving strategies have already been studied in psychological and traffic-related research (e.g., Anagnostopoulou et al., 2016; Günther et al., 2020; Sanguinetti et al., 2018; Vaezipour et al., 2016). Persuasion is a communication form that aims at influencing individuals by changing beliefs, values, or attitudes (O'Keefe, 2002). In this context, framing is an increasingly popular persuasive strategy that is used in environmental research to trigger behavior change (e.g., Dogan et al., 2014; Spence et al., 2014; Steinhorst & Klöckner, 2018). For this, a message highlights specific behavioral consequences of a pro-environmental behavior (e.g., $CO_2$ or monetary savings) triggering changes in attitude and, ideally, behavior (Steinhorst et al., 2015; Steinhorst & Klöckner, 2018).

Although framing has already been studied with regard to eco-driving (see Dogan et al., 2014), the long-term effects have not been analyzed yet and effects on (reported) behavior were also neglected. Furthermore, while environmental (addressing behavioral consequences for the biosphere) and monetary framing (addressing behavioral consequences for the self/own wallet) have been repeatedly compared with regard to pro-environmental behaviors, altruistic framing (addressing behavioral consequences for other people/living things) has been neglected so far.

Hence, the goal of the present study was to compare environmentally, monetarily, and altruistically framed eco-driving tips and their effects on perceived eco-driving worthiness as well as intended and self-reported eco-driving behavior (change). For this, a longitudinal online experiment was conducted to collect subjective data of vehicle owners.

**Eco-driving**

As already reported, depending on which behaviors are included, fuel-efficient behaviors have consumption saving potentials varying around 5 and 45 % (Af Wåhlberg, 2007; Alam & McNabola, 2014; Barkenbus, 2010; Beusen et al., 2009; Carrese et al., 2013; Sivak & Schoettle, 2012; Zarkadoula et al., 2007). Fuel consumption reductions are associated with $CO_2$ emission and pollutant reductions, which significantly contribute to climate change mitigation and everybody's health if a majority of people eco-drives (Barkenbus, 2010; Keyvanfar et al., 2018). Although it is undisputed that the number of electric vehicles on the road will steadily increase (IEA, 2022b), it is also obvious that many years will pass before combustion vehicles are no longer driven and purchased (Barkenbus, 2010). Until then, it is imperative that many people adopt a pro-environmental driving style in order to counteract climate change. For the present study, eight eco-driving behaviors that could be easily implemented during the course of the present study were selected (see Table 18).

As outlined earlier, although many individuals know how to eco-drive (see also study 1; McIlroy & Stanton, 2017; Strömberg et al., 2015), this knowledge is probably insufficient to motivate individuals to drive fuel- or energy-efficiently. Therefore, researchers hypothesize that addressing motivation is key to trigger pro-environmental behavior change (Bolderdijk et al., 2018). This can be implemented via goal-framed messages, which raise awareness and trigger motivations by highlighting the consequences of desirable pro-environmental behaviors (Dogan et al., 2014; Lindenberg & Steg, 2007; Pelletier & Sharp, 2008; Steinhorst & Klöckner, 2018).

Table 18

*The eco-driving behaviors presented to participants (study 4)*

| **Eco-driving behavior** |
|---|
| Check tire pressure regularly and ensure that tires are not underinflated |
| Improve aerodynamics of vehicle (e.g., remove roof luggage box) |
| Choose energy-efficient travel routes |
| Do not carry unnecessary weight in the vehicle |
| Avoid hard acceleration and braking as well as strong speed fluctuations and let vehicle roll out |
| Avoid very high speeds |
| Reduce electrical consumer use (e.g., heating, air conditioning) |
| Turn off engine at stops/use automatic start-stop system |

*Note*. For references, see Barkenbus (2010), Dogan et al. (2014), Huang et al. (2018), Kramer & Petzoldt (2022a), Nègre & Delhomme (2017), Sanguinetti et al. (2017), Sivak & Schoettle (2012), and Strömberg et al. (2015).

**Framing interventions**

In recent years, multiple studies have investigated which interventions are most promising for getting people to adopt pro-environmental behaviors (e.g., Günther et al., 2020; Kacperski & Kutzner, 2020; Schultz, 1999; Schwartz et al., 2015; Steinhorst & Klöckner, 2018; Van den Broek et al., 2017). A cost-efficient and easy-to-implement method to foster pro-environmental behavior that has recently been gaining popularity is framing. Framing is based on the theoretical assumption that highlighting the most important positive (e.g., monetary/$CO_2$ savings) or negative consequences (e.g., reduced fun) that are already inherent in a behavior (e.g., eco-driving) can activate certain goals, which motivates the recipient of a message to perform a behavior or refrain from it (Carfora et al., 2019).

Framing is implemented in current studies by communicating a desirable behavior (or non-behavior) in such a way that the associated consequences (e.g., savings) are highlighted in addition to the behavior (e.g., refrain from using a clothes dryer because it saves $CO_2$/money; Steinhorst & Klöckner, 2018). In previous research, authors have mainly examined two predominant motives for pro-environmental behaviors by emphasizing either the monetary or the environmental consequences of a behavior (e.g., Bolderdijk, Steg, et al., 2013; Dogan et al., 2014; Steinhorst & Klöckner, 2018). Economic theories assume that people are mainly motivated by egoistic beliefs (Miller, 1999); therefore, individuals should be motivated by the monetary consequences of a behavior (e.g., Lai, 2015; Schall & Mohnen, 2017). On the other hand, there are (mainly psychological) theories that assume environmental and moral concerns as determinants of behavior, which have been effective to explain pro-environmental behavior (e.g., VBN Theory, NAM; Lindenberg & Steg, 2007). Based on these economic and psychological theories, environmental framing, addressing environmental motives, and monetary framing, addressing egoistic motives, were investigated repeatedly for pro-environmental behaviors in past research (Bolderdijk, Steg, et al., 2013; Dogan et al., 2014; Schwartz et al., 2015; Steinhorst & Klöckner, 2018).

For example, Steinhorst and Klöckner (2018) investigated environmental (e.g., "Replace an old dishwasher – moderate $CO_2$ reduction") and monetary (e.g., "Replace an old dishwasher – moderate monetary savings") framing interventions on energy saving motivations, intentions, and behavior by sending framed energy saving tips to customers of a local German energy provider. Although both framing interventions effectively motivated short-term energy saving intentions, only environmental framing increased environmental intrinsic motivation. Likewise, Dogan et al. (2014) found that environmental (e.g., "You are driving on a motorway with a 120-km/h speed limit. You still have 100 km to reach your destination. If you drive 100 km/h instead of 120 km/h, you would save 2.40 kg $CO_2$ emissions.") and monetary framing (e.g., "…you would save € 1.70 for this trip.") did affect eco-driving intentions, but environmental (i.e., $CO_2$) savings were perceived worthier than monetary savings. Bolderdijk, Steg, et al. (2013) found that individuals felt better about environmental ("Want to protect the environment? Check your car's tire pressure") than about economic ("Want to save money? Check your car's tire pressure") tire-check appeals. In a field study, the researchers extended these insights by showing that only environmental framing increased the interest in free tire-check coupons.

However, only focusing on environmental and monetary framing neglects the fact that pro-environmental behavior may also offer socially or altruistically desirable consequences. Indeed, it is often argued that not all individuals behave pro-environmentally for environmental reasons (e.g., because they do not believe in climate change or view environmental concerns as hysteria; Unsworth & McNeill, 2017) or monetary reasons (e.g., because they are too small; Dogan et al., 2014) but possibly for social or altruistic reasons (e. g., because pro-environmental behavior contributes to the community's well-being; Asensio & Delmas, 2015). Eco-driving does not only benefit the biosphere because of $CO_2$ reductions and the wallet due to fuel savings but also has altruistic benefits by reducing pollutant emissions that threaten human health (Ye et al., 1999). For example, Asensio and Delmas (2015) found that health-based messaging, which highlighted the health problems of electricity production for people (e.g., cancer, asthma), outperformed monetary messaging for pro-environmental behavior change at home (i.e., energy saving activities).

To summarize, in recent research, framing interventions were very popular for motivating pro-environmental behavior change. Although research has shown that framing interventions can effectively influence pro-environmental behavior in multiple domains (e. g., Dogan et al., 2014; Steinhorst & Klöckner, 2018), it also indicated that some framing interventions (e.g., environmental/altruistic framing) motivate behavior change more effectively than others do (e.g., monetary framing; Asensio & Delmas, 2015; Schwartz et al., 2015). In the following, it is discussed why framing interventions are helpful for pro-environmental behavior change and why environmental and altruistic framing might be superior for strong and long-term behavior change than monetary framing.

**Possible mechanisms of framing intervention effects**

According to the Self-Concordance Model (Sheldon & Elliot, 1999; Sheldon & Kasser, 1995), personality integration and (long-term) behavior is influenced by the coherence between personal strivings (e.g., eco-driving) and individuals' personal goals at a higher (e.g., environmental protection) or the same level (e.g., safe driving). Hence, according to the model, a behavior (i.e., personal striving) is pursued sustainably when it is freely chosen and helps to achieve higher-order values (i.e., bringing out possible selves). Individuals who report many helpful connections between higher-order possible selves and lower-order personal strivings put more effort in achieving their strivings and hence, are more likely to do so (Sheldon & Kasser, 1995). As outlined before, Unsworth and McNeill (2017) found that individuals associate sustainable energy use or commuting behaviors with several higher-order goals, such as environmental protection and altruistic benefits (e.g., helping others) but also with financial benefits. The coherence between pro-environmental behaviors and individuals' higher-order goals influenced the implementation of pro-environmental behaviors. Based on these findings, the authors concluded that it might not only be useful to emphasize the coherence of a pro-environmental behavior and normative goals (e.g., "do something for the environment/other people") but also the coherence between a pro-environmental behavior and egoistic gain (e.g., "save money") goals (Lindenberg & Steg, 2007).

However, the authors of the Self-Concordance Model assume that, depending on the content of the higher-order goals and values, the coherence between higher-order goals and goal strivings is more or less effective in influencing long-term behavioral effort. In detail, as reported earlier, although the coherence between personal strivings and intrinsic as well as extrinsic goals may be helpful for positive behavioral outcomes (e.g., Sheldon & Kasser, 1995; Unsworth & McNeill, 2017), intrinsic vertical coherence is assumed to be more predictive of sustained effort towards desirable activities than extrinsic vertical coherence. For example, Sheldon and Kasser (1995) showed that goal strivings that are coherent with the higher-order goal of personal growth or finding meaning in life are followed more sustainably and are more likely to be achieved than goal strivings that are coherent with the higher-order goal of financial success and status improvement. Therefore, according to the model, coherence between a behavior and intrinsically meaningful goals such as protecting the environment or people's health should influence a behavior more strongly and sustainably than coherence between a behavior and egoistic goals such as monetary gains or status improvements. Because Unsworth and McNeill (2017) only examined the general effect of vertical coherence on pro-environmental behavior (i.e., not separately for intrinsic and extrinsic goals), their results do not contradict this reasoning. Findings of Vansteenkiste et al. (2004) support the assumptions of the model by showing that recycling motivation and behavior were more successfully stimulated when recycling was made coherent with personal intrinsic (e.g., community benefits) than personal extrinsic (e.g., financial success) goals.

In line with this, in the past, researchers identified multiple reasons why addressing extrinsic goals may not be helpful in motivating pro-environmental behavior change (for an overview, see Bolderdijk & Steg, 2015). To recapitulate, it is reported that highlighted extrinsic goals activate economical cost-benefit analyses, which can lead to pro-environmental decisions being made and pro-environmental behaviors being implemented only when the benefits are considered valuable enough to outweigh the costs (Bolderdijk & Steg, 2015). Furthermore, monetary interventions seem to be able to influence behavior initially but the effect does not last (because of weak and extrinsic motivations; Steinhorst & Klöckner, 2018) and individuals return to their initial behavior (Af Wåhlberg, 2007). For these and other reasons, several researchers do not recommend the use of (small) monetary rewards for motivating pro-environmental behaviors (Dogan et al., 2014).

In conclusion, interventions for pro-environmental behaviors should reinforce meaningful intrinsic goals instead of egoistic extrinsic goals (Sheldon & Kasser, 1995). Although both intervention methods (i.e., interventions strengthening intrinsic and extrinsic goals) might stimulate pro-environmental behavior, interventions with extrinsic benefits run the risk of not promoting stable and long-term behavior change because the small monetary benefits are not considered valuable and meaningful enough (Dogan et al., 2014) and can undermine or disrupt environmental intrinsic motivations (Steinhorst & Klöckner, 2018). Therefore, framing interventions that strengthen meaningful intrinsic goals (e.g., environmental and altruistic framing) are hypothesized to produce stronger and more long-lasting behavioral changes than those interventions that highlight extrinsic benefits (e.g., monetary framing).

**Effects of framing interventions on worthiness of behavioral consequences**

As outlined, although monetary incentives are popular among policymakers to motivate pro-environmental behavior (Bolderdijk, Steg, et al., 2013), researchers report that monetary benefits do not only involve beneficial instrumental but also harmful cognitive effects (Bolderdijk & Steg, 2015). For example, studies found that extrinsic monetary incentives are not perceived as worthy and (intrinsically) motivating enough to motivate pro-environmental behaviors (Bolderdijk & Steg, 2015; Lindenberg & Steg, 2007; Steinhorst & Klöckner, 2018). With regard to eco-driving, Dogan et al. (2014) found that individuals consider the small monetary benefits of eco-driving (that can be achieved due to lower fuel consumption) as less worth the effort than the environmental benefits (i.e., $CO_2$ emissions savings). Likewise, Spence et al. (2014) found that individuals reported that reducing energy use is “not worth it” when energy feedback is provided in pounds. In contrast, when $CO_2$ feedback is given to individuals, they report rather high motivations to save energy. Hence, environmental benefits appear to be considered valuable and motivating by individuals regardless of whether they understand how significant or insignificant the savings are (Gaker et al., 2011). This might be also true for altruistic benefits that address the valuable and intrinsically meaningful benefits of eco-driving for the health of people and other species (i.e., “something bigger”; Asensio & Delmas, 2015). Consequently, it is expected that the $CO_2$ or pollutant (e.g., Nitrogen oxides) emissions savings within environmental and altruistic framing interventions are perceived as worthier of pro-environmental action (i.e., eco-driving) than the small extrinsic monetary savings within monetary framing (Dogan et al., 2014; Steinhorst & Klöckner, 2018).

**Effects of framing interventions on intentions**

The results of framing interventions on pro-environmental intentions illustrate that significant effects on short-term pro-environmental intentions are found regardless of whether monetary or environmental benefits are emphasized (Dogan et al., 2014; Steinhorst & Klöckner, 2018). For example, Spence et al. (2014) found that environmental and monetary framing equally influenced intentions to reduce energy use. Furthermore, as reported above, Dogan et al. (2014) as well as Steinhorst and Klöckner (2018) found that monetary and environmental framing interventions increased pro-environmental intentions. However, other studies also found that monetary framing was inferior to environmental or altruistic framing with regard to pro-environmental intentions (Asensio & Delmas, 2015; Schwartz et al., 2015). For example, Schwartz et al. (2015) found that monetary framing was not as effective as environmental framing in motivating the willingness to enroll in an energy-saving program. However, this study did not include a control group, which is why it cannot be concluded that monetary framing is inferior to any framing intervention.

Overall, based on empirical research, it can be concluded that framing interventions independent of their specific content are more helpful to promote pro-environmental intentions than no intervention. Based on theoretical considerations, it is assumed that this is the case because highlighting the coherence between higher-order goals and personal strivings influences short-term intentions (i.e., positive behavioral outcomes) independent of the specific content of the higher-order goal (being intrinsic or extrinsic; Sheldon & Kasser, 1995; Unsworth & McNeill, 2017). However, previous research also suggests that intrinsically framed benefits may be superior to extrinsically framed benefits with regard to influencing intentions (Schwartz et al., 2015; Sheldon & Kasser, 1995). It is hypothesized that this is the case because intrinsic vertical coherence results in stronger motivational and behavioral outcomes than extrinsic vertical coherence (Dogan et al., 2014; Sheldon & Kasser, 1995; Steinhorst & Klöckner, 2018).

**Effects of framing interventions on behavior change**

It is expected that medium-term pro-environmental behavior change is influenced by framing interventions in the same way that short-term pro-environmental intentions are. For example, past studies showed that interventions that influenced intrinsic beliefs (e.g., Bolderdijk, Steg, et al., 2013) as well as interventions that offered small monetary incentives (e.g., Lai, 2015) affected pro-environmental behavior change initially. This is in line with the outlined theoretical assumptions that state that goal-framed behavioral information should result in medium-term pro-environmental behavior change independent of framing content, because this information will motivate behavior changes temporarily by strengthening either personal intrinsic or extrinsic goals (Sheldon & Kasser, 1995). However, past studies also showed that behavioral changes influenced by monetary interventions were only weak and not persistent (Af Wåhlberg, 2007; Beusen et al., 2009; Degraeuwe & Beusen, 2013). This is also in line with theoretical assumptions that suggest that only interventions highlighting meaningful intrinsic information (e.g., environmental and altruistic framing) activate deep motivational and cognitive processes (e.g., higher perceived worthiness). This is why individuals who receive this kind of framing should implement stronger medium-term behavior changes than individuals who receive monetarily framed information. Hence, since small monetary benefits are not considered worthy enough to show high pro-environmental efforts (Dogan et al., 2014), behavioral changes following monetary framing interventions should be rather weak in the medium-term, indicating that long-term behavior changes are unlikely to occur.

**The present study**

The aim of the study was twofold: first, the short-term effects of differently framed eco-driving tips (e.g., “Avoid very high speeds. – This will save 1.95kg $CO_2$/€ 1.01/harmful carbon monoxide emissions.”) on the perceived worthiness of eco-driving savings and on eco-driving intention were investigated. Second, the medium-term effects of framing interventions on self-reported eco-driving behavior change were analyzed. For this purpose, a longitudinal online experiment was conducted over the period of one month. The present study design and length as well as the intervention material was strongly guided by the study of Dogan et al. (2014) as well as Steinhorst and Klöckner (2018). However, these findings were expanded by investigating not only environmental and monetary but also altruistic framing effects. Furthermore, the research on framing and eco-driving was expanded by analyzing not only the effects on worthiness of behavioral consequences and intention (see Dogan et al., 2014) but also on reported eco-driving behavior (see Fig. 13). Therefore, this study contributes to the understanding of the effectiveness of interventions for high-impact pro-environmental transport behaviors (eco-driving) by analyzing short- and medium-term effects and considering multiple motives (environmental, altruistic, and egoistic motives). An online study was particularly suitable in this regard, because a high number of test persons could be recruited and individuals could report about their behavior in everyday life. The anonymity of an online study has the advantage that participants tend to be less affected by social desirability (Batinic et al., 2002). Furthermore, this method was suitable due to general guidelines and restrictions of the global COVID-19 pandemic at the time of study conduction.

Participants were recruited via e-mail invitation to take part in the longitudinal online experiment. Participants went through two online survey periods, in November (T0 and T1) and December 2020 (T2) (see Fig. 13). Participants received the intervention within the first questionnaire during the survey period in November 2020 and the same intervention as a reminder e-mail two weeks later. Based on the procedure of a similar study (Steinhorst & Klöckner, 2018) and because it was aimed to ensure that participants do not forget or loose the intervention material, the intervention was sent to the participants twice. The study was conducted in Germany with drivers who drive regularly and are registered in a participants panel of a German vehicle manufacturer (most of these participants are living in the south of Germany where the vehicle manufacturer is located). Because these drivers own a vehicle and drive regularly, they could adapt and change their driving behavior effectively during the course of the longitudinal study. Furthermore, behavioral changes by rather frequent drivers are particularly important because of the high impact potential on transport-related emission mitigation. Participants reported eco-driving worthiness, intentions, and behavior (changes) via self-report (i.e., answers on items in an online survey) based on past and current self-observed driving behavior in everyday life. Although exact driving journeys during the study period could not be assessed due to the non-use of GPS trackers, it is likely that most participants based their online responses on everyday driving tours (e.g., to work/shopping centers). Based on the above reported expectations, the following hypotheses derived from empirical research and theoretical assumptions were tested.

*Hypothesis 1. (H1).* Individuals who receive environmentally and altruistically framed eco-driving tips will rate eco-driving as more worth the effort than individuals who receive monetarily framed eco-driving tips.

*Hypothesis 2a. (H2a).* Individuals who receive framed eco-driving tips (i.e., environmentally, altruistically, or monetarily framed tips) will report stronger eco-driving intention than individuals who receive no framed tips (i.e., the control group).

*Hypothesis 2b. (H2b).* Individuals who receive environmentally or altruistically framed eco-driving tips will report stronger eco-driving intention than individuals who receive monetarily framed eco-driving tips.

*Hypothesis 3a. (H3a).* Individuals who receive framed eco-driving tips (i.e., environmentally, altruistically, or monetarily framed tips) will report stronger (medium-term) eco-driving behavior change than individuals who receive no framed tips (i.e., the control group).

*Hypothesis 3b. (H3b).* Individuals who receive environmentally or altruistically framed eco-driving tips will report stronger (medium-term) eco-driving behavior change than individuals who receive monetarily framed eco-driving tips.

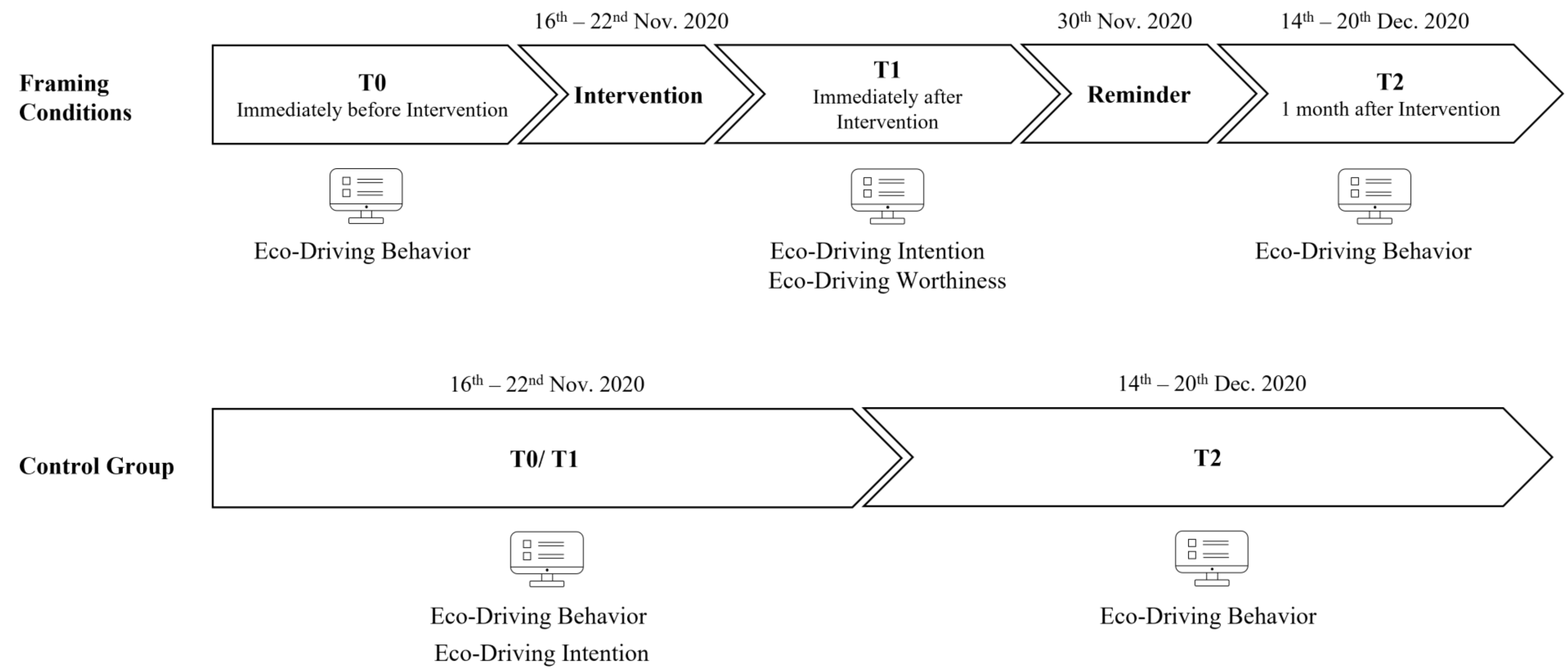



*Figure 13*. Study design, procedure, and collected variables (study 4).

## 9.2 Method

### Study design

To test the study hypotheses, 402 vehicle drivers were invited to participate in the online study based on sample sizes of previous studies that investigated the effect of framing on pro-environmental behaviors (Dogan et al., 2014; Kacperski & Kutzner, 2020; Steinhorst & Klöckner, 2018). This sample size was also sufficiently large according to the results of an a-priori power analysis ($N$ = 136) with G*Power (Faul et al., 2007), assuming a medium effect size ($f$ = .25, $\alpha$ = .05; power = .80).

For the present study, participants were randomly assigned to one of four experimental conditions at T0 in November 2020 as part of the first online questionnaire: Environmental framing group, altruistic framing group, monetary framing group, or control group. All framing groups received eight eco-driving tips (e.g., "avoid very high speeds"; see Appendix A for the full material) and the fuel saving potential that is possible by implementing each tip (based on an analysis by Sivak & Schoettle, 2012; see also McIlroy & Stanton, 2017). Dependent on the framing content, participants additionally received the $CO_2$ (environmental framing), pollutant (altruistic framing), or monetary (monetary framing) savings potential that was achievable by implementing the respective eco-driving tip based on a hypothetical driving scenario. As dependent variables, the perceived eco-driving worthiness as well as the short-term eco-driving intentions were measured. Furthermore, the self-reported eco-driving behavior was measured before the intervention and one month after the intervention to assess the reported eco-driving behavior change (see Fig. 13).

### Participants

German vehicle drivers who are registered in a participants pool of a large German vehicle manufacturer were contacted. Most of these participants reside in the south of Germany, where the location of the vehicle manufacturer is. Individuals living in this part of Germany can be considered as a relevant target group for the present study since vehicle ownership (Nobis & Kuhnimhof, 2018) and annual mileage (Statistische Ämter des Bundes und der Länder, 2019) among people is high. Hence, it is beneficial if eco-driving strategies are adopted by people living in this area. Based on information provided by the participants during panel registration, it was possible to contact only subjects who owned a vehicle with an internal combustion engine and drove more than or equal to 3000 km a year. These criteria were selected to ensure that only drivers who drive regularly and can implement the eco-driving tips during the study period participated in the study and to ensure that the framed fuel savings reported in the tips could be at least partially transferred to the participants' vehicles. Individuals who fulfilled these criteria received a non-binding e-mail invitation for the study from the operator of the participants panel. Interested subjects were able to register online for study participation. After the minimum sample size (i.e., 400 participants) was reached, no further participation was possible. However, two additional participants who struggled with the study application were accepted.

The first questionnaire was completed by 338 participants of whom 283 also completed the second questionnaire one month later. There were no sociodemographic differences between the dropout and the remaining sample, which is why only the sociodemographic results of T2 are reported (see Table 19). Furthermore, the dropout rate was not specific for the condition in which the participants were grouped (see Table 20). Using *t*-tests, it was calculated whether there was a significant difference in the dependent variables at T1 between the dropout and the remaining sample to see whether individuals who perceived the savings as not worth the effort or those with no eco-driving intentions dropped out of the study. The analyses showed no significant difference between the two samples for either worthiness of savings or eco-driving intention, $|t| < 1.68$, $p >.099$. Participants who did not drive a vehicle with an internal combustion engine were excluded as the tips were related to fuel consumption reduction ($n_{T1} = 10$, $n_{T2} = 9$). Participants who completed the first questionnaire in less than ten minutes were excluded as it was assumed that the tips and questions could not be read carefully enough in this time ($n_{T1} = 10$, $n_{T2} = 9$). At T2, items for manipulation control were used and participants were excluded who stated that they had not read, downloaded, or discussed the tips ($n = 17$), as well as participants who could not reproduce the main framing reason and not more than one tip ($n = 20$; Steinhorst & Klöckner, 2018). Because reducing pollution would also protect the environment, answers from participants from the altruistic framing group that were related to the environment and sustainability were accepted. Excluding participants who did not pass the manipulation check did not significantly change the sample characteristics ($|t| < 0.47$, $p >.644$, $|\chi^2| < 0.33$, $p >.563$).

The final sample consisted of 281 participants at T1 and 228 participants at T2. At T1, there were 70 participants in the environmental framing group, 65 in the altruistic framing group, 72 in the monetary framing group, and 74 in the control group. At T2, there were 54 participants in the environmental framing group, 54 in the altruistic framing group, 58 in the monetary framing group, and 62 in the control group. The mean age was 43.38 years ($SD = 14.60$; Range = 20–69). About the same number of women and men took part in the study (female = 51.3%). The majority of participants had a university degree (53%), 23% had a university entrance certificate, 18% had completed vocational training, and 6% had an entrance for practical education. Participants held a valid driver's license for an average of 25.04 years. The participants drove 15,000 km per year on average (median). Participants received a monetary compensation of €30 if they completed all online questionnaires of the longitudinal online study. All subjects gave consent and the ethics committee of the vehicle manufacturer approved the study.

Table 19

*Differences between dropout after time and remaining sample at T2 (study 4)*

| Variables | Dropout ($n$ = 55) | Remaining ($n$ = 283) | Difference testing |
|---|---|---|---|
| Age | $M$ = 39.87, $SD$ = 11.82 | $M$ = 43.29, $SD$ = 14.36 | $t(88.04) = 1.89$, $p = .062$ |
| Gender | m = 32, f = 23 | m = 148, f = 135 | $\chi^2(1, N = 283) = 0.43$, $p = .514$ |
| Education | Univ. degree = 43.6%, Univ. entr. = 23.6%, Voc. training = 27.3%, Entr. prac. ed. = 5.4% | Univ. degree = 51.9%, Univ. entr. = 22.3%, Voc. training = 19.4%, Entr. prac. ed. = 6.4% | $\chi^2(8, N = 283) = 8.26$, $p = .409$ |
| License | $M$ = 21.49, $SD$ = 11.03 | $M$ = 25.01, $SD$ = 13.84 | $t(78.70) = 1.97$, $p = .053$ |
| Mileage | $Mdn$ = 15,000 | $Mdn$ = 15,000 | $t(65.98) = -0.92$, $p = .363$ |

*Note*. m = male, f = female. Univ. degree = University degree, Univ. entr. = University entrance certificate, Voc. training = Vocational training, Entr. prac. ed. = Entrance for practical education.

Table 20

*Number of participants in the dropout and remaining sample by experimental groups (study 4)*

| | Dropout Sample | Remaining Sample |
|---|---|---|
| Environmental Framing | 16 | 71 |
| Altruistic Framing | 11 | 74 |
| Monetary Framing | 16 | 69 |
| Control Group | 12 | 69 |
| Total | **55** | **283** |

*Note.* The chi-square test to analyze whether dropout behavior was specific to an experimental group was not significant, $\chi^2(3) = 1.51$, $p = .680$.

**Material**

**Intervention**

The intervention was strongly guided by the material developed by Steinhorst and Klöckner (2018). All participants in the intervention conditions received eight eco-driving tips (see Table 18) with possible fuel saving potentials that are achievable when the tip is implemented on a hypothetical driving tour. The fuel saving potentials were based on an analysis by Sivak and Schoettle (2012) and were transformed from a percentage value to an absolute amount measured in liters based on the hypothetical scenario of driving a gasoline-powered vehicle with an average consumption of 7 l/100 km for a route of 200 km.

The environmental framing group additionally received the amount of $CO_2$ saving that corresponds to the fuel saving (calculated based on a report by EPA, 2005). Because several researchers point out that for most people the concept of $CO_2$ is rather unfamiliar and difficult to understand (Avineri & Waygood, 2013; Coulter et al., 2007; Kacperski & Kutzner, 2020), participants additionally received the reference of how long it would take a 23 m tall and 80 year old beech tree to reabsorb this amount of $CO_2$ (Steinhorst & Klöckner, 2018). The calculations from $CO_2$ to days of absorption by a beech tree were based on the assumption that the beech would absorb 12.5 kg $CO_2$ per year (co2online, 2009). Participants received a short explanation of the concept of $CO_2$ absorption.

The altruistic framing group was given the tips with the fuel saving potentials and associated reductions of pollutants (e.g., NOx, CO; Fonseca et al., 2010; Sivak & Schoettle, 2012). Unlike for $CO_2$, it was not possible to convert the fuel saving amount into an exact amount of pollutant savings (because of lacking research on this), which is why participants were told that they could significantly reduce harmful pollutant emissions, and thereby, help to protect (human) health and life on earth.

The monetary framing group received the monetary savings associated with the fuel saving amount based on actual gasoline prices in Germany to that time (€1.20/liter). Because most people are familiar with monetary amounts and can adequately understand monetary value without additional cues, no additional phrase that linked the monetary amount to a bigger achievement was included (contrary to the procedure for the environmental and altruistic framing group).

The tips in the intervention conditions were preceded by an introductory text highlighting the respective framing reason and its importance. Tips with greater fuel savings received a higher number of frame corresponding icons (tree, heart with hands, Euro sign; see Table 21). Tips with the greatest fuel savings and behavioral consequences ($CO_2$, pollutant, and monetary savings) received four icons, tips with medium savings received three or two icons, and tips with the lowest savings potentials received one icon. This was intended to communicate significant behavioral effects in a simple and illustrative way (see Steinhorst & Klöckner, 2018). At the end of the framing message, participants saw the total saving potential that is achievable on the hypothetical driving trip and were encouraged to implement the tips over the following weeks. The control group received no tips and no introductory text (see Appendix A for the full material).

Table 21

*Intervention material (study 4)*

| Group | Exemplary Tip |
|---|---|
| Environmental Framing | **Avoid very high speeds**<br>If you avoid very high speeds, you can reduce fuel consumption by up to 0.84 liters on your route. This corresponds to a $CO_2$ saving of about 1.95 kg. The beech would be busy absorbing this amount of $CO_2$ for about 57 days.<br> |
| Altruistic Framing | **Avoid very high speeds**<br>If you avoid very high speeds, you can reduce fuel consumption by up to 0.84 liters on your route. By implementing this behavior, you can significantly contribute to the reduction of carbon monoxide (CO) caused by road traffic; thus, you can contribute to the protection of everyone's health.<br> |
| Monetary Framing | **Avoid very high speeds**<br>If you avoid very high speeds, you can reduce fuel consumption by up to 0.84 liters on your route. This corresponds to a monetary saving of 1.01€.<br>€€€ |
| Control Group | - |

*Note*. Participants in the intervention conditions received eight differently framed eco-driving tips, which varied in the amount of saved fuel; hence, in the $CO_2$ emissions or monetary savings potential. For the altruistic framing condition, tips varied for the saved pollutant type (e.g., CO, $NO_X$). Tips with greater fuel savings received a higher number of frame corresponding icons.

**Measures**

*Sociodemographic information (T0).* Participants were asked about their age in years in an open format. Furthermore, participants indicated their gender (1 = *female*, 2 = *male*, 3 = *non-binary*). Participants also indicated their highest educational degree based on a scale that offered choices of possible degrees in Germany (see Table 19). Moreover, participants reported their driving license ownership in years and the average number of kilometers driven with their vehicle per year in an open format. In addition, subjects were asked about the drive type of their most frequently driven vehicle (1 = *gasoline*, 2 = *diesel*, 3 = *gas*, 4 = *hybrid*, 5 = *electro*, 6 = *fuel cell*).

*Worthiness of savings (T1).* It was measured whether the participants perceived the amount of savings highlighted in the tips (i.e., $CO_2$, pollutant, and monetary savings) worth the effort of implementing the respective eco-driving behavior. For this, eight items measuring worthiness of eco-driving savings were used (e.g., "The savings I can achieve by driving an energy-efficient route are…"; Dogan et al., 2014). Participants rated each item on a 7-point Likert scale (1 = *not at all worth the effort* to 7 = *totally worth the effort*). Participants' responses were averaged to get a single value for all participants. The internal consistency of the scale was acceptable (see Table 22). Participants in the control group did not answer the worthiness items because they did not receive the eco-driving tips with corresponding savings potentials.

*Eco-driving intention (T1).* The intention of implementing the eco-driving tips during the study period was measured by asking participants how much they intended to implement each eco-driving tip in the following weeks (e.g., "I intent to avoid hard braking and acceleration as well as strong speed fluctuations and let the vehicle coast ("sail") whenever possible."). Participants rated their intention on a 7-point Likert scale (1 = *strongly disagree* to 7 = *strongly agree*). The item responses were averaged. The internal consistency of the scale was acceptable (see Table 22).

*Eco-driving behavior (T0 & T2).* Eco-driving behavior was measured using the same scale at T0 and T2. Participants rated eight items representing the eco-driving behaviors that were used in the message framing conditions (e.g., "I avoid very high speeds.") on a 7-point Likert scale (1 = *never*, 4 = *sometimes*, 7 = *always*). At T0, eco-driving behavior was measured before presenting the eco-driving tips and the framed savings. Therefore, eco-driving behavior at T0 was intended to be a baseline measure. All item responses were averaged. Higher values indicated stronger eco-driving behavior regarding the eight behaviors that were used in the tips. The internal consistency of the scale was acceptable (see Table 22). However, one item of the behavior scale at T2 had to be excluded (i.e., "I checked the tire pressure of my vehicle regularly and ensured that the tires were not underinflated.”) for the calculation of McDonald’s omega (and the following analyses), because it did not fit the identified factor structure.

Table 22

*Descriptive statistics for worthiness of savings, eco-driving intention, and reported eco-driving behavior in all experimental conditions (study 4)*

| | Time | McDonald‘s omega (ω) | Altruistic Framing | | | Environmental Framing | | | Monetary Framing | | | Control Group | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *M* | *SD* | *n* | *M* | *SD* | *n* | *M* | *SD* | *n* | *M* | *SD* | *n* |
| Worthiness of Savings | T1 | .85 | 5.62 | 0.87 | 65 | 5.62 | 0.93 | 70 | 5.27 | 1.09 | 72 | - | - | - |
| Eco-Driving Intention | T1 | .80 | 5.57 | 0.86 | 65 | 5.48 | 1.07 | 70 | 5.23 | 1.13 | 72 | 5.39 | 1.03 | 74 |
| Eco-Driving Behavior | T0 | .76 | 4.93 | 0.96 | 65 | 4.97 | 0.98 | 70 | 4.79 | 1.02 | 72 | 4.87 | 1.00 | 74 |
| | T2 | .79 | 5.35 | 0.95 | 54 | 5.40 | 0.81 | 54 | 5.15 | 0.98 | 58 | 4.86 | 1.13 | 62 |

**Procedure**

Participants could register for the study via an online link if they were interested in participation. At study start, interested participants received the online link to the first questionnaire, which was sent via e-mail by the first author of this study. After giving consent, participants could open the questionnaire. In the questionnaire, they first generated and entered their individual code, which was used to match the two questionnaires. Participants then reported sociodemographic questions and received a definition of eco-driving (see Appendix B). After this, they completed the eco-driving behavior scale and subsequently received the framed eco-driving tips or not (the control group received no framed tips). Lastly, participants completed the worthiness and intention scale.

After two weeks, individuals in the intervention conditions received an e-mail with the intervention material as a reminder. After again two weeks, all participants received the second questionnaire link via e-mail. In this online questionnaire, participants first had to generate and enter their code again. They then answered manipulation control questions and again received the eco-driving definition (see Appendix B). Subsequently, participants completed the eco-driving behavior scale. After completing all questionnaires of the study, participants could receive their monetary compensation by clicking on a link, which redirected them to an external online page where they could confirm online participation.

In all questionnaires, participants were informed that their participation was voluntary and that the answers were anonymized. Both online questionnaires took approximately 20 to 30 minutes to complete. The questionnaires included other scales that are not relevant for the present study, which is why they are not reported. During the study period, there was an imposed lockdown in Germany due to the ongoing COVID-19 pandemic. Because of that, there were occasional reports that driving frequency was significantly reduced compared to the time before the pandemic (see also Anke et al., 2021). However, since this was probably the case for every participant, the results of the participants are still comparable.

## 9.3 Results

All statistical analyses were calculated in R (R Core Team, 2020). The hypotheses on short-term effects of framing conditions on worthiness of savings and eco-driving intention at T1 (H1, H2a, H2b) were tested using one-way ANOVAs with user-defined contrasts. Multiple studies indicate that instead of using the overall ANOVA-$F$-test, it is preferable to use a-priori contrasts that test specific hypotheses. This has the advantage of testing questions that are specific while at the same time profiting from increased statistical power (Konietschke et al., 2013; Steiger, 2004; Wiens & Nilsson, 2017). The hypotheses on long-term behavior effects (H3a, H3b) were tested using a linear-mixed effects model (LMM) to analyze differences between eco-driving behavior at T0 and T2.

To test H1, H2a, and H2b, the experimental conditions were included as a categorical variable for which contrasts were defined based on the specific hypotheses (see below). The *F*-value and associated *p*-value as well as the $\eta p^2$ as a measure of effect size are reported for each effect. Prior to the analyses, it was checked it the data met the preconditions for calculating ANOVAs. Inspecting the visual plots, no violation of homoscedasticity or normality of residuals was found.

For the investigation of long-term effects on reported eco-driving behavior, a LMM with the package "lme4" was calculated (Bates, Mächler, et al., 2015). The model contained two fixed main effects for experimental condition (environmental framing, altruistic framing, monetary framing, control group) and time (T0 and T2) as well as interactions between condition and time. To test H3a and H3b, user-defined contrasts for the experimental conditions were included based on the respective hypothesis (see below). It was accounted for by-subject variation by including random intercepts for subjects. For investigating significance, the package "lmerTest" (Kuznetsova et al., 2017) was used, which estimates degrees of freedom and calculates *p*-values based on Satterwhite's method. Beta estimates with *t*-tests, *p*-values, and 95% confidence intervals (*95% CI*) are reported for each effect. For the model fit, the marginal ($R^2_m$) and conditional ($R^2_c$) $R^2$ are reported for the LMMs based on Nakagawa and Schielzeth (2013). $R^2_m$ represents the variance explained by the fixed factors only while $R^2_c$ represents the variance explained by the model with both the fixed and the random factors (intercept). Prior to the analysis, it was checked if the data met the preconditions of linear mixed-effects models. Inspecting the visual plots, no violation of homoscedasticity or normality of residuals was found.

**Descriptive statistics**

Table 22 displays the descriptive statistics of the study at T0, T1, and T2. Participants in all conditions rated the worthiness of savings highly; however, participants in the environmental and altruistic framing conditions rated worthiness higher than participants in the monetary framing condition. Moreover, participants in all conditions reported a high intention to implement the eight eco-driving tips. However, consistent with the findings on worthiness of savings, the reported eco-driving intention in the environmental and altruistic framing condition was descriptively higher than in the monetary framing and in the control condition. Individuals in the monetary framing group reported lower eco-driving intention than individuals in the control group. The reported eco-driving behavior was also rather high and in all framing conditions higher at T2 than at T0. The environmental and altruistic framing conditions showed the greatest difference whereas the control group showed no positive difference with regard to eco-driving behavior.

**Short-term results on worthiness of savings**

Testing the effect of framing on worthiness of eco-driving savings, two user-defined contrasts were included. Assuming that intrinsically framed tips would be perceived as worthier than extrinsically framed tips (see H1), monetary framing (MF; coded − 2) was compared with altruistic (AF; coded +1) and environmental framing (EF; coded +1). For exploratory reasons, environmental (coded +1) and altruistic framing (coded − 1) were compared with each other (MF = 0). The control group was excluded from this analysis because these participants did not answer the worthiness items ($n = 207$).

H1 was supported by the results. Table 23 displays that worthiness of savings significantly differed between the altruistic/environmental ($M_{AF} = 5.62$, $SD_{AF} = 0.87$; $M_{EF} = 5.62$; $SD_{EF} = 0.93$) and monetary framing group ($M_{MF} = 5.27$, $SD_{MF} = 1.09$). No significant difference between the altruistic and environmental framing groups was found with regard to worthiness of savings (see Table 23).

Table 23

*Results of one-way ANOVA with user-defined contrasts predicting worthiness of eco-driving savings (study 4)*

| Predictor | *SS* | *df* | *MS* | *F* | *p* | $\eta p^2$ |
|---|---|---|---|---|---|---|
| Experimental Conditions | 5.60 | 2 | 2.80 | 2.95 | .055 | .03 |
| Contrast 1: EF/AF vs. MF | 5.59 | 1 | 5.59 | 5.90 | .016* | .03 |
| Contrast 2: EF vs. AF | 0.00 | 1 | 0.00 | 0.00 | .967 | .00 |
| Error | 193.51 | 204 | 0.95 | | | |

*Note*. EF = environmental framing, AF = altruistic framing, MF = monetary framing.
*$p < .05$.

**Short-term results on eco-driving intention**

For the investigation of the study's hypotheses regarding short-term effects on eco-driving intention, the control group was included and three user-defined contrasts were tested ($n$ = 281). Testing H2a, it was investigated if framing groups (each coded +1) reported higher eco-driving intentions than the control group (CON; coded − 3). Testing H2a, intrinsically (EF and AF each coded +1) and monetarily framed tips (coded − 2) were compared. For exploratory purposes, environmental (coded +1) and altruistic (coded − 1) framing were compared with each other.

Neither H2a nor H2b was supported by the results of the one-way ANOVA. The analysis showed neither a significant difference between the framing groups and the control group nor a significant difference between the intrinsic (altruistic/environmental) and extrinsic (monetary) framing groups for eco-driving intention (see Table 24). However, the contrast comparing altruistic/environmental ($M_{AF}$ = 5.57, $SD_{AF}$ = 0.86; $M_{EF}$ = 5.48; $SD_{EF}$ = 1.07) and monetary framing ($M_{MF}$ = 5.23; $SD_{MF}$ = 1.13) showed a small effect size and narrowly missed significance (see Contrast 2 in Table 24). The environmental and altruistic framing group (see Contrast 3 in Table 24) did not significantly differ regarding eco-driving intention.

Table 24

*Results of one-way ANOVA with user-defined contrasts predicting eco-driving intention (study 4)*

| Predictor | *SS* | *df* | *MS* | *F* | *p* | $\eta p^2$ |
|---|---|---|---|---|---|---|
| Experimental Conditions | 4.46 | 3 | 1.49 | 1.40 | .244 | .02 |
| Contrast 1: FG vs. CON | 0.06 | 1 | 0.06 | 0.06 | .811 | .00 |
| Contrast 2: EF/AF vs. MF | 4.11 | 1 | 4.11 | 3.87 | .050 | .01 |
| Contrast 3: EF vs. AF | 0.29 | 1 | 0.29 | 0.27 | .602 | .00 |
| Error | 294.20 | 277 | 1.06 | | | |

*Note*. FG = framing groups, CON = control group, EF = environmental framing, AF = altruistic framing, MF = monetary framing.

**Long-term results on eco-driving behavior**

First, testing H3a, it was tested if the framing groups (each coded +1) significantly differed from the control group (coded − 3) with regard to eco-driving behavior change. Then, testing H3b, the difference between the monetary framing group (coded − 2) and the environmental and altruistic framing group (each coded +1) was investigated. Lastly, the difference between the environmental (coded +1) and the altruistic framing group (coded − 1) regarding eco-driving behavior change was tested exploratively.

The fixed effects of the model explained 4.1% of the variance ($R^2_m$ = .041) while the whole model including the random effect explained 73.6% of the variance ($R^2_c$ = .736). The analysis showed that eco-driving behavior significantly increased from T0 to T2 (see Table 25). The experimental groups did not report significantly different eco-driving behavior at baseline, $t < 1.14$, $p >.260$ (see Table 25). Supporting H3a, it was found that the framing groups reported a significantly stronger increase (average increase for AF was +0.42, for EF +0.43, and for MF +0.36) for eco-driving behavior between T0 and T2 than the control group (average increase for CON was −0.01). The results did not support H3b as there was no significant difference between the intrinsic (environmental and altruistic) and extrinsic (monetary) framing group for eco-driving behavior change (see Table 25). Likewise, no significant difference between the environmental and altruistic framing group for eco-driving behavior change was found (see Table 25).

Table 25

*Results of linear mixed-effects model with user-defined contrasts predicting reported eco-driving behavior (study 4)*

| Random Effects | | | *Variance* | | *SD* |
|---|---|---|---|---|---|
| Subjects (intercept) | | | 0.721 | | 0.849 |
| Residual | | | 0.274 | | 0.523 |
| **Fixed Effects** | **β** | ***t*** | ***df*** | ***p*** | ***95% CI*** |
| Intercept | .00 | 74.74 | 293.71 | .000*** | [4.817, 5.075] |
| Contrast 1: FG vs. CON | .06 | 0.96 | 293.71 | .336 | [-0.146, 0.433] |
| Contrast 2: EF/AF vs. MF | .07 | 1.13 | 293.71 | .261 | [-0.134, 0.499] |
| Contrast 3: EF vs. AF | .02 | 0.35 | 293.71 | .727 | [-0.307, 0.441] |
| Time | .12 | 4.58 | 224.00 | .000*** | [0.149, 0.341] |
| Contrast 1 * Time | .09 | 2.68 | 224.00 | .008** | [0.081, 0.511] |
| Contrast 2 * Time | .01 | 0.32 | 224.00 | .748 | [-0.196, 0.274] |
| Contrast 3 * Time | .00 | -0.12 | 224.00 | .906 | [-0.295, 0.261] |

*Note*. FG = framing groups, CON = control group, EF = environmental framing, AF = altruistic framing, MF = monetary framing.

** $p < .01$. *** $p < .001$.

## 9.4 Discussion

The aim of the present study was to investigate the effects of differently framed eco-driving tips on the worthiness of eco-driving savings, eco-driving intention, and reported eco-driving behavior (change). The tips highlighted different consequences of eco-driving behaviors; i.e., the environmental ($CO_2$ emissions), altruistic (pollutant emissions), or monetary savings potential of implementing each tip. For analyzing the effects of the framed eco-driving tips, a longitudinal online experiment with 402 drivers was conducted. The results of the analyses for every outcome are discussed in the following.

**Effects on worthiness of savings**

Supporting and extending findings of Dogan et al. (2014), the analyses showed that intrinsically (environmentally and altruistically) framed tips outperformed extrinsically (monetarily) framed tips in terms of worthiness of eco-driving savings (which supports H1). Hence, independent of the specific content of the intrinsic interventions (addressing benefits for the environment or the community), this framing method seems to be superior for perceiving eco-driving worth the effort, compared to a framing intervention that highlights only small monetary benefits (Dogan et al., 2014). These findings are in line with the assumptions of the Self-Concordance Model, indicating that framed intrinsic goals might be more successful for pro-environmental attitude change than framed extrinsic goals (Sheldon & Kasser, 1995; Vansteenkiste et al., 2004).

Although it may initially seem surprising that monetary benefits are not highly motivating, this result has been found repeatedly in the literature (Asensio & Delmas, 2015; Dogan et al., 2014; Steinhorst & Klöckner, 2018). Hence, various studies confirm that small monetary benefits cannot sufficiently trigger attitudinal and behavioral changes in diverse domains (e.g., academic performance, health behaviors, pro-environmental behaviors) because the (small) monetary amount is often not considered valuable enough (Gneezy & Rustichini, 2000; Moller et al., 2014; Vansteenkiste et al., 2004). In fact, some of the tips used in the study could only generate cent amount savings that are not even equivalent to the price of a small bread roll. In line with this, Gneezy and Rustichini (2000) conclude from their famous study that practitioners should either "pay enough or not pay at all". However, behavioral consequences addressing meaningful intrinsic benefits (e.g., $CO_2$ emission savings) are considered valuable regardless of whether they are very high or not (Dogan et al., 2014; Gaker et al., 2011).

Therefore, based on the present results, it is assumed that interventions that highlight how to reduce $CO_2$ emissions or pollutants can be helpful in motivating individuals to pursue eco-driving strivings. Although monetary savings are also considered valuable, the present results show that these are not considered as much worth the effort as community and environmental benefits (Dogan et al., 2014).

**Effects on eco-driving intention**

With regard to eco-driving intention, the results showed that the framing groups did not report stronger eco-driving intentions than the control group, which is in contrast to prior expectations and past empirical research (e.g., Dogan et al., 2014; Steinhorst & Klöckner, 2018). Hence, H2a must be rejected. The results showed that individuals in the environmental and altruistic framing group reported slightly higher intention for future eco-driving behavior than individuals in the monetary framing group did. However, this result must be interpreted with caution as it narrowly missed statistical significance. Hence, H2b cannot be considered proven by the results. Nevertheless, the descriptively stronger eco-driving intention of individuals who were assigned to the environmental and altruistic framing conditions is consistent with the results on eco-driving worthiness and is in line with theoretical hypotheses, assuming that intrinsic vertical coherence should result in stronger pro-environmental intentions than extrinsic vertical coherence (Sheldon & Kasser, 1995).

In line with Steinhorst & Klöckner (2018), it is reasoned that the insignificant difference between the control group and the framing groups for eco-driving intention might be due to the fact that all individuals received eco-driving information in the scale items. It could be assumed that for individuals in the control group this information was motivating enough to report high eco-driving intention (see also Dogan et al., 2014). In addition, it could be that most individuals are already aware of the benefits of eco-driving (independent of persuasive messages) and generally report high intentions to implement the behavior when asked (Pampel et al., 2015, 2017). These possible reasons for the insignificant difference in eco-driving intention between the framing groups and the control group may also explain why no *significant* differences between individuals in the altruistic/environmental and monetary framing groups were found.

**Effects on reported eco-driving behavior**

Regarding reported behavior after one month, the results indicate that while individuals in the control group reported no increase for eco-driving four weeks after the first questionnaire, individuals in the framing groups reported a slight increase. Thus, although the framing groups did not report higher short-term intentions after receiving the intervention than the control group (that did not receive any intervention), they subjectively implemented eco-driving more strongly. Hence, H3a was proven by the results. However, individuals who read the community/environmental benefits of eco-driving did not report stronger eco-driving behavior than individuals who read the monetary benefits. Therefore, H3b was not supported by the results. In addition, there was no significant difference in reported behavior between the environmental and altruistic framing group. Therefore, although persuasive messages of every kind influenced medium-term behavior changes, contrary to the initial expectations, interventions with highly valued behavioral consequences ($CO_2$ or pollutant emissions savings) did not influence stronger behavior changes than interventions highlighting behavioral consequences that are considered less worthy (monetary savings).

One reason why community and ecological benefits were considered more valuable than monetary benefits but all framing groups reported an increase in behavior could be that, despite the emphasis on monetary benefits, individuals in the monetary framing group knew about the ecological benefits of eco-driving which motivated them to show eco-driving behavior (see also Dogan et al., 2014; Steinhorst & Klöckner, 2018). Moreover, it could be that highlighting benefits and giving eco-driving information alone is already sufficient for motivating behavior change even if the benefits are not considered valuable by individuals (see for example, informational interventions; Hopper & Nielsen, 1991). Furthermore, it could be possible that although all individuals reported high eco-driving intention after reading the eco-driving information in the questionnaire, an effect known in the literature as the intention-behavior gap (Sheeran & Webb, 2016) occurred for individuals in the control group. Hence, although individuals in the control group had high eco-driving intentions, they struggled to follow through with this striving in the long-term because they were not motivated again.

To conclude, while intrinsic benefits were more motivating for individuals in the short-term, information about eco-driving including highlighted benefits (regardless of content) was important in influencing medium-term behavior change. Consistent with the assumptions of the Self-Concordance Model, it is concluded that strengthening vertical coherence within framing interventions can influence pro-environmental driving behavior change (Sheldon & Kasser, 1995; Unsworth & McNeill, 2017). However, also consistent with the model assumptions, extrinsic vertical coherence is associated with potential negative outcomes, such as reduced perceived worthiness of behavioral effort. Hence, future longitudinal studies should examine whether or not the effects of monetary framing interventions on eco-driving fade over time.

This would not only have important theoretical conclusions but also conclusive practical implications for intervention development.

**Suggestions for future research**

Based on the results, informational interventions highlighting behavioral consequences ($CO_2$, pollutant, or monetary savings) can motivate eco-driving behavior successfully. However, because community and environmental benefits were perceived as worthier than small monetary benefits, it is suggested that highlighting intrinsic benefits is more likely to induce long-term behavior changes. Hence, in line with Dogan et al. (2014), it is recommended that policy makers and marketers should not consider monetary motivators exclusively but should also consider alternative possibilities of motivating pro-environmental behaviors. For example, additionally to communicating the safety risks of speeding on large street billboards, they could display $CO_2$ emission consequences or messages and images that communicate environmental/health consequences of speeding (e.g., destroyed forests, number of asthma cases in a neighboring village). It could also be helpful if in-vehicle assistance systems advise concrete eco-driving behaviors and their potential environmental (e.g., $CO_2$, $NO_X$) savings.

However, the present results, which show that every type of framing can be beneficial, also suggest that individuals may value different behavioral consequences, which is why tailored interventions could be effective. For example, people who deeply care about profits and money may prefer monetarily framed information whereas environmentally concerned people may be more likely to prefer environmentally framed information. Previous research suggests that tailored interventions may be more helpful than one-fits-all solutions (Van den Broek et al., 2017). Hence, future studies should examine the effect of framing interventions tailored to the preferences and characteristics of individuals.

Although the present results are promising and indicate that framing measures can be helpful, it has to be emphasized that rather small effects were found. Although it is possible that the sample size was not large enough, it must also be considered whether the effect of information and highlighted benefits is not very large and may be only of limited impact on actual behavior change. For example, other studies found that pure information or framed behavioral information showed only small effects and often no effects in the long term (Abrahamse et al., 2005, 2007; Sloot et al., 2021). It can be assumed that changing driving behavior is so costly that much stronger interventions such as high monetary or hedonic (e.g., gamified) incentives are more effective (Corcoba Magaña & Muñoz-Organero, 2015; Lai, 2015). At the same time, assuming eco-driving involves high behavioral costs, it is possible that making this behavior easier will be effective for pro-environmental behavior change. Hence, future studies should investigate whether the activation of in-vehicle eco-assist functions can reduce fuel and energy consumption. If this is indeed effective, it should be analyzed how individuals can be motivated to switch them on (Kutzner et al., 2021). Furthermore, future studies should investigate how to remind people of the benefits of an energy-efficient driving style during driving, assuming that most people forget about their intentions in everyday life.

**Limitations and strengths**

Some limitations of the present study need to be discussed in the following. First, at the time of the study, German fuel prices were significantly lower than in previous and subsequent years (ADAC, 2023). Therefore, it could be that the participants did not respond to the monetary framing manipulation since fuel was cheap during the study period anyway. Indeed, studies found that people adjust their driving behavior in times when fuel prices are high (Austin, 2008). Therefore, it could be that monetary framing might be more motivating during times when fuel prices are high.

Furthermore, it should be noted that effects on actual behavior were not examined. Some studies find that intended, reported, and actual pro-environmental behavior can differ (Abrahamse et al., 2009). However, other studies reported that subjectively reported behavior is a good predictor of actual behavior and socially desirable response behavior plays a minor role for pro-environmental behavior (Milfont, 2009). Furthermore, objective measures of eco-driving like fuel consumption come with serious drawbacks, such as being dependent on a number of uncontrollable factors (e.g., weather, traffic conditions).

Another point that should be considered is that the control group did not receive a reminder or any information after the first questionnaire. This has two drawbacks; first, it cannot be ruled out that the medium-term results on behavior change were not simply due to the fact that individuals in the framing conditions were reminded that the study is still going on (and therefore, showed stronger eco-driving efforts) and individuals in the control group were not. Second, sending reminders to the framing conditions could have generated memory effects making eco-driving behaviors more accessible in the memory of the individuals in the intervention conditions, compared to individuals in the control group who received no reminder. Furthermore, it cannot be ruled out that the long-term results were due to demand characteristics of the study. Accordingly, the present study suffers from the possibility that individuals in the intervention groups have driven more fuel-efficiently during the study because they thought they were expected to do so.

In addition, the framing interventions differed in their presentation. For example, environmental and monetary framing emphasized specific numerical examples whereas altruistic framing did not include concrete numerical examples. This was because there is a lack of literature that report numerical pollution reduction values for eco-driving behaviors. Furthermore, $CO_2$ benefits were highlighted in the environmental *and* in the altruistic framing condition but referred to different consequences (i.e., the environment vs. human health). Although these limitations need to be considered, the results are still valuable because benefits of pro-environmental behavior go beyond the environment and one's own benefit. Future research should investigate if other behavioral consequences (e.g., reduced noise emissions) can also positively influence eco-driving.

Additionally, it might be a limitation that the eco-driving tips included the behaviors "avoiding objects that increase aerodynamic drag" and "checking tire pressure regularly". First, it might be that improving the vehicle's aerodynamics was not possible for everyone because participants did not have a roof box or were not on vacation during the time of the study. Furthermore, it is likely that several participants of the study own a vehicle that automatically checks the tire pressure. If this was the case, some participants might have reported high values for these items without having to take a lot of effort. Nevertheless, improving aerodynamics also involves closing the windows and individuals still need to take some effort if they are reminded by the vehicle that the tire pressure is too low. However, to extend the results, future researchers should investigate other eco-driving tips, especially those with large altruistic, environmental, and monetary consequences (e.g., carpooling).

Although these limitations must be taken into account when interpreting the present results, the strengths of the study should also be highlighted. First, the present study used a longitudinal design, which allowed to examine medium-term behavior changes. Researchers highlight the importance of longitudinal designs in the context of pro-environmental behaviors, because it is necessary that individuals change and maintain these behaviors over time (i.e., develop strong habits; Steg & Vlek, 2009). Future studies are encouraged to use longitudinal designs and observe actual behavior in the field to extend the present findings.

In addition, the present study examined a number of multiple framing effects. So far, altruistic framing effects have been neglected in environmental research although altruistic framing could motivate those people who are not convinced of climate change or do not have strong environmental motivations (Unsworth & McNeill, 2017). It is important that future studies make use of a range of different (motivational) intervention techniques and further investigate framing effects in particular, as the (long-term) effects of many (formerly studied) traditional methods (e.g. informational interventions, monetary incentives) are questionable (Abrahamse et al., 2005; Bolderdijk & Steg, 2015; Steg & Vlek, 2009).

**Conclusion**

The transport sector is one of the sectors that needs to change fundamentally in order to make its contribution to climate protection in the future. In this context, new technologies and incentives for mobility alternatives alone are not enough; individuals must also be prepared to adapt their driving behavior. To support individuals with this task, effective and innovative interventions are needed that motivate people to adapt their driving behavior in a way that saves energy or fuel. The present results indicate that environmental and altruistic framing measures can be promising interventions to *motivate* pro-environmental driving behaviors, which is in line with previous studies (Asensio & Delmas, 2015; Dogan et al., 2014; Steinhorst & Klöckner, 2018). However, when it comes to behavior, information about eco-driving behaviors and their positive consequences regardless of content seems to be helpful. Nevertheless, a one-time intervention might be only of minor impact and future studies should analyze if other interventions or combined/tailored interventions have strong and long-lasting effects on actual eco-driving.

# 10 Study 5: Carbon savings, fun, and money: The effectiveness of multiple motives for eco-driving and green charging with electric vehicles in Germany

## 10.1 Introduction

Together, electricity production and transport are responsible for over two-thirds of global $CO_2$ emissions in 2019 (IEA, n.d. b). To address climate change and meet the goals of the Paris Agreement, the EU, as a significant $CO_2$ emitter, has determined far-reaching countermeasures to reduce these emissions. One declared goal is to reduce greenhouse gas emissions from electricity generation by 55 % in 2030 (compared with 1990) and to decarbonize electricity generation until 2050 (EEA, 2023). In addition to this, the European Commission has committed to the goal of reducing transport-related emissions by 90 % in 2050 (European Commission, n.d.).

Accordingly, almost all vehicles must be $CO_2$ neutral by then. Associated subsidies as well as an increased ecological awareness are already leading to a huge demand for electric vehicles (EVs), which will continue to rise in the future (Al-Alawi & Bradley, 2013). However, researchers highlight that the largest share of an EV's lifetime emissions is produced by the electricity required for charging, as long as this electricity is not $CO_2$ neutral (Frischknecht et al., 2018). Therefore, in order to meet the outlined goals, it becomes obvious that EVs must be charged with electricity from renewable sources (green electricity; Degirmenci & Breitner, 2017). Hence, EV owners need to decide in favor of charging stations that offer green electricity. A second solution that contributes to the declared goals of the EU is energy-efficient driving (eco-driving). Eco-driving will remain important with EVs to counteract the waste of valuable resources like green electricity.

Therefore, the desired decarbonization of the energy and transport sector in the future requires numerous changes, which include not only new technologies (e.g., EVs) but also changes in user behavior, such as the acceptance of charging stations providing green electricity (green charging stations) as well as the adoption of energy-efficient driving behaviors (Cattaneo, 2019). Since both using green charging stations and eco-driving may be associated with external costs (e.g., physical effort, cognitive resources, or time losses; see study 3), it is necessary to investigate how to facilitate these behaviors for future EV owners. Therefore, in the present study, it was investigated whether an intervention with informational and contextual incentives encourages people to choose a green charging station and to eco-drive with an EV.

**Green charging**

To make EVs a pro-environmental alternative to the currently dominant internal combustion engine vehicles, they need to be charged with green electricity (Degirmenci & Breitner, 2017). Smart charging can act as a method to integrate volatile green electricity into the power grid and to stabilize the grid when EVs become a mass solution (Daina et al., 2017; Eider et al., 2017; Eurelectric, 2015; Richardson, 2013). However, users need to accept this technology to achieve the described benefits, especially when the smart grid provides green electricity. Therefore, it is the task of psychological research to identify how (future) owners of EVs can be motivated to use green (smart) charging stations. This question arises especially given the fact that the usage of these charging stations may incur behavioral costs (initially; e.g., in terms of effort, time losses etc.).

Previous research reports that charging is influenced by the actual state of charge, dwell time, charging speed, costs, and inconvenience (Jabeen et al., 2013; Lee et al., 2020; Morrissey et al., 2016; Robinson et al., 2013; Wen et al., 2016). Because most individuals charge at home or semi-public stations (e.g., at work), researchers conclude that inconvenience, inflexibility, and monetary costs are the most significant behavioral barriers to public (smart) charging station usage (Jabeen et al., 2013; Kacperski et al., 2022; Lee et al., 2020; Morrissey et al., 2016; Robinson et al., 2013). Indeed, charging at public places, which will become more important in the future (e.g., at shopping centers; Lee et al., 2021), will likely come with behavioral barriers (in terms of time, effort, etc.).

For example, a recent study (Kacperski & Kutzner, 2020) investigated how to influence behavior when green (smart) charging stations require detours because they are not directly on the way but provide excessive green electricity, which a customer needs to use (i.e., for charging an EV). It can also be assumed that charging stations providing renewable electricity require detours because they are not (initially) widely available. In these cases, such stations either require a driving detour (e.g., when charging while waiting) or a walking detour (e.g., when charging while doing another activity; see study 3). For example, it might be the case that individuals want to charge their vehicle when being at work but charging stations providing green electricity are significantly farther away from the workplace than conventional stations (not providing green electricity), leading to a greater walking effort from the station to work when deciding in favor of the pro-environmental charging station. It can be assumed that walking detours are perceived as especially costly because they involve not only a loss of time but also additional physical effort. For example, in study 3, it was found that the greater the walking detour, the less willing people were to opt for a charging station with green electricity.

In detail, in the hypothetical scenario in which a charging station was 15 walking minutes away from a desired destination (i.e., a shopping center), only a minority opted for the green alternative in this study.

To counteract these behavioral costs, previous studies identified several factors that motivate individuals to accept smart and green charging stations, such as financial (Eurelectric, 2015; Franke et al., 2018; Huber et al., 2020; Tarroja & Hittinger, 2021) and socio-environmental aspects (Kacperski & Kutzner, 2020; Schmalfuß et al., 2015; Will & Schuller, 2016). Furthermore, in a field study, individuals emphasized that the acceptance of charging stations that are associated with behavioral costs could be increased by hedonic motivators (i.e., gamification; Schmalfuß et al., 2015). However, although there is previous research on how to motivate green charging behavior, studies are still scarce given the importance and urgency of this topic.

**Eco-driving**

In this study, eco-driving is understood as involving all those operational behaviors (i.e., driving behaviors on the road) that positively influence the energy efficiency of an EV (Sivak & Schoettle, 2012). Eco-driving includes several driving behaviors, such as reducing the use of electrical consumers, accelerating moderately, not driving at extreme speeds, and anticipating traffic flow (Günther et al., 2017; Helmbrecht et al., 2013b; Sivak & Schoettle, 2012). For the present study, eco-driving behaviors that have proven to affect the energy efficiency of EVs were selected (see Appendix C).

Although many drivers know how to eco-drive (see study 1; McIlroy & Stanton, 2017; Pampel et al., 2015; Strömberg et al., 2015) and consider the behaviors to be rather easy to implement (Delhomme et al., 2013), few people eco-drive in everyday life (Nègre & Delhomme, 2017; Pampel et al., 2017). Among other reasons, this seems to be because driving behavior is largely automated, which is why eco-driving requires conscious control and high effort (Barkenbus, 2010; Stavros et al., 2019). In fact, individuals perceive pro-environmental driver behaviors as involving high behavioral costs (Osbaldiston & Schott, 2012). In line with this, studies on the effectiveness of eco-driving interventions have produced mixed results (Beusen et al., 2009; Degraeuwe & Beusen, 2013; Zarkadoula et al., 2007). For example, Af Wåhlberg (2007) found that although an eco-driving training for bus drivers showed strong effects on driving behavior during training, the effects did not transfer into individuals' everyday life. This aligned with other studies showing that the effects of an eco-driving training on behavior could not be translated into long-term pro-environmental driving behavior (Beusen et al., 2009; Degraeuwe & Beusen, 2013).

Hence, because informative training interventions showed only short-term effects on behavior, researchers identified motivational interventions as key (Günther et al., 2017; Ünal et al., 2018). However, it must be taken into account that although some eco-driving behaviors with internal combustion engine vehicles can be transferred to EVs (e.g., driving at moderate speeds; Neumann et al., 2015), new behaviors that have an impact on energy consumption may be unknown to many drivers (e.g., regenerative braking; Cocron et al., 2013). Therefore, information and education about eco-driving behaviors will continue to be important because many future EV drivers are probably inexperienced with the operation of EVs. However, eco-driving information alone might not be enough and interventions should address motivations too so that existing driving habits can be overridden. Furthermore, because most future drivers will be inexperienced with driving an EV, eco-assist features giving real-time feedback (Fors et al., 2015) or influencing consumption directly (Kutzner et al., 2021) are a promising approach to assist individuals with reducing EV energy consumption. In fact, drivers also report that structural approaches like in-vehicle assistance features are preferred over other intervention strategies (Schießl et al., 2013). Hence, the question is: How can we motivate people to turn on these assistance functions and implement eco-driving behaviors while driving an EV?

**Psychological and contextual factors of pro-environmental driver behaviors**

It is obvious that (effortful) pro-environmental behaviors such as eco-driving or charging at stations that require walking detours are influenced not only by environmental beliefs but also by contextual factors (e.g., time, effort, money; Perlaviciute & Steg, 2014; Steg & Vlek, 2009). For example, walking detours may hinder the decision to use a smart charging station that provides green electricity because of the time loss and the high physical effort (see study 3). Similarly, individuals may not eco-drive because they experience pressure from other drivers (e.g., to drive fast; Fleiter et al., 2012; Leandro, 2012). Furthermore, psychological factors such as environmental beliefs, norms, attitudes, and motivations play an important role for pro-environmental behaviors, such as eco-driving (see study 1; Lauper et al., 2015; Ünal et al., 2018) or green charging (Schmalfuß et al., 2015). For example, research found that individuals who are convinced that $CO_2$ emission mitigation is important and the biosphere needs to be protected show stronger pro-environmental behaviors (including eco-driving) than individuals who are less convinced of these aspects (study 1; Ünal et al., 2018). To summarize, psychological and contextual factors need to be considered when investigating high-cost pro-environmental (driver) behaviors (Perlaviciute & Steg, 2014; Steg & Vlek, 2009).

Indeed, several empirical studies in the environmental literature support this assumption. For example, in study 3, it was found that the effectiveness of psychological interventions depended on the behavioral costs (walking effort, monetary benefit) of a green charging decision. In a similar vein, Kacperski and Kutzner (2020) found that both activated environmental beliefs and contextual benefits influenced a green charging decision. In conclusion, there are two important determinants of pro-environmental driver behaviors; psychological and contextual factors. Therefore, individuals need to be convinced of the environmental impact of a behavior and secondly, the behavioral costs of a pro-environmental behavior should not be too high or instead addressed by appropriate interventions (e.g., monetary benefits).

Another important determinant of pro-environmental behaviors that is often largely neglected in environmental research is habit. Researchers indicate that habits may often hinder individuals to behave pro-environmentally (Klöckner & Blöbaum, 2010). For example, people may not drive fuel-efficiently in their daily lives because driving is a largely automated (habitual) behavior that requires a lot of effort to be changed (Pampel et al., 2018). Similarly, charging behavior may be rather habitual. However, researchers point out that especially for new pro-environmental behaviors that occur with the introduction of novel technologies (such as EVs), new habits can be created (Verplanken & Wood, 2006). Hence, when appropriate interventions are used in an early stage of the adoption of new behavioral patterns, individuals can overcome old and create new habits (Verplanken & Wood, 2006).

In conclusion, psychological and contextual factors as well as habits may influence pro-environmental behaviors in general and eco-driving and charging behavior in particular. Therefore, to stimulate pro-environmental behaviors that are associated with behavioral costs, it is critical to consider environmental attitudes and motivations as well as contextual factors (Steg & Vlek, 2009). Using appropriate interventions to address these factors (i.e., interventions that motivate and facilitate pro-environmental behavior) may not only be successful to promote (new) pro-environmental behaviors but also to overcome old and create new habits.

**Interventions for pro-environmental driver behaviors**

Past research has extensively studied which interventions motivate individuals to start and maintain pro-environmental behaviors (e.g., Dogan et al., 2014; Hunecke et al., 2001; Kacperski & Kutzner, 2020; Sloot et al., 2019; Steinhorst & Klöckner, 2018). However, the effects have been mixed so far. For example, as indicated, studies have shown that single informational interventions (interventions influencing knowledge, attitudes, norms, or motivations) were not successful to change rather costly pro-environmental behaviors (Steg & Vlek, 2009). For example, Abrahamse et al. (2009) found that such interventions influenced the intention to reduce car use but not actual car use. Furthermore, in study 3 only small effects of single interventions on high-cost green charging behavior were found.

This has led many researchers to conclude that for high-cost behaviors, which are determined by psychological and contextual factors, interventions addressing multiple motives might be more promising (Steg & Vlek, 2009). For example, Lindenberg and Steg (2007) argue that in situations in which well-being or convenience is significantly reduced, it is not enough that individuals know how and why they should behave pro-environmentally. Likewise, this knowledge is insufficient when individuals want to protect their resources (e.g., money). Instead, in such situations hedonic and contextual factors need to be considered too; for example, by making the behavior more enjoyable or low-cost (Lindenberg & Steg, 2007). Therefore, in these kind of situations, it is suggested to stimulate multiple motives instead of addressing only one (Lindenberg & Steg, 2007). This may also be helpful considering the fact that people have different values and motives and thus, are motivated by different goals (Van den Broek et al., 2017).

Previous studies found that combined interventions that address multiple motives influenced high-cost pro-environmental behavior successfully. For example, Graham et al. (2011) found that combining environmental and cost benefits influenced reductions in car use. Furthermore, Günther et al. (2020) showed that a combination of gamified and financial rewards influenced eco-driving with an EV in a large field study. These effects persisted even after the strategies were removed. Additionally, Kacperski et al. (2022) found in a recent study that a mixed financial-environmental incentive could shift charging behavior to times when higher shares of renewable electricity are in the power grid. Thus, because they address multiple motives and goals, combined interventions may be promising for effortful, not inherently fun pro-environmental driver behaviors. Therefore, in this study, it was aimed to investigate the effectiveness of a combined intervention addressing the normative, hedonic, and gain goal frame for effortful (future) driver behaviors. To achieve this, three intervention techniques were combined that were effective in influencing various pro-environmental behaviors in the past.

First, goal framing was used, which aims at influencing normative attitudes and perceptions by highlighting favorable or unfavorable behavioral consequences (Pelletier & Sharp, 2008). For example, making $CO_2$ savings salient can reinforce the normative goal that, in turn, can motivate pro-environmental behaviors (Avineri & Waygood, 2013; Lindenberg & Steg, 2007). In fact, $CO_2$ framing was shown to influence travel decisions (Avineri & Waygood, 2013; Schrills et al., 2020), eco-driving intentions (Bolderdijk, Steg, et al., 2013; Dogan et al., 2014), electricity saving intentions (Asensio & Delmas, 2015; Schwartz et al., 2015), and the choice of a "green" route with a green charging station along the way (Kacperski & Kutzner, 2020). Hence, providing $CO_2$ emissions information has the potential to promote sustainable transportation decisions although individuals are not fully aware of the magnitude of the emissions savings (Gaker et al., 2011).

However, framing alone showed limited effects on actual behavior (Steinhorst & Klöckner, 2018), especially when the behavior is effortful, such as saving energy or fuel (see study 2; Osbaldiston & Schott, 2012). Hence, goal framing was combined with two other intervention techniques that address the hedonic and the gain goal frame. To address hedonic values and goals, gamification was shown to be a suitable approach. Gamification includes various elements, such as collecting points and displaying scores and leaderboards, or rewarding trophies (Nousias et al., 2019). As outlined before, this method has proven to be effective in promoting eco-driving (Corcoba Magaña & Muñoz-Organero, 2015) as well as energy conservation (Morganti et al., 2017). Furthermore, individuals reported that gamification might be a helpful strategy to influence green smart charging behavior (Schmalfuß et al., 2015).

To address the gain goal frame it can be helpful to provide monetary incentives (Hunecke et al., 2001). Monetary incentives were shown to influence eco-driving of drivers and to motivate individuals to save energy (Bolderdijk et al., 2011; Lai, 2015; Van Der Linden, 2015). Furthermore, studies showed that charging behavior is strongly influenced by monetary costs (Jabeen et al., 2013). For example, most EV owners prefer at home (Jabeen et al., 2013) or free (Robinson et al., 2013) charging. Hence, studies support the assumption that effortful charging behavior (because of detours or reduced flexibility) can be promoted by financial benefits (see study 3).

Overall, previous research indicated that environmental benefits and gamified as well as financial incentives were successful in influencing pro-environmental charging behavior and eco-driving. In addition, single interventions addressing only one motive showed small and diminishing effects, while combined approaches revealed more promising results. Although researchers suggest that combined interventions may be more helpful to change effortful pro-environmental (driver) behavior than single interventions (Steg & Vlek, 2009), studies that design and test such an approach are scarce in current literature. Furthermore, studies that examine the effectiveness of an intervention that addresses normative, hedonic, and monetary motives for driving and charging behavior are scarce. However, as these behaviors gain relevance every year from now on, studies should investigate strategies on how to motivate future EV owners to show these behaviors, because they are (e.g., eco-driving) or might be (e.g., charging) associated with behavioral costs.

**The present study**

Past research indicated that individuals perceive eco-driving as a rather high-cost behavior (Osbaldiston & Schott, 2012); hence, it is unlikely that a majority of individuals eco-drives in their daily life when it is not motivated to do so. Furthermore, as pointed out earlier, green charging stations that are associated with behavioral costs (e.g., walking detours due to insufficient infrastructure) may not be used by a majority of individuals if the costs are not compensated by motivating interventions (Kacperski & Kutzner, 2020). Therefore, without appropriate interventions addressing multiple motives, only a minority will adopt effortful energy-efficient driving activities or choose a green charging station that is associated with personal behavioral costs.

Given that many drivers will switch from conventional to battery-powered vehicles in the future and are unlikely to have a deep understanding of the operation of EVs, it is important to investigate whether these drivers can be motivated to act pro-environmentally when effective interventions are used. This question arises especially in Germany due to the aim of the government to integrate more renewable electricity into the power grid in future years (Klaus et al., 2010). This electricity should be used for electric vehicles to make them a green alternative (Degirmenci & Breitner, 2017) but should also be consumed only sparingly because renewable electricity is highly volatile in supply (Richardson, 2013). Hence, the aim of the present study was to investigate if a combined intervention with informational ($CO_2$ framing), hedonic (gamification), and monetary (reward) elements could trade-off high behavioral costs of a green charging decision and eco-driving behavior in a hypothetical scenario with potential future EV drivers.

For this, an experimental driving study was conducted and a prototypical smartphone-based app was developed that displays charging stations and EV eco-driving tips. In the app, participants of the present study could choose between two charging stations, where they should park and charge an EV after a real-world drive (a high-effort green charging station vs. a low-effort non-green charging alternative) and inform themselves about eco-driving with an EV. To examine the effectiveness of the combined intervention for charging and driving behavior before and during the drive with the EV, individuals were randomly assigned to the intervention or the control group. Individuals in the intervention group were given persuasive normative, hedonic, and monetary information in the app. In detail, participants in the intervention group saw $CO_2$ emission saving potentials that were associated with charging at the two stations and implementing the eco-driving tips ($CO_2$ framing). Furthermore, participants in the intervention group could earn points by making green charging choices (i.e., selecting the charging station that provides green electricity) and implementing eco-driving behaviors during the drive with the EV (gamification). Similarly, financial benefits could be obtained by making green charging station decisions and implementing eco-driving behaviors during the drive (reward). All strategies were combined to address multiple motives. Individuals who were given this persuasive information (i.e., individuals in the intervention group) were compared to individuals who saw no persuasive information (i.e., individuals in the control group) with regard to the charging choice (green vs. non-green) as well as eco-driving interest before and eco-driving behavior during the real-world drive with the EV. It was assumed that individuals accept behavioral costs of a green charging decision and eco-driving more likely when they additionally see the impact of this behavior on the environment ($CO_2$ framing), have fun (gamification), and can personally benefit from the decision/behavior (reward).

Given the positive effects of combined interventions that were outlined above, it was hypothesized that individuals in the intervention group choose the green charging station (i.e., the pro-environmental alternative) that is associated with behavioral costs (i.e., a time loss and physical effort) more often than individuals in the control group (Hypothesis 1). Furthermore, it was hypothesized that people who are assigned to the intervention group are more willing to seek eco-driving information before a real-world drive (Hypothesis 2) and are more likely to implement effortful eco-driving behaviors as evidenced by their energy consumption during a real-world drive, compared to individuals in the control group (Hypothesis 3; see Table 26).

Other variables were integrated into the analysis because they have shown to influence pro-environmental behaviors in the past or were assumed to influence the behavioral outcomes in a way that should be considered. In detail, ecological awareness was integrated into the analysis, because previous studies showed that ecologically aware individuals report higher pro-environmental driver behaviors than individuals who care less about the environment (De Groot & Steg, 2010; Schlüter & Weyer, 2019). Furthermore, the perceived importance of biospheric values, i.e., values about protecting and respecting the environment and nature (De Groot & Steg, 2007, 2008), was integrated into the analysis, because previous research indicated that individuals who prioritize biospheric values behave more pro-environmentally in the transport and energy sector than individuals who value the biosphere to a lesser extent (see study 1; Jakovcevic & Steg, 2013; Poortinga et al., 2004; Schultz et al., 2005). Moreover, the individuals' experience with EVs was integrated into the analysis, assuming that individuals who have past experience with EVs might differ from individuals with no EV experience (e.g., they drive more energy-efficiently or know several eco in-vehicle functions due to past experience). In a similar vein, it was included if individuals already purchase green electricity for their households into the analysis for the charging choice, assuming that individuals who already purchase green electricity might be more willing to choose the green charging station (because they have already committed to choosing green instead of non-green electricity at home) than individuals who do not purchase green electricity at home. In addition, within an exploratory analysis, it was investigated if ecological awareness, the importance of biospheric values, and gender moderated the effect of the intervention condition on the behavioral outcomes, assuming that those individuals who care about the environment and females (past research showed that females behave more pro-environmentally than men do; Dietz et al., 2003; Hunter et al., 2004; Klineberg et al., 1998; Zelezny et al., 2000) are more willing to behave pro-environmentally when the environmental option is highlighted by combined interventions.

## 10.2 Method

**Design**

To test the hypotheses, an experimental driving study was conducted in the period from August 09 to August 27, 2021 in a between-subjects design. Accordingly, participants were randomly assigned to either the intervention group, in which participants were presented with normative, hedonic, and reward information for charging options and eco-driving before a real-world EV drive, or the control group without persuasive information. The study was conducted on the company site of a German vehicle manufacturer (located in the south of Germany) and on public roads. This seemed necessary in the present case as it allowed the participants to experience the real consequences of their decision (i.e., the walking effort when parking and charging the vehicle at the green charging station and the eco-driving effort) and to measure energy consumption in a real-drive situation (i.e., the implementation of eco-driving tips) while still largely controlling the experimental conditions.

In the study, all participants were asked to select one out of two charging stations before the real-world drive with the EV (via the smartphone app). One of these stations was significantly farther away from an after-drive destination (i.e., the green charging station) than the other (i.e., the non-green alternative). If the participants were interested, they could choose whether or not to inform themselves about eco-driving behaviors in the app before the drive (i.e., request eco-driving tips). This knowledge could later be used to eco-drive with the EV on public roads. However, only half of the participants (i.e., participants in the intervention group) were additionally motivated to choose the green charging station and to display and implement eco-driving tips by receiving $CO_2$ emission information and having the possibility to collect points that provide financial benefits and help to do well in an after-drive ranking.

As dependent variables, it was measured if participants selected the green or the non-green charging station. Furthermore, it was measured how many eco-driving tips participants requested in the app. Additionally, it was measured if individuals implemented the tips during the real-world drive by measuring their energy consumption (see Table 26).

Participants were recruited via a company-owned participants panel of the vehicle manufacturer. All participants of this panel reside in Germany. The study was disguised as an opportunity to drive a modern battery-powered vehicle. The study lasted a maximum of 90 min and the participants received an expense allowance of €50. All participants participated voluntarily, the data was analyzed anonymously, and the study was approved by an internal ethics committee.

Table 26

*Dependent variables, experimental groups, and hypotheses (study 5)*

| Dependent variable | Intervention group | Control group | Hypothesis |
|---|---|---|---|
| **Charging decision**<br><br>*Low-effort non-green charging station*<br>*vs.*<br>*High-effort green charging station* | - $CO_2$ emission information for green and non-green charging<br>- Earn points for green but not for non-green charging<br>- Earn reward for green but not for non-green charging | No additional information | 1) Individuals in the interventio group choose the effortful greei charging station more often thai individuals in the control group |
| **Eco-driving interest**<br><br>*0-8 requested eco-driving tips* | - $CO_2$ saving information for implementing the tips<br>- Earn points for implementing the tips<br>- Earn reward for implementing the tips | No additional information | 2) Individuals in the interventio group request more eco-driving than individuals in the control group |
| **Eco-driving behavior**<br><br>*Energy consumption during a real-world drive* | - | - | 3) Individuals in the interventio group show stronger eco-drivin behavior indicated by their low energy consumption during a re world drive than individuals in control group |

**Participants**

Before conducting the study, a power analysis was calculated for the logistic regression of the binary charging decision (i.e., green vs. non-green) in G*Power (Faul et al., 2007) to determine the minimum sample size. A medium effect (*OR* = 3.24) was expected based on data of a similar study (Kacperski & Kutzner, 2020), using α of .05 and a power of .80. The analysis yielded a sample size of at least 90 participants, which was the minimum sample size that was aimed to be reached.

Based on information in the participants database (i.e., information that participants entered when they registered in the participants panel), no participants who owned vehicles with an electric drive system and drove <3,500 km annually were invited. These criteria were selected due to the fact that it was aimed to recruit possible *future* EV owners that are yet rather unexperienced with these vehicles and thus, can develop *new* behaviors. Furthermore, because the study was a driving study, it was aimed to recruit only safe drivers that drive regularly.

In total, 103 participants were invited. Based on predefined exclusion criteria, participants with poor German language skills and those who submitted an incomplete questionnaire or encountered technical problems during the study were excluded ($n$ = 4). Participants who indicated in the manipulation control questions that there were only conventional charging stations on the company site were also excluded ($n$ = 5). These participants were excluded, assuming that they did not believe that some of the charging stations could charge intelligently with green electricity. Hence, this question was asked to ensure that participants believed that the two charging stations that they could select in the app (i.e., the green smart charging station and the conventional charging station providing non-green energy) differed regarding their functionality and provided electricity (which was not actually the case).

The final sample consisted of 94 participants, of which 47 were in the intervention group and 47 were in the control group. The participants were on average 40.3 years old (*SD* = 12.5, Range = 19–59; 50 % female). 48.9% of the participants had a university degree. Participants held a valid driver's license for an average of 22 years (*SD* = 12.0) and drove an average of 21,223 km annually. Furthermore, 59% of participants indicated that they had past usage experience with EVs. There were no sociodemographic differences between individuals in the intervention and control group ($|t| < 0.13$, $p > .877$; $|\chi^2| < 9.45$, $p > .221$).

**Procedure**

After arriving at the laboratory, the participants completed a brief pre-survey on sociodemographic data. They then received information about green smart charging and the smartphone application that displays charging stations and EV eco-driving tips. Participants were told that this was a prototypical app tested for future market introduction. All participants (i.e., participants in the intervention and control group) were informed that the app displays smart and conventional charging stations on the company site. Participants were told that to select a charging station in the app, they need to enter the arrival and departure time and location as well as the desired state of charge at departure. Moreover, participants received the information that after doing this, the app displays which charging stations are available, how far they are away from the destination they want to get to, when the charging process is completed, and with which electricity the vehicle is charged (see Fig. 15). Furthermore, all participants were informed that they could display eco-driving tips in the app and that the app was intelligently linked to the vehicle, allowing it to track and evaluate driving patterns and settings (e.g., energy consumption, state of charge). However, only participants in the intervention group were informed that the app additionally displays how much $CO_2$ is produced during the electricity generation of the charged amount and how much $CO_2$ can be saved by implementing the eco-driving tips. They also received the information that they could collect points when they charge at specific charging stations or implement eco-driving tips. They were informed that these points are counted and evaluated within a ranking after the study. Furthermore, they were informed that they could gain monetary rewards when they collect points.

After being presented with the app information and instructions, all participants received a safety briefing and subsequently entered the EV for a real-world drive on public roads. Before starting the trip, participants were handed a smartphone with the opened prototypical app. In this app, they had to choose one out of the two charging stations, at which they had to park and charge the vehicle after the drive. All participants saw two charging stations. One of these was associated with only a low after-drive walking effort (back to the laboratory; i.e., 0.5 walking minutes) but did not provide electricity form 100 % renewable sources (i.e., the low-effort non-green charging station). The other one was associated with a significantly higher after-drive walking effort (10 walking minutes) but provided green electricity (i.e., the high-effort green charging station; see Fig. 15). After selecting a charging station, participants could request up to eight eco-driving tips in the app or not. After each tip, participants could either start the trip or display the next tip. After choosing the charging station and displaying eco-driving tips or not, participants handed the smartphone back to the experimenter. After this, participants could adjust their seating position and set everything in the vehicle the way they wanted (including turning on eco assistance functions, of which they were informed about when they requested the eco-driving tips). The experimenter did not inform the participants about the functions of the vehicle but assisted with the setting if the participants needed help. This was followed by a 20-minute driving task with the battery electric vehicle under the guidance of the experimenter. After the drive, the participants parked the vehicle at their chosen charging station.

Due to internal safety regulations, participants were not allowed to charge the vehicle themselves (which they did not know at the time of their decision), so they were told that an instructed experimenter would do so. After this, the participants and the experimenter walked back to the laboratory. Once back at the lab, participants filled out a follow-up questionnaire. In the end, they answered the manipulation control question (i.e., the question whether they believed that the charging stations that were displayed in the app differed regarding their functionality and provided electricity). Finally, participants were informed about the purpose of the study and participants in the intervention group were informed that the collected points were not tracked; hence, there was no evaluation and comparison to other study participants (i.e., no ranking). Furthermore, all participants (i.e., participants in the intervention and control group) were informed that they would receive the maximal achievable amount that was possible by selecting the green charging station and implementing all eco-driving tips (which was €5) irrespective of their charging decisions and eco-driving behavior due to ethical reasons of fairness.

**Materials**

**Smartphone application**

Using Microsoft Office Power Point, a prototypical smartphone application was developed in the form of a click dummy, which could be displayed on a smartphone and appeared real and functional due to the activated buttons. Past studies showed that smartphone applications are useful for entering charging information for smart charging (Kacperski & Kutzner, 2020; Schmalfuß et al., 2015) and real-world examples show that these applications are also popular for providing eco-driving tips and feedback (Energypedia, n.d.). In the application, participants had to choose their preferred charging station before driving on public roads. Before the participants were asked to choose a charging station at which the vehicle was to be fully recharged after the drive, they saw the start screen with information that was preset by the experimenter and hence, could not be changed (see Fig. 14). The start screen indicated that the EV should be charged to 100 % (i.e., 100 % state of charge at departure) and that 10 % should be charged as fast as possible (i.e., the safety buffer due to possible delayed charging at the green *smart* charging station; Schmalfuß et al., 2015).

After reading the preliminary information, the participants were shown a list of two charging stations with the conventional charging station (“E-Charge Station”) displayed first because it was located directly in front of the laboratory (0.5 after-drive walking minutes). This charging station supplied the EV with electricity from the German electricity mix, which is not $CO_2$ neutral, indicating that this station was the non-sustainable option (Umweltbundesamt, 2020). Below, the participants were shown the green charging station (“GreenCharge Station”), which was further away from the lab (10 walking minutes) and supplied the vehicle with electricity from renewable energy sources (100 % green electricity), which is why this option represented the pro-environmental alternative (see Fig. 15).

After the participants chose a charging station, they could decide whether to have eco-driving tips displayed or to start the trip directly. If participants selected the eco-driving tips, they could display up to eight tips (see Fig. 16 and Appendix C for the full list of tips).

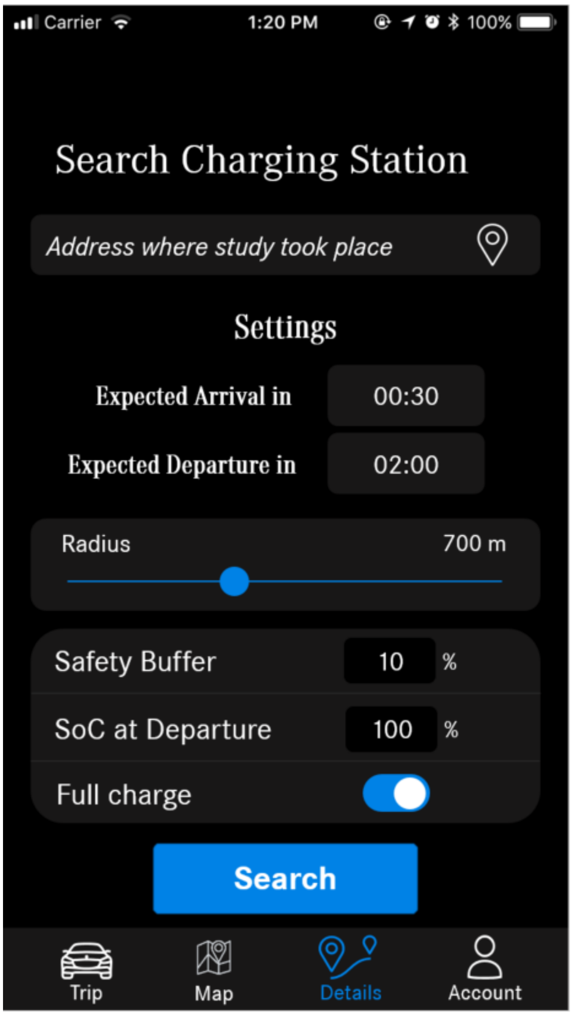
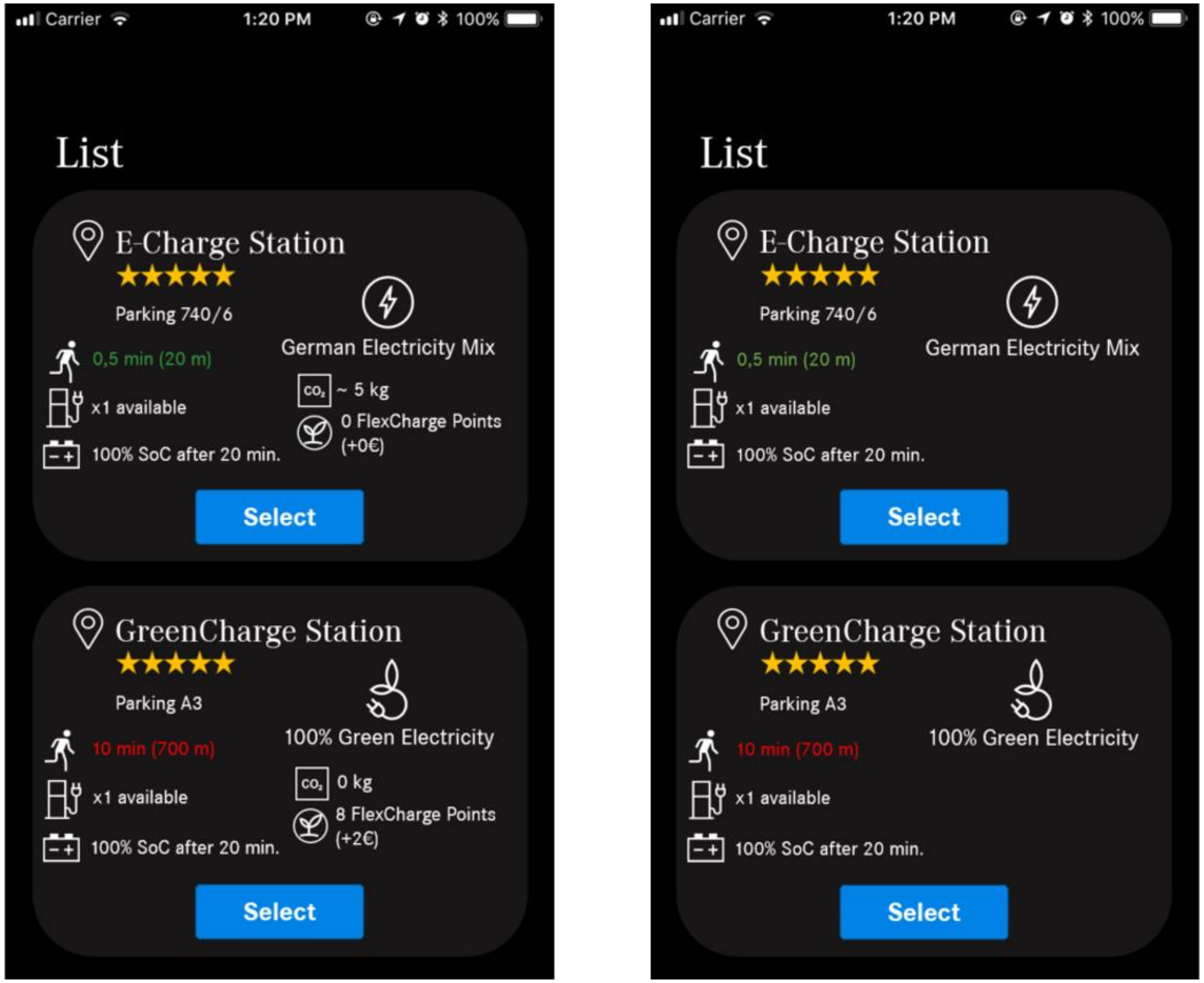


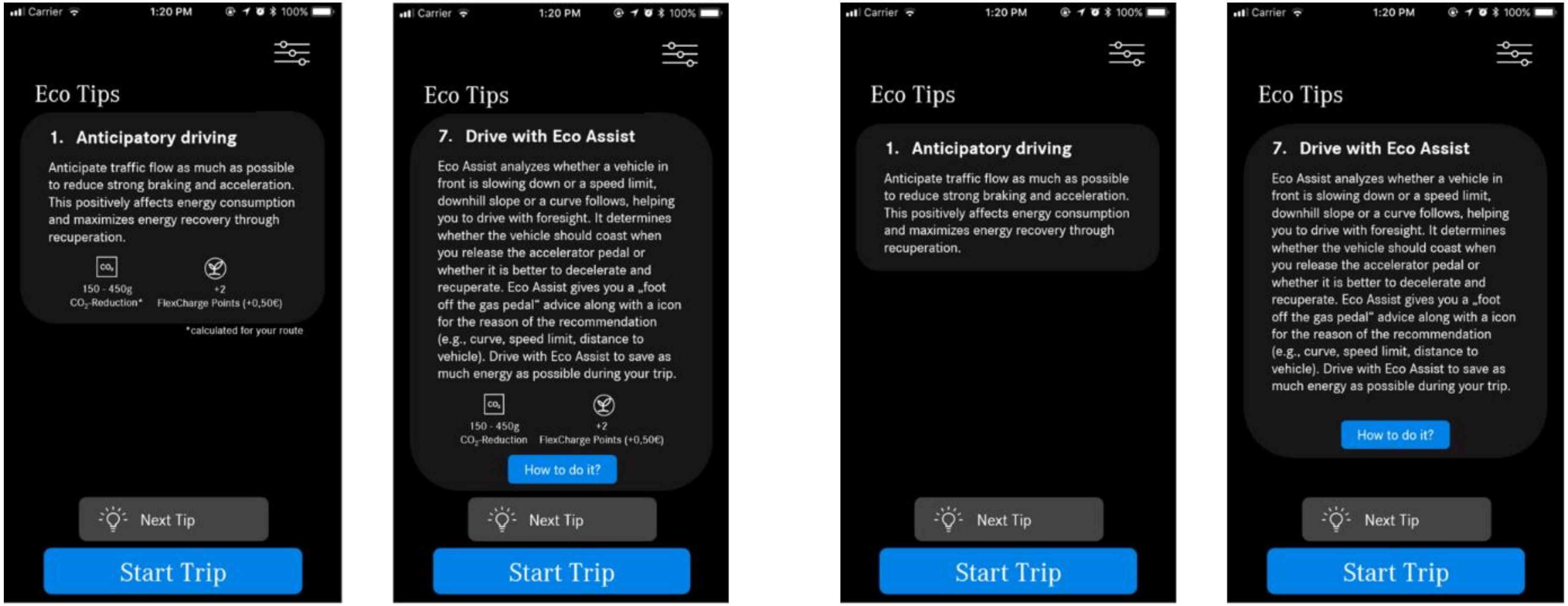

*Figure 14.* Default settings for searching a charging station in the smartphone app (study 5).

*Note.* The electric vehicle should be charged to 100% SoC (i.e., State of Charge). This information was displayed on an IPhone SE.




(a) (b)

*Figure 15*. Presented charging station lists in the prototypical smartphone app for (a) the intervention group and (b) the control group (study 5).




(a) (b) (c) (d)

*Figure 16.* Exemplary eco-driving tips (i.e., tip 1 and 7) in the prototypical smartphone app for (a) + (b) the intervention group and (c) + (d) the control group (study 5).

**Intervention**

Participants were randomly assigned to either the intervention or the control group. Participants who were assigned to the intervention group were nudged toward pro-environmental choices by persuasive incentives. In detail, participants saw how much $CO_2$ is generated during electricity production of the charged amount at the two charging stations and the $CO_2$ emissions saving potential for implementing the eco-driving tips (i.e., $CO_2$ framing). In addition, the participants were informed in the pre-questionnaire that they could collect so called “FlexCharge” points in the app and that the collected amount of points was compared in a ranking with the performance of other study participants after the drive (i.e., gamification). Because individuals thought that the vehicle tracked and evaluated the individuals’ driving patterns, it was ensured that participants thought that the points they scored could be tracked. In addition, financial benefits could be achieved by collecting these points. One point was equivalent to €0.25 (i.e., reward). The participants were informed that the collected monetary benefits were paid out with the allowance after the study.

For the charging decisions, participants were shown how much $CO_2$ was produced during electricity generation, which was 5 kg for the conventional charging station and 0 kg for the smart charging station (because electricity was $CO_2$-neutral). For the green smart charging decision, eight “FlexCharge” points and €2 could be obtained, which corresponded to the amount previous research used for smart charging decisions (Kacperski & Kutzner, 2020; see Fig. 15). For the conventional charging station, participants could not receive any points or financial reward.

There were varying numbers of points (and thus, financial rewards) to be gained for performing the eight eco-driving tips. Higher points corresponded to behavior that was of higher impact on energy consumption (and the environment). Table A1 displays the eco-driving behaviors that were displayed in the smartphone app and the displayed $CO_2$ saving potential as well as the corresponding amount of points and monetary reward that was achievable by implementing the respective tip. The $CO_2$ saving estimations for the eco-driving tips were based on recent research on the saving potential for the selected eco-driving behaviors (see Table A1).

Participants in the control group saw the same app visualizations but no persuasive information. Hence, participants in this group only knew that one charging station charged the vehicle with green electricity and the other not, and that one was closer to the after-drive destination (i.e., the laboratory) than the other. Furthermore, participants in the control group could also display eco-driving tips but they did not receive any other persuasive information. Hence, both groups had the same knowledge about the app and could display the same information but only individuals in the intervention group additionally were informed about persuasive incentives (see Figs. 15 and 16).

**Drive task**

All participants drove the same 12 km route on public roads that was preset in the navigation system. Participants drove an electric sport utility vehicle (SUV; WLTP = 21.7 kWh/100 km). The route took around 20 min and included built-up and rural stretches and a short stretch on the highway. The EV has three eco functions that assist drivers with energy-efficient driving behaviors, of which participants were informed if they displayed the eco-driving tips (i.e., eco score, eco assist, eco mode; see Appendix C). However, the individuals could also know about these functions if they knew the vehicle's equipment.

Participants who activated the *eco score* assistance function received feedback in the vehicle's dashboard about the driver's energy-efficient driving style with respect to three criteria: acceleration, steady driving, and sailing. The parameters are displayed as progress bars, 100 % colored green when people drive with maximum energy efficiency. Likewise, the display indicates how many bonus kilometers one has already achieved by driving energy-efficiently.

If participants drove with *eco assist* activated, they were given instructions on driving behaviors in the vehicle's dashboard depending on the situation. The in-vehicle assist system investigates whether a vehicle ahead is slowing down, a speed limit is approaching, or a downhill slope or curve is following, and accordingly gives instructions to release the accelerator pedal and the reason for this recommendation. Depending on the situation, the vehicle then decelerates and recuperates or sails.

The activated *eco mode* automatically reduces the performance of certain functions (e.g., acceleration, air conditioning) and the haptic accelerator pedal gives feedback when the optimal speed is reached. All systems (i.e., eco score, eco assist, eco mode) could be activated by all participants (including participants in the control group) before (or during) the drive; however, the systems were not activated when the participants got into the vehicle (i.e., they were not activated by default). Because the experimenter accompanied the participants during the drive, it could be noted if participants switched on any of these systems. All systems could be activated independently (i.e., individuals could activate all, only a few, or none of the three systems). The experimenter did not inform the individuals about these systems but assisted them if they wanted to activate these (e.g., after they read about these in the app or knew about them without prior information).

**Measures**

After the drive, participants returned to the laboratory on the company site and completed a follow-up questionnaire. This questionnaire measured, among other things, the following variables that were relevant for the present study.

*Ecological awareness.* Participants were asked about their ecological awareness using a validated scale (Schlüter & Weyer, 2019). The scale measures individuals' awareness of ecological issues (e.g., "Currently, most people behave with little environmental awareness.") on a 7-point Likert scale (1 = *strongly disagree* to 7 = *strongly agree*). One item was omitted because there was the concern that participants would respond to it with strong reactance ("Environmental precautions should be forced even if they cause job losses."). The scale indicated acceptable reliability (see Table 27). Two items were recoded so that higher scores reflected higher ecological awareness.

*Biospheric values.* For measuring the participants' perceived importance of biospheric values, a value scale was used that was developed and validated by previous research (De Groot & Steg, 2007, 2008; Steg, Perlaviciute, et al., 2014). Participants had to indicate how important four biospheric values are for them as "guiding principles in their lives" on a 9-point Likert scale (−1 = *as opposed to my guiding principles*, 1 = *not at all important* to 8 = *extremely important*; e.g., "Preventing pollution: protecting natural resources"). Internal consistency of the biospheric scale was high (see Table 27).

*Further independent variables.* Participants were asked whether they currently purchase green electricity for their household on a binary scale (0 = *no*, 1 = *yes*). Similarly, participants were asked if they have had any usage experience with EVs in the past on a two-item scale (0 = *no*, 1 = *yes*).

*Dependent variables.* As dependent variables, the charging decision, the number of requested eco-driving tips, and the participants' energy consumption during the drive were measured. The charging decision was binary (0 = *conventional charging choice*, 1 = *green charging choice*) that the experimenter noted based on the information in the app. Also based on the information in the app, the experimenter noted the number of tips that participants requested (0–8). By programming the click dummy app accordingly, the experimenters were able to see on the last landing page of the app which charging station was selected by participants and how many tips the participants requested (however, this information was encrypted so that individuals did not know what it meant). Hence, when the participants handed the smartphone back to the experimenter before the ride, this information could be read and noted on a data sheet. After the drive, the experimenter read the energy consumption for the route, which was specified in kilowatt-hours per 100 km (kWh/100 km), from the vehicle display and reset the settings for the next participant.

As a combined intervention was used, a question was included asking participants who selected the green charging station about the most persuasive content of the intervention. This was intended to identify which intervention technique could have been most successful to convince individuals to choose the green charging station. As answer options, participants could select $CO_2$ framing, gamification, and reward (multiple choice possible).

**Statistical analysis**

The statistical analysis was calculated in R (R Core Team, 2020). For the first hypothesis, a logistic regression model (binomial family) using the glm command from the lme4 package was computed (Bates, Mächler, et al., 2015). Five main effects were integrated: experimental group (dummy coded; 1 = *intervention group*, 0 = *control group*), ecological awareness, biospheric values, EV experience, and purchase of green electricity. The *z*-value with associated *p*-value and odds ratio (*OR*) with associated 95% confidence interval (*95% CI*) are reported.

Due to highly skewed count data for the eco-driving tips (i.e., a high number of zero requested tips; see Table 28), a hurdle regression using the pscl package was used (Jackman, 2007), which predicted the data better than a negative binomial regression ($AIC_{NegativeBinomialRegression} = 449.14$, $AIC_{HurdleRegression} = 222.27$). A hurdle regression models the results for a variable in two parts. The first part models the likelihood of getting the value 0 or larger counts (i.e., the zero hurdle model; probit model) and the second part models the likelihood of getting non-zero (positive) values (i.e., the count model; logit model). Both models can be interpreted separately but are the result of one analysis (Zeileis et al., 2008). Four main effects were included: experimental group (dummy coded; 1 = *intervention group*, 0 = *control group*), ecological awareness, biospheric values, and EV experience. For each effect, the *z*-values with associated *p*-values (one-tailed) and the *OR* with associated *95% CI* are reported.

For the prediction of energy consumption, a linear multiple regression with five main effects was calculated: experimental group (dummy coded; 1 = *intervention group*, 0 = *control group*), number of requested eco-driving tips, ecological awareness, biospheric values, and EV experience. For each effect, the *t*-values with associated *p*-values (one-tailed), the β-value and the *95% CI* are reported.

Furthermore, for every outcome, the results of the exploratory analyses are reported, in which it was investigated if ecological awareness, biospheric values, or gender moderated the effect of the intervention on the dependent variables. Prior to the analysis, it was checked if the data met the preconditions of calculating the regression models. Inspecting the visual plots, no violation of homoscedasticity or normality of residuals for the analyses on eco-driving interest and behavior was found. Furthermore, no violation of multicollinearity ($r$ < .80) for the variables that were entered in the analyses was found (see Table 27).

Table 27

*Descriptive statistics and zero-order correlations of the main variables (study 5)*

| Predictor | α | Min | Max | *M* | *SD* | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Ecological awareness | .70 | 2.33 | 7.00 | 5.11 | 0.89 | | | | | | |
| 2. Biospheric values | .86 | 1.25 | 8.00 | 6.60 | 1.32 | .44** | | | | | |
| 3. EV experience | - | 0[1] | 1[2] | 0.59 | - | -.10 | .10 | | | | |
| 4. Green energy purchase | - | 0[1] | 1[2] | 0.60 | - | .01 | .09 | .14 | | | |
| 5. Green charging choice | - | 0[1] | 1[2] | 0.51 | - | .42*** | .29** | .08 | .06 | | |
| 6. Eco-driving tips | - | 0 | 8 | 1.71 | 3.16 | .34*** | .27** | .13 | .06 | .24* | |
| 7. Energy consumption (in kWh/100 km) | - | 21.40 | 30.60 | 24.34 | 1.67 | -.16 | .07 | .02 | -.04 | -.01 | -.22* |

*Note*. *N* = 94. EV = Electric vehicle.

[1] no. [2] yes.

* *p* < .05. ** *p* < .01. *** *p* < .001

## 10.3 Results

**Descriptive statistics**

Table 27 shows descriptive statistics and correlations for the main variables of the study. As shown, participants reported high ecological awareness and high personal importance of biospheric values. Although both variables were moderately correlated, the correlation (being <.80; VIF = 1.24) does not indicate severe multicollinearity, which is why both variables were integrated into the regression analyses. Table 27 further indicates that 59% of the participants had past usage experience with an EV and 60% of them purchased green electricity for their own households. Regarding the dependent variables, it can be seen that around half of the participants opted for the green charging station. Furthermore, participants requested an average of 1.7 EV eco-driving tips (*SD* = 3.16) and had an average energy consumption of 24.34 kWh/100 km (*SD* = 1.67), which is moderately high based on the EV the participants were driving (ADAC, 2022).

Looking at the correlations, it is noticeable that ecological awareness and biospheric values were positively associated with the decision for the green charging station. The usage experience with EVs and the purchase of green electricity for one's own household showed only a small correlation with this decision. The number of tips that participants requested in the app correlated with ecological awareness and the importance of biospheric values with low to moderate strength. Again, there was little correlation between EV experience and the number of requested tips while the smart charging decision showed a small correlation with the amount of requested tips. Regarding energy consumption, it is noticeable that the correlations were largely negative. It must be noted that a lower consumption is desirable in terms of environmental friendliness. Table 27 shows that ecological awareness correlated negatively with energy consumption. Similarly, eco-driving tips correlated negatively with energy consumption while the other correlations were close to zero.

Table 28 displays that the individuals in the intervention and control group did not significantly differ for the variables that were additionally added into the regression analysis. Hence, individuals in both groups had similar high ecological awareness. Furthermore, participants in both groups rated the importance of biospheric values highly and had only slightly different EV experience. Likewise, there was only a slight difference between individuals in both groups regarding the purchase of green electricity for one's own household. Regarding the dependent variables, it can be seen that 60% of the intervention group and 43% of the control group chose the smart charging station. Moreover, participants from the intervention group requested 1.0 eco-driving tip more than participants in the control group.

Differences in energy consumption are hardly evident between the two groups. Furthermore, Table 28 displays that only few participants switched on the eco assistance systems of the vehicle. However, individuals in the intervention group (who also requested more tips) switched on the eco systems slightly more often than individuals in the control group.

Table 29 displays that individuals who drove with and without activated assistance systems had similar consumption after the trip. However, when the assistance systems were switched on, energy consumption was slightly lower (this needs to be taken with caution, because this finding was not validated by inferential statistics).

Table 28

*Means (or rather relative frequencies for binary variables) and standard deviations (in brackets) of independent and dependent variables for the intervention and control group (study 5)*

| | | | Intervention group | Control group |
|---|---|---|---|---|
| Variable | Min | Max | *M* | *M* |
| Ecological awareness | 2.33 | 7.00 | 5.14 (0.77) | 5.07 (1.01) |
| Biospheric values | 1.25 | 8.00 | 6.62 (1.23) | 6.58 (1.41) |
| EV experience | 0[1] | 1[2] | 0.55 | 0.62 |
| Green energy purchase | 0[1] | 1[2] | 0.64 | 0.55 |
| Green charging choice | 0[1] | 1[2] | 0.60 | 0.43 |
| Eco-driving tips | 0 | 8 | 2.21 (3.37) | 1.21 (2.87) |
| Energy consumption (in kWh/100km) | 21.40 | 30.60 | 24.40 (1.52) | 24.28 (1.82) |
| Eco score activation | 0[1] | 1[2] | 0.13 | 0.02 |
| Eco assist activation | 0[1] | 1[2] | 0.09 | 0.04 |
| Eco mode activation | 0[1] | 1[2] | 0.19 | 0.00 |

*Note*. $N = 94$. EV = Electric vehicle.

[1] no/off. [2] yes/on.

Table 29

*Means and standard deviations for energy consumption when eco functions were on vs. off (study 5)*

| | Energy consumption when on | | Energy consumption when off | |
|---|---|---|---|---|
| Eco systems | *M* | *SD* | *M* | *SD* |
| Eco score | 22.86 | 1.39 | 24.46 | 1.64 |
| Eco assist | 23.45 | 1.44 | 24.40 | 1.67 |
| Eco mode | 23.54 | 1.62 | 24.42 | 1.66 |

*Note*. $N = 94$.

**Hypothesis testing**

**Charging choice**

The results of the mixed effects logistic regression predicting the charging decision showed that one variable significantly predicted the green charging decision. Participants with high ecological awareness chose the green charging station significantly more often than individuals with lower ecological awareness. This effect was of medium strength, $z = 3.18$, $p = .001$, $OR = 3.23$, *95% CI* [1.651; 7.124]. However, Table 30 displays that participants from the intervention group chose the green charging station not significantly more often than participants from the control group did, $z = 1.79$, $p = .073$, $OR = 2.39$, *95% CI* [0.938; 6.441]. The other variables also had no significant effect on the green charging decision (see Table 30).

Checking the interaction effect between ecological awareness, biospheric values, gender and the experimental condition exploratively indicated that neither of these variables moderated the effect of the intervention on green charging, $|z| < 0.26$, $p > .798$. Furthermore, no effect of gender on the charging choice was found, $z = -0.19$, $p = .851$. Thirty-five participants voluntarily stated the most persuasive content of the intervention for choosing the green charging station. 88.6% of the participants indicated that the $CO_2$ benefits (i.e., $CO_2$ framing) were most convincing for choosing the green charging station ($n = 31$). Ten participants (28.6%) reported that collecting "FlexCharge" points to do well in the ranking (i.e., gamification) was most persuasive for choosing the green charging station, while nine participants (25.7%) reported that the monetary benefits (i.e., reward) were most persuasive to choose green charging.

Table 30

*Parameter estimates of logistic regression predicting green charging (study 5)*

| Predictor | *z* | *p* | *OR* | *95% CI* |
|---|---|---|---|---|
| Intercept | -3.82 | .000 | 0.00 | [0.000; 0.013] |
| Experimental group | 1.79 | .073 | 2.39 | [0.938; 6.441] |
| Ecological awareness | 3.18 | .001** | 3.23 | [1.651; 7.124] |
| Biospheric values | 0.90 | .366 | 1.21 | [0.813; 1.888] |
| EV experience | 1.30 | .192 | 1.88 | [0.731; 5.001] |
| Green energy purchase | 0.11 | .916 | 1.05 | [0.406; 2.700] |

*Note*. $N = 94$. EV = Electric vehicle.

** $p < .01$.

**Eco-driving tips**

For the number of displayed eco-driving tips, the calculated hurdle regression shows that there are significant effects for the zero hurdle model but not for the count model. Therefore, the results in Table 31 for the zero hurdle model indicate that the chance of having at least one tip displayed was higher for participants in the intervention group than for participants in the control group, $z = 2.38$, $p = .018$, $OR = 4.00$, *95% CI* [1.274; 12.538]. This effects was of medium strength. Similarly, the chance of displaying at least one tip was higher for participants with high ecological awareness than for participants with lower environmental awareness, $z = 2.99$, $p = .003$, $OR = 4.00$, *95% CI* [1.612; 9.912]. The other variables showed no significant effects. None of the variables predicted the count data (see Table 31; Count model).

In the context of the explorative analysis, the results indicate that ecological awareness, biospheric values, and gender did not moderate the intervention effect neither for the zero hurdle model, $|z| < 0.45$, $p > .656$, nor for the count model, $|z| < 1.26$, $p > .207$. Furthermore, there was no effect of gender on the number of displayed eco-driving tips neither for the zero hurdle, $z = -1.79$, $p = .074$, nor for the count model, $z = 0.37$, $p = .713$.

Table 31

*Parameter estimates of hurdle regression predicting amount of requested eco-driving tips (study 5)*

| Predictor | *z* | *p* | *OR* | *95% CI* |
|---|---|---|---|---|
| Count model coefficients | | | | |
| Intercept | 2.10 | .036* | 0.00 | [1.132; 33.929] |
| Experimental group | -1.24 | .216 | 0.81 | [0.579; 1.131] |
| Ecological awareness | -0.43 | .670 | 0.94 | [0.691; 1.268] |
| Importance of biospheric values | 0.39 | .670 | 1.05 | [0.824; 1.335] |
| EV experience | 1.65 | .093 | 1.36 | [0.944; 1.960] |
| Zero hurdle model coefficients | | | | |
| Intercept | -4.09 | .000*** | 0.00 | [0.000; 0.002] |
| Experimental group | 2.38 | .018* | 4.00 | [1.274; 12.538] |
| Ecological awareness | 2.99 | .003** | 4.00 | [1.612; 9.912] |
| Importance of biospheric values | 1.36 | .175 | 1.54 | [0.826; 2.870] |
| EV experience | 0.82 | .414 | 1.57 | [0.530; 4.677] |

*Note*. $N = 94$. EV = Electric vehicle.

* $p < .05$. ** $p < .01$. *** $p < .001$.

**Energy consumption**

For energy consumption, a linear multiple regression was calculated including all variables reported above. This regression model was not statistically significant, $F(5, 88) = 1.86$, $p = .109$. However, although the global model was not significant, the results of the regression indicated that the amount of requested tips significantly predicted energy consumption with low strength, $t(88) = -2.08$, $p = .040$, $\beta = -0.23$, *95% CI* [-0.240; -0.006]. The other variables showed no significant effect, $|t| < 1.79$, $p > .078$. This is why a backward stepwise linear regression model was applied to identify possible predictors for energy consumption. For this, the train() function from the caret package (Kuhn et al., 2007) and 10-fold cross-validation to estimate the average prediction error (RMSE) of each of the possible five models were used. This metric was also used to identify the best model; hence, the model that minimizes the RMSE. For an optimal and simple model, this procedure suggested to include only one variable, which was the amount of requested eco-driving tips. Therefore, solely the amount of displayed tips was included. The regression model was significant, $F(1, 92) = 4.70$, $p = .033$, indicating that the amount of tips significantly predicted energy consumption with a low effect size, $t(92) = -2.17$, $p = .033$, $\beta = -0.22$, *95% CI* [-0.223; -0.010].

The interaction effects between experimental condition and ecological awareness, biospheric values, as well as gender were again not statistical significant, $|t| < 1.29$, $p > .203$. Furthermore, the main effect of gender on energy consumption was not statistically significant, $t(84) = -0.08$, $p = .935$.

## 10.4 Discussion

Because single interventions have often shown only limited effects on effortful pro-environmental behaviors in the past (Sloot et al., 2021; Steinhorst & Klöckner, 2018), the present experimental study examined the effectiveness of a combined intervention (addressing multiple motives) on moderate- and high-cost pro-environmental tactical (choosing a charging station) and operational (eco-driving) driver behaviors. For this, it was investigated if a combined intervention promotes pro-environmental decisions of potential future EV owners. This seems to be especially important since, according to the plans of the EU, all individuals need to switch to electric vehicles in the (near and distant) future.

In the present experimental driving study with 94 participants, it was found that individuals who were assigned to a combined intervention with informational, hedonic, and monetary incentives chose a smart charging station that offers renewable electricity more often than individuals in the control group (+17%). However, this effect was not statistically significant. Nevertheless, the results showed that, prior to a real-world drive, participants in the intervention group were more likely to have at least one eco-driving tip displayed in a prototypical smartphone-based app, compared to participants in the control group. It was further found that ecological awareness was related to the green charging station choice and eco-driving interest. Regarding energy consumption, the results showed that individuals in the intervention group had not significantly lower energy consumption after the real-world drive than participants in the control group. Instead, those individuals who had eco-driving tips displayed had a lower energy consumption than individuals who saw fewer or no tips.

Although individuals in the intervention group were more likely to choose the green charging station descriptively, the effect was not statistically significant and the results indicated only a small effect size (Chen et al., 2010). Even though null effects cannot be clearly explained, several potential reasons for this effect need to be discussed (which, of course, should be considered with caution). First, it may be that the combination of multiple interventions led to unexpected effects, such as the undermining effect of intrinsic motivation when offering monetary benefits (Deci, Ryan, et al., 1999). Providing financial rewards could have disrupted ecological intrinsic motivations and thus, paradoxically, not increased the decision rate for the green charging station (Bolderdijk & Steg, 2015). Furthermore, although the monetary incentives may have had the desired effect, the incentives could have been too small to motivate effortful behavior (Dogan et al., 2014; Gneezy & Rustichini, 2000). In addition, it is possible that a dilution effect occurred because too many motives were addressed; therefore, it is possible that, against the expectations, a single intervention would have been more helpful (Carfora et al., 2019; Weaver et al., 2012). This assumption seems possible also because, according to the participants, compared to the reward and gamification intervention, the $CO_2$ emission information was the most persuasive reason for selecting the green charging station. This is consistent with findings from other studies, indicating that environmental but not monetary framing is successful in motivating energy conservation and eco-driving (Dogan et al., 2014; Schwartz et al., 2015; Spence et al., 2014). Hence, it would be helpful to analyze the effect of the three interventions individually and see if one intervention alone might have been sufficient.

Although these reasons seem possible, it is important to note that the intervention did significantly influence the willingness to seek for eco-driving tips. Hence, other reasons for not finding an effect on the charging choice should be discussed. For example, it may be that participants wanted to lower the physical effort for the experimenter who accompanied the participants during the study. One must equally note that the sample size was determined based on the assumption of a medium effect size (Kacperski & Kutzner, 2020). However, other studies found rather small effects of persuasive strategies (e.g., Lai, 2015). Therefore, it may be that the sample size was too small to detect an effect of the intervention. Indeed, a post-hoc power analysis revealed that to detect a small effect ($OR = 2.39$) with a sample size of 94, only a power of 58% is achieved.

With regard to the requested eco-driving tips, the combined intervention motivated individuals to display at least one tip. This is in line with other studies that found that combinations of hedonic and normative (Ebermann & Brauer, 2016) or rather hedonic and monetary (Günther et al., 2020) interventions can influence effortful pro-environmental mobility behaviors. Hence, the combined intervention that encouraged people to save $CO_2$ emissions, collect points and rewards, and do well in a ranking raised interest for EV eco-driving tips.

However, with regard to energy consumption, there was no effect of the combined intervention but an effect of requested eco-driving tips. Therefore, not persuasive incentives but information about eco-driving behaviors (that individuals in the intervention and the control group could view) activated the goal to drive energy-efficiently during a real-world drive with an EV, which resulted in a reduced energy consumption. Unfortunately, the small number of participants who had the tips displayed and the assistance systems switched on did not allow to investigate whether switching on the assistance systems mediated the effect of eco-driving tips on energy consumption. Nevertheless, it is noticeable that although individuals in the intervention and control group had the possibility to activate driving feedback that supports the driver with consumption reduction activities, the results provide initial indications that individuals in the intervention group made slightly more use of such systems. Therefore, it might be that, although technical measures are more likely to be accepted by individuals than behavior change interventions (Poortinga et al., 2003), only few people use such measures in the vehicle if they are not motivated to do so. The present study results provide initial indications that combined interventions might be helpful to inform individuals about these and to motivate activation.

However, a recent study (Kutzner et al., 2021) found that although a behavioral intervention increased in-vehicle eco mode activation, behavioral changes (i.e., pressing the gas pedal stronger) counteracted the positive effect of assistance function activation. While in the present study it was found that eco assistance function activation could reduce energy consumption descriptively, this effect (and driving behavior adaptions) was not investigated in an inferential statistical analysis. Hence, future studies should not only investigate how individuals can be motivated to turn on eco functions but also how to change driving behavior so that positive effects of assistance function activation are not overridden. It is suggested that eco-driving tips informing individuals about driving behavior changes and eco assist functions can be a promising solution for that.

To summarize, the present findings indicate that a combined intervention approach can motivate effortful pro-environmental behaviors. Although the findings are not entirely conclusive, addressing multiple motives and giving detailed information can be helpful for effortful behaviors that future EV owners need to adopt. In the present study, the claim of several researchers is addressed that interventions should not only focus on one single motive but instead should stimulate multiple motives. Although this claim can be repeatedly found in the literature (Abrahamse et al., 2005; Lindenberg & Steg, 2007; Steg & Vlek, 2009), studies that investigate such an approach for high-cost pro-environmental behaviors are still scarce. Hence, the study contributes to the understanding if combined interventions addressing multiple motives can be helpful for these behaviors.

**Limitations**

A limiting factor of the study is that longitudinal effects were not examined. Since pro-environmental behaviors need to be shown in the long-term by a majority of individuals (Ke et al., 2019), longitudinal studies should analyze the effects of environmental interventions in the future.

In addition, the study setting limits the generalizability of the present results as social desirability may have influenced the outcomes. Furthermore, the time loss when choosing the green charging station might have played an only minor role because participants took some time to participate in the study anyway. Certainly, the artificial setting of the study limits ecological validity, which is why future researchers should replicate the findings in the field. However, the main aim of the study was to test the effectiveness of a combined intervention on pro-environmental driver behaviors because previous studies failed to produce strong effects when using single interventions (Af Wåhlberg, 2007; Sloot et al., 2021; Steinhorst & Klöckner, 2018). For this, a controlled setting is essential. Nevertheless, future studies should extend the present results and examine if such interventions can also be helpful in the real life of drivers (e.g., via a temporary test EV ownership or car sharing studies).

Future studies should also consider the effect of other behavioral costs on charging behavior (e.g., different tariffs, slower charging, need to provide additional information, etc.). It is important to highlight that while a walking (or driving) detour can be a barrier to green charging, this factor will likely lose importance when charging infrastructure expands in the next years. Therefore, other more typical behavioral costs and their effects on user behavior should be investigated more strongly.

Furthermore, the high ecological awareness of the participants reduces the generalizability of the results to other groups/samples. In addition, participants in the present study registered in a participants panel of a vehicle manufacturer, which could mean that they are highly interested in new technologies. Consequently, it cannot be ruled out that participants of the present study were more interested in charging and eco-driving behaviors than a more randomly selected sample of the general population. Furthermore, the participants of the present study might have differed regarding sociodemographic characteristics that were not asked for in the questionnaire but could have affected the study results. This is why future studies should replicate the present findings with a representative sample.

Moreover, a limitation of the present study is that participants may have strongly differed in terms of their EV and charging experience (although attempts were made to prevent this by recruiting accordingly). Hence, future studies should collect prior EV and charging experience by assessing the kilometers previously driven with an EV as well as the amount of prior charging decisions, so that these factors can be better controlled for.

A further limitation of the study is that there was no manipulation check for the implementation of the eco-driving tips. Although data on whether individuals switched on the assistance functions was collected, it was not analyzed if participants implemented the other tips or if they paid attention to the in-vehicle feedback (e.g., to the recommendations of the eco assist function or the performance feedback of the eco score). As a dependent variable, only energy consumption was measured, which should serve as an indication of whether the tips were implemented or not. Hence, future studies analyzing eco-driving performance should also collect data on whether several eco-driving behaviors are implemented or not (e.g., via other vehicle data). Furthermore, future studies should test a broader range of eco-driving behaviors (especially those with a high impact on energy consumption, e.g., remaining a constant speed; Günther et al., 2017) to extend the present results. Although it might limit ecological validity, it is also advisable that future studies investigate the effect of eco-driving behaviors in a driving simulator because energy consumption is affected by several uncontrollable factors during real-world drives (e.g., traffic congestion, weather), which could have negatively affected the results of the present study (Al-Wreikat et al., 2021; Lois et al., 2019).

**Implications and conclusion**

The results of the study suggest that combined interventions that address multiple motivations should be further investigated for effortful pro-environmental (driver) behaviors. Although the combination of the strategies did not help to increase green charging decisions significantly, a descriptive trend that deserves further consideration was identified. It is hypothesized that it is important to address cognitive resources and behavioral costs so that ecological motivations influence costly and effortful pro-environmental behaviors and decisions (Langenbach et al., 2020). While pro-environmental motivations are addressed via normative incentives, behavioral costs can be addressed by hedonic and monetary incentives. Several strategies can be helpful to achieve this and require further investigation (e.g., defaults, social norms; Kutzner et al., 2021). Because research examining combined interventions for pro-environmental behavior is limited so far, researchers should study the effects of such interventions more strongly, especially for high-cost behaviors that are influenced by multiple motives.

The results imply that combined interventions can be helpful to increase interest in eco-driving tips. For reducing energy consumption, however, informative tips are more helpful (including information on how to switch on in-vehicle assistance systems). Although the effect of activated assistance systems on energy consumption was not examined, it is possible that such systems help to reduce energy consumption (see Table 29). Because these systems gain in significance in future (battery electric) vehicles, it might be useful for future studies to focus on how to motivate individuals to switch on these functions permanently, because they can contribute to minimizing (cognitive) effort during driving (e.g., the effort to interrupt deeply rooted driving habits). Furthermore, future studies should investigate if switching on such systems reduces energy consumption and how individuals can be motivated to adapt their behavior to the recommendations of these systems (Kutzner et al., 2021).

In addition, because ecological awareness influenced green charging decisions and the number of requested eco-driving tips, researchers should develop and analyze interventions that can promote ecological awareness. Researchers are aware of the phenomenon that persuasive incentives often work only for people who are already intrinsically motivated to perform the behavior (Van Velsen et al., 2019). The crucial question is how to promote ecological awareness via effective interventions and which (cost-effective) measures work to get a majority of (non-ecologically aware) people to engage in multiple pro-environmental behaviors. High-impact pro-environmental behaviors shown by a majority of individuals are highly essential for emission mitigation, which is now more important than it ever has been because $CO_2$ emissions in 2021 rebounded to their highest level in history (IEA, 2022a).

# 11 General discussion

## 11.1 Summary of empirical research findings

The aim of the present dissertation was to investigate the role of motivational and contextual factors (i.e., behavioral costs) on high-impact pro-environmental driver decisions and behaviors. In addition, the dissertation aimed at investigating which interventions can effectively promote pro-environmental driver decisions and behaviors. Therefore, five studies examined the following research questions:

- Do autonomous and self-concordant motivations predict pro-environmental driver decisions and behaviors (studies 1, 2)?
- What is the relationship between behavioral costs and psychological factors/interventions for pro-environmental driver decisions and behaviors (studies 2, 3)?
- Which interventions are effective for promoting pro-environmental driver decisions and behaviors (studies 3, 4, 5)?

The results of the empirical studies reported here indicate that autonomous and self-concordant motivations are predictive of pro-environmental driver behaviors (studies 1, 2). In detail, the results of the studies show that drivers show strong strategic, tactical, and operational eco-driving behaviors when they are convinced that these behaviors are personally important and promote the achievement of higher-order intrinsic and meaningful goals (study 1). However, this motivation is especially important when the eco-driving behaviors are associated with moderate behavioral costs (study 2). In contrast, if eco-driving behaviors are perceived as rather low-effort, high motivations are not as necessary because most drivers (even those with low motivations) will engage in these behaviors (study 2). These findings are extended by findings showing that the effectiveness of interventions also depends on behavioral costs (study 3). Hence, such interventions aimed at promoting eco-driving behaviors are most effective when behavioral costs are moderate. This leads to the conclusion that interventions are not necessarily needed when behavioral costs are very low, because most people will behave pro-environmentally even when they are not motivated by persuasive interventions. On the other hand, eco-driving interventions seem insufficient when behavioral costs are very high since mere persuasion is not sufficient to convince even highly motivated individuals to engage in high-cost behaviors.

Addressing the second main aim of this dissertation, i.e., examining the effectiveness of interventions on pro-environmental driver behaviors, indicated that, in line with previous findings, for behaviors that are associated with moderate behavioral costs, interventions that emphasize the benefits for the environment and the community (i.e., personally meaningful intrinsic goals) are particularly valued by drivers (study 4). However, with respect to influencing reported behavior, it was shown that interventions that emphasize personal monetary benefits (i.e., extrinsic goals) could also be helpful (study 4). Nevertheless, the results indicated only small effects of informational interventions highlighting desirable behavioral consequences. Based on this and consistent with previous researchers' claims (Diekmann & Preisendörfer, 2003; Li et al., 2019; Linder et al., 2021; Steg, Bolderdijk, et al., 2014; Steg & Vlek, 2009), another study was conducted to investigate whether, considering that for moderate-cost behaviors both psychological *and* contextual factors are important and environmental *and* monetary benefits can influence such behaviors, a combined intervention addressing multiple motives (i.e., normative, hedonic, *and* egoistic goals) can influence actual pro-environmental driver behavior. Although this empirical study indicated mixed results, initial evidence emerges that such an intervention can be effective for moderate-cost driver behaviors.

To conclude, the findings of the empirical studies reported here show that individuals eco-drive when they are convinced that this is the right thing to do for the sake of the environment *and* when the behavior is associated with rather moderate costs. Hence, for moderate-cost behaviors, informational interventions can convince individuals to eco-drive. However, combining multiple intervention techniques may be even more promising, especially regarding the fact that some eco-driving behaviors are habitual (Verplanken & Wood, 2006) or high-cost, requiring strong interventions and hard (instead of only soft) measures.

In the following chapters, the empirical results are discussed in detail and with respect to the research questions. Furthermore, theoretical and practical implications of the present empirical findings are outlined and open research questions arising from the present results are identified.

## 11.2 Discussion of research questions

*Research question 1: Do autonomous and self-concordant motivations predict pro-environmental driver decisions and behaviors (studies 1, 2)?*

Focusing on the results of studies 1 and 2, the answer to this question is clearly "yes". As already shown in other behavioral domains (e.g., sports, academic learning; Sheldon & Elliot, 1998; Silva et al., 2010; Taylor et al., 2014; Williams et al., 2002) as well as in some pro-environmental behavioral domains (e.g., pro-environmental vehicle choice; De Groot & Steg, 2010; Lavergne et al., 2010), it is decisive that individuals have autonomous rather than controlled motivations for showing high eco-driving effort. Study 1 shows that striving self-determination, i.e., the extent to which individuals prefer autonomous (including intrinsic) rather than controlled motivations for eco-driving, predicted eco-driving effort, which in turn significantly predicted strategic, tactical, and operational driver decisions in the transport domain. Accordingly, it is important that individuals strive for eco-driving because they enjoy this behavior and it is a personally meaningful goal striving to them rather than because they would feel guilty if they did not strive for it or because striving for eco-driving provides external benefits (e.g., monetary savings). These results are extended by the findings that identified connections between eco-driving and higher-order environmental (i.e., biospheric) goals as well as higher-order hedonic goals predicted the effort individuals put into eco-driving strivings, which in turn predicted behavior. Although individuals identified the strongest link between eco-driving and higher-order biospheric values, they also identified a connection between goals for enjoyment/fun and eco-driving.

In summary, the results of study 1 replicate previous research findings that showed that autonomous and moral (biospheric) motivations significantly influenced pro-environmental behavior (Bamberg & Schmidt, 2003; De Groot et al., 2007; Jakovcevic & Steg, 2013; Lavergne et al., 2010; Steg, Bolderdijk, et al., 2014; Thøgersen, 1996; Unsworth & McNeill, 2017; Van der Werff et al., 2013). Consistent with other research, it is concluded that if individuals feel the moral obligation to contribute to climate protection, they are more likely to behave pro-environmentally than if they feel the need to behave pro-environmentally because of guilty emotions or external pressure (Lavergne et al., 2010; Van der Werff et al., 2013). Hence, these findings are not surprising since they extend previous research on eco-driving behaviors. However, it is interesting that individuals identified links between eco-driving and hedonic values, which in turn motivated eco-driving. There are two possible reasons for this finding, which are discussed in the following.

Van der Werff et al. (2013) reasoned that, in the environmental domain, two different forms of intrinsic motivation need to be distinguished, which they call enjoyment-based and obligation-based intrinsic motivation. According to their understanding, enjoyment-based intrinsic motivation arises from the behavior itself being enjoyable whereas obligation-based intrinsic motivation reflects that one feels an obligation to act pro-environmentally, which can result in pleasant feelings. The authors reason that pro-environmental behaviors are inherently more likely to involve little enjoyment and are more likely to require effort. For example, taking the bus or cycling requires more effort and time than taking the own vehicle. Likewise, turning down heating in winter is less comfortable. In a similar vein, eco-driving is also likely to involve effort for most people because they need to monitor their driving behavior and follow rules that they may have not learned at first. However, participants in study 1 reported that eco-driving is associated with fun, which influenced behavior. Nevertheless, from this finding it is not clear whether people actually think it is fun to drive energy- or fuel-efficiently (i.e., enjoyment-based intrinsic motivation) or whether eco-driving creates pleasant feelings because of its $CO_2$ emission mitigation or nature protection contribution (i.e., obligation-based intrinsic motivation).

On the one hand, it can be assumed that the activity of eco-driving is fun since some behaviors are likely to elicit pleasure. For example, it can be fun to drive on empty roads because one has chosen an energy-efficient route. Furthermore, it can be enjoyable not to commute to work alone but to take friends and colleagues (i.e., carpooling). Similarly, some driving behaviors on the road (e.g., recuperation) can be fun. However, on the other hand, eco-driving can also be fun because this behavior contributes to the well-being of the environment and nature, which generates pleasure and well-being even if those behaviors are not inherently pleasurable (i.e., the activity itself being fun).

In line with the distinction of Van der Werff et al. (2013), Venhoeven et al. (2013) point out that, with regard to pro-environmental behaviors, it is important to distinguish between two levels of well-being; hedonic and eudaimonic well-being. As with enjoyment-based intrinsic motivation, pro-environmental behaviors that elicit pleasure (e.g., vegan food can be more delicious for some people) generate hedonic well-being. Behaving pro-environmentally because of the pleasure that is associated with achieving higher-order meaningful goals generates eudaimonic well-being. Accordingly, because behaving pro-environmentally or morally creates good feelings and avoids bad feelings, individuals can experience pleasure when acting pro-environmentally. By thereby becoming a “good” person and fulfilling the moral obligation to help nature, (eudaimonic) enjoyment and pleasure can be felt (Venhoeven et al., 2013, 2016).

It is likely that the findings of study 1 are due to obligation-based intrinsic motivation or eudaimonic well-being since the vast majority of eco-driving behaviors are not necessarily associated with fun. In fact, studies showed that driving pleasure might discourage people from driving pro-environmentally or making pro-environmental decisions in the transport context (Jensen, 1999; Nilsson & Küller, 2000; Sandqvist & Kriström, 2001; Steg, 2005; Stradling et al., 1999). The link between eco-driving and hedonic values that was predictive of behavior is thereby more likely due to the reason that individuals feel pleasure when eco-driving because they contribute to “something bigger”. Hence, it can be reasoned that eco-driving generates obligation-based intrinsic motivation, which in turn influences the feeling of joy and pleasure that motivates behavior. Therefore, it might be that individuals eco-drive when they feel that this behavior is meaningful and freely chosen and serves the achievement of higher-order important goals (Venhoeven et al., 2013). Future studies need to analyze if these assumptions are correct.

In contrast, emphasizing controlling goals such as monetary benefits may be less convincing for eco-driving, because the findings of study 1 indicate that individuals identify little coherence between eco-driving and higher-order egoistic goals and that this coherence fails to predict eco-driving. Accordingly, the coherence between egoistic goals and eco-driving may not be sufficient to drive high eco-driving effort. Likewise, it was found that the coherence between altruistic goals and eco-driving did not predict eco-driving effort. However, there are benefits of eco-driving for the community and other human beings and previous studies found that altruistic goals are related to pro-environmental behaviors (De Groot & Steg, 2010). Therefore, it could be that individuals did not identify possible altruistic benefits of eco-driving because they are not as well associated with this behavior as biospheric benefits (see, for a discussion, chapter 6.4).

Study 2 replicates the findings that drivers implement eco-driving behaviors, at least according to self-report, primarily when they feel autonomous, intrinsic, and self-concordant motivations to do so. In this study, it was found that self-determined motivations for eco-driving i.e., pursuing eco-driving due to intrinsic, identified, or integrated reasons as opposed to external, introjected, or amotivations, predicted easy, moderate, *and* difficult eco-driving behaviors. Autonomous motivations thus appear to be an important source for pursuing eco-driving goals. Hence, motivating pro-environmental behaviors because of a personal commitment to nature and higher-order important biospheric goals is as important to eco-driving behaviors as perceiving free will in pursuing those goals.

It must be emphasized, however, that study 2 examined the results of study 1 and study 4 with the goal of understanding the relationship between self-determined motivations and behavioral costs of eco-driving. As demonstrated earlier, eco-driving is not necessarily an inherently joyful behavior but is more likely to include behavioral costs. Past studies indicated that individuals are more likely to perceive eco-driving as an effortful and strenuous behavior (Osbaldiston & Schott, 2012; Pampel et al., 2018). As for many other pro-environmental behaviors, it is therefore likely that eco-driving is associated with behavioral costs. Hence, study 2 was conducted with the main aim of investigating the interaction between motivations and behavioral costs of eco-driving, which will be discussed in more detail in response to the following research question.

*Research question 2: What is the relationship between behavioral costs and psychological factors/interventions for pro-environmental driver decisions and behaviors (studies 2, 3)?*

Researchers have long argued that although psychological factors are likely to be crucial in predicting pro-environmental behaviors (De Groot & Steg, 2010; Ünal et al., 2018; Van der Werff et al., 2013), the relationship between external and individual factors must also be considered (Li et al., 2019; Linder et al., 2021; Steg, Bolderdijk, et al., 2014; Steg & Vlek, 2009). Because most pro-environmental behaviors involve behavioral costs for people, it is not sufficient to consider merely psychological factors, such as motivations and knowledge. Indeed, different pro-environmental behaviors involve different levels of behavioral costs.

For example, recycling is often more likely to have low behavioral costs and turning off lights when they are not needed also tends to require low behavioral costs (Osbaldiston & Schott, 2012; Steg, 2023). In contrast to this, it is highly costly to have photovoltaic panels installed or to take the train on vacation. Eco-driving behaviors also involve behavioral costs, which can range from low to high. For example, Delhomme et al. (2013) found that individuals perceive anticipatory driving as rather easy, while maintaining a constant speed is considered more costly. Some strategic behaviors like buying electric cars can be perceived as even more costly because these vehicles are still rather expensive.

Because of this, researchers hypothesize that psychological factors *and* behavioral costs should be taken into account when predicting pro-environmental behaviors (Steg, Bolderdijk, et al., 2014; Steg & Vlek, 2009). Although it is critical to understand how these factors affect specific pro-environmental behaviors, there is little research on this. Indeed, most studies investigated the relationship between psychological and contextual factors with regard to only few pro-environmental behaviors (e.g., recycling; Andersson & Von Borgstede, 2010; Best & Kneip, 2011; Guagnano et al., 1995). Therefore, research that examines how these factors affect other pro-environmental behaviors is needed, especially with regard to behaviors that have a high impact on the environment (such as eco-driving). Consequently, this dissertation investigated how (subjective and objective) behavioral costs and psychological factors/interventions affect various eco-driving behaviors in two online studies.

Study 2 showed that individuals perceive different eco-driving behaviors as differently costly. This follows from data on behavioral frequency (infrequent behavior means higher behavioral difficulty) and subjective behavioral difficulty (individuals indicated how costly a behavior is to them). For example, drivers surveyed in study 2 experienced vehicle maintenance to be rather easy, while driving behaviors were considered moderately costly and alternative transport mode choices (such as public transport) were considered highly costly. Further, many drivers perceive avoiding high speeds to be costly, suggesting that individuals enjoy driving fast.

Interestingly, contrary to the predictions of the Campbell Paradigm (Kaiser, 2021), psychological factors (i.e., self-determined motivations) and behavioral costs were found not to have a compensatory effect on pro-environmental behavior, but instead to have an interaction effect on behavior. The interaction effect was negative, indicating that the negative influence of behavioral costs on eco-driving behavior was lower the higher the individuals' self-determined motivations were. Furthermore, self-determined motivations were found to predict moderate- and high-cost behaviors better than low-cost behaviors. Thus, contrary to the LCH (Diekmann & Preisendörfer, 2003), psychological factors were more predictive of moderate- and high- instead of rather low-cost behaviors. These results are consistent with the A-B-C Model and the Effort Hypothesis (Guagnano et al., 1995; Schultz & Oskamp, 1996). However, it must be considered that individuals generally reported high eco-driving frequency in the online questionnaires. Therefore, it is possible that the behaviors that were categorized as moderately costly were in fact perceived as rather low-cost by individuals. Accordingly, the studied eco-driving behaviors may not have fully explored the range of behavioral costs and none of the studied behaviors might have been perceived as extremely costly.

The results of study 3 help to provide some further insight into the relationship between psychological motivations and behavioral costs of eco-driving. Study 3 examined how behavioral costs of a pro-environmental charging decision influenced the effectiveness of psychological interventions on behavior. To do this, 286 drivers made several hypothetical charging decisions in an online study that were more or less effortful to them in a hypothetical situation in which they were BEV owners. The results showed that interventions influenced pro-environmental charging decisions in situations (i.e., were superior to no intervention) when the charging decision was associated with moderate behavioral costs. The results showed that when behavioral benefits or negligible costs of the charging decision were present, interventions were not predictive of the decision because the majority of people chose the environmentally friendly charging station anyway. When behavioral costs were very high, interventions were also not helpful because the costs were too high and only a minority chose the pro-environmental charging station. However, in situations with moderate behavioral costs, interventions were effective and motivated individuals to accept the costs of the pro-environmental charging decision.

Therefore, results of studies 2 and 3 indicate that psychological and contextual factors interactively affect strategic and tactical as well as operational eco-driving behaviors. Accordingly, the studies find no support for the Campbell Paradigm, which assumes additive effects of both determinants (Kaiser, 2021). Instead, the findings were in line with the theories that predict an interaction between the two factors for pro-environmental behavior. Specifically, it was found that when driver behaviors have no extra costs or negligible extra costs, environmental motivations and values are not successful at predicting behavior. Therefore, in such cases, psychological interventions addressing motivations, knowledge, attitudes, or values (Abrahamse & Matthies, 2018) might be of limited effectiveness. The majority of people will choose the pro-environmental alternative or behave pro-environmentally in such situations even without strong environmental beliefs. A minority will not; but these individuals will be very difficult to persuade anyway. In contrast, in situations that require a rather moderate extra effort, environmental motivations and interventions are crucial. Thus, interventions that stimulate environmental motivations are particularly suitable in moderate-cost situations. At very high behavioral costs, only a few highly motivated individuals will choose to behave pro-environmentally. However, this proportion might be small and an intervention that only appeals to motivations will most likely not be successful.

Overall, however, it is difficult to draw clear conclusions for the validity of the theories discussed in chapter 3.3. This is because the unambiguous classification of behavioral costs is difficult to obtain (i.e., Assuming that curbside recycling is a low-cost behavior, which eco-driving behavior is of similar cost?). Nevertheless, there is initial support that psychological factors and interventions are likely to be critical for behaviors involving costs that are rather moderately high. This conclusion is drawn for the investigated strategic, tactical, and operational eco-driving behaviors with ICEVs and BEVs.

Future studies should replicate these findings for eco-driving behaviors in field studies and, most importantly, use objective measures of behavior. This is especially important because the present findings are based on subjectively reported behavioral data from online studies, which may be biased by socially desirable response behavior. In addition, the theoretical assumptions for the relationship between psychological and contextual factors should be tested on a range of other pro-environmental behaviors to extend their applicability and to draw clearer conclusions about their validity. Furthermore, other psychological factors should be investigated for this relationship (e.g., attitude, knowledge). Research on this is scarce in current environmental psychology and thus, should be tackled by future studies.

*Research question 3: Which interventions are effective for promoting pro-environmental driver decisions and behaviors (studies 3, 4, 5)?*

To answer this research question, the results from studies 3, 4, and 5 are considered. These studies tested the effectiveness of single interventions on eco-driving behaviors (i.e., studies 3, 4) as well as analyzed the effectiveness of a combined intervention for adopting new eco-driving behaviors (i.e., study 5). Study 3 examined how pro-environmental charging decisions that future BEV drivers are likely to make could be promoted by three different interventions. Therein, it was shown that not only framing interventions that emphasize the positive $CO_2$ emission consequences but also descriptive norms and gamified applications were useful to influence a pro-environmental charging decision that was associated with moderate behavioral costs. In this context, the interventions were intended to reinforce the normative goal (i.e., "to act appropriately") by stimulating either the positive consequences of the behavior on the environment, providing information that other people contribute to environmental protection or creating positive feelings because one can contribute to the environment *and* have fun while doing it. All of these intervention techniques were shown to be effective in influencing a pro-environmental charging decision. Accordingly, previous research, showing that interventions emphasizing that a behavior is moral *and* fun are helpful in influencing pro-environmental behaviors, is supported (Avineri & Waygood, 2013; Bolderdijk, Steg, et al., 2013; Dogan et al., 2014; Douglas & Brauer, 2021; Günther et al., 2020; Steinhorst & Klöckner, 2018; Van der Linden, 2013; Vansteenkiste et al., 2004).

Study 4 examined the effectiveness of framing in a longitudinal online study with ICEV drivers. The study examined whether framing is more effective when normative intrinsic goals are framed compared to egoistic extrinsic goals. Results showed that although individuals find that $CO_2$ and pollutant emissions savings are more worth the eco-driving effort, monetary framing that emphasizes the monetary savings of eco-driving also influenced reported eco-driving behavior changes. Accordingly, study 4 indicated that informational interventions that emphasize the positive benefits of eco-driving behavior could influence moderate-cost driving behavior changes. However, overall, only small effects were found and it must be noted that only *reported* behavior was examined. Likewise, study 3 examined self-reported behavior effects in a hypothetical situation and found rather small to moderate effects.

Several researchers suggest that stronger effects could be achieved with interventions that combine informational and structural components (Steg & Vlek, 2009; Verplanken & Wood, 2006). The results of studies 3 and 4 indicate that multiple intervention techniques can have an effect on reported behavior. Hence, interventions that address moral motivations and norms *and* those that reinforce structural benefits of a behavior (i.e., monetary rewards) were effective in influencing eco-driving behavior. Thus, it can be hypothesized that a combined intervention that combines multiple benefits (i.e., combines the normative goal frame with the hedonic and gain goal frame) may be particularly effective (Lindenberg & Steg, 2007). This assumption also arises in light of the fact that individuals value different benefits and many researchers have called for interventions tailored to these preferences (Van den Broek et al., 2017). Thus, an intervention that combines many motives could be helpful for people with different preferences and values.

Consequently, another study (i.e., study 5) was conducted that investigated whether a combined intervention can influence actual pro-environmental charging and driving behavior. Hence, it was investigated whether a moderate-cost charging decision and driving behaviors could be influenced by a combined intervention in a laboratory/driving study. The advantage of this study was that individuals could experience the actual behavioral costs of their decisions and behaviors (e.g., the walking effort of choosing a distant charging station) and that objective behavioral measures could be used (e.g., energy consumption). Although this intervention with normative, hedonic, and egoistic incentives did not *significantly* affect the pro-environmental charging decision, there was a descriptive trend towards more pro-environmental decisions when the intervention was present. Furthermore, the combined intervention led individuals to express eco-driving interest with a BEV before a real-world drive. The number of informative eco-driving tips for BEVs that individuals requested and read had an impact on energy consumption during driving. Therefore, it is concluded that a combined intervention can increase interest in eco-driving behaviors. The results of study 5 also indicate that, from a participants' point of view, $CO_2$ framing (which was one of the used intervention strategies), strengthening the normative goal frame, had the most persuasive effect for showing the pro-environmental behaviors.

Hence, all of the conducted studies (i.e., studies 3, 4, 5) showed that *behavioral information* (e.g., tips) and *$CO_2$ framing* are valued by individuals and can influence behavior. Furthermore, other informational interventions such as descriptive norms or gamified interfaces could influence self-reported behavior successfully (see study 3). Therefore, it can be assumed that for moderate-cost driver behaviors, informational interventions are sufficient to influence behavior. However, because the combined intervention in study 5 was not compared with a single intervention (e.g., a single framing intervention), it is not clear if framing would have been sufficient to influence eco-driving interest of individuals in this study.

Because only small intervention effects on reported and actual behavior were found, future studies should investigate whether these effects also transfer into the daily lives of drivers. Some researchers raised doubts of the fact that informational interventions affect repetitive behaviors, such as eco-driving. They propose that for repetitive behaviors, structural changes or a combined intervention of informational and structural elements is more likely to influence behavior changes (Verplanken & Wood, 2006). Hence, although it was found that informational interventions changed driving behavior, these effects need to be considered with caution since it was not investigated if these behavior changes translate into individuals' everyday life. However, it can be speculated that informational interventions may be especially helpful (and sufficient) when drivers purchase a BEV because individuals experience a context change and can generate new (driving and charging) habits (Verplanken & Wood, 2006).

## 11.3 Implications of research findings

Overall, the results of this thesis suggest that autonomous motivations and behavioral costs are important for eco-driving behaviors. However, specifically, the results show that both factors need to be considered interactively. In the past, several studies found that pro-environmental eco-driving behaviors are predicted by psychological and contextual factors in an additively manner. In particular, several studies found that travel mode choice was predicted additively by both factors (Hunecke et al., 2001; Kaiser et al., 2021; Taube et al., 2018). Furthermore, driving behaviors (i.e., turning off engine at stops) have also been found to be additively predicted by psychological factors and behavioral costs (Taube et al., 2018). In contrast, however, Keizer et al. (2019) found interaction effects between both determinants for pro-environmental transport behavior and thus, found evidence for the validity of the A-B-C Model. Therefore, it is not yet clear how psychological and contextual factors affect eco-driving behaviors.

The results of this dissertation provide valuable evidence that theories that assume interaction effects between psychological and contextual factors help to explain pro-environmental driver behaviors. Specifically, the predictions of the A-B-C Model (Guagnano et al., 1995) or the Effort Hypothesis (Schultz & Oskamp, 1996) are more in line with the present results on eco-driving behaviors than those of the Campbell Paradigm (Kaiser, 2021). Support for this was found in two studies that indicated that psychological and contextual factors not only showed an interaction effect when predicting eco-driving behavior (study 2) but also that psychological motivations were most predictive of behaviors with rather moderate behavioral costs (studies 2, 3). Therefore, *theoretically*, this dissertation provides initial evidence that theories assuming interaction effects (especially the A-B-C Model) can be useful in predicting pro-environmental driver decisions and behaviors, which supports previous findings of Keizer et al. (2019). However, more research (especially on the classification of behavioral costs) is needed to draw clear theoretical conclusions for the validity of theories assuming interaction effects (i.e., A-B-C-Model, Effort Hypothesis, LCH).

Furthermore, the dissertation provides support for the predictive power of the assumptions of two different motivational theories. The results indicate that not only self-determined and autonomous motivations of Self-Determination Theory (Ryan & Deci, 2000) but also striving coherence of the Self-Concordance Model (Sheldon & Elliot, 1999; Sheldon & Kasser, 1995) can predict eco-driving behaviors (studies 1, 2). Although the application of motivational theories is rare in environmental literature, research has already shown empirical evidence that the determinants of both theories can predict pro-environmental behaviors (De Groot & Steg, 2010; Lavergne et al., 2010; Unsworth & McNeill, 2017). The findings of the studies in this dissertation extend these insights and allow the conclusion that self-determined, autonomous, and self-concordant motivations also play a crucial role for eco-driving behaviors. Furthermore, as already indicated above, external factors and the behavioral costs of pro-environmental driver behaviors are also important determinants of eco-driving. Based on these results, it is hypothesized that external factors may act as moderators between psychological factors and behavior. However, it should be noted that the contextual and motivational variables studied in this dissertation explain only parts of eco-driving, which is why variables of other models (e.g., NAM, TPB) may also be crucial for pro-environmental behaviors.

Therefore, in the future, integrative models and theories that consider multiple determinants and their interactions should be developed and tested for the prediction of various pro-environmental behaviors (Sniehotta et al., 2014). For this purpose, it is suitable to integrate assumptions and determinants of a variety of theoretical approaches. Such integrative models cannot only deepen and broaden the understanding of pro-environmental behaviors but also serve as a helpful basis for developing effective interventions. For example, Klöckner (2013) tested an integrative framework and found that a combination of determinants from multiple theories (i.e., NAM, VBN, TPB) and additional determinants (i.e., habits) effectively predicted pro-environmental behavior. This integrative approach incorporated several theories that have been well studied in environmental psychology to date.

However, only focusing on the determinants of the NAM, VBN, and TPB neglects the fact that other determinants and theoretical assumptions that received little research attention in the past also explain parts of pro-environmental behavior. Therefore, in the future, it is important to shift the research focus to previously neglected theories and determinants, which can broaden and deepen the understanding of pro-environmental behaviors. This dissertation takes a first step in this direction, providing evidence that integrative frameworks should be supplemented with self-determined/self-concordant motivations and contextual factors as well as their relationship. Both determinants appear to be important in predicting pro-environmental driver behaviors. Previous studies indicate that they also play a crucial role in other pro-environmental behaviors, which is why the inclusion of these variables into integrative behavioral models seems reasonable (De Groot & Steg, 2010; Guagnano et al., 1995; Hunecke et al., 2001; Kaiser et al., 2021; Unsworth & McNeill, 2017).

In addition, the present results support the assumptions of the GFT (Lindenberg & Steg, 2007), according to which interventions can successfully influence behavior when the normative goal is strengthened (studies 3, 4) or when the normative goal frame is made compatible with the hedonic and gain goal frame (study 5). For (low- and moderate-cost) eco-driving behaviors, information about how to eco-drive with (study 4) or without additional nudges (study 5) seemed to be successful in influencing behavior. For charging behaviors, small nudges in app interfaces were motivating to select pro-environmental charging stations (study 3). Eco-driving interest was promoted via a combined intervention and individuals indicated that $CO_2$ framing was the most persuasive strategy (study 5). Thus, in general, this dissertation supports mainly the effectiveness of the first strategy, i.e., to strengthen the normative goal frame. Whether an informational intervention focusing on normative goals without hedonic and reward incentives would have been sufficient to increase eco-driving interest in study 5 can only be answered speculatively, which is why future studies should test whether combined interventions for driving and charging behavior are necessary or whether they are only crucial for behaviors with high costs.

Important *practical* implications also arise from the results of this dissertation. First, based on the results that self-determined motivations can buffer the negative effect of high behavioral costs on behavior, it is recommended to use interventions that strengthen these motivations. Three aspects have to be considered for this: a) the autonomy of the individuals has to be maintained and strengthened, b) the competence of the individuals has to be strengthened, and c) it is advisable that the sense of belonging and relatedness is strengthened (Deci & Ryan, 1985; Vaezipour et al., 2016). For instance, feedback interventions, shared goals/commitment strategies, or gamified applications are suitable for this (see study 3; Abrahamse et al., 2007; An, 2020; Aparicio et al., 2012; Sheldon & Filak, 2008; Van de Velde et al., 2010). Hence, in practice, driver assistance systems that feedback the individual's eco-driving performance or the performance in comparison to others could be a helpful strategy to promote eco-driving and reduce fuel and energy consumption. These systems should be communicated appropriately, activated by default, or come with small benefits for users (and avoid auditory stimuli to increase intention to use; see Degirmenci & Breitner, 2023). It could also be beneficial to implement systems that show the progress towards a global goal shared with other people (e.g., how much $CO_2$ could be saved within a friends/neighbor/colleague group due to eco-driving activities).

Social norms can also be helpful to strengthen moral and environmental motivations (Lindenberg & Steg, 2007, 2013). Such norms can strengthen people's aspiration to follow the norm or reinforce the feeling that one's own behavior is worthwhile because other people are also acting pro-environmentally (Corral-Verdugo et al., 2002; Farrow et al., 2017). However, social norm interventions must be applied thoroughly. For example, it is disadvantageous if descriptive norms are fed back when people are above the norm because this can lead to rebound effects (i.e., behaving less pro-environmentally because one is "doing too much"; Schultz et al., 2007). Furthermore, descriptive norms cannot be used with new behaviors because it is likely that only few individuals adopt new behaviors right away. In such situations, injunctive or dynamic norms may be more suitable (Loschelder et al., 2019). Furthermore, several research findings indicate that norms (i.e., descriptive and injunctive) should be used in combination when they both promote a desirable behavior (i.e., are congruent; Cialdini, 2003; Schultz et al., 2008; Smith et al., 2012).

For example, eco-driving could be promoted by showing smileys or growing trees to feedback to the driver that certain behaviors are approved/are considered positively within the society (injunctive norm). On specific roads, it could be a beneficial strategy to feedback the driver how his/her eco-driving performance compares to the performance of the most successful eco-driver (descriptive norm). For green charging behavior, charging stations could communicate that an "increasing number" of people charge at this station (dynamic norm) or the specific amount of BEV owners that charged at this station on the respective day (descriptive norm; see study 3).

In addition, interventions that increase the ecological awareness or higher-order biospheric goals of individuals (see studies 1, 3, 4, 5) are also promising in influencing pro-environmental driver behaviors. Interventions such as framing (Dogan et al., 2014; Steinhorst & Klöckner, 2018), environmental labeling (Thøgersen, 2000), or environmental nudges (Kutzner et al., 2021) that highlight which products, alternatives, or behaviors are beneficial or less harmful to the environment are suitable for this purpose. For instance, charging stations offering green electricity could be designed in green color with trees and leaves on it while stations offering grey electricity could be designed in grey color. Furthermore, charging station apps that highlight stations offering green electricity as pro-environmental (e.g., via a leaf) could motivate individuals to decide in favor of these kind of stations.

In this dissertation, it was also found that highlighting monetary benefits that can be achieved by behaving pro-environmentally could encourage behavior (see study 4). Offering small monetary incentives could also be helpful, such as small rebates for pro-environmental alternatives (see study 5; Kacperski & Kutzner, 2020). For example, monetary discounts for charging stations with green electricity should be granted to motivate BEV drivers to choose green as opposed to grey charging stations. Furthermore, eco-driving assistance systems could calculate and demonstrate the monetary savings achieved due to eco-driving activities during a ride based on current fuel prices. It should be noted, however, that monetary benefits should not be too large so that they fully justify the behavior, because in such situations individuals will attribute their behavior solely to achieving monetary benefits, which may inhibit the development of desirable environmental beliefs and prevent the occurrence of spillover effects (Bolderdijk & Steg, 2015). Nevertheless, provided *small* monetary benefits are a cost-effective intervention solution, they can be recommended for moderate-cost driver behaviors based on the present research findings.

For high-cost behaviors, interventions that stimulate environmental motivations and knowledge (i.e., informational interventions) are probably not sufficient to influence pro-environmental behavior (see study 3). For such behaviors, structural interventions should be used and combined with informational interventions. For example, it was found that individuals view the avoidance of high speeds as highly costly (see study 2). Hence, speed limits can be a useful structural strategy to discourage speeding behavior (Huang et al., 2018) and highway billboards showing accidents or environmental degradation could be used additionally to strengthen environmental or safety goals. Furthermore, structural incentives can be offered for rides that transport multiple people (e.g., free parking spaces; Keyvanfar et al., 2018; Rose & Hinds, 1976). Moreover, improving the charging infrastructure (with pro-environmental charging stations) might be a useful structural strategy to motivate green charging behavior. In addition, inexpensive public transportation tickets as well as taxes and high registration and fuel costs may reduce car use (Keyvanfar et al., 2018; Pritchard, 2010; Rose & Hinds, 1976; Schoenau & Müller, 2017). Furthermore, navigation systems that show the most fuel-efficient route or assistance systems that promote eco-driving can also be helpful to reduce the behavioral costs of eco-driving (Ericsson et al., 2006; Kutzner et al., 2021). In addition, driving automation and additional automated eco-driving applications could provide a valuable structural strategy to promote eco-driving (e.g., Araghi et al., 2023). Thus, if behaviors are associated with high costs, structural strategies can be used in addition to informational interventions to influence behavior successfully.

For low-cost behaviors, cost-effective informational interventions should be used to motivate individuals to engage in pro-environmental behaviors. Even if many individuals already engage in the respective behavior, cost-effective interventions can still persuade a few undecided individuals or increase the knowledge of inexperienced people.

From a *methodological* perspective, it is noticeable that study 1 developed a comprehensive eco-driving questionnaire that captures strategic, tactical, as well as operational driver behaviors. This questionnaire should be validated in future studies and encourage researchers to consider a range of different driver behaviors. Furthermore, based on the results of studies 2 and 3, it can be concluded that different methods of measuring behavioral costs are possible and produce valid results. Hence, subjective questionnaires as well as objective and behavioral frequency classifications were helpful for classifying behavioral costs of eco-driving. However, the different methods of measuring behavioral costs should be given special consideration when interpreting the results. It is unclear whether the behaviors that were considered low-cost are actually comparable to each other (and to other low-cost pro-environmental behaviors like recycling). Therefore, future studies should examine which method produces the most valid and objective classification results and (if possible) allows comparisons across multiple behaviors. This will allow more valid and conclusive support for the models that hypothesize relationships between psychological factors and behavioral costs for pro-environmental behaviors (see chapter 3.3).

## 11.4 Open questions and outlook

In the following, open questions that arise based on the findings of this dissertation are presented, which should be tackled by future research. Researchers are encouraged to study the strategic, tactical, *and* operational driver decisions that were examined in this dissertation more deeply (i.e., identify other determinants) and strengthen the insights about intervention effects by testing other approaches, and examining these effects in other cultures and countries.

*What determinants add to the understanding of pro-environmental driver behavior change?*

To understand how pro-environmental driver behaviors can be effectively motivated, they need to be understood in depth. Therefore, it is necessary to know the crucial determinants of the behavior. This dissertation contributes to the understanding of two important determinants, which are autonomous/self-determined motivations and behavioral costs. Past research has identified a number of other important determinants, such as knowledge, norms, and values (Af Wåhlberg, 2007; Jakovcevic & Steg, 2013; Nordlund & Garvill, 2003; Steg et al., 2006; Ünal et al., 2018; Zarkadoula et al., 2007).

Certainly, however, it can be assumed that there are other critical determinants of pro-environmental driver behaviors that have not been analyzed so far. For example, habits play a major role in most pro-environmental behaviors. Habits have been shown to mitigate the influence of intentions on behavior. For example, in a meta-analysis, Ouellette and Wood (1998) found that annual or semiannual behaviors were predicted by intentions successfully, whereas the predictive influence of intentions tended to be poor for frequently repeated behaviors (daily or weekly behaviors; i.e., habits). In this regard, researchers call for the inclusion of habits as determinants in established behavioral theories or newly developed frameworks (Klöckner, 2013). Driving behavior can be considered as a deeply rooted habit (Pampel et al., 2018). Certainly, however, only some behaviors are strongly habitual (e.g., changing gears, breaking) while others tend to be less repetitive (e.g., switching on heating, checking tire pressure). Therefore, future studies should tackle the question which driver behaviors are strongly habitual and which are not. This will lead to different conclusions for the use of interventions since their effectiveness depends on whether a behavior is habitual or not. Verplanken and Wood (2006) provide an overview of which interventions should be used when behaviors are frequently performed *and* rather rarely repeated. Hence, future studies should examine the role of habits for strategic, tactical, and operational eco-driving behaviors and test different strategies for driver behaviors that are of different behavioral frequency.

In addition, future studies should consider other previously neglected impact factors, such as self-efficacy or self-control. Self-efficacy describes the belief that one has the ability to achieve goals and perform actions in certain situations (Bandura, 1997). Self-control describes the ability to regulate thoughts and actions to achieve desirable outcomes (De Ridder et al., 2017). Both characteristics are critical in the pursuit of strenuous goals (Englert et al., 2020; Moritz et al., 2000; Schüler et al., 2019; Wolf et al., 2018). It has already been found that these determinants are also important in the pursuit of environmental goals (Lauren et al., 2016; Mannem et al., 2023; Wyss et al., 2022), which often require high effort and behavioral costs (Steg & Vlek, 2009). Thus, it can be hypothesized that self-efficacy as well as self-control are important determinants of pro-environmental driver behaviors and may be especially beneficial for overcoming behavioral barriers (e.g., follow eco-driving rules even when one is under time pressure; Dogan et al., 2011). Researchers suggest that these abilities help to neglect behaviors that have immediate rewards but are environmentally harmful in favor of behaviors that have rather distant but important community and environmental benefits (Baumgartner et al., 2019; Duckworth et al., 2016; Langenbach et al., 2020). These abilities are also associated with higher autonomous motivations and thus, may influence important determinants of driver behaviors (see studies 1, 2; Converse et al., 2018; Muraven, 2008).

Assuming that self-efficacy and self-control are important determinants of driver behaviors, important implications for the effectiveness of interventions emerge too. For example, self-regulatory strategies such as implementation intentions could be of significance in driver behavior change. These strategies are known as if-then plans (e.g., “If I commute to work, then I will take the train instead of the car.”) that help determine how to behave in certain situations and under certain conditions (Gollwitzer, 1999; Oettingen et al., 2000). They can also help formulate specific strategies in the face of behavioral barriers that can then be used to regulate behavior successfully (Steg et al., 2016). Such if-then plans can also help neutralize the dilemma of competing goals (e.g., environmental vs. time goals; Dogan et al., 2011), strengthen self-identity, and strengthen the normative goal frame (Steg et al., 2016). Therefore, in addition to considering self-efficacy and self-control as determinants of driver behavior, the influence of implementation intentions for driver behaviors should also be examined. For example, Lauper et al. (2015) found initial evidence that this strategy has an important influence on eco-driving.

As additional determinants, future studies should consider the influence of sociodemographic variables. The investigation of sociodemographic variables for driver behavior is not well understood to date. However, past studies found that gender, age, education level, income, and place of residence have an impact on pro-environmental behavior (López-Mosquera, 2016; Mantovani et al., 2017; Sánchez et al., 2016). Such variables can also be assumed to play a role for pro-environmental driver behaviors (Delhomme et al., 2013). For example, research found that men tend to exhibit higher speeds on the road than women do (Harré et al., 1996). Similarly, it is only logical to assume that drivers with higher incomes are more likely to be able to afford BEVs, which are currently still highly expensive, and individuals who live in cities are more likely to be able to switch to public transportation than individuals who live in rural areas. Therefore, it is important to study the influence of demographic variables more intensively. In addition, it is worthwhile to consider them as moderators for intervention effects. Although studies 3 and 5 found no significant influence of gender on pro-environmental driver behavior, other sociodemographic variables (e.g., income, place of residence) might affect pro-environmental behaviors (e.g., vehicle purchase) or moderate intervention effects, which is why it is advisable to consider these in future studies.

*Are there other interventions that show strong effects on pro-environmental driver behavior changes?*

Environmental intervention research has a long tradition of developing and testing interventions that can significantly influence behavior (change) of individuals in everyday life (Avineri & Waygood, 2013; Bolderdijk, Steg, et al., 2013; Boomsma & Steg, 2014; De Groot et al., 2013; Dogan et al., 2014; Goldstein et al., 2008; Hopper & Nielsen, 1991; Lai, 2015; Loschelder et al., 2019; Osbaldiston & Schott, 2012; Schall & Mohnen, 2017; Schultz, 1999; Schultz et al., 2007, 2015; Steinhorst & Klöckner, 2018; Van den Broek et al., 2017; Van der Linden, 2013). Despite the myriad of research reports on this, evidence on which interventions are particularly effective is still mixed. This might be partly due to the fact of the publication problem, because most journals still follow the publication strategy of only publishing significant findings, which can distort and overestimate the effectiveness of interventions on pro-environmental behavior (for a journal issue that published high-quality reports that found no effects of several interventions on pro-environmental behavior, see Lange & Brick, 2021). Although the interventions examined in these studies have shown significant effects on behavior, the effect sizes tended to be small. Hence, future studies should study interventions more intensively (also with regard to everyday behavior) and consider the following approaches that have recently shown promising results in the environmental domain.

First, some recent research indicates that default interventions can have a strong impact on pro-environmental behaviors (Kuhn et al., 2021; Kutzner et al., 2021; Pichert & Katsikopoulos, 2008; Vetter & Kutzner, 2016). Defaults are nudging interventions that are preselected (i.e., default) settings that require an active action if they want to be changed by individuals (Schubert, 2016; Thaler & Sunstein, 2009). This intervention approach can play an important role, for example, in turning on (eco) systems (Kutzner et al., 2021) or making pro-environmental choices (e.g., when shopping; Kuhn et al., 2021). Defaults eliminate the need for individuals to make active choices, often causing individuals to not change these settings because of inertia, loss aversion, or the assumption that the preselected option is the "right" choice (Schubert, 2016).

Research found that such interventions could have an important impact on computer configurations (Brown & Krishna, 2004), privacy settings (Johnson et al., 2002), research participation (Paunov et al., 2019), and medical decisions (Halpern et al., 2013). For example, it is striking that in countries where people are added to the organ donor registry without actively signing up (and have to opt out if they do not want to be an organ donor; e.g., Austria), many more people are organ donors than in countries where individuals must actively sign up to be an organ donor (e.g., Germany; Johnson & Goldstein, 2003; McKenzie et al., 2006). Recent studies suggest that default interventions can also be helpful for pro-environmental behaviors. For example, Vetter and Kutzner (2016) found that default manipulations motivated people to select green rather than grey electricity. Similarly, Kutzner et al. (2021) found that default settings of eco assistance functions in cars motivated people to drive with these assistance systems turned on. To deepen the understanding of the effectiveness of default strategies, default settings should be investigated for other pro-environmental driver behaviors and research should tackle the question of how rebound effects (i.e., overriding the positive effect of activated systems by undesirable behaviors; see Kutzner et al., 2021) can be avoided. Based on the present study results, it is assumed that such interventions can be particularly effective, as they reduce cognitive effort (i.e., behavioral costs; Langenbach et al., 2020), which might be particularly important for several driver behaviors (see studies 2, 3).

In addition to default interventions, future studies should examine tailored interventions. Indeed, a number of researchers conclude that information is more effective when it is tailored to individuals' values and needs (Abrahamse et al., 2007; Boomsma et al., 2016; Boomsma & Steg, 2014; Van den Broek et al., 2017). This follows from findings that individuals draw attention particularly to value-congruent information, which is why it can be assumed that interventions tailored to values could be more effective than one-fits-all solutions (Nordlund & Garvill, 2002; Perlaviciute & Steg, 2014). For example, research found that, when choosing a restaurant, individuals with biospheric values are more likely to pay attention to biospheric aspects (e.g., organic food options), while those with altruistic values are more likely to pay attention to altruistic aspects (e.g., working conditions), and individuals with hedonic values are more likely to pay attention to hedonistic aspects (e.g., tastiness of the food; Steg, 2014). Therefore, interventions for pro-environmental behaviors should be tailored to individuals' values and needs. For instance, Boomsma and Steg (2014) found that value-congruent information about reduced street lighting influenced acceptance of a pro-environmental street lighting measure. Van den Broek et al. (2017) found that when information of pro-environmental behavior was congruent with individuals' preferred values it was more persuasive than when it was not. Therefore, the authors conclude that environmental campaigns should be tailored to individuals' interests.

These insights may suggest that the framing interventions examined in study 4 could be differentially effective. For example, individuals who prefer egoistic values might want to know about the monetary benefits of eco-driving (i.e., monetary framing), whereas individuals who prefer biospheric values might want to know about the environmental benefits of eco-driving (i.e., environmental framing). This also suggests that personalized feedback could be effective in influencing pro-environmental driver behavior. Indeed, personalized information was effective in influencing energy conservation at home (Shipworth, 2000). Similarly, Brouwer et al. (2015) concluded that personalized feedback helps drivers to drive pro-environmentally, and Vaezipour et al. (2016) concluded from their study results that drivers also prefer personalizable information of in-vehicle functions. Accordingly, future studies should focus on examining personalized interventions for various eco-driving behaviors.

*Do intervention effects persist over time?*

In the studies of this dissertation, the effectiveness of interventions was examined only over a short period. However, behavioral changes (especially driving behavior changes) must be practiced over a long period of time (i.e., become a new habit) to have a considerable effect on climate change mitigation. Therefore, studies need to examine the long-term effects of interventions more intensively. Many studies indicate that behavioral effects of environmental interventions decrease over time (Abrahamse et al., 2005; Steinhorst & Klöckner, 2018). This was also found for eco-driving behaviors. For example, eco-driving training courses have shown to have an immediate impact on behavior but the effects diminish over time until they disappear altogether (Af Wåhlberg, 2007; Beusen et al., 2009). With financial interventions, there is a risk that behavior will revert to baseline behavior after the incentives are removed (Bolderdijk & Steg, 2015; Zeiske et al., 2021). Therefore, researchers conclude that interventions influencing the environmental and moral beliefs of individuals are more promising for long-term behavior change (Bolderdijk & Steg, 2015). Furthermore, cost-effective interventions are especially desirable because they can be implemented immediately and sustained over a long period. However, the effectiveness of such interventions should be investigated in future studies via longitudinal study designs (Abrahamse et al., 2005), because long-term behavior change is crucial, especially for repetitive behaviors such as driving.

*Do interventions promote positive or negative spillover effects?*

Researchers point out that positive spillover effects of behavior changes are particularly desirable (Steinhorst et al., 2015; Thøgersen, 1999). Therefore, optimally, pro-environmental behavior changes in one domain should motivate pro-environmental actions in other domains (i.e., positive spillover; Thøgersen & Crompton, 2009). For example, Thøgersen and Ölander (2003) found that recycling behavior changes were related to later purchases of organic products and pro-environmental transport decisions. In addition, Thøgersen and Noblet (2012) found that everyday pro-environmental consumer behaviors were related to the acceptance of green electricity sources (i.e., wind power).

However, some studies showed that negative spillover effects (i.e., showing a pro-environmental behavior reduces the likelihood of showing other pro-environmental behaviors; Thøgersen & Crompton, 2009), which is also known as moral licensing (Gholamzadehmir et al., 2019), could also occur. For example, Tiefenbeck et al. (2013) found that weekly feedback on water consumption reduced water use but increased electricity use. Thus, past moral behavior may lead individuals to think that they have the “right” to behave in a less environmentally friendly manner in another domain (Gholamzadehmir et al., 2019). For example, it could be that individuals buy a BEV but do not drive it in a pro-environmental manner, since they have already proven to be an environmentally friendly person when buying the BEV, "allowing" them to act environmentally harmful elsewhere (moral licensing). However, regarding this specific behavior, research found opposite effects in the past (Ryghaug & Toftaker, 2014). Nevertheless, future studies should investigate this more intensively to deepen the understanding of spillover effects.

Regarding intervention effects, Steinhorst et al. (2015) found that only environmental framing motivated positive spillover effects, while monetary framing did not lead to any spillover effects (Van der Werff & Steg, 2018). Hence, positive spillover effects may depend on the intervention strategy that is used to motivate pro-environmental behavior. Nilsson et al. (2017) provides an overview over which interventions might be most promising to generate positive spillover effects (e.g., via enhancing self-perception/self-identity).

In conclusion, interventions and motivated behavior changes can cause both positive *and* negative spillover effects. Therefore, future studies investigating pro-environmental behaviors and interventions should consider whether influenced and implemented pro-environmental driver behaviors motivate or discourage other pro-environmental behaviors. Positive spillover effects (i.e., large-scale behavior changes in many behavioral domains) are important considering the ongoing climate change.

*Can the present results be generalized to other countries and cultures?*

Another important question that should be addressed in future studies is whether the determinants and interventions examined in the empirical studies in this dissertation also play a role in other countries and cultures. Some researchers suggest that interventions are likely to have different effects in individualistic and collectivistic cultures (Smith et al., 2012). For example, a study found that injunctive norms worked better for individuals from collectivistic cultures, and descriptive norms worked better for people from individualistic cultures (Walker et al., 2006). Since it can be assumed that individuals from individualistic cultures are more likely to prefer what suits their needs and values whereas individuals from collectivistic cultures are more likely to do what suits the norm or obligation (Smith et al., 2012; Triandis, 1995), it is possible that interventions have different effects in different cultures. Research on how interventions play out in different cultures is scarce to date. Hence, it is recommended that future research tackles this more intensively.

Furthermore, based on the fact that environmental awareness is differently pronounced in different countries, it can be assumed that the effectiveness of environmental interventions depends on the country they are investigated in. For example, environmental awareness tends to be high in Germany (Bohner & Schlüter, 2014), where all of the studies presented in this dissertation were conducted. Hence, it should be investigated if these interventions can also promote driver behavior changes in other countries where environmental awareness might be lower. In addition, when studying driver behaviors in different countries, it is important to consider contextual differences that could affect behavior. For example, the availability of public transportation is higher in some countries (e.g., Sweden) than in others (e.g., Italy), which is why reducing vehicle use may not be equally costly across countries.

To summarize, future studies are advised to examine the determinants and interventions for pro-environmental driver behaviors in different countries and cultures. Nevertheless, interventions should be prioritized in countries that have a high impact on global $CO_2$ emissions, as these are the countries where behavior changes are most urgent (e.g., Germany).

## 11.5 Conclusion

Although (as the previous chapter clearly demonstrates) there is still much work to be done to better understand and influence the promotion of pro-environmental driver behaviors, the present thesis includes novel and valuable insights for environmental and traffic psychology research that need to be briefly summarized in this final chapter. This dissertation examined the influence of key determinants and behavioral interventions on strategic, tactical, and operational eco-driving decisions and behaviors. The five empirical studies presented in this dissertation have shown that consistent with research findings on other pro-environmental behaviors, autonomous, self-determined, and self-concordant motivations as well as behavioral costs play a critical role in predicting various eco-driving behaviors. However, psychological and contextual factors indicated a negative interaction effect on pro-environmental driver behavior. Furthermore, the studies revealed that behavioral costs influence the effectiveness of various behavioral interventions developed to promote green driver behavior changes. The following key take aways can be concluded based on the presented studies:

- Individuals are more likely to engage in a pro-environmental driver behavior if they believe that this behavior is important and the right thing to do for protecting the environment and nature (i.e., are autonomously motivated) than if they are forced to do so or feel internal pressure to do so (i.e., are externally motivated)

- High self-determined/autonomous motivations for eco-driving are especially important for engaging in pro-environmental driver decisions and behavior when the behavioral costs of the decision or behavior increase
- Different behavioral interventions (soft measures) can promote eco-driving behaviors - both individually used and in combination
- The effectiveness of behavioral interventions is influenced by the presence of behavioral costs - the impact of behavioral interventions is strongest for low- and moderate-cost behaviors

These findings have important implications for theoretical research frameworks and for practical measures. They can help to better understand pro-environmental behaviors in general and eco-driving in particular. Furthermore, these findings will help to develop and use behavioral interventions in a more tailored fashion which can contribute to more effective pro-environmental (driver) behavior changes.

As the transport sector is one of the sectors which needs to increase greenhouse gas emissions savings strongly in the upcoming years, the present thesis can be seen as input for researchers and policy makers on how to motivate people to do their part in achieving this goal. Combined interventions with informative and structural strategies are needed for high-cost (or repetitive) behaviors, while interventions that influence motivation are helpful for low- and moderate-cost behaviors. Therefore, future studies and real-life policy decisions should consider soft (i.e., motivational/informational) interventions for low- and moderate-cost behaviors and investigate if hard (i.e., structural) measures combined with soft (i.e., psychological) measures influence high-cost (or habitual) behaviors. Only by continuously investigating how behaviors and decisions of road transport users can be changed, it will be possible to reduce the environmental impact of the transport sector as innovative technological advances and new laws and regulations will take effect too slowly.

# References

Abrahamse, W., & Matthies, E. (2018). Informational strategies to promote pro-environmental behaviour: Changing knowledge, awareness and attitudes. In L. Steg & J. I. M. De Groot (Eds.), *Environmental Psychology: An Introduction* (Issue November, pp. 224–232).

Abrahamse, W., Steg, L., Gifford, R., & Vlek, C. (2009). Factors influencing car use for commuting and the intention to reduce it: A question of self-interest or morality? *Transportation Research Part F: Traffic Psychology and Behaviour*, *12*(4), 317–324. https://doi.org/10.1016/j.trf.2009.04.004

Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T. (2005). A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology*, *25*(3), 273–291. https://doi.org/10.1016/j.jenvp.2005.08.002

Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T. (2007). The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents. *Journal of Environmental Psychology*, *27*(4), 265–276. https://doi.org/10.1016/j.jenvp.2007.08.002

ADAC. (2022, December 07). *Mercedes EQC im Test: Wie gut ist der Elektro-SUV?* https://www.adac.de/rund-ums-fahrzeug/autokatalog/marken-modelle/mercedes-benz/mercedes-eqc-elektro-suv/

ADAC. (2023, June 01). *Spritpreis-Entwicklung: Benzin- und Dieselpreise seit 1950*. https://www.adac.de/verkehr/tanken-kraftstoff-antrieb/deutschland/kraftstoffpreisentwicklung/

Af Wåhlberg, A. E. (2007). Long-term effects of training in economical driving: Fuel consumption, accidents, driver acceleration behavior and technical feedback. *International Journal of Industrial Ergonomics*, *37*(4), 333–343. https://doi.org/10.1016/j.ergon.2006.12.003

Aguiar-Castillo, L., Clavijo-Rodriguez, A., De Saa-Perez, P., & Perez-Jimenez, R. (2019). Gamification as an approach to promote tourist recycling behavior. *Sustainability (Switzerland)*, *11*(8), 1–18. https://doi.org/10.3390/su11082201

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior*. Englewood Cliffs.

Al-Alawi, B. M., & Bradley, T. H. (2013). Review of hybrid, plug-in hybrid, and electric vehicle market modeling studies. *Renewable and Sustainable Energy Reviews*, *21*, 190–203. https://doi.org/10.1016/j.rser.2012.12.048

Alam, M. S., & McNabola, A. (2014). A critical review and assessment of eco-driving policy & technology: Benefits & limitations. *Transport Policy*, *35*, 42–49. https://doi.org/10.1016/j.tranpol.2014.05.016

Allcott, H., & Rogers, T. (2014). The short-run and long-run effects of behavioral interventions. *American Economic Review*, *104*(10), 3003–37. https://doi.org/10.1257/aer.104.10.3003

Altman, I. (1976). Environmental psychology and social psychology. *Personality and Social Psychology Bulletin*, *2*(2), 69–113. https://doi.org/10.1177/014616727600200207

Al-Wreikat, Y., Serrano, C., & Sodré, J. R. (2021). Driving behaviour and trip condition effects on the energy consumption of an electric vehicle under real-world driving. *Applied Energy*, *297,* 117096. https://doi.org/10.1016/j.apenergy.2021.117096

An, F., & Ross, M. (1996). A simple physical model for high power enrichment emissions. *Journal of the Air and Waste Management Association*, *46*(3), 216–223. https://doi.org/10.1080/10473289.1996.10467455

An, Y. (2020). Designing effective gamified learning experiences. *International Journal of Technology in Education*, *3*(2), 62–69. https://doi.org/10.46328/ijte.v3i2.27

Anagnostopoulou, E., Bothos, E., Magoutas, B., Schrammel, J., & Mentzas, G. (2016). *Persuasive technologies for sustainable urban mobility*. Presented at the Persuasive 2016 Workshop "Where are we bound for? Persuasion in Transport Applications". https://doi.org/10.48550/arXiv.1604.05957

Anas, A., & Lindsey, R. (2011). Reducing urban road transportation externalities: Road pricing in theory and in practice. *Review of Environmental Economics and Policy*, *5*(1), 66–88. https://doi.org/10.1093/reep/req019

Andersson, M., & Von Borgstede, C. (2010). Differentiation of determinants of low-cost and high-cost recycling. *Journal of Environmental Psychology*, *30*(4), 402–408. https://doi.org/10.1016/j.jenvp.2010.02.003

Ando, R., Nishihori, Y., & Ochi, D. (2010). Development of a system to promote eco-driving and safe-driving. In S. Balandin, R. Dunaytsev, & Y. Koucheryavy (Eds.), *Smart Spaces and Next Generation Wired/Wireless Networking* (pp. 207–218). Springer.

Anke, J., Francke, A., Schaefer, L. M., & Petzoldt, T. (2021). Impact of SARS-CoV-2 on the mobility behaviour in Germany. *European Transport Research Review*, *13*(1). https://doi.org/10.1186/s12544-021-00469-3

Antimova, R., Nawijn, J., & Peeters, P. (2012). The awareness/attitude-gap in sustainable tourism: A theoretical perspective. *Tourism Review*, *67*(3), 7–16. https://doi.org/10.1108/16605371211259795

Aparicio, A. F., Vela, F. L. G., Sánchez, J. L. G., & Montes, J. L. I. (2012). Analysis and application of gamification. *Proceedings of the 13th International Conference on Interacción Persona-Ordenador, 17, 1–2.* https://doi.org/10.1145/2379636.2379653

Araghi, F. M., Rabinwoitz, A., Ang, C. C., Sharma, S., Kadav, P., Meyer, R. T., Bradley, T., & Asher, Z. D. (2023). Identifying and assessing research gaps for energy efficient control of electrified autonomous vehicle eco-driving. In V. K. Kukkala, & S. Pasricha (Eds.), *Machine Learning and Optimization Techniques for Automotive Cyber-Physical Systems* (pp. 759-786). Springer. https://doi.org/10.1007/978-3-031-28016-0_27

Arkesteijn, K., & Oerlemans, L. (2005). The early adoption of green power by Dutch households: An empirical exploration of factors influencing the early adoption of green electricity for domestic purposes. *Energy Policy*, *33*(2), 183–196. https://doi.org/10.1016/S0301-4215(03)00209-X

ARM Research Facility. (2021, February 16). *MOSAiC: A sustained echo of data*. Department of Energy – Office of Science. https://www.arm.gov/news/facility/post/68016

Aruga, K., Islam, M. M., & Jannat, A. (2021). Does staying at home during the COVID-19 pandemic help reduce $CO_2$ emissions? *Sustainability (Switzerland)*, *13*(15), 8534. https://doi.org/10.3390/su13158534

Asensio, O. I., & Delmas, M. A. (2015). Nonprice incentives and energy conservation. *Proceedings of the National Academy of Sciences of the United States of America (PNAS)*, *112*(6), E510–E515. https://doi.org/10.1073/pnas.1401880112

Atkinson, R. W., Barratt, B., Armstrong, B., Anderson, H. R., Beevers, S. D., Mudway, I. S., Green, D., Derwent, R. G., Wilkinson, P., Tonne, C., & Kelly, F. J. (2009). The impact of the congestion charging scheme on ambient air pollution concentrations in London. *Atmospheric Environment*, *43*(34), 5493–5500. https://doi.org/10.1016/j.atmosenv.2009.07.023

Austin, D. (2008). *Effects of Gasoline Prices on Driving Behavior and Vehicle Markets*. The Congress of the United States – Congressional Budget Office. https://www.cbo.gov/sites/default/files/110th-congress-2007-2008/reports/01-14-gasolineprices.pdf

Austin, P. C., & Hux, J. E. (2002). A brief note on overlapping confidence intervals. *Journal of Vascular Surgery*, *36*(1), 194–195. https://doi.org/10.1067/mva.2002.125015

Avineri, E., & Waygood, E. O. D. (2013). Applying valence framing to enhance the effect of information on transport-related carbon dioxide emissions. *Transportation Research Part A: Policy and Practice*, *48*, 31–38. https://doi.org/10.1016/j.tra.2012.10.003

Bamberg, S., & Schmidt, P. (2003). Incentives, morality, or habit? Predicting students' car use for university routes with the models of Ajzen, Schwartz, and Triandis. *Environment and Behavior*, *35*(2), 264–285. https://doi.org/10.1177/0013916502250134

Bandura, A. (1997). *Self-efficacy: The exercise of control*. Freemann.

Barkenbus, J. N. (2010). Eco-driving: An overlooked climate change initiative. *Energy Policy*, *38*(2), 762–769. https://doi.org/10.1016/j.enpol.2009.10.021

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, *68*(3), 255–278. https://doi.org/10.1016/j.jml.2012.11.001

Barszcz, S. J., Oleszkowicz, A. M., Bak, O., & Słowińska, A. M. (2022). The role of types of motivation, life goals, and beliefs in pro-environmental behavior: The Self-Determination Theory perspective. *Current Psychology*. https://doi.org/10.1007/s12144-022-02995-2

Barth, M., & Boriboonsomsin, K. (2009). Energy and emissions impacts of a freeway-based dynamic eco-driving system. *Transportation Research Part D: Transport and Environment*, *14*(6), 400–410. https://doi.org/10.1016/j.trd.2009.01.004

Bates, D., Kliegl, R., Vasishth, S., & Baayen, R. H. (2015). Parsimonious mixed models. *ArXiv Preprint, arXiv: 1506.04967*. https://doi.org/10.48550/arXiv.1506.04967

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *ArXiv Preprint, arXiv: 1406.5823*. https://doi.org/10.48550/arXiv.1406.5823

Batinic, B., Reips, U.-D., & Bosnjak, M. (2002). *Online social sciences*. Hogrefe & Huber Publishers.

Baumgartner, T., Langenbach, B. P., Gianotti, L. R. R., Müri, R. M., & Knoch, D. (2019). Frequency of everyday pro-environmental behaviour is explained by baseline activation in lateral prefrontal cortex. *Scientific Reports*, *9*, 1–7. https://doi.org/10.1038/s41598-018-36956-2

Beck, A. L., Chitalia, S., & Rai, V. (2019). Not so gameful: A critical review of gamification in mobile energy applications. *Energy Research & Social Science*, *51*, 32–39. https://doi.org/10.1016/j.erss.2019.01.006

Beloufa, S., Vailleau, B., Boucheix, J.-M., Kemeny, A., & Merienne, F. (2014). Eco-driving with electric cars: Effect of continuous and on-demand feedback on driving behavior and safety. *5th International Conference on Applied Human Factors and Ergonomics, Krakow*, *2014*, 158–164.

Bentler, P. M. (1992). On the fit of models to covariances and methodology to the Bulletin. *Psychological Bulletin*, *112*(3), 400–404. https://doi.org/10.1037/0033-2909.112.3.400

Berkman, E. T. (2016). Self-regulation training. In K. D. Vohs & R. F. Baumeister (Eds.), *Handbook of Self-Regulation: Research, Theory and Applications (3rd Edition)* (pp. 440–457). Guilford.

Berkovsky, S., Freyne, J., & Oinas-Kukkonen, H. (2012). Influencing individually: Fusing personalization and persuasion. *ACM Transactions on Interactive Intelligent Systems*, *2*(2), 1–8. https://doi.org/10.1145/2209310.2209312

Best, H., & Kneip, T. (2011). The impact of attitudes and behavioral costs on environmental behavior: A natural experiment on household waste recycling. *Social Science Research*, *40*(3), 917–930. https://doi.org/10.1016/j.ssresearch.2010.12.001

Beusen, B., Broekx, S., Denys, T., Beckx, C., Degraeuwe, B., Gijsbers, M., Scheepers, K., Govaerts, L., Torfs, R., & Panis, L. I. (2009). Using on-board logging devices to study the longer-term impact of an eco-driving course. *Transportation Research Part D: Transport and Environment*, *14*(7), 514–520. https://doi.org/10.1016/j.trd.2009.05.009

Bingham, C., Walsh, C., & Carroll, S. (2012). Impact of driving characteristics on electric vehicle energy consumption and range. *IET Intelligent Transport Systems*, *6*(1), 29–35. https://doi.org/10.1049/iet-its.2010.0137

Black, J. S., Stern, P. C., & Elworth, J. T. (1985). Personal and contextual influences on household energy adaptations. *Journal of Applied Psychology*, *70*(1), 3–21. https://doi.org/10.1037//0021-9010.70.1.3

Bohner, G., & Schlüter, L. E. (2014). A room with a viewpoint revisited: Descriptive norms and hotel guests' towel reuse behavior. *PLoS ONE*, *9*(8), e106606. https://doi.org/10.1371/journal.pone.0104086

Bolderdijk, J. W., Geller, S. E., & Lehman, P. K. (2018). Encouraging pro-environmental behaviour with rewards and penalties. In L. Steg & J. I. M. de Groot (Eds.), *Environmental Psychology: An Introduction* (pp. 233–242). John Wiley & Sons Ltd.

Bolderdijk, J. W., Gorsira, M., Keizer, K., & Steg, L. (2013). Values determine the (in)effectiveness of informational interventions in promoting pro-environmental behavior. *PLoS ONE*, *8*(12), 1–7. https://doi.org/10.1371/journal.pone.0083911

Bolderdijk, J. W., Knockaert, J., Steg, L., & Verhoef, E. T. (2011). Effects of Pay-As-You-Drive vehicle insurance on young drivers' speed choice: Results of a Dutch field experiment. *Accident Analysis and Prevention*, *43*(3), 1181–1186. https://doi.org/10.1016/j.aap.2010.12.032

Bolderdijk, J. W., & Steg, L. (2015). Promoting sustainable consumption: The risks of using financial incentives. In J. Thøgersen & L. Reisch (Eds.), *Handbook of Research on Sustainable Consumption* (pp. 328–342). Edward Elgar Publishing. https://doi.org/10.4337/9781783471270.00033

Bolderdijk, J. W., Steg, L., Geller, E. S., Lehman, P. K., & Postmes, T. (2013). Comparing the effectiveness of monetary versus moral motives in environmental campaigning. *Nature Climate Change*, *3*(4), 413–416. https://doi.org/10.1038/nclimate1767

Boomsma, C., Goodhew, J., Goodhew, S., & Pahl, S. (2016). Improving the visibility of energy use in home heating in England: Thermal images and the role of visual tailoring. *Energy Research & Social Science*, *14*, 111–121. https://doi.org/10.1016/j.erss.2016.01.005

Boomsma, C., & Steg, L. (2014). The effect of information and values on acceptability of reduced street lighting. *Journal of Environmental Psychology*, *39*, 22–31. https://doi.org/10.1016/j.jenvp.2013.11.004

Boriboonsomsin, K., Vu, A., & Barth, M. (2010). *Eco-driving: Pilot evaluation of driving behavior changes among U.S. drivers*. University of California Transportation Center.

Brouwer, R. F. T., Stuiver, A., Hof, T., Kroon, L., Pauwelussen, J., & Holleman, B. (2015). Personalised feedback and eco-driving: An explorative study. *Transportation Research Part C: Emerging Technologies*, *58*, 760–771. https://doi.org/10.1016/j.trc.2015.04.027

Brown, C. L., & Krishna, A. (2004). The skeptical shopper: A metacognitive account for the effects of default options on choice. *Journal of Consumer Research*, *31*(3), 529–539. https://doi.org/10.1086/425087

Brown, K. W., & Kasser, T. (2005). Are psychological and ecological well-being compatible? The role of values, mindfulness, and lifestyle. *Social Indicators Research*, *74*(2), 349–368. https://doi.org/10.1007/s11205-004-8207-8

Brown, M. W., & Cudeck, R. (1989). Single sample cross-validation indices for covariance structures. *Multivariate Behavioral Research*, *24*(4), 445–455. https://doi.org/10.1207/s15327906mbr2404_4

Buekers, J., Van Holderbeke, M., Bierkens, J., & Int Panis, L. (2014). Health and environmental benefits related to electric vehicle introduction in EU countries. *Transportation Research Part D: Transport and Environment*, *33*, 26–38. https://doi.org/10.1016/j.trd.2014.09.002

Calvo, T. G., Cervelló, E., Jiménez, R., Iglesias, D., & Murcia, J. A. M. (2010). Using self-determination theory to explain sport persistence and dropout in adolescent athletes.

*Spanish Journal of Psychology*, *13*(2), 677–684. https://doi.org/10.1017/S1138741600002341

Carfora, V., Catellani, P., Caso, D., & Conner, M. (2019). How to reduce red and processed meat consumption by daily text messages targeting environment or health benefits. *Journal of Environmental Psychology*, *65*, 1–9. https://doi.org/10.1016/j.jenvp.2019.101319

Carrese, S., Gemma, A., & La Spada, S. (2013). Impacts of driving behaviours, slope and vehicle load factor on bus fuel consumption and emissions: A real case study in the city of Rome. *Procedia – Social and Behavioral Sciences*, *87*, 211–221. https://doi.org/10.1016/j.sbspro.2013.10.605

Carroll, J., Brazil, W., Howard, M., & Denny, E. (2022). Imperfect emissions information during flight choices and the role of $CO_2$ labelling. *Renewable and Sustainable Energy Reviews*, *165*, 112508. https://doi.org/10.1016/j.rser.2022.112508

Cattaneo, C. (2019). Internal and external barriers to energy efficiency: Which role for policy interventions? *Energy Efficiency*, *12*(5), 1293–1311. https://doi.org/10.1007/s12053-019-09775-1

Cellina, F., Bucher, D., Mangili, F., Simão, J. V., Rudel, R., & Raubal, M. (2019). A large scale, app-based behaviour change experiment persuading sustainable mobility patterns: Methods, results and lessons learnt. *Sustainability (Switzerland)*, *11*(9), 2674. https://doi.org/10.3390/su11092674

Chen, H., Cohen, P., & Chen, S. (2010). How big is a big odds ratio? Interpreting the magnitudes of odds ratios in epidemiological studies. *Communications in Statistics: Simulation and Computation*, *39*(4), 860–864. https://doi.org/10.1080/03610911003650383

Cheng, T., Woon, D. K., & Lynes, J. K. (2011). The use of message framing in the promotion of environmentally sustainable behaviors. *Social Marketing Quarterly*, *17*(2), 48–62. https://doi.org/10.1080/15245004.2011.570859

Christy, K. R., & Fox, J. (2014). Leaderboards in a virtual classroom: A test of stereotype threat and social comparison explanations for women's math performance. *Computers and Education*, *78*, 66–77. https://doi.org/10.1016/j.compedu.2014.05.005

Cialdini, R. B. (2003). Crafting normative messages to protect the environment. *Current Directions in Psychological Science*, *12*(4), 105–109. https://doi.org/10.1111/1467-8721.01242

Cialdini, R. B., Demaine, L. J., Sagarin, B. J., Barrett, D. W., Rhoads, K., & Winter, P. L. (2006). Managing social norms for persuasive impact. *Social Influence*, *1*(1), 3–15. https://doi.org/10.1080/15534510500181459

Cialdini, R. B., Reno, R. R., & Kallgren, C. A. (1990). A focus theory of normative conduct: Recycling the concept of norms to reduce littering in public places. *Journal of Personality and Social Psychology*, *58*(6), 1015–1026. https://doi.org/10.1037/0022-3514.58.6.1015

Cialdini, R. B., & Trost, M. R. (1998). Social influence: Social norms, conformity and compliance. In D. T. Gilbert, S. T. Fiske, & G. Lindzey (Eds.), *The handbook of social psychology* (pp. 151–192). McGraw-Hill.

Cieslik, W., Szwajca, J., & Golimowsky, J. (2020). The possibility of energy consumption reduction using the ECO driving mode based on the RDC test. *Combustion Engines*, *49*, 59–69. https://doi.org/10.19206/CE-2020-310

co2online. (2009, June 25). Wie viele Bäume braucht es, um eine Tonne $CO_2$ zu binden. https://www.co2online.de/service/klima-orakel/beitrag/wie-viele-baeume-braucht-es-um-eine-tonne-co2-zu-binden-10658/

Cocron, P., Bühler, F., Franke, T., Neumann, I., Dielmann, B., & Krems, J. F. (2013). Energy recapture through deceleration – regenerative braking in electric vehicles from a user perspective. *Ergonomics*, *56*(8), 1203–1215. https://doi.org/10.1080/00140139.2013.803160

Cohen, J. (1992). A power primer. *Psychological Bulletin*, *112*(1), 155–159. https://doi.org/10.1016/j.jorganchem.2011.01.025

Converse, B. A., Juarez, L., & Hennecke, M. (2018). Self-control and the reasons behind our goals. *Journal of Personality and Social Psychology*, *116*(5), 860–883. https://doi.org/10.1037/pspp0000188

Corcoba Magaña, V., & Muñoz-Organero, M. (2015). GAFU: Using a gamification tool to save fuel. *IEEE Intelligent Transportation Systems Magazine*, *7*(2), 58–70. https://doi.org/10.1109/MITS.2015.2408152

Cornelissen, G., Pandelaere, M., Warlop, L., & Dewitte, S. (2008). Positive cueing: Promoting sustainable consumer behavior by cueing common environmental behaviors as environmental. *International Journal of Research in Marketing*, *25*(1), 46–55. https://doi.org/10.1016/j.ijresmar.2007.06.002

Corral-Verdugo, V., Frías-Armenta, M., Pérez-Urias, F., Orduña-Cabrera, V., & Espinoza-Gallego, N. (2002). Residential water consumption, motivation for conserving water and the continuing tragedy of the commons. *Environmental Management*, *30*(4), 527–535. https://doi.org/10.1007/s00267-002-2599-5

Costa, D. L., & Kahn, M. E. (2013). Energy conservation "nudges" and environmentalist ideology: Evidence from a randomized residential electricity field experiment. *Journal of the European Economic Association*, *11*(3), 680–702. https://doi.org/10.1111/jeea.12011

Coulter, A., Clegg, S., Lyons, G., Chatterton, T., & A., Musselwhite. C. B. (2007). *Exploring public attitudes to personal carbon dioxide emission information*. London: Department for Transport.

Cristea, M., Paran, F., & Delhomme, P. (2012). The role of motivations for eco-driving and social norms on behavioural intentions regarding speed limits and time headway. *World Academy of Science, Engineering and Technology*, *66*, 998–1003.

Curran, P. J., West, S. G., & Finch, J. F. (1996). The robustness of test statistics to nonnormality and specification error in confirmatory factor analysis. *Psychological Methods*, *1*(1), 16–29. https://doi.org/10.1037/1082-989X.1.1.16

Daina, N., Sivakumar, A., & Polak, J. W. (2017). Electric vehicle charging choices: Modelling and implications for smart charging services. *Transportation Research Part C: Emerging Technologies*, *81*, 36–56. https://doi.org/10.1016/j.trc.2017.05.006

De Groot, J. I. M., Abrahamse, W., & Jones, K. (2013). Persuasive normative messages: The influence of injunctive and personal norms on using free plastic bags. *Sustainability (Switzerland)*, *5*(5), 1829–1844. https://doi.org/10.3390/su5051829

De Groot, J. I. M., & Steg, L. (2007). Value orientations and environmental beliefs in five countries: Validity of an instrument to measure egoistic, altruistic and biospheric value orientations. *Journal of Cross-Cultural Psychology*, *38*(3), 318–332. https://doi.org/10.1177/0022022107300278

De Groot, J. I. M., & Steg, L. (2008). Value orientations to explain beliefs related to environmental significant behavior: How to measure egoistic, altruistic, and biospheric value orientations. *Environment and Behavior*, *40*(3), 330–354. https://doi.org/10.1177/0013916506297831

De Groot, J. I. M., & Steg, L. (2010). Relationships between value orientations, self-determined motivational types and pro-environmental behavioural intentions. *Journal of Environmental Psychology*, *30*(4), 368–378. https://doi.org/10.1016/j.jenvp.2010.04.002

De Groot, J. I. M., Steg, L., & Dicke, M. (2007). Transportation trends from a moral perspective: Value orientations, norms and reducing car use. In F. N. Gustavsson (Ed.), *New Transportation Research Progress* (pp. 67–91). Nova Science Publishers.

De Ridder, D., Adriaanse, M., & Fujita, K. (2017). Self-control in health and well-being. In D. De Ridder, M. Adriaanse, & K. Fujita (Eds.), *The Routledge International Handbook of Self-Control in Health and Well-Being* (pp. 1–7). Routledge.

De Young, R. (1996). Some psychological aspects of reduced consumption behavior: The role of intrinsic satisfaction and competence motivation. *Environment and Behavior*, *28*(3), 358–409. https://doi.org/10.1177/0013916596283005

Deci, E. L., Betley, G., Kahle, J., Abrams, L., & Porac, J. (1981). When trying to win: Competition and intrinsic motivation. *Personality and Social Psychology Bulletin*, *7*(1), 79–83. https://doi.org/10.1177/014616728171012

Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin*, *125*(6), 627–668. https://doi.org/10.1037/0033-2909.125.6.627

Deci, E. L., & Moller. (2014). The psychological of getting paid: An integrated perspective. In E. Bijleveld, & H. Aarts (Eds.), *The Psychological Science of Money* (pp. 189–211). Springer. https://doi.org/10.1007/978-1-4939-0959-9

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. Springer Science & Business Media.

Deci, E. L., & Ryan, R. M. (1987). The support of autonomy and the control of behavior. *Journal of Personality and Social Psychology*, *53*(6), 1024–1037. https://doi.org/10.1037/0022-3514.53.6.1024

Deci, E. L., & Ryan, R. M. (2000). The “what” and “why” of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry*, *11*(4), 227–268. https://doi.org/10.1360/982004-431

Deci, E. L., & Ryan, R. M. (2008). Self-determination theory: A macrotheory of human motivation, development, and health. *Canadian Psychology*, *49*(3), 182–185. https://doi.org/10.1037/a0012801

Deci, E. L., Ryan, R. M., & Koestner, R. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin*, *125*(6), 627–668. https://doi.org/10.1037/0033-2909.125.6.627

Deci, E. L., Ryan, R. M., & Williams, G. C. (1996). Need satisfaction and the self-regulation of learning. *Learning and Individual Differences*, *8*(3), 165–183. https://doi.org/10.1016/S1041-6080(96)90013-8

Degirmenci, K., & Breitner, M. H. (2017). Consumer purchase intentions for electric vehicles: Is green more important than price and range? *Transportation Research Part D: Transport and Environment*, *51*, 250–260. https://doi.org/10.1016/j.trd.2017.01.001

Degirmenci, K., & Breitner, M. H. (2023). Gamification and sensory stimuli in eco-driving research: A field experiment to reduce energy consumption in electric vehicles. *Transportation Research Part F: Psychology and Behaviour*, *92*, 266–282. https://doi.org/10.1016/j.trf.2022.10.014

Degraeuwe, B., & Beusen, B. (2013). Corrigendum to “Using on-board data logging devices to study the longer-term impact of an eco-driving course.” *Transportation Research Part D: Transport and Environment*, *19*, 48–49. https://doi.org/10.1016/j.trd.2012.11.003

Delhomme, P., Cristea, M., & Paran, F. (2013). Self-reported frequency and perceived difficulty of adopting eco-friendly driving behavior according to gender, age, and environmental concern. *Transportation Research Part D: Transport and Environment*, *20*, 55–58. https://doi.org/10.1016/j.trd.2013.02.002

Destatis. (n.d.). *Die Datenbank des Statistischen Bundesamtes*. Destatis: Statistisches Bundesamt. Retrieved May 15, 2021, from https://www-genesis.destatis.de/genesis/online

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining “gamification”. *Proceedings of the 15th International Academic*

*MindTrek Conference: Envisioning Future Media Environments, 2011*, *September*, 9–15. https://doi.org/10.1145/2181037.2181040

Deuten, S., Gómez Vilchez, J. J., & Thiel, C. (2020). Analysis and testing of electric car incentive scenarios in the Netherlands and Norway. *Technological Forecasting and Social Change*, *151*, 119847. https://doi.org/10.1016/j.techfore.2019.119847

Diekmann, A., & Preisendörfer, P. (2003). Green and greenback: The behavioral effects of environmental attitudes in low-cost and high-cost situations. *Rationality and Society*, *15*(4), 441–472. https://doi.org/10.1177/1043463103154002

Diekmann, A., & Preisendörfer, P. (2009). Das Feldexperiment von Best und Die Low-Cost-Hypothese. Eine Erwiderung / The field study by Best and the Low-Cost Hypothesis. A reply. *Zeitschrift für Soziologie*, *38*(6), 535–539. https://doi.org/10.1515/zfsoz-2009-0605

Diener, E., Suh, E. M., Lucas, R. E., & Smith, H. L. (1999). Subjective well-being: Three decades of progress. *Psychological Bulletin*, *125*(2), 276–302. https://doi.org/10.1006/pupt.1998.0157

Dietz, T., Gardner, G. T., Gilligan, J., Stern, P. C., & Vandenbergh, M. P. (2009). Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions. *Proceedings of the National Academy of Sciences of the United States of America (PNAS)*, *106*(44), 18452–18456. https://doi.org/10.1073/pnas.0908738106

Dietz, T., Kalof, L., & Stern, P. C. (2003). Gender, values, and environmentalism. *Social Science Quarterly*, *83*(1), 353–36. https://doi.org/10.1111/1540-6237.00088

Diewald, S., Möller, A., Stockinger, T., Roalter, L., Koelle, M., Lindemann, P., & Kranz, M. (2015). Gamification-supported exploration and practicing for automotive user interfaces and vehicle functions. In T. Reiners, & L. Wood (Eds.), *Gamification in Education and Business* (pp. 637–661). Springer. https://doi.org/10.1007/978-3-319-10208-5_32

Do Valle, P. O., Rebelo, E., Reis, E., & Menezez, J. (2005). Combining behavioral theories to predict recycling involvement. *Environment and Behavior, 37*(3), 364–396. https://doi.org/10.1177/0013916504272563

Dogan, E., Bolderdijk, J. W., & Steg, L. (2014). Making small numbers count: Environmental and financial feedback in promoting eco-driving behaviours. *Journal of Consumer Policy*, *37*(3), 413–422. https://doi.org/10.1007/s10603-014-9259-z

Dogan, E., Steg, L., & Delhomme, P. (2011). The influence of multiple goals on driving behavior: The case of safety, time saving, and fuel saving. *Accident Analysis and Prevention*, *43*(5), 1635–1643. https://doi.org/10.1016/j.aap.2011.03.002

Douglas, B. D., & Brauer, M. (2021). Gamification to prevent climate change: a review of games and apps for sustainability. *Current Opinion in Psychology*, *42*, 89–94. https://doi.org/10.1016/j.copsyc.2021.04.008

Duckworth, A. L., White, R. E., Matteucci, A. J., & Gross, J. J. (2016). A stitch in time: Strategic self-control in high school and college students. *Journal of Educational Psychology*, *108*(3), 329–341. https://doi.org/10.1037/edu0000062.A

Dunlap, R. E., Van Liere, K. D., Mertig, A. G., & Jones, R. E. (2000). New trends in measuring environmental attitudes: Measuring endorsement of the New Ecological Paradigm: A revised NEP scale. *Journal of Social Issues*, *56*(3), 425–442. https://doi.org/10.1111/0022-4537.00176

Ebermann, C., & Brauer, B. (2016). The role of goal frames regarding the impact of gamified persuasive systems on sustainable mobility behavior. *Reserach Papers*, 174. http://aisel.aisnet.org/ecis2016_rp

EEA. (2019, December 17). *Passenger car ownership in Europe*. https://www.eea.europa.eu/data-and-maps/daviz/passenger-car-ownership-passenger-cars-5#tab-chart_1

EEA. (2023, June 02). *Greenhouse gas emission intensity of electricity generation in Europe*. https://www.eea.europa.eu/ims/greenhouse-gas-emission-intensity-of-1

Eider, M., Sellner, D., Berl, A., Basmadjian, R., De Meer, H., Klingert, S., Schulze, T., Kutzner, F., Kacperski, C., & Stolba, M. (2017). Seamless electromobility. *E-Energy 2017 - Proceedings of the 8th International Conference on Future Energy Systems*, 316–321. https://doi.org/10.1145/3077839.3078461

Emmons, R. A. (1992). Abstract versus concrete goals: Personal striving level, physical illness, and psychological well-being. *Journal of Personality and Social Psychology*, *62*(2), 292–300. https://doi.org/10.1037/0022-3514.62.2.292

Energypedia. (n.d.). *Eco Driving Tools*. Retrieved March 03, 2023, from https://energypedia.info/wiki/Eco_Driving_Tools

Energy Saving Trust. (2017). *Efficient driving in electric and low-emission vehicles*.

Englert, C., Graham, J. D., & Bray, S. R. (2020). Self-control in sport and exercise psychology. *Sport, Exercise, and Performance Psychology*, *9*(2), 161–166. https://doi.org/10.1037/spy0000205

EPA. (n.d.). *Driving More Efficiently*. U.S. Department of Energy. Retrieved July 30, 2023, from https://www.fueleconomy.gov/feg/driveHabits.jsp

EPA. (2005). Average carbon dioxide emissions resulting from gasoline and diesel fuel. *EPA420-F-05-001*.

Ericsson, E., Larsson, H., & Brundell-Freij, K. (2006). Optimizing route choice for lowest fuel consumption - Potential effects of a new driver support tool. *Transportation Research Part C: Emerging Technologies*, *14*(6), 369–383. https://doi.org/10.1016/j.trc.2006.10.001

Eurelectric. (2015). *Smart charging: Steering the charge, driving the change*. Eurelectric Bruxelles, Belgium.

European Commission. (2020a). *New Eurobarometer Survey: Protecting the environment and climate is important for over 90% of European citizens* (Issue March 03). https://ec.europa.eu/commission/presscorner/detail/en/ip_20_331

European Commission. (2020b). *A fundamental transport transformation: Commission presents its plan for green, smart and affordable mobility* (Issue December 09). https://ec.europa.eu/commission/presscorner/detail/en/ip_20_2329

European Commission. (n.d.). *2030 Climate Target Plan*. Retrieved July 30, 2023, from https://ec.europa.eu/clima/policies/eu-climate-action/2030_ctp_en

Eurostat. (2022, April 07). *Fuels consumption still affected by COVID-19 in 2021*. https://ec.europa.eu/eurostat/de/web/products-eurostat-news/-/ddn-20220407-1#:~:text=While%20in%202020%2C%20EU%20Member,70.4%20million%20tonnes%20in%202021

Evans, L., Maio, G. R., Corner, A., Hodgetts, C. J., Ahmed, S., & Hahn, U. (2013). Self-interest and pro-environmental behaviour. *Nature Climate Change*, *3*(2), 122–125. https://doi.org/10.1038/nclimate1662

Farrow, K., Grolleau, G., & Ibanez, L. (2017). Social norms and pro-environmental behavior: A review of the evidence. *Ecological Economics*, *140*, 1–13. https://doi.org/10.1016/j.ecolecon.2017.04.017

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*, 175–191. https://doi.org/10.3758/BF03193146

Feather, N. T. (1995). Values, valences, and choice: The influence of values on the perceived attractiveness and choice of alternatives. *Journal of Personality and Social Psychology*, *68*(6), 1135–1151. https://doi.org/10.1037/0022-3514.68.6.1135

Fehr, E., & Falk, A. (2002). Psychological foundations of incentives. *European Economic Review*, *46*(4–5), 687–724. https://doi.org/10.1016/S0014-2921(01)00208-2

Fijnheer, J. D. Lou, Van Oostendorp, H., & Veltkamp, R. (2019). Household energy conservation intervention: A game versus dashboard comparison. *International Journal of Serious Games*, *6*(3), 23–36. https://doi.org/10.17083/ijsg.v6i3.300

Fleiter, J. J., Lennon, A., & Watson, B. (2012). How do other people influence your driving speed? Exploring the “who” and the “how” of social influences on speeding from a qualitative perspective. *Transportation Research Part F: Traffic Psychology and Behaviour*, *13*(1), 49–62. https://doi.org/10.1201/b12320

Fonseca, N., Casanova, J., & Espinosa, F. (2010). Influence of driving style on fuel consumption and emissions in diesel-powered passenger car. *18th International Symposium Transport and Air Pollution, TAP 2010, 1–6*.

Fontaras, G., Zacharof, N. G., & Ciuffo, B. (2017). Fuel consumption and $CO_2$ emissions from passenger cars in Europe – Laboratory versus real-world emissions. *Progress in Energy and Combustion Science*, *60*, 97–131. https://doi.org/10.1016/j.pecs.2016.12.004

Fors, C., Kircher, K., & Ahlström, C. (2015). Interface design of eco-driving support systems – Truck drivers’ preferences and behavioural compliance. *Transportation Research Part C: Emerging Technologies*, *58*, 706–720. https://doi.org/10.1016/j.trc.2015.03.035

Franco, F. Lo, Ricco, M., Mandrioli, R., & Grandi, G. (2020). Electric vehicle aggregate power flow prediction and smart charging system for distributed renewable energy self-consumption optimization. *Energies*, *13*(18), 1–25. https://doi.org/10.3390/en13195003

Franke, T., Arend, M. G., McIlroy, R. C., & Stanton, N. A. (2017). What drives ecodriving? Hybrid electric vehicle drivers' goals and motivations to perform energy efficient driving behaviors. *Advances in Intelligent Systems and Computing*, *484*, 451–461. https://doi.org/10.1007/978-3-319-41682-3_38

Franke, T., Schmalfuß, F., Rauh, N. (2018). Human factors and ergonomics in the individual adoption and use of electric vehicles. In A. Thatcher, & P. Yeow (Eds.), *Ergonomics and Human Factors for a Sustainable Future* (pp. 135–160). Palgrave Macmillan. https://doi.org/10.1007/978-981-10-8072-2_6

Frischknecht, R., Messmer, A., & Stolz, P. (2018). *Aktualisierung Umweltaspekte von Elektroautos*. Bundesamt für Umwelt (BAFU).

Fuj, E. T., Hennessy, M., & Mak, J. (1985). An evaluation of the validity and reliability of survey response data on household electricity conservation. *Evaluation Review*, *9*(1), 93–104. https://doi.org/10.1177/0193841X8500900106

Gaker, D., Vautin, D., Vij, A., & Walker, J. L. (2011). The power and value of green in promoting sustainable transport behavior. *Environmental Research Letters*, *6*(3). https://doi.org/10.1088/1748-9326/6/3/034010

Galvin, R. (2017). Energy consumption effects of speed and acceleration in electric vehicles: Laboratory case studies and implications for drivers and policymakers. *Transportation Research Part D: Transport and Environment*, *53*, 234–248. https://doi.org/10.1016/j.trd.2017.04.020

Gansser, O. A., & Reich, C. S. (2023). Influence of the New Ecological Paradigm (NEP) and environmental concerns on pro-environmental behavioral intention based on the Theory of Planned Behavior (TPB). *Journal of Cleaner Production*, *382*, 134629. https://doi.org/10.1016/j.jclepro.2022.134629

García-Villalobos, J., Zamora, I., San Martín, J. I., Asensio, F. J., & Aperribay, V. (2014). Plug-in electric vehicles in electric distribution networks: A review of smart charging approaches. *Renewable and Sustainable Energy Reviews*, *38*, 717–731. https://doi.org/10.1016/j.rser.2014.07.040

Gardner, B., & Abraham, C. (2007). What drives car use? A grounded theory analysis of commuters' reasons for driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, *10*(3), 187–200. https://doi.org/10.1016/j.trf.2006.09.004

Gaudreau, P., Carraro, N., & Miranda, D. (2012). From goal motivation to goal progress: The mediating role of coping in the Self-Concordance Model. *Anxiety, Stress & Coping*, *25*(5), 507–528. https://doi.org/10.1080/10615806.2011.628015

Gensheimer, J., Turner, A. J., Shekhar, A., Wenzel, A., Keutsch, F. N., & Chen, J. (2021). What are the different measures of mobility telling us about surface transportation $CO_2$ emissions during the COVID-19 pandemic? *Journal of Geophysical Research: Atmospheres*, *126*(11), 1–11. https://doi.org/10.1029/2021JD034664

Geske, J., & Schumann, D. (2018). Willing to participate in vehicle-to-grid (V2G)? Why not! *Energy Policy*, *120*(1), 392–401. https://doi.org/10.1016/j.enpol.2018.05.004

Gholamzadehmir, M., Sparks, P., & Farsides, T. (2019). Moral licensing, moral cleansing and pro-environmental behaviour: The moderating role of pro-environmental attitudes. *Journal of Environmental Psychology*, *65*, 101334. https://doi.org/10.1016/j.jenvp.2019.101334

Gifford, R., & Nilsson, A. (2014). Personal and social factors that influence pro-environmental concern and behaviour: A review. *International Journal of Psychology*, *49*(3), 141–157. https://doi.org/10.1002/ijop.12034

Gneezy, U., & Rustichini, A. (2000). Pay enough or don't pay at all. *Quarterly Journal of Economics*, *115*(3), 791–810. https://doi.org/10.1162/003355300554917

Goldstein, N. J., Cialdini, R. B., & Griskevicius, V. (2008). A room with a viewpoint: Using social norms to motivate environmental conservation in hotels. *Journal of Consumer Research*, *35*(3), 472–482. https://doi.org/10.1086/586910

Gollwitzer, P. M. (1999). Implementation intentions: Strong effects of simple plans. *American Psychologist*, *54*(7), 493–503. https://doi.org/10.1037/0003-066X.54.7.493

Gomes, D. G. E. (2022). Should I use fixed effects or random effects when I have fewer than five levels of a grouping factor in a mixed-effects model? *PeerJ*, *10*, 1–16. https://doi.org/10.7717/peerj.12794

Graham, J., Koo, M., & Wilson, T. D. (2011). Conserving energy by inducing people to drive less. *Journal of Applied Social Psychology*, *41*(1), 106–118. https://doi.org/10.1111/j.1559-1816.2010.00704.x

Green-Demers, I., Pelletier, L. G., & Ménard, S. (1997). The impact of behavioural difficulty on the saliency of the association between self-determined motivation and environmental behaviours. *Canadian Journal of Behavioural Science*, *29*(3), 157–166. https://doi.org/10.1037/0008-400x.29.3.157

Guagnano, G. A., Dietz, T., & Stern, P. C. (1994). Willingness to pay for public goods: A test of the Contribution Model. *Psychological Science*, *5*(6), 411–415. https://doi.org/10.1111/j.1467-9280.1994.tb00295.x

Guagnano, G. A., Stern, P. C., & Dietz, T. (1995). Influences on attitude-behavior relationships: A natural experiment with curbside recycling. *Environment and Behavior*, *27*(5), 699–718. https://doi.org/10.1177/001391659527500

Günther, M., Kacperski, C., & Krems, J. F. (2020). Can electric vehicle drivers be persuaded to eco-drive? A field study of feedback, gamification and financial rewards in Germany. *Energy Research and Social Science*, *63*, 101407. https://doi.org/10.1016/j.erss.2019.101407

Günther, M., Rauh, N., & Krems, J. F. (2017). Conducting a study to investigate eco-driving strategies with battery electric vehicles – A multiple method approach. *Transportation Research Procedia*, *25*, 2242–2256. https://doi.org/10.1016/j.trpro.2017.05.431a

Habib, M. A., & Anik, M. A. H. (2021). Impacts of COVID-19 on transport modes and mobility behavior: Analysis of public discourse in Twitter. *Transportation Research Record: Journal of the Transportation Research Board*, 1–14. https://doi.org/10.1177/03611981211029926

Hair Jr., J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate Data Analysis (8th Ed.)*. Cengage Learning, EMEA.

Halpern, S. D., Loewenstein, G., Volpp, K. G., Cooney, E., Vranas, K., Quill, C. M., McKenzie, M. S., Harhay, M. O., Gabler, N. B., Silva, T., Arnold, R., Angus, D. C., & Bryce, C. (2013). Default options in advance directives influence how patients set goals for end-of-life car. *Health Affairs*, *32*(2), 408–417. https://doi.org/10.1377/hlthaff.2012.0895.Default

Hamari, J., Hassan, L., & Dias, A. (2018). Gamification, quantified-self or social networking? Matching users' goals with motivational technology. *User Modeling and User-Adapted Interaction, 28*(1), 53–74. https://doi.org/10.1007/s11257-018-9200-2

Hamari, J., & Koivisto, J. (2015). "Working out for likes": An empirical study on social influence in exercise gamification. *Computers in Human Behavior*, *50*, 333–347. https://doi.org/10.1016/j.chb.2015.04.018

Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., & Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in Human Behavior*, *54*, 170–179. https://doi.org/10.1016/j.chb.2015.07.045

Harland, P., Staats, H., & Wilke, H. A. M. (1999). Explaining proenvironmental intention and behavior by personal norms and the theory of planned behavior. *Journal of Applied Social Psychology*, *29*(12), 2505–2528. https://doi.org/10.1111/j.1559-1816.1999.tb00123.x

Harland, P., Staats, H., & Wilke, H. A. M. (2007). Situational and personality factors as direct or personal norm mediated predictors of pro-environmental behavior: Questions derived from Norm-Activation Theory. *Basic and Applied Social Psychology*, *29*(4), 323–334. https://doi.org/10.1080/01973530701665058

Harré, N., Field, J., & Kirkwood, B. (1996). Gender differences and areas of common concern in the driving behaviors and attitudes of adolescents. *Journal of Safety Research*, *27*(3), 163–173. https://doi.org/10.1016/0022-4375(96)00013-8

Harvey, J., Thorpe, N., & Fairchild, R. (2013). Attitudes towards and perceptions of eco-driving and the role of feedback systems. *Ergonomics*, *46*(3), 507–521. https://doi.org/10.1080/00140139.2012.751460

Hawcroft, L. J., & Milfont, T. L. (2010). The use (and abuse) of the new environmental paradigm scale over the last 30 years: A meta-analysis. *Journal of Environmental Psychology*, *30*(2), 143–158. https://doi.org/10.1016/j.jenvp.2009.10.003

Heath, Y., & Gifford, R. (2002). Extending the theory of planned behavior: Predicting the use of public transportation. *Journal of Applied Social Psychology*, *32*(10), 2154–2189. https://doi.org/10.1111/j.1559-1816.2002.tb02068.x

Helmbrecht, M., Bengler, K., & Vilimek, R. (2013a). Adaptations in driving efficiency with electric vehicles. In M. Kurosu (Ed.), *Human-Computer Interaction. Application and Services. HCI 2013. Lecture Notes in Computer Science, Vol. 8005* (pp. 578–585). Springer. 578–585. https://doi.org/10.1007/978-3-642-39262-7_65

Helmbrecht, M., Bengler, K., & Vilimek, R. (2013b). Strategies for efficient driving with electric vehicles. In E. Brandenburg, L. Doria, A. Gross, T. Günzler, & H. Smieszek (Eds.), *Grundlagen und Anwendungen der Mensch-Maschine-Interaktion – Foundations and applications of human-machine interaction. 10. Berliner Werkstatt Mensch-Maschine-Systeme* (pp. 83–91). Technische Universität Berlin.

Hertwich, E. G., & Peters, G. P. (2009). Carbon footprint of nations: A global, trade-linked analysis. *Environmental Science and Technology*, *43*(16), 6414–6420. https://doi.org/10.1021/es803496a

Heyman, J., & Ariely, D. (2004). Effort for payment – A tale of two markets. *Psychological Science*, *15*(11), 787–793. https://doi.org/10.1111/j.0956-7976.2004.00757.x

Hines, J. M., Hungerford, H. R., & Tomera, A. N. (1987). Analysis and synthesis of research on responsible environmental behavior: A meta-analysis. *The Journal of Environmental Education*, *18*(2), 1–8. https://doi.org/10.1080/00958964.1987.9943482

Hollnagel, E., Nåbo, A., & Lau, I. V. (2005). A systemic model for driver-in-control. *Driving Assessment Conference*, *2*, 86–91. https://doi.org/10.17077/drivingassessment.1101

Hopper, J. R., & Nielsen, J. M. (1991). Recycling as altruistic behavior: Normative and behavioral strategies to expand participation in a community recycling program. *Environment and Behavior*, *23*(2), 195–220. https://doi.org/10.1177/0013916591232004

Howell, R. A. (2014). Investigating the long-term impacts of climate change communications on individuals' attitudes and behavior. *Environment and Behavior*, *46*(1), 70–101. https://doi.org/10.1177/0013916512452428

Hrimech, H., Beloufa, S., Merienne, F., Boucheix, J. M., Cauchard, F., Vedrenne, J., & Kemey, A. (2016). The effects of the use of serious game in eco-driving training. *Frontiers in ICT*, *3*(22), 1–12. https://doi.org/10.3389/fict.2016.00022

Hsee, C. K., & Zhang, J. (2010). General evaluability theory. *Perspectives on Psychological Science*, *5*(4), 343–355. https://doi.org/10.1177/1745691610374586

Hsu, C. L., & Lu, H. P. (2004). Why do people play on-line games? An extended TAM with social influences and flow experience. *Information and Management*, *41*(7), 853–868. https://doi.org/10.1016/j.im.2003.08.014

Hu, L. T., & Bentler, P. M. (1998). Fit indices in covariate structure modeling: Sensitivity to underparameterized model misspecification. *Psychological Methods*, *3*, 424–453. https://doi.org/10.1037/1082-989X.3.4.424

Huang, Y., Ng, E. C. Y., Zhou, J. L., Surawski, N. C., Chan, E. F. C., & Hong, G. (2018). Eco-driving technology for sustainable road transport: A review. *Renewable and Sustainable Energy Reviews*, *93*, 596–609. https://doi.org/10.1016/j.rser.2018.05.030

Huber, J., Jung, D., Schaule, E., & Weinhardt, C. (2020). Goal framing in smart charging - Increasing BEV users' charging flexibility with digital nudges. *Proceedings of the 27th European Conference on Information Systems (ECIS), Stockholm and Uppsala, Sweden, June 8-14.*

Huber, J., Lohmann, K., Schmidt, M., & Weinhardt, C. (2021). Carbon efficient smart charging using forecasts of marginal emission factors. *Journal of Cleaner Production*, *284,* 124766. https://doi.org/10.1016/j.jclepro.2020.124766

Huber, J., Schaule, E., Jung, D., & Weinhardt, C. (2019). Quo vadis smart charging? A literature review and expert survey on technical potentials and user acceptance of smart charging systems. *World Electric Vehicle Journal*, *10*(4), 1–19. https://doi.org/10.3390/wevj10040085

Huber, M. Z., & Hilty, L. M. (2015). Gamification and sustainable consumption: Overcoming the limitations of persuasive technologies. *Advances in Intelligent Systems and Computing*, *310*, 367–385. https://doi.org/10.1007/978-3-319-09228-7_22

Hunecke, M., Blöbaum, A., Matthies, E., & Höger, R. (2001). Responsibility and environment: Ecological norm orientation and external factors in the domain of travel mode choice behavior. *Environment and Behavior*, *33*(6), 830–852. https://doi.org/10.1177/00139160121973269

Hunter, L. M., Hatch, A., & Johnson, A. (2004). Cross-national gender variation in environmental behaviors. *Social Science Quarterly*, *85*(3), 677–694. https://doi.org/10.1111/j.0038-4941.2004.00239.x

IEA. (n.d. a). *Fuel Consumption of Cars and Vans*. Retrieved July 28, 2023, from https://www.iea.org/energy-system/transport/cars-and-vans

IEA. (n.d. b). *Tracking Transport 2021*. Retrieved September 23, 2021, from https://www.iea.org/reports/tracking-transport-2021

IEA. (2009). *Transport energy and $CO_2$: Moving towards sustainability*. https://doi.org/10.1787/9789264073173-en

IEA. (2020, July 03). *Global energy-related $CO_2$ emissions by sector*. https://www.iea.org/data-and-statistics/charts/global-energy-related-co2-emissions-by-sector

IEA. (2021, November 10). *Greenhouse Gas Emissions from Energy Data Explorer*. https://www.iea.org/reports/greenhouse-gas-emissions-from-energy-overview

IEA. (2022a, March 08). *Global $CO_2$ emissions rebounded to their highest level in history in 2021*. https://www.iea.org/news/global-co2-emissions-rebounded-to-their-highest-level-in-history-in-2021

IEA. (2022b). *Global EV Outlook 2022*. https://www.iea.org/reports/global-ev-outlook-2022

IPCC. (2021). Climate Change 2021: The Physical Science Basis. In V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leizzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekci, R. Yu, & B. Zhou (Eds.), *Contribution of Working Group 1 to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1–2391). Cambridge University Press. https://doi.org/10.1017/9781009157896

IPCC. (2022a). Climate Change 2022: Impacts, Adaption and Vulnerability. In H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegrìa, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, & B. Rama (Eds.), *Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1–3056). Cambridge University Press. https://doi.org/10.1017/9781009325844

IPCC. (2022b). Climate Change 2022: Mitigation of Climate Change. In P. R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. Van Diemen, D. McCollum, M. Pathak, S. Some, S. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, & J. Malley (Eds.), *Working Group ii to the Sixth Assessment of the Intergovernmental Panel on Climate Change* (pp. 1–2913). Cambridge University Press. https://doi.org/10.1017/9781009157926

IRENA. (2019). *Innovation outlook: Smart charging for electric vehicles*. https://www.irena.org/publications/2019/May/Innovation-Outlook-Smart-Charging

Izagirre-Olaizola, J., Fernández-Sainz, A., & Vicente-Molina, M. A. (2015). Internal determinants of recycling behaviour by university students: A cross-country comparative analysis. *International Journal of Consumer Studies*, *39*(1), 25–34. https://doi.org/10.1111/ijcs.12147

Jabeen, F., Olaru, D., Smith, B., Braunl, T., & Speidel, S. (2013). Electric vehicle battery charging behaviour: Findings from a driver survey. *Australasian Transport Research Forum, ATRF 2013 - Proceedings*, *Brisbane, Australia*, *2–4,* 1–15.

Jackman, S. (2007). *The pscl Package*. http://pscl.stanford.edu/

Jäger, G., Hofer, C., & Füllsack, M. (2019). The benefits of randomly delayed charging of electric vehicles. *Sustainability (Switzerland)*, *11*(13), 1–11. https://doi.org/10.3390/su11133722

Jakovcevic, A., & Steg, L. (2013). Sustainable transportation in Argentina: Values, beliefs, norms and car use reduction. *Transportation Research Part F: Traffic Psychology and Behaviour*, *20*, 70–79. https://doi.org/10.1016/j.trf.2013.05.005

Jamshidian, M., Jalal, S., & Jansen, C. (2014). Missmech: An R package for testing homoscedasticity, multivariate normality, and missing completely at random (MCAR). *Journal of Statistical Software*, *56*(6), 1–31. https://doi.org/10.18637/jss.v056.i06

Jensen, M. (1999). Passion and heart in transport – A sociological analysis on transport behaviour. *Transport Policy*, *6*(1), 19–33. https://doi.org/10.1016/S0967-070X(98)00029-8

Johnson, E. J., Bellman, S., & Lohs, G. L. (2002). Defaults, framing and privacy: Why opting in-opting out. *Marketing Letters*, *13*(1), 5–15. https://doi.org/10.1023/A:1015044207315

Johnson, E. J., & Goldstein, D. (2003). Do defaults save lives ? *Science*, *302*(5649), 1338–1339. https://doi.org/10.1126/science.1091721

Jones, C. M., & Kammen, D. M. (2011). Quantifying carbon footprint reduction opportunities for U.S. households and communities. *Environmental Science & Technology*, *45*(9), 4088–4095. https://doi.org/10.1021/ja01045a004

Judge, T. A., Erez, A., Bono, J. E., & Locke, E. A. (2005). Core self-evaluations and job and life satisfaction: The role of self-concordance and goal attainment. *Journal of Applied Psychology*, *90*(2), 257–268. https://doi.org/10.1037/0021-9010.90.2.257

Kacperski, C., & Kutzner, F. (2020). Financial and symbolic incentives promote ‘green’ charging choices. *Transportation Research Part F: Traffic Psychology and Behaviour*, *69*, 151–158. https://doi.org/10.1016/j.trf.2020.01.002

Kacperski, C., Ulloa, R., Klingert, S., Kirpes, B., & Kutzner, F. (2022). Impact of incentives for greener battery electric vehicle charging – A field experiment. *Energy Policy*, *161*, 112752. https://doi.org/10.1016/j.enpol.2021.112752

Kaiser, F. G. (2021). Climate change mitigation within the Campbell paradigm: Doing the right thing for a reason and against all odds. *Current Opinion in Behavioral Sciences*, *42*, 70–75. https://doi.org/10.1016/j.cobeha.2021.03.024

Kaiser, F. G., Kibbe, A., & Hentschke, L. (2021). Offsetting behavioral costs with personal attitudes: A slightly more complex view of the attitude-behavior relation. *Personality and Individual Differences*, *183*, 111158. https://doi.org/10.1016/j.paid.2021.111158

Ke, X., Du, H. S., & Wagner, C. (2019). Encouraging individuals to go green by gamification: An empirical study. *Proceedings of the 23rd Pacific Asia Conference on Information Systems: Secure ICT Platform for the 4th Industrial Revolution, PACIS 2019*. https://aisel.aisnet.org/pacis2019/229

Keizer, M., Sargisson, R. J., Van Zomeren, M., & Steg, L. (2019). When personal norms predict the acceptability of push and pull car-reduction policies: Testing the ABC model and low-cost hypothesis. *Transportation Research Part F: Traffic Psychology and Behaviour*, *64*, 413–423. https://doi.org/10.1016/j.trf.2019.06.005

Kesenheimer, J. S., & Greitemeyer, T. (2021). Going green (and not being just more pro-social): Do attitude and personality specifically influence pro-environmental behavior? *Sustainability (Switzerland)*, *13*(6), 1–12. https://doi.org/10.3390/su13063560

Keyvanfar, A., Shafaghat, A., Muhammad, N. Z., & Ferwati, M. S. (2018). Driving behaviour and sustainable mobility-policies and approaches revisited. *Sustainability (Switzerland)*, *10*(4), 1–27. https://doi.org/10.3390/su10041152

Kim, Y., Lee, I., & Kang, S. (2015). Eco assist techniques through real-time monitoring of BEV energy usage efficiency. *Sensors (Switzerland)*, *15*(7), 14946–14959. https://doi.org/10.3390/s150714946

Klaus, T., Vollmer, C., Werner, K., Lehmann, H., Müschen, K. (2010). *2050: 100% - Energy Target 2050: 100% Renewable Electricty Supply*. Umweltbundesamt, Dessau-Roßlau.

Klineberg, S. L., McKeever, M., & Rothenbach, B. (1998). Demographic predictors of environmental concern: It does make a difference how it's measured. *Social Science Quarterly*, *79*(4), 734–753. https://www.jstor.org/stable/42863844

Klöckner, C. A. (2013). A comprehensive model of the psychology of environmental behaviour – A meta-analysis. *Global Environmental Change*, *53*(9), 1023–1038. https://doi.org/10.1016/j.gloenvcha.2013.05.014

Klöckner, C. A., & Blöbaum, A. (2010). A comprehensive action determination model: Toward a broader understanding of ecological behaviour using the example of travel mode choice. *Journal of Environmental Psychology*, *30*(7491), 574–586. https://doi.org/10.1016/j.jenvp.2010.03.001

Koestner, R., Lekes, N., Powers, T. A., & Chicoine, E. (2002). Attaining personal goals: Self-concordance plus implementation intentions equals success. *Journal of Personality and Social Psychology*, *83*(1), 231–244. https://doi.org/10.1037/0022-3514.83.1.231

Kollmuss, A., & Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research*, *8*(3), 239–260. https://doi.org/10.1080/13504620220145401

Konietschke, F., Bösiger, S., Brunner, E., & Hothorn, L. A. (2013). Are multiple contrast tests superior to the ANOVA? *International Journal of Biostatistics*, *9*(1), 63–73. https://doi.org/10.1515/ijb-2012-0020

Kormos, C., Gifford, R., & Brown, E. (2015). The influence of descriptive social norm information on sustainable transportation behavior: A field experiment. *Environment and Behavior*, *47*(5), 479–501. https://doi.org/10.1177/0013916513520416

Kraftfahr-Bundesamt. (2019). *Statistik - Verkehr in Kilometern (VK). Revisionsbericht*.

Kramer, J., & Petzoldt, T. (2022a). The role of self-concordance for self-reported strategic, tactical, and operational eco-driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, *84*, 83–98. https://doi.org/10.1016/j.trf.2021.11.005

Kramer, J., & Petzoldt, T. (2022b). A matter of behavioral cost: Contextual factors and persuasive interventions interactively influence "green" charging decisions. *Journal of Environmental Psychology*, *84,* 101878. https://doi.org/10.1016/j.jenvp.2022.101878

Kramer, J., & Petzoldt, T. (2023a). Environmental, altruistic, or monetary benefits? A longitudinal online experiment on how framed behavioral consequences affect self-reported eco-driving of German vehicle owners. *Transportation Research Part F: Psychology and Behaviour, 93,* 204-221. https://doi.org/10.1016/j.trf.2023.01.006

Kramer, J., & Petzoldt, T. (2023b). *Behavioral costs moderate the relationship between environmental motivations and eco-driving*. Manuscript submitted for publication.

Kramer, J., Riza, L., & Petzoldt, T. (2023). Carbon savings, fun, and money: The effectiveness of multiple motives for eco-driving and green charging with electric vehicles in Germany. *Energy Research & Social Science*, *99*, 103054. https://doi.org/10.1016/j.erss.2023.103054

Kristoffersen, T. K., Capion, K., & Meibom, P. (2011). Optimal charging of electric drive vehicles in a market environment. *Applied Energy*, *88*(5), 1940–1948. https://doi.org/10.1016/j.apenergy.2010.12.015

Kuhn, M., Wing, J., Weston, S., & Williams, A. (2007). *The caret Package*. https://cran.r-project.org/web/packages/caret/index.html

Kuhn, S., Ihmels, M., & Kutzner, F. (2021). Organic defaults in online-shopping: Immediate effects but no spillover to similar choices. *Journal of Consumer Behaviour*, *20*(2), 271–287. https://doi.org/10.1002/cb.1850

Kutzner, F., Kacperski, C., Schramm, D., & Waenke, M. (2021). How far can we get with eco driving tech? *Journal of Environmental Psychology*, *76,* 101626. https://doi.org/10.1016/j.jenvp.2021.101626

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). lmerTest Package: Tests in linear mixed effects models. *Journal of Statistical Software*, *82*(13), 1–26. https://doi.org/10.18637/jss.v082.i13

Lacroix, K. (2018). Comparing the relative mitigation potential of individual pro-environmental behaviors. *Journal of Cleaner Production*, *195*, 1398–1407. https://doi.org/10.1016/j.jclepro.2018.05.068

Lai, W. T. (2015). The effects of eco-driving motivation, knowledge and reward intervention on fuel efficiency. *Transportation Research Part D: Transport and Environment*, *34*, 155–160. https://doi.org/10.1016/j.trd.2014.10.003

Landais, L. L., Damman, O. C., Schoonmade, L. J., Timmermans, D. R. M., Verhagen, E. A. L. M., & Jelsma, J. G. M. (2020). Choice architecture interventions to change physical activity and sedentary behavior: A systematic review of effects on intention, behavior and health outcomes during and after intervention. *International Journal of Behavioral Nutrition and Physical Activity*, *17*(1), 1–37. https://doi.org/10.1186/s12966-020-00942-7

Lange, F., & Brick, C. (2021). Changing pro-environmental behavior: Evidence from (un)successful intervention studies. *Sustainability (Switzerland)*, *13*, 1–5. https://doi.org/doi.org/10.3390/su2147748

Lange, F., & Dewitte, S. (2023). Non-monetary reinforcement effects on pro-environmental behavior. *Journal of Economic Psychology*, *97*, 102628. https://doi.org/10.1016/j.joep.2023.102628

Langenbach, B. P., Berger, S., Baumgartner, T., & Knoch, D. (2020). Cognitive resources moderate the relationship between pro-environmental attitudes and green behavior. *Environment and Behavior*, *52*(9), 979–995. https://doi.org/10.1177/0013916519843127

Lauper, E., Moser, S., Fischer, M., & Matthies, E. (2016). Explaining car drivers' intention to prevent road-traffic noise: An application of the Norm Activation Model. *Environment and Behavior*, *48*(6), 826–853. https://doi.org/10.1177/0013916515570476

Lauper, E., Moser, S., Fischer, M., Matthies, E., & Kaufmann-Hayoz, R. (2015). Psychological predictors of eco-driving: A longitudinal study. *Transportation Research Part F: Traffic Psychology and Behaviour*, *33*, 27–37. https://doi.org/10.1016/j.trf.2015.06.005

Lauren, N., Fielding, K. S., Smith, L., & Louis, W. R. (2016). You did, so you can and you will: Self-efficacy as a mediator of spillover from easy to more difficult pro-environmental behaviour. *Journal of Environmental Psychology*, *48*, 191–199. https://doi.org/10.1016/j.jenvp.2016.10.004

Lavergne, K. J., Sharp, E. C., Pelletier, L. G., & Holtby, A. (2010). The role of perceived government style in the facilitation of self-determined and non self-determined motivation for pro-environmental behavior. *Journal of Environmental Psychology*, *30*(2), 169–177. https://doi.org/10.1016/j.jenvp.2009.11.002

Leandro, M. (2012). Young drivers and speed selection: A model guided by the Theory of Planned Behavior. *Transportation Research Part F: Traffic Psychology and Behaviour*, *15*, 219–232. https://doi.org/10.1016/j.trf.2011.12.011

Lee, J. H., Chakraborty, D., Hardman, S. J., & Tal, G. (2020). Exploring electric vehicle charging patterns: Mixed usage of charging infrastructure. *Transportation Research Part D: Transport and Environment*, *79*, 102249. https://doi.org/10.1016/j.trd.2020.102249

Lee, S. S., Kim, Y., & Roh, T. (2023). Pro-environmental behavior on electric vehicle use intention: Integrating value-belief-norm theory and theory of planned behavior. *Journal of Cleaner Production*, *418*, 138211. https://doi.org/10.1016/j.jclepro.2023.138211

Lee, Z. J., Lee, G., Lee, T., Jin, C., Lee, R., Low, Z., Chang, D., Ortega, C., & Low, S. H. (2021). Adaptive charging networks: A framework for smart electric vehicle charging. *IEEE Transactions on Smart Grid*, *12*(5), 4339–4350. https://doi.org/10.1109/TSG.2021.3074437

Lehman, P. K., & Geller, S. (2004). Behavior analysis and environmental protection: Accomplishments and the potential for more. *Behavior and Social Issues*, *13*(1), 13–32. https://doi.org/10.5210/bsi.v13i1.33

Levin, I. P., Schneider, S. L., & Gaeth, G. J. (1998). All frames are not created equal: A typology and critical analysis of framing effects. *Organizational Behavior and Human Decision Processes*, *76*(2), 149–188. https://doi.org/10.1006/obhd.1998.2804

Li, D., Zhao, L., Ma, S., Shao, S., & Zhang, L. (2019). What influences an individual's pro-environmental behavior? A literature review. *Resources, Conservation and Recycling*, *146*, 28–34. https://doi.org/10.1016/j.resconrec.2019.03.024

Lindenberg, S., & Steg, L. (2007). Normative, gain and hedonic goal frames guiding environmental behavior. *Journal of Social Issues*, *63*(1), 117–137. https://doi.org/10.1111/j.1540-4560.2007.00499.x

Lindenberg, S., & Steg, L. (2013). Goal-Framing Theory and norm-guided environmental behavior. In H. Van Trijp (Ed.), *Encouraging Sustainable Behavior* (pp. 37–54). Psychology Press. https://doi.org/10.4324/9780203141182

Linder, N., Rosenthal, S., Sörqvist, P., & Barthel, S. (2021). Internal and external factors' influence on recycling: Insights from a laboratory experiment with observed behavior. *Frontiers in Psychology*, *12*, 1–12. https://doi.org/10.3389/fpsyg.2021.699410

Liu, Y., Sheng, H., Mundorf, N., Redding, C., & Ye, Y. (2017). Integrating Norm Activation Model and Theory of Planned Behavior to understand sustainable transport behavior: Evidence from China. *International Journal of Environmental Research and Public Health*, *14*(12), 1593. https://doi.org/10.3390/ijerph14121593

Locke, E. A., & Latham, G. P. (2006). New directions in goal-setting theory. *Current Directions in Psychological Science*, *15*(5), 265–268. https://doi.org/10.1111/j.1467-8721.2006.00449.x

Lois, D., Wang, Y., Boggio-Marzet, A., & Monzon, A. (2019). Multivariate analysis of fuel consumption related to eco-driving: Interaction of driving patterns and external factors. *Transportation Research Part D: Transport and Environment*, *72*, 232–242. https://doi.org/10.1016/j.trd.2019.05.001

López-Mosquera, N. (2016). Gender differences, theory of planned behavior and willingness to pay. *Journal of Environmental Psychology*, *45*, 165–175. https://doi.org/10.1016/j.jenvp.2016.01.006

Loschelder, D. D., Siepelmeyer, H., Fischer, D., & Rubel, J. A. (2019). Dynamic norms drive sustainable consumption: Norm-based nudging helps café customers to avoid disposable to-go-cups. *Journal of Economic Psychology*, *75,* 102146. https://doi.org/10.1016/j.joep.2019.02.002

Maloney, M. P., & Ward, M. P. (1973). Ecology: Let's hear from the people: An objective scale for the measurement of ecological attitudes and knowledge. *American Psychologist*, *28*(7), 583–586. https://doi.org/10.1037/h0034936

Mannem A., Tangari, A. H., & Baran, M. J. (2023). I've got the power: Encouraging pro-environmental behavior through messaging. *Journal of Business Research*, *168*, 114228. https://doi.org/10.1016/j.jbusres.2023.114228

Mannetti, L., Pierro, A., & Livi, S. (2004). Recycling: Planned and self-expressive behaviour. *Journal of Environmental Psychology*, *24*(2), 227–236. https://doi.org/10.1016/j.jenvp.2004.01.002

Mantovani, A., Tarola, O., & Vergari, C. (2017). End-of-pipe or cleaner production? How to go green in presence of income inequality and pro-environmental behavior. *Journal of Cleaner Production*, *160*, 71–82. https://doi.org/10.1016/j.jclepro.2017.01.110

Martin, E., Chan, N., & Shaheen, S. (2012). How public education on ecodriving can reduce both fuel use and greenhouse gas emissions. *Transportation Research Record*, *2287*, 163–173. https://doi.org/10.3141/2287-20

Matuschek, H., Kliegl, R., Vasishth, S., Baayen, H., & Bates, D. (2017). Balancing type I error and power in linear mixed mod. *Journal of Memory and Language*, *94*, 305–315. https://doi.org/10.1016/j.jml.2017.01.001

McConky, K., Chen, R. B., & Gavi, G. R. (2018). A comparison of motivational and informational contexts for improving eco-driving performance. *Transportation Research Part F: Traffic Psychology and Behaviour*, *52*, 62–74. https://doi.org/10.1016/j.trf.2017.11.013

McDonald, R. P., & Ho, M. H. R. (2002). Principles and practice in reporting structural equation analyses. *Psychological Methods*, *7*(1), 64–82. https://doi.org/10.1037/1082-989X.7.1.64

McHugh, M. L. (2012). Interrater reliability: The kappa statistic. *Biochemica Medica*, *22*(3), 276–282. https://hrcak.srce.hr/89395

McIlroy, R. C., & Stanton, N. A. (2017). What do people know about eco-driving? *Ergonomics*, *60*(6), 754–769. https://doi.org/10.1080/00140139.2016.1227092

McIlroy, R. C., Stanton, N. A., & Harvey, C. (2014). Getting drivers to do the right thing: A review of the potential for safely reducing energy consumption through design. *IET Intelligent Transport Systems*, *8*(4), 388–397. https://doi.org/10.1049/iet-its.2012.0190

McKenzie, C. R. M., Liersch, M. J., & Finkelstein, S. R. (2006). Recommendations implicit in policy defaults. *Psychological Science*, *17*(5), 414–420. https://doi.org/10.1111/j.1467-9280.2006.01721.x

Mekler, E. D., Brühlmann, F., Opwis, K., & Tuch, A. N. (2013). Do points, levels and leaderboards harm intrinsic motivation? An empirical analysis of common gamification elements. *Gamification '13: Proceedings of the First International Conference on Gameful Design,* 66–73. https://doi.org/10.1145/2583008.2583017

Mertens, S., Herberz, M., Hahnel, U. J. J., & Brosch, T. (2022). The effectiveness of nudging: A meta-analysis of choice architecture interventions across behavioral domains. *Proceedings of the National Academy of Sciences of the United States of America*, *119*(1), 1–10. https://doi.org/10.1073/pnas.2107346118

Meteyard, L., & Davies, R. A. I. (2020). Best practice guidance for linear mixed-effects models in psychological science. *Journal of Memory and Language*, *112*, 104092. https://doi.org/10.1016/j.jml.2020.104092

Michon, J. A. (1985). Critical view of driver behavior models: What do we know, what should we do? In L. Evans, & R. C. Schwing (Eds.), *Human Behavior and Traffic Safety* (pp. 485–524). Springer. https://doi.org/10.1007/978-1-4613-2173-6_19

Milfont, T. L. (2009). The effects of social desirability on self-reported environmental attitudes and ecological behaviour. *Environmentalist*, *29*(3), 263–269. https://doi.org/10.1007/s10669-008-9192-2

Miller, D. T. (1999). The norm of self-interest. *American Psychologist*, *54*(2), 1053–1060. https://doi.org/10.1037/0003-066X.54.12.1053

Miller, D. T., & Prentice, D. A. (2016). Changing norms to change behavior. *Annual Review of Psychology*, *67*, 339–361. https://doi.org/10.1146/annurev-psych-010814-015013

Moller, A. C., Buscemi, J., McFadden, H. G., Hedecker, D., & Spring, B. (2014). Financial motivation undermines potential enjoyment in an intensive diet and activity intervention. *Journal of Behavioral Medicine*, *37*, 819–827. https://doi.org/10.1007/s10865-013-9542-5

Morganti, L., Pallavicini, F., Cadel, E., Candelieri, A., Archetti, Fr., & Mantovani, F. (2017). Gaming for earth: Serious games and gamification to engage consumers in pro-environmental behaviours for energy efficiency. *Energy Research & Social Science*, *29*, 95–102. https://doi.org/10.1016/j.erss.2017.05.001

Moritz, S. E., Feltz, D. L., Fahrbach, K. R., & Mack, D. E. (2000). The relation of self-efficacy measures to sport performance: A meta-analytic review. *Research Quarterly for Exercise and Sport*, *71*(3), 280–294. https://doi.org/10.1080/02701367.2000.10608908

Morrissey, P., Weldon, P., & O'Mahony, M. (2016). Future standard and fast charging infrastructure planning: An analysis of electric vehicle charging behaviour. *Energy Policy*, *89*, 257–270. https://doi.org/10.1016/j.enpol.2015.12.001

Mouratidis, A., Lens, W., & Vansteenkiste, M. (2010). How you provide corrective feedback makes a difference: The motivating role of communicating in an autonomy-supporting way. *Journal of Sport and Exercise Psychology*, *32*(5), 619–637. https://doi.org/10.1123/jsep.32.5.619

Mulcahy, R., Russell-Bennett, R., & Iacobucci, D. (2020). Designing gamified apps for sustainable consumption: A field study. *Journal of Business Research*, *106*, 377–387. https://doi.org/10.1016/j.jbusres.2018.10.026

Muraven, M. (2008). Autonomous self-control is less depleting. *Journal of Personality*, *42*(3), 763–770. https://doi.org/10.1016/j.jrp.2007.08.002.Autonomous

Nakagawa, S., & Schielzeth, H. (2013). A general and simple method for obtaining $R^2$ from generalized linear mixed-effects models. *Methods in Ecology and Evolution*, *4*(2), 133–142. https://doi.org/10.1111/j.2041-210x.2012.00261.x

Nègre, J., & Delhomme, P. (2017). Drivers' self-perceptions about being an eco-driver according to their concern for the environment, beliefs on eco-driving, and driving behavior. *Transportation Research Part A: Policy and Practice*, *105*, 95–105. https://doi.org/10.1016/j.tra.2017.08.014

Neumann, I., Franke, T., Cocron, P., Bühler, F., & Krems, J. F. (2015). Eco-driving strategies in battery electric vehicle use – How do drivers adapt over time? *IET Intelligent Transport Systems*, *9*(7), 746–753. https://doi.org/10.1049/iet-its.2014.0221

Nguyen, H. V., Le, M. T. T., & Do, L. T. (2022). Intrinsic motivation for reducing single-use plastics: The compensation effects of basic psychological needs. *Resources, Conservation and Recycling*, *185*, 106482. https://doi.org/10.1016/j.resconrec.2022.106482

Nilsson, A., Nilsson, A., Bergquist, M., & Schultz, W. P. (2017). Spillover effects in environmental behaviors, across time and context: A review and research agenda. *Environmental Education Research*, *23*(4), 573–589. https://doi.org/10.1080/13504622.2016.1250148

Nilsson, M., & Küller, R. (2000). Travel behaviour and environmental concern. *Transportation Research Part D: Transport and Environment*, *5*(3), 211–234. https://doi.org/10.1016/S1361-9209(99)00034-6

Nobis, C., & Kuhnimhof, T. (2018). *Mobilität in Deutschland – MiD Ergebnisbericht.* Bundesamt für Verkehr und digitale Infrastruktur.

Nolan, J. M., Schultz, P. W., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2008). Normative social influence is underdetected. *Personality and Social Psychology Bulletin*, *34*, 913–923. https://doi.org/10.1177/0146167208316691

Noppers, E. H., Keizer, K., Bolderdijk, J. W., & Steg, L. (2014). The adoption of sustainable innovations: Driven by symbolic and environmental motives. *Global Environmental Change*, *25*(1), 52–62. https://doi.org/10.1016/j.gloenvcha.2014.01.012

Nordlund, A. M., & Garvill, J. (2002). Value structures behind proenvironmental behavior. *Environment and Behavior*, *34*(6), 740–756. https://doi.org/10.1177/001391602237244

Nordlund, A. M., & Garvill, J. (2003). Effects of values, problem awareness, and personal norm on willingness to reduce personal car use. *Journal of Environmental Psychology*, *23*(4), 336–347. https://doi.org/10.1016/S0272-4944(03)00037-9

Nousias, S., Tselios, C., Bitzas, D., Amaxilatis, D., Montesa, J., Lalos, A. S., Moustakas, K., & Chatzigiannakis, I. (2019). Exploiting gamification to improve eco-driving behaviour: The GamECAR approach. *Electronic Notes in Theoretical Computer Science*, *343*, 103–116. https://doi.org/10.1016/j.entcs.2019.04.013

Ntoumanis, N., Healy, L. C., Sedikides, C., Duda, J., Stewart, B., Smith, A., & Bond, J. (2014). When the going gets tough: The "Why" of goal striving matters. *Journal of Personality*, *82*(3), 225–236. https://doi.org/10.1111/jopy.12047

Nunnally, J. C. (1967). *Psychometric theory*. McGraw-Hill.

Nunnally, J. C. (1978). *Psychometric theory (2nd ed.)* (2nd ed.). McGraw-Hill.

Oaten, M., & Cheng, K. (2006). Improved self-control: The benefits of a regular program of academic study. *Basic and Applied Social Psychology*, *28*(1), 1–16. https://doi.org/10.1207/s15324834basp2801_1

Oettingen, G., Hönig, G., & Gollwitzer, P. M. (2000). Effective self-regulation of goal attainment. *International Journal of Educational Research*, *33*(7–8), 705–732. https://doi.org/10.1016/S0883-0355(00)00046-X

O'Keefe, D. J. (2002). Guilt as a mechanism of persuasion. In J. P. Dillard & M. Pfau (Eds.), *The persuasion handbook: Developments in theory and practice* (pp. 329–344). Sage.

Olszewski, R., Pałka, P., & Turek, A. (2018). Solving "Smart City" transport problems by designing carpooling gamification schemes with multi-agent systems: The case of the so-called "Mordor of Warsaw". *Sensors (Switzerland)*, *18*(1), 141. https://doi.org/10.3390/s18010141

Osbaldiston, R., & Schott, J. P. (2012). Environmental sustainability and behavioral science: Meta-analysis of proenvironmental behavior experiments. *Environment and Behavior*, *44*(2), 257–299. https://doi.org/10.1177/0013916511402673

Osbaldiston, R., & Sheldon, K. M. (2003). Promoting internalized motivation for environmentally responsible behavior: A prospective study of environmental goals. *Journal of Environmental Psychology*, *23*(4), 349–357. https://doi.org/10.1016/S0272-4944(03)00035-5

Ouellette, J. A., & Wood, W. (1998). Habit and intention in everyday life: The multiple processes by which past behavior predicts future behavior. *Psychological Bulletin*, *124*(1), 54–74. https://doi.org/10.1037/0033-2909.124.1.54

Pampel, S. M., Jamson, S. L., Hibberd, D., & Barnard, Y. (2017). The activation of eco-driving mental models: Can text messages prime drivers to use their existing knowledge and skills? *Cognition, Technology and Work*, *19*(4), 743–758. https://doi.org/10.1007/s10111-017-0441-3

Pampel, S. M., Jamson, S. L., Hibberd, D. L., & Barnard, Y. (2015). How I reduce fuel consumption: An experimental study on mental models of eco-driving. *Transportation Research Part C: Emerging Technologies*, *58*, 669–680. https://doi.org/10.1016/j.trc.2015.02.005

Pampel, S. M., Jamson, S. L., Hibberd, D. L., & Barnard, Y. (2018). Old habits die hard? The fragility of eco-driving mental models and why green driving behavior is difficult to sustain. *Psychology and Behaviour*, *57*, 139–150. https://doi.org/10.1016/j.trf.2018.01.005

Paul, J., Modi, A., & Patel, J. (2016). Predicting green product consumption using theory of planned behavior and reasoned action. *Journal of Retailing and Consumer Services*, *29*, 123–134. https://doi.org/10.1016/j.jretconser.2015.11.006

Paunov, Y., Wänke, M., & Vogel, T. (2019). Ethical defaults: Which transparency components can increase the effectiveness of default nudges? *Social Influence*, *14*(3–4), 104–116. https://doi.org/10.1080/15534510.2019.1675755

Payton, M. E., Greenstone, M. H., & Schenker, N. (2003). Overlapping confidence intervals or standard error intervals: What do they mean in terms of statistical significance? *Journal of Insect Science*, *3*(1), 34. https://doi.org/10.1093/jis/3.1.34

Pelletier, L. G., Baxter, D., & Huta, V. (2011). Personal autonomy and environmental sustainability. In V. Chirkov, R. Ryan, & K. Sheldon (Eds.), *Human Autonomy in Cross-Cultural Context. Cross-Cultural Advancements in Positive Psychology* (pp. 257–277). Springer. https://doi.org/10.1007/978-90-481-9667-8_12

Pelletier, L. G., Fortier, M. S., Vallerand, R. J., & Bri, N. M. (2001). Associations among perceived autonomy support, forms of self-regulation, and persistence: A prospective study. *Motivation and Emotion*, *25*, 279–306. https://doi.org/10.1023/A:1014805132406

Pelletier, L. G., & Sharp, E. (2008). Persuasive communication and proenvironmental behaviours: How message tailoring and message framing can improve the integration of behaviours through self-determined motivation. *Canadian Psychology*, *49*(3), 210–217. https://doi.org/10.1037/a0012755

Pelletier, L. G., Tuson, K. M., Green-Demers, I., Noels, K., & Beaton, A. M. (1998). Why are you doing things for the environment? The Motivation Toward the Environment Scale (MTES). *Journal of Applied Social Psychology*, *28*(5), 437–468. https://doi.org/10.1111/j.1559-1816.1998.tb01714.x

Penn, D. J. (2003). The evolutionary roots of our environmental problems: Toward a Darwinian ecology. *Quarterly Review of Biology*, *78*(3), 275–301. https://doi.org/10.1086/377051

Perlaviciute, G., & Steg, L. (2014). Contextual and psychological factors shaping evaluations and acceptability of energy alternatives: Integrated review and research agenda. *Renewable and Sustainable Energy Reviews*, *35*, 361–381. https://doi.org/10.1016/j.rser.2014.04.003

Perlaviciute, G., & Steg, L. (2015). The influence of values on evaluations of energy alternatives. *Renewable Energy*, *77*, 259–267. https://doi.org/10.1016/j.renene.2014.12.020

Pettersson, S. (2013). Elviis - Final report to göteborg energy forskningsstiftelse. Viktoria report. http://urn.kb.se/resolve?urn=urn:nbn:se:ri:diva-26025.

Pichert, D., & Katsikopoulos, K. V. (2008). Green defaults: Information presentation and pro-environmental behaviour. *Journal of Environmental Psychology*, *28*, 63–73. https://doi.org/10.1108/07363760210420540

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, *88*(5), 879–903. https://doi.org/10.1037/0021-9010.88.5.879

Poortinga, W., Steg, L., & Vlek, C. (2004). Values, environmental concern, and environmental behavior: A study into household energy use. *Environment and Behavior*, *36*(1), 70–93. https://doi.org/10.1177/0013916503251466

Poortinga, W., Steg, L., Vlek, C., & Wiersma, G. (2003). Household preferences for energy-saving measures: A conjoint analysis. *Journal of Economic Psychology*, *24*(1), 49–64. https://doi.org/10.1016/S0167-4870(02)00154-X

Poortinga, W., Whitmarsh, L., & Suffolk, C. (2013). The introduction of a single-use carrier bag charge in Wales: Attitude change and behavioural spillover effects. *Journal of Environmental Psychology*, *36*, 240–247. https://doi.org/10.1016/j.jenvp.2013.09.001

Prati, G., Albanesi, C., & Pietrantoni, L. (2017). The interplay among environmental attitudes, pro-environmental behavior, social identity, and pro-environmental institutional climate: A longitudinal study. *Environmental Education Research*, *23*(2), 176–191. https://doi.org/10.1080/13504622.2015.1118752

Pritchard, J. (2010). Virtual rewards for driving green. *The Behavior Analyst*, *33*(2), 185–187. https://doi.org/10.1007/BF03392216

R Core Team. (2020). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.r-project.org/

Richardson, D. B. (2013). Electric vehicles and the electric grid: A review of modeling approaches, impacts, and renewable energy integration. *Renewable and Sustainable Energy Reviews*, *19*, 247–254. https://doi.org/10.1016/j.rser.2012.11.042

Ro, M., Brauer, M., Kuntz, K., Shukla, R., & Bensch, I. (2017). Making Cool Choices for sustainability: Testing the effectiveness of a game-based approach to promoting pro-environmental behaviors. *Journal of Environmental Psychology*, *53*, 20–30. https://doi.org/10.1016/j.jenvp.2017.06.007

Robert Koch Institut. (2020). *Coronavirus Disease 2019 (COVID-19) – Daily Situation Report of the Robert Koch Institute. Updated Status for Germany.*

Robinson, A. P., Blythe, P. T., Bell, M. C., Hübner, Y., & Hill, G. A. (2013). Analysis of electric vehicle driver recharging demand profiles and subsequent impacts on the carbon content of electric vehicle trips. *Energy Policy*, *61*, 337–348. https://doi.org/10.1016/j.enpol.2013.05.074

Rose, H. S., & Hinds, D. H. (1976). South Dixie Highway contraflow bus and car-pool lane demonstration project. *Transportation Research Record*, *606*, 18–22. http://worldcat.org/isbn/0309024838

Rosseel, Y. (2012). Lavaan: An R package for structural equation modeling and more. Version 0.5-12 (BETA). *Journal of Statistical Software*, *48*(2), 1–36. https://doi.org/10.18637/jss.v048.i02

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Ryghaug, M., & Toftaker, M. (2014). A transformative practice? Meaning, competence, and material aspects of driving electric cars in Norway. *Nature and Culture*, *9*(2), 1–18. https://doi.org/10.3167/nc.2014.090203

Sagaria, S., Neto, C., & Baptista, P. (2021). Modelling approach for assessing influential factors for EV energy performance. *Sustainable Energy Technologies and Assessments*, *44*, 100984. https://doi.org/10.1016/j.seta.2020.100984

Sánchez, M., López-Mosquera, N., & Lera-López, F. (2016). Improving pro-environmental behaviours in Spain – The role of attitudes and socio-demographic and political factors. *Journal of Environmental Policy & Planning*, *18*(1), 47–66. https://doi.org/10.1080/1523908X.2015.1046983

Sandqvist, K., & Kriström, S. (2001). *Getting along without a family car*. Institutionen för individ, omvärld och lärande (Issue 3).

Sanguinetti, A., Dombrovski, K., & Sikand, S. (2018). Information, timing, and display: A design-behavior framework for improving the effectiveness of eco-feedback. *Energy Research & Social Science*, *39*, 55–68. https://doi.org/10.1016/j.erss.2017.10.001

Sanguinetti, A., Kurani, K., & Davies, J. (2017). The many reasons your mileage may vary: Toward a unifying typology of eco-driving behaviors. *Transportation Research Part D: Transport and Environment*, *52*, 73–84. https://doi.org/10.1016/j.trd.2017.02.005

Sanguinetti, A., Queen, E., Yee, C., & Akanesuvan, K. (2020). Average impact and important features of onboard eco-driving feedback: A meta-analysis. *Transportation Research Part F: Traffic Psychology and Behaviour*, *70*, 1–14. https://doi.org/10.1016/j.trf.2020.02.010

Sass, W., Pauw, J. B. de, Donche, V., & Van Petegem, P. (2018). "Why (should) I do something for the environment?" profiles of Flemish adolescents' motivation toward the environment. *Sustainability (Switzerland)*, *10*(7). https://doi.org/10.3390/su10072579

Schall, D. L., & Mohnen, A. (2017). Incentivizing energy-efficient behavior at work: An empirical investigation using a natural field experiment on eco-driving. *Applied Energy*, *185*, 1757–1768. https://doi.org/10.1016/j.apenergy.2015.10.163

Schall, D. L., Wolf, M., & Mohnen, A. (2016). Do effects of theoretical training and rewards for energy-efficient behavior persist over time and interact? A natural field experiment on eco-driving in a company fleet. *Energy Policy*, *97*, 291–300. https://doi.org/10.1016/j.enpol.2016.07.008

Schießl, C., Fricke, N., & Staubach, M. (2013). Identification and analysis of motives for eco-friendly driving within the eco-move project. *IET Intelligent Transport Systems*, *7*(1), 46–54. https://doi.org/10.1049/iet-its.2011.0145

Schlüter, J., & Weyer, J. (2019). Car sharing as a means to raise acceptance of electric vehicles: An empirical study on regime change in automobility. *Transportation Research Part F: Traffic Psychology and Behaviour*, *60*, 185–201. https://doi.org/10.1016/j.trf.2018.09.005

Schmalfuß, F., Mair, C., Döbelt, S., Kämpfe, B., Wüstemann, R., Krems, J. F., & Keinath, A. (2015). User responses to a smart charging system in Germany: Battery electric vehicle driver motivation, attitudes and acceptance. *Energy Research and Social Science*, *9*, 60–71. https://doi.org/10.1016/j.erss.2015.08.019

Schoenau, M., & Müller, M. (2017). What affects our urban travel behavior? A GPS-based evaluation of internal and external determinants of sustainable mobility in Stuttgart (Germany). *Transportation Research Part F: Traffic Psychology and Behaviour*, *48*, 61–73. https://doi.org/10.1016/j.trf.2017.05.004

Schönbrodt, F. D., & Perugini, M. (2013). At what sample size do correlations stabilize? *Journal of Research in Personality*, *47*(5), 609–612. https://doi.org/10.1016/j.jrp.2013.05.009

Schrills, T., Zoubir, M., Stahl, J., Drozniak, K., & Franke, T. (2020). Good boy here or bad boy far away? Effects of digital nudging on booking decisions in car sharing. In D. Harris, & W. C. Li (Eds.), *Engineering Psychology and Cognitive Ergonomics. Cognition and Design. HCII 2020. Lecture Notes in Computer Science, vol 12187*. Springer. https://doi.org/10.1007/978-3-030-49183-3_31

Schubert, C. (2016). Green nudges: Do they work? Are they ethical? *Ecological Economics, 132*, 329–342. https://doi.org/10.1016/j.ecolecon.2016.11.009

Schüler, J., Zimanyi, Z., & Wegner, M. (2019). Paved, graveled, and stony paths to high performance: Theoretical considerations on self-control demands of achievement goals based on implicit and explicit motives. *Performance Enhancement & Health*, *7*(1-2), 100146. https://doi.org/10.1016/j.peh.2019.100146

Schulte-Fischedick, M., Shan, Y., & Hubacek, K. (2021). Implications of COVID-19 lockdowns on surface passenger mobility and related $CO_2$ emission changes in Europe. *Applied Energy*, *300*, 117396. https://doi.org/10.1016/j.apenergy.2021.117396

Schultz, P. W. (1999). Changing behavior with normative feedback interventions: A field experiment on curbside recycling. *Basic and Applied Social Psychology*, *21*(1), 25–36. https://doi.org/10.1207/s15324834basp2101_3

Schultz, P. W., Estrada, M., Schmitt, J., Sokoloski, R., & Silva-Send, N. (2015). Using in-home displays to provide smart meter feedback about household electricity consumption: A randomized control trial comparing kilowatts, cost, and social norms. *Energy*, *90*, 351–358. https://doi.org/10.1016/j.energy.2015.06.130

Schultz, P. W., Gouveia, V. V., Cameron, L. D., Tankha, G., Schmuck, P., & Franěk, M. (2005). Values and their relationship to environmental concern and conservation behavior. *Journal of Cross-Cultural Psychology*, *36*(4), 457–475. https://doi.org/10.1177/0022022105275962

Schultz, P. W., Khazian, A. M., & Zaleski, A. C. (2008). Using normative social influence to promote conservation among hotel guests. *Social Influence*, *3*(1), 4–23. https://doi.org/10.1080/15534510701755614

Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2007). The constructive, destructive, and reconstructive power of social norms: Reprise. *Psychological Science*, *18*(5), 429–434. https://doi.org/10.1177/1745691617693325

Schultz, P. W., & Oskamp, S. (1996). Effort as a moderator of the attitude-behavior relationship: General environmental concern and recycling. *Social Psychology Quarterly*, *59*(4), 375–383. https://doi.org/10.2307/2787078

Schultz, P. W., & Zelezny, L. (1999). Values as predictors of environmental attitudes: Evidence for consistency across 14 countries. *Journal of Environmental Psychology*, *19*(3), 255–265. https://doi.org/10.1006/jevp.1999.0129

Schwartz, D., De Bruin, W. B., Fischhoff, B., & Lave, L. (2015). Advertising energy saving programs: The potential environmental cost of emphasizing monetary savings. *Journal of Experimental Psychology: Applied*, *21*(2), 158–166. https://doi.org/10.1037/xap0000042

Schwartz, S. H. (1977). Normative influences on altruism. In L. Berkowitz (Ed.), *Advances in experimental social psychology* (10th ed., pp. 221–279). Academic Press.

Schwartz, S. H. (1992). Universals in the content and structure of values: Theoretical advances and empirical tests in 20 countries. *Advances in Experimental Social Psychology*, *25*, 1–65. https://doi.org/10.1016/S0065-2601(08)60281-6

Schwartz, S. H. (1994). Are there universal aspects in the structure and contents of human values? *Journal of Social Issues*, *50*(4), 19–45. https://doi.org/10.1111/j.1540-4560.1994.tb01196.x

Shanmugavel, N., & Balakrishnan, J. (2023). Influence of pro-environmental behaviour towards behavioural intention of electric vehicles. *Technological Forecasting and Social Change*, *187*, 122206. https://doi.org/10.1016/j.techfore.2022.122206

Sheeran, P., & Webb, T. L. (2016). The intention–behavior gap. *Social and Personality Psychology Compass*, *10*(9), 503–518. https://doi.org/10.1111/spc3.12265

Sheldon, K. M., & Elliot, A. J. (1999). Goal striving, need satisfaction, and longitudinal well-being: The self-concordance model. *Journal of Personality and Social Psychology*, *76*(3), 482–497. https://doi.org/10.1037/0022-3514.76.3.482

Sheldon, K. M., & Filak, V. (2008). Manipulating autonomy, competence, and relatedness support in a game-learning context: New evidence that all three needs matter. *British*

*Journal of Social Psychology*, *47*(2), 267–283. https://doi.org/10.1348/014466607X238797

Sheldon, K. M., & Houser-Marko, L. (2001). Self-concordance, goal attainment, and the pursuit of happiness: Can there be an upward spiral? *Journal of Personality and Social Psychology*, *80*(1), 152–165. https://doi.org/10.1037//0022-3514.80.1.152

Sheldon, K. M., & Kasser, T. (1995). Coherence and congruence: Two aspects of personality integration. *Journal of Personality and Social Psychology*, *68*(3), 531–543. https://doi.org/10.1037/0022-3514.68.3.531

Sheldon, K. M., Ryan, R. M., Deci, E. L., & Kasser, T. (2004). The independent effects of goal contents and motives on well-being: It's both what you pursue and why you pursue it. *Personality and Social Psychology Bulletin*, *30*(4), 475–486. https://doi.org/10.1177/0146167203261883

Sheldon, K. M., & Elliot, A. J. (1998). Not all personal goals are personal: Comparing autonomous and controlled reasons for goals as predictors of effort and attainment. *Personality and Social Psychology Bulletin*, *24*(5), 546–557. https://doi.org/10.1177/0146167298245010

Shi, D., Wang, L., & Wang, Z. (2019). What affects individual energy conservation behavior: Personal habits, external conditions or values? An empirical study based on a survey of college students. *Energy Policy*, *128*, 150–161. https://doi.org/10.1016/j.enpol.2018.12.061

Shipworth, M. (2000). *Motivating Home Energy Action - A handbook of what works*. Australian Greenhouse Office.

Sidique, S. F., Lupi, F., & Joshi, S. V. (2010). The effects of behavior and attitudes on drop-off recycling activities. *Resources, Conservation and Recycling*, *54*(3), 163–170. https://doi.org/10.1016/j.resconrec.2009.07.012

Silva, M. N., Vieira, P. N., Coutinho, S. R., Minderico, C. S., Matos, M. G., Sardinha, L. B., & Teixeira, P. J. (2010). Using self-determination theory to promote physical activity and weight control: A randomized controlled trial in women. *Journal of Behavioral Medicine*, *33*(2), 110–122. https://doi.org/10.1007/s10865-009-9239-y

Sims, R., Schaeffer, R., Creutzig, F., Cruz-Núnez, X., D'Agosto, M., Dimitriu, D., Figuero Meza, M. J., Fulton, L., Kobayashi, S., Lah, O., McKinnon, A., Newman, P., Ouyang, M., Schauer, J. J., Sperling, D., & Tiwari, G. (2014). Transport. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlomer, C. von Stechow, T. Zwickel, & J. C. Minx (Eds.), *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://doi.org/10.1007/978-3-319-12457-5_15.

Sivak, M., & Schoettle, B. (2012). Eco-driving: Strategic, tactical, and operational decisions of the driver that influence vehicle fuel economy. *Transport Policy*, *22*, 96–99. https://doi.org/10.1016/j.tranpol.2012.05.010

Sloot, D., Jans, L., & Steg, L. (2019). In it for the money, the environment, or the community? Motives for being involved in community energy initiatives. *Global Environmental Change*, *57,* 101936. https://doi.org/10.1016/j.gloenvcha.2019.101936

Sloot, D., Jans, L., & Steg, L. (2021). Is an appeal enough? The limited impact of financial, environmental, and communal appeals in promoting involvement in community environmental initiatives. *Sustainability (Switzerland)*, *13*(3), 1–30. https://doi.org/10.3390/su13031085

Smith, A. L., Ntoumanis, N., Duda, J. L., & Vansteenkiste, M. (2011). Goal striving, coping, and well-being: A prospective investigation of the self-concordance model in sport. *Journal of Sport and Exercise Psychology*, *33*(1), 124–145. https://doi.org/10.1123/jsep.33.1.124

Smith, A., Ntoumanis, N., & Duda, J. (2007). Goal striving, goal attainment, and well-being: Adapting and testing the self-concordance model in sport. *Journal of Sport and Exercise Psychology*, *29*(6), 763–782. https://doi.org/10.1123/jsep.29.6.763

Smith, J. R., Louis, W. R., Terry, D. J., Greenaway, K. H., Clarke, M. R., & Cheng, X. (2012). Congruent or conflicted? The impact of injunctive and descriptive norms on environmental intentions. *Journal of Environmental Psychology*, *32*(4), 353–361. https://doi.org/10.1016/j.jenvp.2012.06.001

Smith, S. M., Haugtvedt, C. P., & Petty, R. E. (1994). Attitudes and recycling: Does the measurement of affect enhance behavioral prediction? *Psychology & Marketing*, *11*(4), 359–374. https://doi.org/10.1002/mar.4220110405

Sniehotta, F. F., Presseau, J., & Araújo-Soares, V. (2014). Time to retire the theory of planned behaviour. *Health Psychology Review*, *8*(1), 1–7. https://doi.org/10.1080/17437199.2013.869710

Spence, A., Leygue, C., Bedwell, B., & O'Malley, C. (2014). Engaging with energy reduction: Does a climate change frame have the potential for achieving broader sustainable behaviour? *Journal of Environmental Psychology*, *38*, 17–28. https://doi.org/10.1016/j.jenvp.2013.12.006

Stanton, N. A., & Allison, C. K. (2020). Driving towards a greener future: An application of cognitive work analysis to promote fuel-efficient driving. *Cognition, Technology and Work*, *22*(1), 125–142. https://doi.org/10.1007/s10111-019-00554-7

Statistische Ämter des Bundes und der Lander. (2019). *Fahrleistungen*. Retrieved July 28, 2023, from https://www.statistikportal.de/de/ugrdl/ergebnisse/verkehr-und-umwelt/fkm

Staubach, M., Schebitz, N., Köster, F., & Kuck, D. (2014). Evaluation of an eco-driving support system. *Transportation Research Part F: Traffic Psychology and Behaviour*, *27*, 11–21. https://doi.org/10.1016/j.trf.2014.09.006

Stavros, N., Lalos, A. S., Tselios, C., Bitzas, D., Amaxilatis, D., Chatzigiannakis, I., Gerasimos, A., & Moustakas, K. (2019). Gamification of ecodriving behaviours through intelligent management of dynamic car and driver information. In *OPPORTUNITIES AND CHALLENGES for European Projects (EPS Portugal 2017/2018 2017)* (pp. 100–123). SCITEPRESS. https://doi.org/10.5220/0008862301000123

Steg, L. (2005). Car use: Lust and must. Instrumental, symbolic and affective motives for car use. *Transportation Research Part A: Policy and Practice*, *39*(2–3), 147–162. https://doi.org/10.1016/j.tra.2004.07.001

Steg, L. (2014). The significance of hedonic values for environmentally relevant attitudes, preferences, and actions. *Environment and Behavior*, *46*(2), 163–192. https://doi.org/10.1177/0013916512454730

Steg, L. (2023). Psychology of climate change. *Annual Review of Psychology*, *74*, 391–421.

Steg, L., Bolderdijk, J. W., Keizer, K., & Perlaviciute, G. (2014). An integrated framework for encouraging pro-environmental behaviour: The role of values, situational factors and goals. *Journal of Environmental Psychology*, *38*, 104–115. https://doi.org/10.1016/j.jenvp.2014.01.002

Steg, L., & De Groot, J. I. M. (2012). Environmental values. In S. D. Clayton (Ed.), *The Oxford Handbook of Environmental and Conservation Psychology* (pp. 81–92). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199733026.013.0005

Steg, L., Dreijerink, L., & Abrahamse, W. (2006). Factors influencing the acceptability of energy policies: A test of VBN theory. *Journal of Environmental Psychology*, *25*, 415–425. https://doi.org/10.1016/j.jenvp.2005.08.003

Steg, L., Lindenberg, S., & Keizer, K. (2016). Intrinsic motivation, norms and environmental behaviour: The dynamics of overarching goals. *International Review of Environmental and Resource Economics*, *9*, 179–207. https://doi.org/10.1561/101.00000077

Steg, L., Perlaviciute, G., Van der Werff, E., & Lurvink, J. (2014). The significance of hedonic values for environmentally relevant attitudes, preferences, and actions. *Environment and Behavior*, *46*(2), 163–192. https://doi.org/10.1177/0013916512454730

Steg, L., & Vlek, C. (2009). Encouraging pro-environmental behaviour: An integrative review and research agenda. *Journal of Environmental Psychology*, *29*(3), 309–317. https://doi.org/10.1016/j.jenvp.2008.10.004

Steiger, J. H. (2004). Beyond the F test: Effect size confidence intervals and tests of close fit in the analysis of variance and contrast analysis. *Psychological Methods*, *9*(2), 164–182. https://doi.org/10.1037/1082-989X.9.2.164

Steinhorst, J., & Klöckner, C. A. (2018). Effects of monetary versus environmental information framing: Implications for long-term pro-environmental behavior and intrinsic motivation. *Environment and Behavior*, *50*(9), 997–1031. https://doi.org/10.1177/0013916517725371

Steinhorst, J., Klöckner, C. A., & Matthies, E. (2015). Saving electricity – For the money or the environment? Risks of limiting pro-environmental spillover when using monetary framing. *Journal of Environmental Psychology*, *43*, 125–135. https://doi.org/10.1016/j.jenvp.2015.05.012

Steinhorst, J., & Matthies, E. (2016). Monetary or environmental appeals for saving electricity? Potentials for spillover on low carbon policy acceptability. *Energy Policy*, *93*, 335–344. https://doi.org/10.1016/j.enpol.2016.03.020

Steinmetz, H. (2015). *Lineare Strukturgleichungsmodelle - Eine Einführung mit R* (2. Auflage). Rainer Hampp Verlag.

Stern, P. C. (2000). Toward a coherent theory of environmentally significant behavior. *Journal of Social Issues*, *56*(3), 407–424. https://doi.org/10.1111/0022-4537.00175

Stern, P. C., & Dietz, T. (1994). The value basis of environmental concern. *Journal of Social Issues*, *50*(3), 65–84. https://doi.org/10.1111/j.1540-4560.1994.tb02420.x

Stillwater, T., & Kurani, K. S. (2013). Drivers discuss ecodriving feedback: Goal setting, framing, and anchoring motivate new behaviors. *Transportation Research Part F: Traffic Psychology and Behaviour*, *19*, 85–96. https://doi.org/10.1016/j.trf.2013.03.007

Stradling, S. G., Meadows, M. L., & Beatty, S. (1999). *Factors affecting car use choices*. Transport Research Institute, Napier University, Edinburgh, UK.

Streiner, D. L. (2003). Starting at the beginning: An introduction to coefficient alpha and internal consistency. *Journal of Personality Assessment*, *80*(1), 99–103. https://doi.org/10.1207/S15327752JPA8001_18

Strömberg, H., Karlsson, I. C. M. A., & Rexfelt, O. (2015). Eco-driving: Drivers' understanding of the concept and implications for future interventions. *Transport Policy*, *39*, 48–54. https://doi.org/10.1016/j.tranpol.2015.02.001

Tabernero, C., & Hernández, B. (2011). Self-efficacy and intrinsic motivation guiding environmental behavior. *Environment and Behavior*, *43*(5), 658–675. https://doi.org/10.1177/0013916510379759

Tarroja, B., & Hittinger, E. (2021). The value of consumer acceptance of controlled electric vehicle charging in a decarbonizing grid: The case of California. *Energy*, *229*, 120691. https://doi.org/10.1016/j.energy.2021.120691

Taube, O., Kibbe, A., Vetter, M., Adler, M., & Kaiser, F. G. (2018). Applying the Campbell Paradigm to sustainable travel behavior: Compensatory effects of environmental attitude and the transportation environment. *Transportation Research Part F: Traffic Psychology and Behaviour*, *56*, 392–407. https://doi.org/10.1016/j.trf.2018.05.006

Taube, O., Ranney, M. A., Henn, L., & Kaiser, F. G. (2021). Increasing people's acceptance of anthropogenic climate change with scientific facts: Is mechanistic information more effective for environmentalists? *Journal of Environmental Psychology*, *73*, 101549. https://doi.org/10.1016/j.jenvp.2021.101549

Taylor, G., Jungert, T., Mageau, G. A., Schattke, K., Dedic, H., Rosenfield, S., & Koestner, R. (2014). A self-determination theory approach to predicting school achievement over time: The unique role of intrinsic motivation. *Contemporary Educational Psychology*, *39*(4), 342–358. https://doi.org/10.1016/j.cedpsych.2014.08.002

Thaler, R., & Sunstein, C. (2009). *Nudge: Improving Decisions about Health, Wealth and Happiness*. Boston Yale University Press.

Thøgersen, J. (1996). Recycling and morality: A critical review of the literature. *Environment and Behavior*, *28*(4), 536–558. https://doi.org/10.1177/0013916596284006

Thøgersen, J. (1999). Spillover processes in the development of a sustainable consumption pattern. *Journal of Economic Psychology*, *20*(1), 53–81. https://doi.org/10.1016/S0167-4870(98)00043-9

Thøgersen, J. (2000). Psychological determinants of paying attention to eco-labels in purchase decisions: Model development and multinational validation. *Journal of Consumer Policy*, *23*, 285–313. https://doi.org/10.1023/A:1007122319675

Thøgersen, J., & Crompton, T. (2009). Simple and painless? The limitations of spillover in environmental campaigning. *Journal of Consumer Policy*, *32*(2), 141–163. https://doi.org/10.1007/s10603-009-9101-1

Thøgersen, J., & Noblet, C. (2012). Does green consumerism increase the acceptance of wind power? *Energy Policy*, *51*, 854–862. https://doi.org/10.1016/j.enpol.2012.09.044

Thøgersen, J., & Ölander, F. (2002). Human values and the emergence of a sustainable consumption pattern: A panel study. *Journal of Economic Psychology*, *23*(5), 605–630. https://doi.org/10.1016/S0167-4870(02)00120-4

Thøgersen, J., & Ölander, F. (2003). Spillover of environment-friendly consumer behaviour. *Journal of Environmental Psychology*, *23*(3), 225–236. https://doi.org/10.1016/S0272-4944(03)00018-5

Tiefenbeck, V., Staake, T., Roth, K., & Sachs, O. (2013). For better or for worse? Empirical evidence of moral licensing in a behavioral energy conservation campaign. *Energy Policy*, *57*, 160–171. https://doi.org/10.1016/j.enpol.2013.01.021

Tivian XI GmbH. (2021). *EFS Survey (Version 21.1)* [Computer software]. https://www.tivian.com/de/

Triandis, H. C. (1995). *Individualism and collectivism*. Routledge.

Tukker, A., & Jansen, B. (2006). Environmental impacts of products: A detailed review of studies. *Journal of Industrial Ecology*, *10*(3), 159–182. https://doi.org/10.1162/jiec.2006.10.3.159

Turaga, R. M. R., Howarth, R. B., & Borsuk, M. E. (2010). Pro-environmental behavior: Rational choice meets moral motivation. *Annals of the New York Academy of Sciences*, *1185*, 211–224. https://doi.org/10.1111/j.1749-6632.2009.05163.x

UCL. (2021, January 04). *Analysis: Here's the carbon cost of your daily coffee - and how to make it climate-friendly*. University College London. https://www.ucl.ac.uk/news/2021/jan/analysis-heres-carbon-cost-your-daily-coffee-and-how-make-it-climate-friendly#:~:text=The%20average%20cup%20of%20coffee,0.06%20kg%20if%20grown%20sustainably.

Umweltbundesamt. (2020, April 08). *Bilanz 2019: $CO_2$-Emissionen pro Kilowattstunde Strom sinken weiter*. https://www.umweltbundesamt.de/presse/pressemitteilungen/bilanz-2019-co2-emissionen-pro-kilowattstunde-strom.

Ünal, A. B., Steg, L., & Gorsira, M. (2018). Values versus environmental knowledge as triggers of a process of activation of personal norms for eco-driving. *Environment and Behavior*, *50*(10), 1092–1118. https://doi.org/10.1177/0013916517728991

Unsworth, K. L., & McNeill, I. M. (2017). Increasing pro-environmental behaviors by increasing self-concordance: Testing an intervention. *Journal of Applied Psychology*, *102*(1), 88–103. https://doi.org/10.1037/apl0000155

U.S. Energy Information Administration. (2022). *How much gasoline does the United States consume?* Retrieved January 10, 2022, from https://www.eia.gov/tools/faqs/faq.php?id=23&t=10#:~:text=In%202021%2C%20about%20134.83%20billion,8.80%20million%20barrels%20per%20day

U.S. Government. (2020). *United States Census Bureau*. https://data.census.gov/cedsci/table?text=B08141&tid=ACSDT5Y2020.B08141

Vaezipour, A., Rakotonirainy, A., & Haworth, N. (2016). Design of a gamified interface to improve fuel efficiency and safe driving. In A. Marcus (Ed.), *Design, User Experience, and Usability: Novel User Experiences. DUXU 2016. Lecture Notes in Computer*

*Science, vol 9747* (pp. 322–332). Springer. https://doi.org/10.1007/978-3-319-40355-7_31

Vaezipour, A., Rakotonirainy, A., Haworth, N., & Delhomme, P. (2017). Enhancing eco-safe driving behaviour through the use of in-vehicle human-machine interface: A qualitative study. *Transportation Research Part A: Policy and Practice*, *100*, 247–263. https://doi.org/10.1016/j.tra.2017.04.030

Van de Velde, L., Verbeke, W., Popp, M., & Van Huylenbroeck, G. (2010). The importance of message framing for providing information about sustainability and environmental aspects of energy. *Energy Policy*, *38*(10), 5541–5549. https://doi.org/10.1016/j.enpol.2010.04.053

Van den Broek, K., Bolderdijk, J. W., & Steg, L. (2017). Individual differences in values determine the relative persuasiveness of biospheric, economic and combined appeals. *Journal of Environmental Psychology*, *53*, 145–156. https://doi.org/10.1016/j.jenvp.2017.07.009

Van der Linden, S. (2013). Exploring beliefs about bottled water and intentions to reduce consumption: The dual-effect of social norm activation and persuasive information. *Environment and Behavior*, *47*(5), 526–550. https://doi.org/10.1177/0013916513515239

Van der Linden, S. (2015). Intrinsic motivation and pro-environmental behaviour. *Nature Climate Change*, *5*(7), 612–613. https://doi.org/10.1038/nclimate2669

Van der Voort, M., Dougherty, M. S., & Van Maarseveen, M. (2001). A prototype fuel-efficiency support tool. *Transportation Research Part C: Emerging Technologies*, *9*(4), 279–296. https://doi.org/10.1016/S0968-090X(00)00038-3

Van der Werff, E., & Steg, L. (2018). Spillover benefits: Emphasizing different benefits of environmental behavior and its effects on spillover. *Frontiers in Psychology*, *9*, 1–16. https://doi.org/10.3389/fpsyg.2018.02347

Van der Werff, E., Steg, L., & Keizer, K. (2013). It is a moral issue: The relationship between environmental self-identity, obligation-based intrinsic motivation and pro-environmental behaviour. *Global Environmental Change*, *23*(5), 1258–1265. https://doi.org/10.1016/j.gloenvcha.2013.07.018

Van der Werff, E., Steg, L., & Keizer, K. (2014). I am what I am, by looking past the present: The influence of biospheric values and past behavior on environmental self-identity. *Environment and Behavior, 46*(5), 626–657. https://doi.org/10.1177/0013916512475209

Van Liere, K. D., & Dunlap, R. E. (1980). The social bases of environmental concern: A review of hypotheses, explanations and empirical evidence. *Public Opinion Quarterly*, *44*(2), 181–197. https://doi.org/10.1086/268583

Van Velsen, L., Broekhuis, M., Jansen-Kosterink, S., & op den Akker, H. (2019). Tailoring persuasive electronic health strategies for older adults on the basis of personal motivation: Web-based survey study. *Journal of Medical Internet Research*, *21*(9), 1–16. https://doi.org/10.2196/11759

Van Vugt, M., Van Lange, P. A., & Meertens, R. M. (1996). Commuting by car or public transportation? A social dilemma analysis of travel mode judgements. *European Journal of Social Psychology*, *26*(3), 373–395. https://doi.org/10.1002/(SICI)1099-0992(199605)26:3<373::AID-EJSP760>3.0.CO;2-1

Vansteenkiste, M., Simons, J., Lens, W., Sheldon, K. M., & Deci, E. L. (2004). Motivating learning, performance, and persistence: The synergistic effects of intrinsic goal contents and autonomy-supportive contexts. *Journal of Personality and Social Psychology*, *87*(2), 246–260. https://doi.org/10.1037/0022-3514.87.2.246

Venhoeven, L. A., Bolderdijk, J. W., & Steg, L. (2013). Explaining the paradox: How pro-environmental behaviour can both thwart and foster well-being. *Sustainability (Switzerland)*, *5*(4), 1372–1386. https://doi.org/10.3390/su5041372

Venhoeven, L. A., Bolderdijk, J. W., & Steg, L. (2016). Why acting environmentally-friendly feels good: Exploring the role of self-image. *Frontiers in Psychology*, *7*, 1–8. https://doi.org/10.3389/fpsyg.2016.01846

Verplanken, B., & Wood, W. (2006). Interventions to break and create consumer habits. *Journal of Public Policy and Marketing*, *25*(1), 90–103. https://doi.org/10.1509/jppm.25.1.90

Vetter, M., & Kutzner, F. (2016). Nudge me if you can - how defaults and attitude strength interact to change behavior. *Comprehensive Results in Social Psychology*, *1*(1–3), 8–34. https://doi.org/10.1080/23743603.2016.1139390

Villacorta, M., Koestner, R., & Lekes, N. (2003). Further validation of the Motivation Toward the Environment Scale. *Environment and Behavior*, *35*(4), 486–505. https://doi.org/10.1177/0013916502250753

Vlachopoulos, S. P., Karageorghis, C. I., & Terry, P. C. (2000). Motivation profiles in sport: A self-determination theory perspective. *Research Quarterly for Exercise and Sport*, *71*(4), 387–397. https://doi.org/10.1080/02701367.2000.10608921

Volkswagen. (2020, September 18). *Der vollelektrische ID.3 | Volkswagen Way To Zero*. Youtube.

Walker, G. J., Courneya, K. S., & Deng, J. (2006). Ethnicity, gender, and the Theory of Planned Behavior: The case of playing the lottery. *Journal of Leisure Research*, *38*(2), 224–248. https://doi.org/10.1080/00222216.2006.11950077

Walsh, C., Carroll, S., Eastlake, A., & Blythe, P. (2010). UK electric vehicle deployment and performance study. *The 25th World Battery Hybrid and Fuel Cell Electric Vehicle Symposium and Exhibition*, *November 2010*, *Shenzhen, China*.

Walter, S. L., Seibert, S. E., Goering, D., & O'Boyle, E. H. (2019). A tale of two sample sources: Do results from online panel data and conventional data converge? *Journal of Business and Psychology*, *34*(4), 425–452. https://doi.org/10.1007/s10869-018-9552-y

Wang, X., & Yao, X. (2020). Fueling pro-environmental behaviors with gamification design: Identifying key elements in ant forest with the kano model. *Sustainability (Switzerland)*, *12*(6). https://doi.org/10.3390/su12062213

Weaver, K., Garcia, S. M., & Schwarz, N. (2012). The presenter's paradox. *Journal of Consumer Research*, *39*(3), 445–460. https://doi.org/10.1086/664497

Wen, Y., MacKenzie, D., & Keith, D. R. (2016). Modeling the charging choices of battery electric vehicle drivers by using stated preference data. *Transportation Research Record*, *2572*(1), 47–55. https://doi.org/10.3141/2572-06

Westin, K., Nordlund, A., Jansson, J., & Nilsson, J. (2020). Goal framing as a tool for changing people's car travel behavior in Sweden. *Sustainability (Switzerland)*, *12*(9), 3695. https://doi.org/10.3390/su12093695

Wiens, S., & Nilsson, M. E. (2017). Performing contrast analysis in factorial designs: From NHST to confidence intervals and beyond. *Educational and Psychological Measurement*, *77*(4), 690–715. https://doi.org/10.1177/0013164416668950

Will, C., & Schuller, A. (2016). Understanding user acceptance factors of electric vehicle smart charging. *Transportation Research Part C: Emerging Technologies*, *71*, 198–214. https://doi.org/10.1016/j.trc.2016.07.006

Williams, G. C., Gagné, M., Ryan, R. M., & Deci, E. L. (2002). Facilitating autonomous motivation for smoking cessation. *Health Psychology*, *21*(1), 40–50. https://doi.org/10.1037/0278-6133.21.1.40

Wolf, B. M., Herrmann, M., & Brandstätter, V. (2018). Self-efficacy vs. action orientation: Comparing and contrasting two determinants of goal setting and goal striving. *Journal of Research in Personality*, *73*, 35–45. https://doi.org/10.1016/j.jrp.2017.11.001

Wong-Parodi, G., Krishnamurti, T., Gluck, J., & Agarwal, Y. (2019). Encouraging energy conservation at work: A field study testing social norm feedback and awareness of monitoring. *Energy Policy*, *130*, 197–205. https://doi.org/10.1016/j.enpol.2019.03.028

Wu, Y., Zhao, X., Rong, J., & Zhang, Y. (2018). The effectiveness of eco-driving training for male professional and non-professional drivers. *Transportation Research Part D: Transport and Environment*, *59*, 121–133. https://doi.org/10.1016/j.trd.2018.01.002

Wynes, S., & Nicholas, K. A. (2017). The climate mitigation gap: Education and government recommendations miss the most effective individual actions. *Environmental Research Letters*, *12*, 074024. https://doi.org/10.1088/1748-9326/aac9cf

Wyss, A. M., Knoch, D., & Berger, S. (2022). When and how pro-environmental attitudes turn into behavior: The role of costs, benefits, and self-control. *Journal of Environmental Psychology*, *79*, 101748. https://doi.org/10.1016/j.jenvp.2021.101748

Ye, S.-H., Zhou, W., Song, J., Peng, B.-C., Yuan, D., Lu, Y.-M., & Qi, P.-P. (1999). Toxicity and health effects of vehicle emissions in Shanghai. *Atmospheric Environment*, *34*(3), 419–429. https://doi.org/10.1016/S1352-2310(99)00306-4

Zarkadoula, M., Zoidis, G., & Tritopoulou, E. (2007). Training urban bus drivers to promote smart driving: A note on a Greek eco-driving pilot program. *Transportation Research Part D: Transport and Environment*, *12*(6), 449–451. https://doi.org/10.1016/j.trd.2007.05.002

Zeileis, A., Kleiber, C., & Jackman, S. (2008). Regression models for count data in R. *Journal of Statistical Software*, *27*(8), 1–25. https://doi.org/10.18637/jss.v027.i08

Zeiske, N., Van der Werff, E., & Steg, L. (2021). The effects of a financial incentive on motives and intentions to commute to work with public transport in the short and long term. *Journal of Environmental Psychology*, *78*, 101718. https://doi.org/10.1016/j.jenvp.2021.101718

Zelezny, L. C., Chua, P.-P., & Aldrich, C. (2000). New ways of thinking about environmentalism: Elaborating on gender differences in environmentalism. *Journal of Social Issues*, *56*(3), 443–457. https://doi.org/10.1111/0022-4537.00177

# Appendix

## A. Full intervention material of study 4

***Environmental framing (translated version)***

### How can you contribute to $CO_2$ emission reduction through your vehicle use?

Globally, greenhouse gases emitted by the transport sector are rising rapidly. The use of fossil fuels produces harmful $CO_2$ emissions that contribute to the significant increase in the average temperature on earth. Climate change has far-reaching and alarming consequences, such as ice melt and sea level rise, increased weather extremes, and increased damage to ecosystems (e.g., coral reefs). Greenhouse gases, especially human-caused $CO_2$ emissions, are one of the main triggers of climate change. The good news is: You can do something and reduce your vehicle-related $CO_2$ emissions. By doing so, you make a significant contribution to environmental protection!

Below, you can find out what you can do and with which vehicle-related behaviors you can save which amount of $CO_2$. Since the meaning of the amount of $CO_2$ saved in kg may not be immediately understandable, we also indicate how long it would take a beech tree to absorb the saved $CO_2$ emissions. Trees have the ability of taking carbon dioxide from the atmosphere and converting it into oxygen as part of photosynthesis ($CO_2$ absorption). $CO_2$ absorption by trees is necessary to counteract global warming. However, trees alone cannot save climate change; we humans must significantly reduce our greenhouse gas emissions in the long term.
In the following tips for environmentally friendly vehicle use, we include how long it takes a 23-meter-tall beech tree, which has lived on earth for 80 years (therefore, it can absorb significantly more $CO_2$ than young trees), to absorb the saved emissions and convert them into oxygen.

Imagine you are driving a 200 km long distance (e.g., Stuttgart - Lake Constance) with your car, which has to be refueled with gasoline. The average consumption of your vehicle is 7 l/100 km. On this route, the following savings are possible (based on scientific findings).

### 1. Avoid hard braking and acceleration

If you avoid hard braking and acceleration as well as strong speed fluctuations and let the vehicle coast ("sail"), you can reduce fuel consumption by up to 3.50 liters on your route. This corresponds to a $CO_2$ saving of about 8.12 kg. The beech tree would be busy absorbing this amount of $CO_2$ for about 237 days.

### 2. Avoid objects that increase the aerodynamic drag of the vehicle

If you avoid objects that increase the aerodynamic drag of the vehicle (e.g., roof luggage box), you can reduce fuel consumption by up to 1.68 liters on your route. This corresponds to a $CO_2$ saving of about 3.90 kg. The beech tree would be busy absorbing this amount of $CO_2$ for about 114 days.

### 3. Avoid very high speeds

If you avoid very high speeds, you can reduce fuel consumption by up to 0.84 liters on your route. This corresponds to a $CO_2$ saving of about 1.95 kg. The beech tree would be busy absorbing this amount of $CO_2$ for about 57 days.

### 4. Choose an energy-efficient travel route

If you choose an energy-efficient travel route (w.r.t. road type, gradient, traffic volume), you can reduce fuel consumption by up to 0.84 liters on your route. This corresponds to a $CO_2$ saving of about 1.95 kg. The beech tree would be busy absorbing this amount of $CO_2$ for about 57 days.

### 5. Reduce use of electrical consumers (e.g., air conditioning)

If you minimize the use of electrical consumers (e.g., air conditioning, seat heating), you can reduce fuel consumption by up to 0.56 liters on your route. This corresponds to a $CO_2$ saving of about 1.30 kg. The beech tree would be busy absorbing this amount of $CO_2$ for about 38 days.

### 6. Switch off the engine at stops or use the automatic start-stop system

If you switch off the engine at stops or use the automatic start-stop function of your vehicle, you can reduce fuel consumption by up to 0.28 liters on your route. This corresponds to a $CO_2$ saving of about 0.65 kg. The beech tree would be busy absorbing this amount of $CO_2$ for about 19 days.

**7. Avoid unnecessary weight in the vehicle**

If you avoid carrying unnecessary weight in your vehicle, you can reduce fuel consumption by up to 0.21 liters on your route. This corresponds to a $CO_2$ saving of about 0.49 kg. The beech tree would be busy absorbing this amount of $CO_2$ for about 14 days.

**8. Avoid underinflated tires**

If you avoid underinflated tires, you can reduce fuel consumption by up to 0.21 liters on your route. This corresponds to a $CO_2$ saving of about 0.49 kg. The beech tree would be busy absorbing this amount of $CO_2$ for about 14 days.

Accordingly, you can save up to 18.85 kg of $CO_2$ emissions on your route, which would take the beech tree approx. 550 days (i.e., considerably more than 1 year!) to absorb this amount of $CO_2$. So you see: By implementing these tips, you can significantly reduce the $CO_2$ emissions of your vehicle (these principles also apply to a diesel and to vehicles with other average fuel consumptions).

**Try implementing these behaviors in the future and realize the full savings potential!**

***Altruistic framing (translated version)***

**How can you contribute to air pollution reduction through your vehicle use?**

The road transport sector has been one of the most significant sources of air pollutants in Germany for some time. According to the Federal Environment Agency, emissions of air pollutants such as nitrogen oxides, particulate matter, or carbon monoxide from the transport sector have been falling since 1990, but in recent years, the decline in emissions has been flattening. Air pollutants pose a concerning health risk to humans because they can trigger various temporary and chronic health damages. These include lung, respiratory, and cardiovascular diseases. There is also a link between these emissions and an increased risk of cancer. The good news is: You can do something about it and reduce the air pollutants by adapting your vehicle use. By doing so, you will significantly contribute to the health of other people, especially those who are permanently exposed to traffic-related air pollution!

Below, you can find tips on vehicle-related behaviors, which you can use to reduce the air pollutants emitted by your vehicle while driving.

Imagine you are driving a 200 km long distance (e.g. Stuttgart - Lake Constance) with your car, which has to be refueled with gasoline. The average consumption of your vehicle is 7 l/100 km. On this route, the following savings are possible (based on scientific findings). Note that even small reductions of extremely harmful emissions can have large health effects.

**1. Avoid hard braking and acceleration**

If you avoid hard braking and acceleration as well as strong speed fluctuations and let the vehicle coast ("sail"), you can reduce fuel consumption by up to 3.50 liters on your route. By implementing this behavior, you can significantly contribute to the reduction of nitrogen oxides ($NO_x$) caused by road traffic; thus, you can contribute to the protection of everyone's health.

**2. Avoid objects that increase the aerodynamic drag of the vehicle**

If you avoid objects that increase the aerodynamic drag of the vehicle (e.g., roof luggage box), you can reduce fuel consumption by up to 1.68 liters on your route. By implementing this behavior, you can contribute to the reduction of carbon monoxide (CO) caused by road traffic; thus, you can contribute to the protection of everyone's health.

**3. Avoid very high speeds**

If you avoid very high speeds, you can reduce fuel consumption by up to 0.84 liters on your route. By implementing this behavior, you can significantly contribute to the reduction of carbon monoxide (CO) caused by road traffic; thus, you can contribute to the protection of everyone's health.

**4. Choose an energy-efficient travel route**

If you choose an energy-efficient travel route (w.r.t. road type, gradient, traffic volume), you can reduce fuel consumption by up to 0.84 liters on your route. By implementing this behavior, you can contribute to the reduction of nitrogen oxides ($NO_x$) caused by road traffic; thus, you can contribute to the protection of everyone's health.

### 5. Reduce use of electrical consumers (e.g., air conditioning)

If you minimize the use of electrical consumers (e.g., air conditioning, seat heating), you can reduce fuel consumption by up to 0.56 liters on your route. By implementing this behavior, you can contribute to the reduction of greenhouse gases (e.g., $CO_2$) caused by road traffic; thus, you can contribute to the protection of other species.

### 6. Switch off the engine at stops or use the automatic start-stop system

If you switch off the engine at stops or use the automatic start-stop function of your vehicle, you can reduce fuel consumption by up to 0.28 liters on your route. By implementing this behavior, you can help reduce smaller fine dust particles ($PM_{2.5}$) caused by road traffic; thus, you can contribute to the protection of everyone's health.

### 7. Avoid unnecessary weight in the vehicle

If you avoid carrying unnecessary weight in your vehicle, you can reduce fuel consumption by up to 0.21 liters on your route. By implementing this behavior, you can contribute to the reduction of greenhouse gases (e.g., $CO_2$) caused by road traffic; thus, you can contribute to the protection of future life.

### 8. Avoid underinflated tires

If you avoid underinflated tires, you can reduce fuel consumption by up to 0.21 liters on your route. By implementing this behavior, you can contribute to the reduction of greenhouse gases (e.g., $CO_2$) caused by road traffic; thus you can contribute to the protection of life in areas particularly threatened by climate change.

Accordingly, by implementing these behaviors, you can significantly contribute to the reduction of air pollution caused by road traffic (these principles also apply to a diesel and to vehicles with other average fuel consumptions). By doing so, you make an important contribution to protecting the health and lives of everyone.

**Try implementing these behaviors in the future and realize the full savings potential!**

***Monetary framing (translated version)***

**How can you gain financial benefits through your vehicle use?**

The importance of the road transport sector has been rising strongly for years. Fossil fuels such as crude oil, natural gas, and coal are becoming increasingly scarce. Energy sources such as crude oil are particularly threatened by the scarcity of resources. Despite occasional declines in the prices of oil and other energy sources caused by special factors (e.g., COVID-19 pandemic), the finite nature of fossil resources and their enormous $CO_2$ impact will probably lead to an increase in the prices of traditional fuels in the long term. The good news is: You can do something about it by achieving fuel savings by adapting your vehicle use. Fuel savings have a positive impact on your wallet!

Below, you can find tips on vehicle-related behaviors and their corresponding monetary savings potential. Although the savings may seem trivial to you at first, they are not negligible if implemented consistently.

Imagine you are driving a 200 km route (e.g., Stuttgart - Lake Constance) with your vehicle, which has to be refueled with gasoline. The average consumption of your vehicle is 7 l/100 km. On this route, the following savings are possible (based on scientific findings).

**1. Avoid hard braking and acceleration**

If you avoid hard braking and acceleration as well as strong speed fluctuations and let the vehicle coast ("sail"), you can reduce fuel consumption by up to 3.50 liters on your route. This corresponds to a monetary saving of 4.20€.

€€€€

**2. Avoid objects that increase the aerodynamic drag of the vehicle**

If you avoid objects that increase the aerodynamic drag of the vehicle (e.g., roof luggage box), you can reduce fuel consumption by up to 1.68 liters on your route. This corresponds to a monetary saving of 2.02€.

€€€

**3. Avoid very high speeds**

If you avoid very high speeds, you can reduce fuel consumption by up to 0.84 liters on your route. This corresponds to a monetary saving of 1.01€.

€€€

**4. Choose an energy-efficient travel route**

If you choose an energy-efficient travel route (w.r.t. road type, gradient, traffic volume), you can reduce fuel consumption by up to 0.84 liters on your route. This corresponds to a monetary saving of 1.01€.

€€€

**5. Reduce use of electrical consumers (e.g., air conditioning)**

If you minimize the use of electrical consumers (e.g., air conditioning, seat heating), you can reduce fuel consumption by up to 0.56 liters on your route. This corresponds to a monetary saving of 0.67€.

€€

**6. Switch off the engine at stops or use the automatic start-stop system**

If you switch off the engine at stops or use the automatic start-stop function of your vehicle, you can reduce fuel consumption by up to 0.28 liters on your route. This corresponds to a monetary saving of 0.34€

€

**7. Avoid unnecessary weight in the vehicle**

If you avoid carrying unnecessary weight in your vehicle, you can reduce fuel consumption by up to 0.21 liters on your route. This corresponds to a monetary saving of 0.25€.

€

**8. Avoid underinflated tires**

If you avoid underinflated tires, you can reduce fuel consumption by up to 0.21 liters on your route. This corresponds to a monetary saving of 0.25€.

€

In total, you can save up to 9.75€ on your route. So, you see: By implementing these tips you can significantly improve the fuel consumption of your vehicle (these principles also apply to a diesel and to vehicles with other average fuel consumptions).

**Try implementing these behaviors in the future and realize the full savings potential!**

## B. Questionnaire material of study 4

***Definition eco-driving***

What does fuel-efficient vehicle use mean?

Before you are asked to answer questions on fuel-efficient vehicle use in the further course of the study, we would like to give you a definition of the term as it is understood in the present study. Fuel-efficient vehicle use includes those strategic decisions (vehicle selection and maintenance), tactical decisions (route selection and vehicle loading), and operational decisions (driving behavior) that reduce fuel or energy consumption, $CO_2$ and pollutant emissions. Consequently, we understand fuel-efficient vehicle use to include not only on-road driving behavior but also purchasing and maintenance behavior, as well as pre-trip behavior. Examples of strategic decisions are the choice of fuel-efficient tires or regular vehicle maintenance. Tactical decisions include choosing an energy-efficient route or reducing additional weight in and on the vehicle. Operational decisions include all those behaviors that are performed during actual driving. This includes moderate acceleration, anticipatory driving, avoiding unnecessary stops and starts, maintaining a steady driving speed, maintaining a moderate speed, or turning off the engine at stops. Whenever the term fuel-efficient vehicle use is used, we are referring to the strategic, tactical, and operational decisions and not exclusively to driving behavior.

Please keep in mind that you cannot answer any question right or wrong. We are interested in your honest opinion. Your answers will be evaluated anonymously.

***Manipulation control questions (only asked in the framing groups)***

The purpose of this study is to examine vehicle use. In the last questionnaire and in the short reminder e-mail two weeks ago, we gave you a few tips on how to make your vehicle use more fuel-efficient. Please remind yourself back to those tips.

1. Have you read, downloaded, or discussed the tips? *(yes/ no)*
2. Please list any tips you remember below. *(open format)*
3. What was the main reason in the introductory text of the tips specifying why it is worthwhile to implement fuel-efficient vehicle use? *(open format)*

## C. Eco-driving behaviors and intervention material of study 5

Table C1

*Eco-driving tips with intervention information that was displayed in the prototypical smartphone application (for descriptions of the in-vehicle eco functions, see section 10.2; study 5)*

| Eco-driving tip | $CO_2$ reduction potential (in % with literature source)[4] | $CO_2$ reduction for trip (in g/kWh) | FlexCharge points | Reward (in €) |
|---|---|---|---|---|
| 1. Anticipatory driving | 10 (Energy Saving Trust, 2017; Bingham et al., 2012; Sagaria et al., 2021) | 150-450 | 2 | 0.50 |
| 2. Turn on eco-mode | 5 (Cieslik et al., 2020) | 75 | 0.5 | 0.13 |
| 3. Avoid strong breaking | 10-30 (Energy Saving Trust, 2017; Bingham et al., 2012; Sagaria et al., 2021) | 150-450 | 2 | 0.50 |
| 4. Avoid extreme speeds | 20 (Galvin, 2017) | 300 | 1.5 | 0.38 |
| 5. Close windows at high speeds | 10 (McIlroy & Stanton, 2017) | 150 | 1 | 0.38 |
| 6. Reduce electrical consumer use (e.g., heating, AC) | 10 (Energy Saving Trust, 2017) | 150 | 1 | 0.25 |
| 7. Turn on eco-assist | 10-30 (Energy Saving Trust, 2017; Bingham et al., 2012; Sagaria et al., 2021) | 150-450 | 2 | 0.50 |
| 8. Turn on eco-score | 10-30 (Energy Saving Trust, 2017; Bingham et al., 2012; Sagaria et al., 2021) | 150-450 | 2 | 0.50 |

[4] The calculations were based on the assumption that the battery electric vehicle requires an average of 30 kWh/100km on the 12 km route and that the electricity comes from the German electricity mix (408g/kWh; Umweltbundesamt, 2020). An average of 30 kWh/100 km was used because the trip contained built-up and rural routes as well as routes on the highway (see ADAC, 2022).

# Consent

Hiermit versichere ich, dass ich die vorliegende Arbeit ohne unzulässige Hilfe Dritter und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe; die aus fremden Quellen direkt oder indirekt übernommenen Gedanken sind als solche kenntlich gemacht. Die Arbeit wurde bisher weder im Inland noch im Ausland in gleicher oder ähnlicher Form einer anderen Prüfungsbehörde vorgelegt.

Die Dissertation wurde bei der Mercedes-Benz Group AG und am Institut für Verkehrsplanung und Straßenverkehr der Technischen Universität Dresden unter der wissenschaftlichen Betreuung von Prof. Dr. Tibor Petzoldt und Dr. Stefan Mattes angefertigt.

Es haben keine früheren erfolglosen Promotionsverfahren stattgefunden.

Die Promotionsordnung des Bereichs Mathematik und Naturwissenschaften der Technischen Universität Dresden, in der Fassung vom 23.02.2011, letzte Änderung 23.05.2018, wird anerkannt.

Tübingen, ________________ ______________________________

Jule Kramer