Driving feedback

Dogan, Ebru

DRIVING FEEDBACK

Psychological factors influencing the effectiveness of feedback

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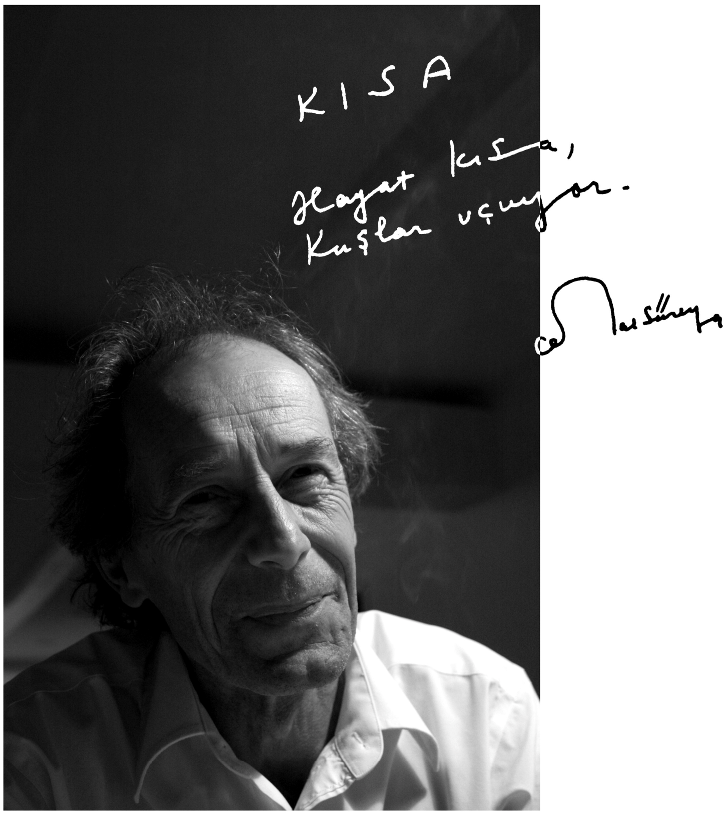
In memoriam

Talib



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CHAPTER 1: General introduction

Traffic and transportation contribute to safety and environmental problems. Traffic accidents are among the major causes of death and injury (WHO, 2009). In the EU 30,800 people died in traffic accidents in 2010. Road user behavior has been identified as the leading cause of these accidents, with violations and errors accounting for almost 80% of the accidents (Sabey & Taylor, 1980; Streff, 1991). In Europe, road transport is also responsible for around 20% of the total carbon dioxide (CO_2) emissions, the main source of greenhouse gas. Although CO_2-emissions from other sectors such as agriculture showed a decline, those from road transport showed an increase by around 26% since 1990 (European Comission, 2010). Safe driving behavior is generally assumed to reduce CO_2-emissions as well. For instance, a smooth driving style, maintaining a steady speed, or early anticipation of traffic situations enhance safety as well as fuel saving (CIECA, 2007). Therefore, understanding and promoting safe and sustainable driver behavior could be a key to reduce undesirable consequences of road transport for safety and environmental quality.

Drivers deviate from safe and sustainable driving for various reasons, which are often related to cognitive limitations or motivational processes. For instance, we may drive fast for the pleasure of doing so without acknowledging the risks involved (e.g., Rothengatter, 1988), fail to realize that we drive too close to the car ahead because we are too tired or distracted (e.g., Barr, Popkin, & Howard, 2009), or consume too much fuel because we are not aware of our energy-inefficient driving style (e.g., Birrell & Young, 2011). In many cases, drivers are not fully aware of the possible negative consequences of engaging in these types of actions. So, how can we increase drivers' awareness of the consequences of their behaviors in order to promote safe and sustainable driver behavior?

Providing feedback, that is, information on the consequences of a specific behavior, has been one of the most widely used strategies to increase awareness of the consequences of one's behaviors and to promote behavioral change (e.g., Abrahamse, Steg, Vlek, & Rothengatter, 2007; Hatakka, Keskinen, Gregersen, Glad, & Hernetkoski, 2002). For instance, information on fuel consumption related to one's acceleration rate has stimulated smoother acceleration, which reduced fuel consumption (Birrell & Young, 2011). Although several studies revealed that feedback is a promising strategy to promote behavior change, little is known how to optimize its effects. What drives the design of feedback to be effective in promoting safe and sustainable driver behavior? In the current thesis, I will address several psychological factors that may influence the effectiveness of feedback concerning driver behavior. I will first define feedback as it is used in the current thesis. Then, in three sections, I will explain cognitive and motivational factors related to the individual, driving context, and feedback content that may affect the effectiveness of feedback. More specifically, I will study how people cope with feedback that does not convey any information on how one could improve one's performance (Chapter 2). Also, I will examine to what extent the effects of feedback depend on the presence of goals other than the one related to feedback (Chapter 3), and on the types of motives that are triggered by feedback content (Chapter 4).

Feedback

Driver behavior is goal-directed and self-regulated (Näätänen & Summala, 1974). Drivers compare the outcomes of their current behavior with their goals or with their evaluations of their skills and abilities, and adjust their behavior or cognitions (e.g., they prioritize goals or adjust self-evaluations of their driving skills) when they perceive a discrepancy between how they think they should be driving and how they are actually driving (cf. Carver & Scheier, 1998). Such regulatory actions are typically based on the consequences of previous actions. Receiving information about the consequences of one's actions is therefore important for self-regulation of driver behavior. However, drivers do not always receive sufficient feedback or they do not detect the natural feedback on the possible negative consequences of their behaviors. For instance, the forgiving nature of road design and the traffic environment implies that not all risky behaviors on the road result in (near) accidents (Brown, 1989). This is particularly relevant for novice drivers who – due to their limited exposure to diverse, specific driving circumstances – may not have experienced natural feedback in different traffic conditions. Additional feedback from external sources could therefore enhance drivers' awareness about the consequences of their own behaviors.

Feedback enables drivers to make a connection between their behaviors and the consequences of these behaviors so that they can take regulatory actions to adapt to the changing situations (Brown, 1989; Kuiken & Twisk, 2001; Fuller, 2008). Feedback can come from different sources. Intrinsic feedback consists of information that arises from one's own sensory-perceptual experience, such as visual cues regarding distance or auditory cues like engine sound (Groeger, 2000; Evans, 2004). Extrinsic feedback, on the other hand, is provided intentionally by an external source such as a trainer or an in-vehicle feedback system. In this thesis I focus on extrinsic feedback.

Extrinsic feedback on driver behavior has been mostly studied in relation to in-vehicle feedback systems providing information on, for example, speed regulation, time-to-contact (i.e., time to crash at a particular velocity), or energy efficiency. Results revealed that extrinsic feedback can be an effective way to improve safe and sustainable driving. For instance, provision of extrinsic feedback appeared to enhance safe driver behavior by increasing drivers' compliance with traffic laws regarding speed limits (e.g., Carsten & Tate, 2005), seat belt use (Lie, Krafft, Kullgren, & Tingvall, 2008), and promoting the adoption of longer time headways (Fairclough, May, & Carter, 1997). Extrinsic feedback was effective in supporting sustainable driver behavior as well. For instance, fuel consumption feedback based on driver's acceleration was found to reduce fuel consumption (Birrell & Young, 2011; Hallihan, Mayer, & Caird, 2011).

Previous research mostly tested the effectiveness of a particular feedback system and driver's interaction with that particular system. Hence, the focus was generally on the effects of the presence of feedback rather than on the circumstances under which feedback would be most effective. However, as yet, little is known about which types of feedback are particularly effective and which factors promote or inhibit the effects of feedback. In the current thesis, I argue that the effects of feedback depend to a great extent on how people deal with it; as such, motivations and cognitions of drivers influence the extent to which feedback is effective. First, I will examine how people cope with non-evaluative feedback that does not clarify how performance can be improved (Chapter 2). Second, I will investigate whether the presence of other important goals than the one related to feedback have an impact on how effective feedback is (Chapter 3). Third, I will study to what extent different consequences emphasized by feedback motivate behavior differently (Chapter 4).

How do drivers respond to non-evaluative feedback?

Feedback is most likely to guide self-regulatory actions when it is evaluative, that is, when it contains information about why the outcomes occurred and how performance could be improved (e.g., Brown, 1989; Kruger & Dunning, 1999). Such feedback facilitates appraisals of one's skills and abilities, and one's understanding of what caused poor or good performance. Based on this, drivers may either adjust their performance or their self-evaluations of performance, both of which may result in less risky driving. Non-evaluative feedback, conversely, signals success or failure but does not provide information on the causes of failure and success, nor on which strategies can be followed to improve performance. How would drivers respond to such non-evaluative feedback? Previous research has shown that drivers generally overestimate their skills and abilities and thus show a self-enhancement bias in their evaluations of skills and abilities (see Sundström, 2008 for a review). Therefore, in many cases, providing non-evaluative feedback may mean negative feedback for the driver: for most drivers, non-evaluative feedback may signal that performance is worse than previously anticipated. How do drivers deal with such negativity given that non-evaluative feedback does not provide cues on how to improve their behavior?

Previous research suggests that negative feedback, in general, may threaten one's self-view, and can induce negative affect. This may motivate drivers to take regulatory actions to enhance one's self-view (Carver & Scheier, 1998; Campbell & Sedikides, 1999). One way of doing so is by changing behavior. However, behavior change in response to non-evaluative feedback is rather unlikely because in this case the feedback does not convey information on how to improve performance. Another way to deal with the negative feedback is to adjust one's self-evaluation, resulting in a more accurate self-view (Trope, 1986). However, this may not be a very likely response either, because people have the tendency to maintain a positive self-view; lowering your self-evaluations is likely to threaten the self-view. As a result, I hypothesize that non-evaluative feedback will generate defensive reactions: people will try to attribute their failure to some external causes rather than to their own performance or inaccurate evaluation of performance (Snyder & Higgins, 1988; Mezulis, Abramson, Hyde, & Hankin, 2004). Thus, I hypothesize that non-evaluative feedback may elicit defensiveness instead of adjustment of self-evaluations or behavior in line with the non-evaluative feedback.

In Chapter 2, I examined drivers' regulatory reactions to non-evaluative feedback using a hazard perception test, that is, a test to assess higher-order safety skills to detect, anticipate, and react to dangers in the road environment. Before performing the test, respondents provided self-evaluations of their expected performance level. Half of the respondents received feedback on their performance in the hazard perception test while the other half, the control group, received no feedback. Feedback could, in theory, be positive or negative relative to participants' initial self-evaluations. Previous research however showed that drivers' self-evaluation of their hazard perception skills is generally positively biased (e.g., Renge, 1998). Hence, non-evaluative feedback is more likely to be negative (rather than positive) relative to self-evaluations of hazard perception skills for many participants. I hypothesized that drivers would react defensively to this negative feedback, that is, they would make external attributions about feedback rather than adjusting their self-evaluations or their behavior.

How does drivers' need to manage multiple goals influence the effectiveness of feedback?

Drivers' regulatory actions are influenced by cognitive load resulting from multiple goals while driving and from demanding driving situations. For most drivers, a key goal while driving is getting safely from A to B. However, once behind the wheel, drivers may have various other goals and motives such as reducing travel time, saving energy, and enjoying the ride. Many times, these goals conflict (Summala, 1985; Means, Salas, Crandall, & Jacobs, 1993). For example, a driver who wants to arrive in a meeting in time may compromise safety by violating the speed limit and discarding feedback on speed. Different factors in the driving context may trigger different goals. For instance, social factors (e.g., committing to arrive at a meeting in time) or demanding traffic situations (e.g., dense traffic) may render a particular goal more important than other competing goals. The necessity to handle multiple goals implies that people may have to prioritize among goals and not act upon feedback when another goal than the goal on which the feedback is given is prioritized.

Drivers need to prioritize among goals to avoid mental load. Factors such as demanding traffic environment (Harms, 1991), time shortage (Hancock & Caird, 1993), or competing goals may increase mental load. Once the level of mental load exceeds what drivers could maintain, drivers reallocate effort, time, and cognitive resources (e.g., attention) according to the priorities of goals and the dynamics of a situation (Brehmer, 1992; Means et al., 1993; Hockey, 1997). For instance, drivers may neglect some tasks such as checking rear-view mirrors, when mental load is high (Brookhuis, De Vries, & De Waard, 1991; Harms, 1991; Hockey, 1997; Cnossen, Rothengatter, & Meijman, 2000). Hence, drivers regulate their goals depending on the priority of competing goals and mental load.

In order to prioritize among competing goals, drivers focus on tasks related to the goals that they prioritize and pay less attention to or even neglect other goals, including the goal on which feedback is provided. For instance, if feedback on both fuel economy and blind spot detection (for lane change) is provided, and lane change is more important than fuel economy at a given time, drivers will focus primarily on feedback on the blind spot detection rather than fuel economy. Hence, in Chapter 3, I argue that drivers may ignore extrinsic feedback when mental load is high, as well as when other goals than the goal on which feedback is provided is prioritized.

In Chapter 3, I used an eco-driving task in the driving simulator, which is characterized by a smooth driving style aimed at saving fuel. My aim was to test whether drivers took regulatory actions in line with feedback on a particular goal under low and high mental load. Mental load was created in two ways. The first was to induce multiple goals, namely, safety, fuel saving, and time saving. The second was to induce demanding situations by varying the complexity of road environment (rural and urban traffic) and by simulating demanding interaction situations with other vehicles. Participants received feedback on their fuel consumption rate. I hypothesized that mental load would influence whether drivers take regulatory actions directed at a particular goal, namely, fuel saving. I expected that when drivers have to balance several goals or when the situational demands are high, they will not act on feedback on fuel consumption. Rather, they would prioritize time saving or safety goals.

To what extent does feedback content affect the effectiveness of feedback?

While goal management may influence whether feedback is used or not, content of feedback may influence drivers' motivation to act upon the feedback. Feedback can be framed in different ways by highlighting different types of consequences of the relevant actions, thereby activating specific motives, which influence decisions on whether to act upon the feedback (cf. Lindenberg & Steg, 2007, see Levin, Schneider, & Gaeth, 1998 for a review). People are more likely to enact a behavior when they believe that the behavior is worthwhile of exerting effort and when the consequences are relevant for their selves (Levin et al., 1998; Rothman, Baldwin, Hertel, & Fuglestad, 2004; Finch et al., 2005). Thus, to motivate drivers to act upon feedback, information about the consequences of a given behavior should be considered worthwhile. I assume that some feedback content may be more motivating than others because consequences of behaviors communicated by feedback will be perceived more worthwhile. In the current thesis I make a distinction between information on financial and environmental consequences of sustainable driver behaviors.

Financial consequences of behaviors are commonly stressed to persuade drivers to adopt safe and sustainable behaviors, presumably because money provides widely understood information to people (Whitmarsh, Seyfang, & O'Neill, 2011). For instance, public campaigns mostly emphasize financial costs of traffic penalties to encourage compliance with traffic rules and emphasize fuel costs to promote sustainable driving. However, driver behavior may not always be motivated by financial considerations. For instance, people may be willing to drive safely in order to protect others rather than to avoid a fine. Thus, by stressing mainly the financial consequences of behavior, one runs the risk of neglecting people's motivation to act safely and pro-environmentally just for the sake of doing so. What would be the implication of using different feedback content, namely, environmental and financial consequences, for safe and sustainable driver behavior?

Following Heyman and Ariely (2004), I assumed that environmental and financial feedback would affect the extent to which the outcomes of safe and sustainable driver behaviors are perceived to be worthwhile. Environmental gains would evoke altruistic motives and would be perceived to be worthwhile even in case of relatively small environmental gains. The important thing in this case is making a contribution to the environment per se rather than the size of the contribution. Financial outcomes, on the other hand, would elicit willingness to invest effort in a behavior as long as the benefits compensate for the effort. However, in the case of safe and sustainable driver behavior, savings of specific behaviors are typically small and thus may not compensate for the effort. Thus, financial savings may not always be perceived to be worthwhile. Hence, motives elicited by different feedback content, namely, financial and environmental, eventually influence how worthwhile outcomes of the behavior are perceived and may even affect drivers' intention to adopt the behavior in question.

In Chapter 4, I addressed the impact of the content of feedback on the effectiveness of feedback on eco-driving behaviors. More specifically, I examined to what extent the content of the feedback affects how worthwhile the outcomes of specific behaviors were perceived to be and drivers' intentions to adopt these behaviors. I manipulated feedback content by presenting environmental (i.e., CO_2-emission reduction) versus financial outcomes of specific eco-driving behaviors in a scenario study. I hypothesized that environmental feedback would be more effective in promoting eco-driving behaviors both in terms of perceived worthiness of the behaviors and the intention to adopt them compared to the financial feedback.

This thesis

In summary, I aim to analyze what drives feedback by addressing three psychological factors that may influence the effectiveness of feedback in the current thesis (see Figure 1). I expected drivers to not act upon feedback when it does not provide clear guidelines on how to improve performance (Chapter 2). Rather, they would make external attributions in order to cope with negative feelings aroused by such feedback. Moreover, I expected that drivers would act upon extrinsic feedback only under low mental load, when they are not overwhelmed by multiple goals and not have to deal with demanding traffic situations (Chapter 3). Finally, I assumed that feedback content affects the extent to which possible outcomes are perceived to be worthwhile and motivating. More specifically, I expected that drivers would perceive the environmental outcomes of safe and sustainable driver behaviors more worthwhile than the financial outcomes of the same behaviors (Chapter 4).

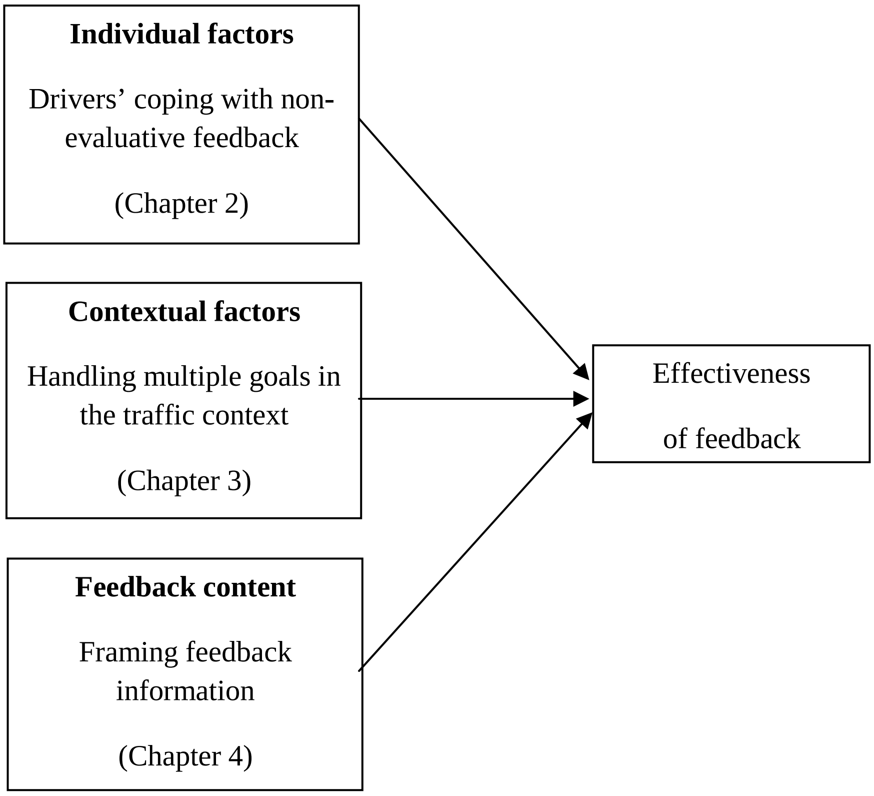

Figure 1 Cognitive and motivational factors that influence the effectiveness of feedback

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CHAPTER 2: How do drivers respond to non-evaluative feedback?

The effects of non-evaluative feedback on drivers' self-evaluation and performance

Abstract

Drivers tend to overestimate their competences, which may result in risk taking behavior. Providing drivers with feedback has been suggested as one of the solutions to overcome drivers' inaccurate self-evaluations. In practice, many tests and driving simulators provide drivers with non-evaluative feedback, which conveys information on the level of performance but not on what caused the performance. Is this type of feedback indeed effective in reducing self-enhancement biases? The current study aimed to investigate the effect of non-evaluative performance feedback on drivers' self-evaluations using a computerized hazard perception test. A between-subjects design was used with one group receiving feedback on performance in the hazard perception test while the other group not receiving any feedback. The results indicated that drivers had a robust self-enhancement bias in their self-evaluations regardless of the presence of performance feedback and that they systematically estimated their performance to be higher than they actually achieved in the test. Furthermore, they devalued the credibility of the test instead of adjusting their self-evaluations in order to cope with the negative feelings following the failure feedback. We discuss the theoretical and practical implications of these counterproductive effects of non-evaluative feedback.

Chapter 2 is based on Dogan, E., Steg, L., & Delhomme, P., & Rothengatter, T. (2012). The effects of non-evaluative feedback on drivers' self-evaluation and performance. *Accident Analysis and Prevention, 45*, 522-528.

1. Introduction

We are motivated to see ourselves in a positive way in order to feel good about ourselves and to maintain a high self-esteem (Steele, 1988). This applies to drivers as well. Drivers very often believe that they drive better than other drivers or that they are more competent than they actually are, showing a self-enhancement bias in their self-evaluations (see Sundström, 2008). Generally, drivers consider themselves to be more skillful than other drivers (Svenson, 1981; DeJoy, 1989; Delhomme, 1991; Gregersen, 1996; McKenna, Stanier, & Lewis, 1991; Groeger & Grande, 1996), indicating that at least some of them overestimate their skills. Different motivational explanations have been offered for the mechanisms underlying the self-enhancement bias in drivers' skill evaluations. McKenna and colleagues (1991) suggested that drivers inflate their own abilities instead of deflating those of other drivers. Walton (1999), on the other hand, found that truck drivers downgraded other drivers' abilities rather than inflating their own abilities. Whichever motivational mechanism explains self-enhancement biases, such biases seem to be persistent for driving skills. In fact, this self-enhancement bias has been found to be even stronger when measured implicitly (Harré & Sibley, 2007), suggesting that drivers' beliefs about the superiority of their driving competence are deeply rooted. Paradoxically, people also believed that they are less susceptible to judgmental biases than others (Pronin, Golvich, & Ross, 2004), which makes these biases even more robust.

The overestimation of skills and competence is associated with perceiving less risks, either by perceiving one's self as a less risky driver (Svenson, 1981) or by perceiving one's own crash risk as lower (DeJoy, 1989; Deery, 1999; Harré & Sibley, 2007). Drivers generally take regulatory actions when they perceive that their competence falls short to meet the demands of the situation (Fuller, 2008). When drivers overestimate their competence, they may expect their performance to be better than it really is. Consequently, when drivers overestimate their skills and underestimate the risks involved, they may be more likely to take risks on the road, for instance, by driving faster. This leaves shorter time margins to detect hazardous situations in time, which in turn may hinder one’s ability to respond timely to dangers as to avoid negative consequences. It is therefore of great importance that drivers have accurate estimations of their competence and abilities (see Rothengatter, 2002).

Kruger and Dunning (1999) suggested that inaccurate self-evaluations of competence, either overestimation or underestimation, is due to lack of metacognition about one’s skills and competence. They suggest four possible feedback-related reasons for inaccurate self-evaluations: lack of feedback, attributing failure feedback to some other causes than lack of skills, not understanding why failure occurred, and not receiving self-corrective information. The driving task is subject to all the aforementioned deficiency factors because of the lack of systematic feedback in and the forgiving nature of the traffic environment for errors. Drivers may not develop a realistic representation of their abilities and competence because not every error or violation made while driving results in adverse consequences such as accidents, near accidents, or penalties, which implies that drivers do not receive explicit feedback on their performance. This is particularly problematic for learner and novice drivers because they are more in need of feedback in order to comprehend the effects of their behaviors on other road users, the road environment, what mistakes they do, and how to avoid such mistakes. Feedback from an instructor or from the environment may enable drivers to develop a sense of possible situations that they may encounter in the traffic environment and their abilities or lack thereof to deal with different traffic situations (Groeger, 2000; Kuiken & Twisk, 2001; Hatakka et al., 2002).

Kuiken and Twisk (2001) emphasized the importance of feedback for a safe calibration (i.e., self-regulation) of skills and driving task demands. In line with the self-regulation theory, they propose that adequate self-assessment of skills is crucial for a safe calibration of driving skills. They propose that provision of comprehensive feedback, by providing information on the way the task was performed and how it could be improved, is needed to enhance safe regulation of driver behavior because it enables drivers to safely match their capabilities with the task demands. A safe match between the capabilities and task demands reflects on driver's goal setting at various stages of the driving task from route choice to the actions taken behind the wheel (cf. Rothengatter, 2002). Similarly, Hatakka and colleagues (2002) suggest that self-evaluation of one's driving skills should be integrated in the driver training in order to develop learner drivers' metacognitive skills for specific tasks of driving such as vehicle control or hazard perception, and that this can be realized by providing drivers with feedback on their performance. Such training is expected to promote learner drivers' self-regulatory behaviors in different road situations and task demands (Kuiken & Twisk, 2001; Hatakka et al., 2002). In more and more European countries structured feedback that focuses on higher order safety skills and self-assessment of them are integrated in the driver training as part of the driver licensing systems (Twisk & Stacey, 2007), with promising effects in the short term. Research revealed that after this training, learners' assessments of their skills were positively correlated with their trainers' assessments of the same skills, suggesting that learners assessed their skills accurately (Mynttinen, Sundström, Koivukoski, Hakuli, Keskinen, & Henriksson, 2009; Mynttinen, Sundström, Vissers, Koivukoski, Hakuli, & Keskinen, 2009; Boccara, Delhomme, Vidal-Gomel, & Rogalski, 2011). The long-term effects of this training have not been studied yet, in other words, it is not clear whether accurate self-assessments observed during the training are retained after the training and whether the training indeed results in less risk taking behavior and accidents.

In the meantime, non-evaluative feedback is increasingly adopted in traffic for training purposes as well. This type of feedback is less comprehensive since typically, information is provided on actual performance levels only. Examples are the increased use of simulators and computer-based tests such as hazard perception tests, which provide non-evaluative feedback on one's driving skills. In essence, people taking these tests learn their absolute scores on a test or their scores relative to other test-takers on particular skills, but do not receive any information on why their score was low or high or on how scores may be improved. Despite being frequently used in driver training we do know little about the effectiveness of non-evaluative performance feedback as given in these instruments.

Research on air traffic control indicates that non-evaluative feedback on performance may be effective in promoting accurate self-evaluations (e.g., Mitchell, Hopper, Daniels, George-Falvy, & James, 1994). Mitchell and colleagues (1994) used a computerized test to simulate an air traffic controller's task, which is a complex rule-driven task requiring participants to learn various rules about safe and efficient landing conditions. Participants received two sorts of non-evaluative feedback: a running feedback score on their performance after each landing and an overall performance score. Mitchell and colleagues found a strong positive correlation between the expected and actual performance scores of participants, suggesting that participants had an accurate view of their performance. Also, the relationship became stronger at the later trials, suggesting that the feedback enabled participants to further improve their self-evaluations in subsequent trials. Participants used two different strategies of self-regulation, that is, the non-evaluative feedback led to an adjustment of either their actual performance or their expected performance score. This suggests that the non-evaluative feedback resulted in a more accurate self-evaluation of performance, which improved the self-regulation of participants’ expected performance throughout the skill acquisition. Could such feedback on performance be beneficial in overcoming the self-enhancement biases for certain driving skills related to drivers’ hazard perception as well? Or is non-evaluative feedback not effective or even counterproductive because, for instance, such feedback does not provide any information on how people can improve their performance? In the current research, we will address this question via a hazard perception test.

Hazard perception is a higher-order safety skill which is used to anticipate the road environment and behavior of other road users (Horswill & McKenna, 2004). Specifically, hazard perception skills involve estimating what threats are present in the environment, as well as knowing what to do in order to avoid and handle those threats. Thus, hazard perception skills cover detection and anticipation of threats as well as one’s assessment of abilities to handle those threats (Grayson, Maycock, Groeger, Hammond, & Field, 2003). While hazard perception skills improve as drivers gain experience, hazard perception does not become automated, but rather becomes a less effortful process with practice (McKenna & Farrand, 1999 as cited in Horswill & McKenna, 2004). Therefore, drivers need to pay attention to information from constantly evolving situations and frequently take action in order to handle dangers safely and in time. As we have mentioned earlier, drivers’ self-regulatory behaviors to avoid hazards may be influenced by overestimation of their competence. This is particularly the case among novice drivers because their higher order safety skills (such as hazard perception skills) to handle relatively complex traffic situations have probably not sufficiently developed yet (OECD-ECMT, 2006). Accurate self-evaluations in a hazard perception task are particularly important because computerized hazard perception tests are integrated as part of licensing system in several countries including the United Kingdom and the Netherlands. What happens when drivers receive non-evaluative feedback telling them that they are in fact not as good as they think they are, and learn that they are overestimating their competence and performance?

The perceived discrepancy between what drivers actually can do and what they believe they can do is assumed to trigger self-regulatory behaviors (cf. Carver & Scheier, 1998, Fuller, 2008). Specifically, feedback may elicit self-regulation by enabling a comparison between the expected and actual situation, and consequently making people aware of any discrepancy or balance between the expected and actual situation (Cervone & Wood, 1995; Carver & Scheier, 1998). An adaptive response to deal with a discrepancy would be to adjust the effort put in the task and try to do better or to adjust the expectations about one’s performance level, which would result in a closer match between one’s expectations and reality. A non-adaptive response to deal with such a discrepancy, on the other hand, would imply not making these adjustments in effort or expectations. This could result in negligence of the feedback or detachment from the task goals such as disengaging from the effort and quitting the task after a few trials, or devaluation of the task if detachment is not possible (cf. Carver & Scheier, 1998; Kuiken & Twisk, 2001). Thus, there may be occasions where non-evaluative feedback does not promote adaptive self-regulation and thus does not reduce the self-enhancement biases. In the current study, we investigated the effect of non-evaluative performance feedback on self-evaluations and actual performance, and whether non-evaluative feedback reduces the self-enhancement bias among young, novice drivers.

We first examined the accuracy of driver's self-evaluations of their hazard perception skills via a computerized test. The performance criterion was the total score obtained at the end of the hazard perception test. Additionally, we examined the effect of non-evaluative feedback on these self-evaluations and on actual performance in subsequent trials of the test. In line with previous studies, we expected the majority of the participants to overestimate their expected performance in the hazard perception test initially in the first trial, before they received feedback (hypothesis 1). This implies that we expect that the majority of the participants would receive negative feedback on their performance, and learn that they performed worse than expected. Based on the studies discussed above, we propose two competing hypotheses for the effects of this negative feedback on self-regulation in later trials. First, the negative feedback can elicit adaptive responses, in which participants adjust their self-evaluations or their performance[1] in the subsequent trials in accordance with the negative feedback in the former trials. This implies that negative feedback results in a lower estimated test score in the subsequent trials compared to the estimated test score in the first trial, and a closer fit between estimated and actual performance in the subsequent trials (hypotheses 2). Alternatively, negative feedback may result in non-adaptive regulatory responses and participants do not change their performance or their estimations of their

[1] Although theoretically it is plausible to expect an adjustment in performance, we think this it is not likely that participants improve their performance because the non-evaluative feedback does not convey information about what they did wrong or what they should do differently to increase their performance.

performance. If participants do not adjust their performance estimations or their actual performance, the discrepancy between the estimated and actual performance will remain. In line with the self-regulation process (Carver & Scheier, 1998; Kuiken &Twisk, 2001), we expect this unresolved discrepancy between expected and actual performance to reflect on participants' performance evaluations and task evaluations (hypothesis 3). Specifically, we expect that the feedback results in a more negative evaluation of one's performance in previous trials, because the feedback makes participants aware of the discrepancy between their expected and actual performance. Also, we expect that the negative feedback will elicit negative feelings. More importantly, we expect that participants will try to restore a positive self-image and feel good about themselves by devaluating the test.

2. Method

2.1. Participants

We tested our hypotheses in an experimental study. The participants were 36 students (11 male, 25 female) from the University of Groningen who held a valid drivers' license for at least one year (M = 2.5 years; SD= 1.17) and had driven an average of 6,505 km since licensure (SD= 4,820). The mean age was 21 years (M= 21.22, SD= 1.44); age ranged from 19 years to 24 years. Participants were recruited via the student participant pool of the University of Groningen and received course credit in return for their participation.

2.2. Hazard perception test

To test our hypotheses, we developed a hazard perception test comprising natural traffic scenes that were recorded around the city of

Groningen, the Netherlands. The recordings were taken from the drivers' point of view during daylight in bright and dry weather conditions. A team of experts watched the recordings to mark the hazardous events following the definition and criteria set out by Grayson and Sexton (2002), who argued that a good hazard perception measure should capture respondent's scanning skills and anticipation of the developing situation rather than detecting only a quick reaction to the situation. Based on this, clips that would detect drivers' anticipation of developing dangers were kept in, while the ones that would create difference only with respect to reaction time to suddenly occurring hazards were left out. The selected clips were then tested in a pilot study. At this stage, we applied two other selection criteria proposed by Grayson and Sexton (2002), namely, a mean score of the hazard event between 2 and 3 (the scoring system is explained below), and significantly different hazard perception scores between experienced and inexperienced participants. Then, all these clips were re-evaluated by the same team of experts. Five of the clips were omitted at this stage because the hazards in those clips did not differentiate between the experienced and inexperienced groups or they were not detected. The remaining 36 clips were used for the test, after the start and end scenes of the hazard situations were adjusted based on the reaction times obtained in the pilot test.

The shortest clip was 22 seconds while the longest one was 69 seconds. The number of hazards in each clip ranged from one to three. Examples of the hazards included were a car emerging from the right, pedestrian getting out of parked car, a lane reduction in a construction area, and a cyclist crossing the road. We developed three different versions of the hazard perception test to be used in three trials, all of which had 12 comparable hazard situations, and took approximately 10 minutes to complete.

The clips were shown to participants on a 19" computer screen with a 3-second interval between the clips. Participants used an external button to respond to the hazard situations. They were instructed to press the button as soon as they thought they should modify their behavior to avoid a potential danger. Participants were informed that their response would not be valid should they press the button more than five times for each hazard situation.

The hazard perception test enabled us to provide participants with feedback in terms of a non-evaluative test scores. To do so, responses were scored following the method developed by Grayson and Sexton (2002), that is, the starting and ending frames of the hazard situations were marked and the time range was divided into 5 equal intervals. As different hazards had different durations and required different response times, the time interval was idiosyncratic for every item. The closer the response to the starting frame of the hazard situation, the higher the points gained for each hazard (5 points for the fastest response and 1 point for the slowest response). We recorded the time frame in which participants responded. The maximum possible score for each version of the hazard perception test was 60, meaning that the participant detected each hazard and reacted to all hazards in a very short time, while the minimum score was 0, meaning that the participant failed to detect any hazard in time.

2.3. Measures

2.3.1. Self-evaluations for the expected performance in the hazard perception test

We measured self-evaluations of the expected performance in the hazard perception test based on Bandura’s (1997) self-efficacy scale, because the structure of the scale enabled us to measure expected performance for different levels, i.e., scores, of the task. Participants were presented a table with possible scores on the hazard perception test, ranging from 20 to 60 with 5-point intervals (9 levels in total). They indicated whether or not they could reach any of the given test scores. The number of level that participants reported that they could execute was summed and used as an indicator of the estimated performance score. For instance, if the participant reported he or she could reach the test scores mentioned in the first four levels, the estimated performance would be 35 in the hazard perception test. Scores on self-evaluations for the estimated performance could range from 20 (i.e., I can detect few hazards in time) to 60 (i.e., I can detect all the hazards present in the video clips in time).

2.3.2. Experience of correspondence between estimated and actual performance

After completing each trial, we measured how participants experienced their test performance. Specifically, we asked participants how successful they felt about their performance in the hazard perception test, and how satisfied and frustrated they were with their performance, respectively. Participants in the experimental group answered these questions after receiving their true performance score, whereas participants in the control group did not receive this feedback. Additionally, participants rated how effortful it was for them to perform at the level they did. Next, the experimental group received a final question asking whether they thought their test score reflected their true performance. This question was not presented to the control group as they did not receive feedback on their test score. Participants answered these four questions on a 7-point scale ranging from 1 - not at all to 7 - very much.

2.4. Procedure and design

The experiment consisted of three trials of the computerized hazard perception test. This enabled us to examine the effects of the non-evaluative feedback on self-evaluations over time. In each trial, participants completed a different version of the hazard perception test. The three versions of the hazard perception test were counterbalanced. Before starting the experiment, participants were given the instructions on the hazard perception test identical to those Grayson and Sexton (2002). Thus, a hazard was defined as “something that a driver should keep an eye on because it could lead to an accident situation” (Grayson & Sexton, 2002, p. 6). Participants were informed that they should press the external button as soon as they recognize a hazard developing. We also mentioned that higher scores on this test would mean safer reactions to a hazard while lower scores would mean unsafer reactions. Afterwards, participants received a brief training on the hazard perception test with three sample clips. During the training we explained how the test worked and how their responses were scored. They were allowed to repeat the training if they needed to. During the training, all participants received non-evaluative feedback on their scores following each clip and then received a total test score once all the clips in the relevant test had been shown. This was done to inform participants about their performance. After the training, participants filled in a questionnaire. The questionnaire included a scale for their self-evaluations of their performance in the hazard perception test in the coming trial as well as a few demographics questions.

Participants were then randomly assigned to the experimental or control group. Participants in the experimental group received performance feedback on their score on the hazard perception task similar to the feedback they received during the training, while participants in the control group did no longer receive feedback. Running feedback was presented after each video clip that informed participants about the score obtained for the particular clip. At the end of the hazard perception test, overall performance feedback was provided reflecting the total score obtained at the end of the test. The feedback (i.e., experimental group, E) and control (i.e., C) groups were similar in license duration, t (34) = -.52, p= .610, (M_E= 2.47, SD_E= 1.23; M_C= 2.68, SD_C= 1.13) and total mileage, t (34) = 1.60, p= .117, (M_E = 7,700 km, SD_E = 5,095 km; M_C = 5,170 km, SD_C = 4,246 km).

Next, participants performed the first hazard perception test and either did or did not receive performance feedback depending on the group in which they were. After completing the first test (for the experimental group after learning their test score), all participants filled in a short scale measuring their experience of the contingency or the discrepancy between their performance and estimated performance in the previous trial. Next, they filled in the self-evaluation scale for their estimated performance in the subsequent trial. The same procedure was repeated after the second and third trials, except that the self-evaluation scale was not administered after the third trial because there were no more trials.

3. Results

In order to test our first hypothesis on the accuracy of the performance estimations on the hazard perception test, we compared the estimated and actual test scores for each trial via paired sample t-test analysis[2]. As expected, performance estimations for the first trial and the actual test scores on this trial significantly differed: participants in both groups overestimated their hazard perception test score ($t(18) = -7.88$, $p < .001$ for the experimental group and $t(18) = -6.53$, $p < .001$ for the control group, see Figure 1).

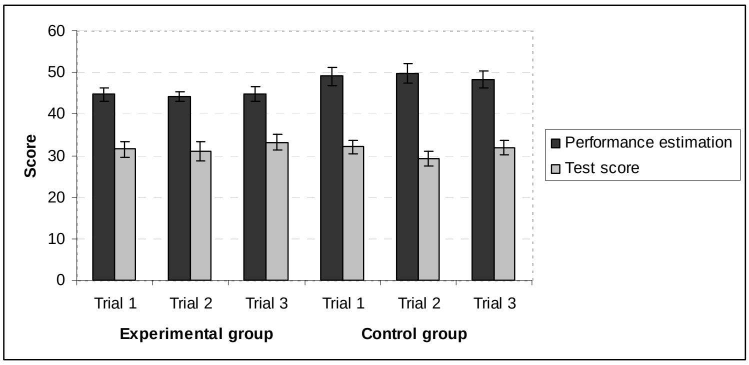

Figure 1 Means and standard error of the means for the performance estimations before the trial and actual performance for three trials

Our second and third hypotheses predicted competing regulatory responses for the discrepancy between the estimated and actual performance. The second hypothesis predicted an adaptive regulatory response, in which the experimental group would adjust their performance expectations in the subsequent trials on the basis of the feedback they received. We expected the majority of the participants in the experimental group to receive negative feedback. Indeed, no participant in the experimental group received positive feedback, i.e., no participant

[2] We computed the difference score between the estimated and actual performance. The difference score was used as the dependent variable in a mixed ANOVA with group as the between measure and trial as the within measure. This analysis revealed no significant results indicating that the discrepancy between the estimated and actual performance was not different between the experimental groups or across trials, $F(2, 68) = .53$, $p > .10$.

performed better than their estimated performance. On the contrary, all participants received negative feedback, i.e., they performed worse than they expected. Figure 1 shows that participants in the experimental group overestimated their performance in all three trials, $t(18) = -5.43$, $p < .001$ for the experimental group in the second trial, and $t(18) = -6.01$ for the experimental group in the third trial. Indeed, neither estimated nor actual performance changed over time. Thus, contrary to the second hypothesis, non-evaluative feedback did not result in adaptive self-regulatory responses. As expected, the control group consistently overestimated their performance as well: $t(18) = -7.35$, $p = < .001$ for the second trial and $t(18) = -8.55$, $p < .001$ in the third trial.

So, we found that the participants showed non-adaptive regulatory responses. How does this reflect on the way they experienced their performance? How do they cope with the discrepancy between their estimated and actual performance? The third hypothesis was about the way participants felt about their performance in the previous trials in case they did not adjust their estimated or actual performance. Since the control group did not receive the performance feedback, we expected the experimental group, who was made aware of a discrepancy between their expected and actual performance, to be less satisfied and more frustrated with their performance and to feel less successful than the control group. We conducted independent sample t-test analysis to compare the satisfaction, frustration, and the perceived success of the performance level in the previous trials for the experimental and control group. After the first trial, the participants in the experimental group were significantly less satisfied ($t(34) = -3.94$, $p < .001$) and marginally more frustrated ($t(34) = 1.80$, $p = .080$) with their performance compared to the control group participants who had not received feedback on their performance on the hazard perception test in the previous trial. Similar results were observed for the responses following the second and the third trials (see Figure 2). In addition, the control group participants considered themselves to be more successful in the preceding trial than the experimental group participants did in all but the first trial, $t(34) = -1.59$, $p > .10$ in the first trial, $t(34) = -4.58$, $p < .001$ in the second trial, and $t(34) = -3.18$, $p = .003$ in the third trial. An independent sample t-test revealed that perceived effort did not differ between the two groups in any trial, $t(34) = -.69$, $p > .10$ in the first trial, $t(34) = .56$, $p > .10$ in the second trial, and $t(34) = .44$, $p > .10$ in the third trial. So, the test was perceived as equally effortful by both groups, and differences in experienced effort cannot explain our results.

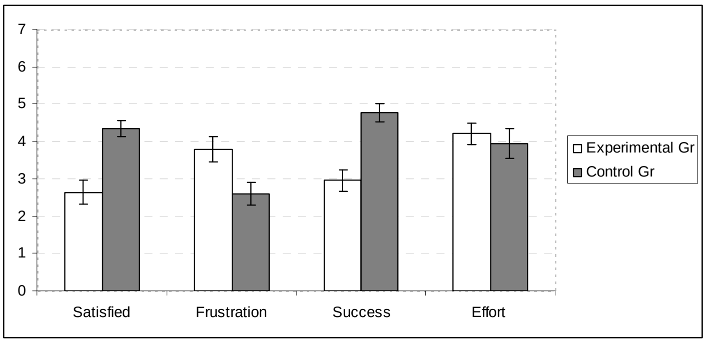

Figure 2 Means and standard error of the means for the items measuring the evaluation of performance in the second trial

In line with our third hypothesis, the maladaptive self-regulatory responses resulted in devaluing the hazard perception test. In all three trials, participants in the experimental group believed that their test scores did not reflect their actual performance well ($M_1 = 2.37$, $SD_1 = 1.11$; $M_2 = 2.21$, $SD_2 = 0.98$; $M_3 = 2.42$, $SD_3 = 1.07$). So, in line with our hypothesis, the experimental group downgraded the credibility of the test, presumably to handle the discrepancy between their estimated and actual performance.

4. Discussion

Drivers' self-serving evaluations of their driving competence and abilities may negatively affect their risk taking behavior and road safety. Self-enhancement biases have been found for various driving skills and appear to be robust. We first tested whether the self-enhancement bias was also apparent for hazard perception skills. In line with our expectation, we found a strong self-enhancement bias: participants systematically overestimated their hazard perception skills and thought they would perform better than they actually did.

Lack of feedback may be one of the reasons why people do not have accurate beliefs about their skills and competence. In the current study, we investigated whether inaccurate self-evaluations can be overcome by giving participants non-evaluative performance feedback. More specifically, we tested whether non-evaluative feedback would result in adjustment of the self-evaluation of one's performance. We did not expect the non-evaluative feedback to result in changes in one's performance, as the feedback did not indicate why participants' performance was lower than they expected (so participants did not learn how to improve their performance), and indeed, actual performance did not change over time. Interestingly, we did not find any effects of the non-evaluative feedback on one's self-evaluations in subsequent trials either. On the contrary, our results indicate a profound self-enhancement effect in terms of performance estimations among both the feedback (experimental) and no-feedback (control) groups. Furthermore, although the test was perceived as similarly effortful by both groups, the experimental group who learned about the discrepancy between their expected and actual performance experienced a higher level of frustration and feeling of failure, and a lower level of satisfaction with their performance than the control group who did not explicitly learn about this discrepancy. Thus, the experimental group experienced negative feelings about their performance, probably as a result of the discrepancy between their estimated and actual performance. Nonetheless, they did not respond to this discrepancy in an adaptive way by adjusting their estimated performance scores or actual performance. Rather, they downgraded the credibility of the hazard perception test by indicating that they believed that their test scores did not reflect their true performance, supporting our third hypothesis.

Why did the experimental group participants, who were explicitly informed about their scores on the hazard perception test and therefore understood that they failed to perform at the level they expected, keep providing higher performance estimations than they actually achieved? Why did they not change their performance assessments on the basis of the feedback on their test score but rather disqualify the test?

One explanation is related to the nature of hazard perception skills. Hazard perception requires integration of several driving skills, which makes it rather ambiguous to assess one's performance on hazard perception skills. Indeed, when a self-evaluation dimension is ambiguous, it may result in self-enhancement biases per se (Dunning, Meyerowitz, & Holzberg, 1989; Ackerman, Beier, & Bowen, 2002). A recent study demonstrated that somewhat experienced young drivers showed self-enhancement biases for their skills and risk assessments even when they were told that their driving skills would be assessed by objective measures, namely, a driving simulator (White, Cunningham, & Titchener, 2011). Furthermore, White and colleagues (2011) argued that computerized tests may not represent the true difficulty of the task involved in various driving situations. Therefore, it is plausible to expect that participants underestimated the difficulty of the computerized task and overestimated their performance to some extent, particularly in the initial trial. We expected this initial self-enhancement effect to diminish in the subsequent trials for the experimental group. However, the robustness of the self-enhancement bias observed in all three trials in the current study calls for further explanation.

The number of hazards detected in all trials, although participants did not know this, was rather high (around 9 out of 12 in each trial), especially considering the experience level of our sample. So, lower-than-expected scores must be due to reaction time latency. Thus, either the importance of reaction time latency was not clear to the participants, despite the information provided beforehand and the training with the initial clips, or participants could not accurately estimate the timing of their reactions to hazardous situations. In fact, Chapman and Underwood (1998) found that novice drivers had a longer fixation time for hazardous situations than experienced drivers. Furthermore, inexperienced drivers had less accurate estimations of time-to-collision (Cavallo & Laurent, 1988). So, it is not surprising that our participants, who were relatively inexperienced drivers, had a higher reaction time latency, despite detecting a rather high number of hazards.

Another explanation to address the robust self-enhancement bias may be that the non-evaluative feedback on the test performance was not effective in changing drivers’ self-evaluations and actual performance because it did not convey information on why participants’ scores were lower than they expected. Thus, non-evaluative feedback was not specific to elicit an adaptive self-regulation (Bandura, 1997). Knowing that their performance expectations were not accurate may not be sufficiently motivating for drivers to change the self-assessments of their competences, but it apparently did induce negative feelings (such as higher frustration and dissatisfaction) among the experimental group that participants could not ignore. Thus, affective self-regulatory process was activated (Carver & Scheier, 1998). When faced with negative feedback without knowing the exact cause of it, the feedback group devalued the task by degrading its credibility instead of adjusting their estimated performance. This may be because they could not disengage from the task due to their commitment to complete the task, despite being frustrated and dissatisfied with their performance (Carver & Scheier, 1998; Twisk & Kuiken, 2001). They may have dealt with these unpleasant feelings due to the disconfirming feedback by downgrading the credibility of the test. Furthermore, non-evaluative feedback of this kind might have created differences between the experimental and control group in how they felt about their performance by triggering two mechanisms: creating a threat to participants' self-view and giving a competitive nature to the hazard perception test. These points will be further elaborated below.

The feedback made participants aware of the discrepancy between their expected and actual performance, which may have threatened their self-perception. We expected this to be the case if participants would not adjust their self-evaluations or performance, that is, we expected that negative feedback would yield negative feelings and external attributions. Apparently, participants coped with these negative feelings by downplaying the credibility of the task (cf. Carver & Scheier, 1998; Kuiken & Twisk, 2001). Hepper, Gramzow, and Sedikides (2010) argued that defensiveness is triggered by a threat to one's self-concept and such defensiveness is notable by attributing failure to the situation or the task rather than to one's ability. Research showing the strength of implicit self-enhancement bias among drivers indicates that driving abilities are core for drivers' self-concept (Harré & Sibley, 2007). Indeed, research indicates that threatening information is especially processed defensively if the information is related to issues that are important for individuals (Pietersma, Dijkstra, & Buunk, 2009). Therefore, non-evaluative feedback may have prompted a self-threat among the feedback group.

Considering the fact that our sample consisted of university students, who are presumably very much used to performance evaluations via grades, the feedback we used might have added a competitive nature to an ordinary risk perception task. Delhomme and Meyer (1998) showed that failure in a speed regulation task resulted in a worse speed regulation among novice drivers especially when the task was presented as a competitive one than a cooperative task. People exhibit a self-serving bias by making external attributions to temporary and specific sources for their failures in order to protect their ego and self-image. However, discounting own responsibility for negative outcomes weakens the motivation and ability to take necessary regulatory actions to change those outcomes (see Mezulis et al., 2004). Therefore, the type of feedback and how it should be given are crucial especially for inexperienced drivers, who are more likely to be influenced by external motivational factors (Delhomme & Meyer, 1998). Using computerized tests or simulators for training driving skills may backfire if trainees do not learn the consequences of their behaviors, and do not learn why their performance was high or low, and how to improve their performance.

In the current study, we were mainly interested in the effect of non-evaluative feedback on self-enhancement biases. In doing so, we focused on participants’ estimated performance rather than their performance goals. It is likely that actual performance is not only related to one’s estimated performance, but also to one’s goals. We did not measure participants’ goals related to their performance in the hazard perception task; and consequently, we do not know whether participants' motivation to not adjust their estimated or actual performance was influenced by their goals. Furthermore, correspondence between specificity of goals and feedback, and the usefulness of feedback for self-regulation are interrelated (Cervone & Wood, 1995). Future research could incorporate goal setting and self-evaluations in order to disentangle their effect on self-regulation. This could improve our understanding of the way affect influences regulatory responses to feedback and how drivers cope with negative feedback.

In conclusion, our results suggest that non-evaluative performance feedback may not be suitable for improving self-evaluations and performance that are measuring (complex) skills because it can alter the way the task is perceived. Most importantly, non-evaluative feedback may not change self-evaluations or performance but rather result in devaluation of the task. Non-evaluative feedback was effective in regulating self-evaluations and expected scores in an air traffic controller task (Mittchell et al., 1994), but our results suggest it is not effective for a driving task. This might be due to the differences between driving task and air traffic controller task in terms of the amount of information available to the operators and the level of automation assisting the operator.

Lack of feedback contributes to self-enhancement biases; nonetheless, the mere presence of feedback is not sufficient for overcoming such biases for driving competence. The content of the feedback seems to be more crucial than the presence of feedback (Kruger & Dunning, 1999). We think that providing drivers with detailed information on what caused their failure or success and what they should do in order to improve their performance is needed for feedback to be effective in reducing self-enhancement biases.

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CHAPTER 3: How does drivers' need to manage multiple goals influence the effectiveness of feedback?

The Influence of Multiple Goals on Driving Behavior: The Case of Safety, Time Saving, and Fuel Saving

Abstract

Due to the innate complexity of the task drivers have to manage multiple goals while driving and the importance of certain goals may vary over time leading to priority being given to different goals depending on the circumstances. This study aimed to investigate drivers' behavioral regulation while managing multiple goals during driving. To do so participants drove on urban and rural roads in a driving simulator while trying to manage fuel saving and time saving goals, besides the safety goals that are always present during driving. A between-subjects design was used with one group of drivers managing two goals (safety and fuel saving) and another group managing three goals (safety, fuel saving, and time saving) while driving. Participants were provided continuous feedback on the fuel saving goal via a meter on the dashboard. The results indicate that even when a fuel saving or time saving goal is salient, safety goals are still given highest priority when interactions with other road users take place and when interacting with a traffic light. Additionally, performance on the fuel saving goal diminished for the group that had to manage fuel saving and time saving together. The theoretical implications for a goal hierarchy in driving tasks and practical implications for eco-driving are discussed.

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1. Introduction

Driving behavior, like other behaviors, is regulated in accordance with drivers' goals and motives (Summala, 1997) and as with other behaviors, drivers can have multiple goals concurrently. Some of these goals can compete with each other, such as avoiding traffic violations while in a hurry to reach a destination. The aim of the current study is to examine drivers' behavioral regulation when they have to manage multiple competing goals that require different driving styles.

When multiple goals are active, drivers have to prioritize some goals over others and will do so based on the importance of the individual goals and dynamic changes in the environment (Means et al., 1993; Cnossen et al., 2000). This is further complicated by the fact that in dynamic situations the importance of different competing goals can shift very quickly with the changes in the situation. For instance, a driver can be concerned with avoiding delays at one moment but shift to stopping immediately upon recognizing a car pulling out of a parking lot.

The primary way that drivers can prioritize between goals is by regulating the effort they put into different tasks. In this way they can keep the driving task under control and hopefully still react if safety critical situations arise. For instance, Harms (1991) found that drivers reduced speed and performed an arithmetic calculation task slower when they were driving through villages, where the mental workload is high due to the complexity of the task environment, when compared to driving on a four lane divided highway. In fact, drivers' performance of the arithmetic task degraded and their speed decreased even further when they had to turn left at intersections, which requires even more attention because of the possible interactions with other road users. Similarly, drivers have been shown to increase headway when performing a secondary task in order to keep with safety margins (Noy, 1989, as cited in Cnossen et al., 2000). Hence, drivers seem to have a tendency to drop subsidiary tasks or adapt their safety margins to prioritize safety over other task goals and to stay in control. In this way they hopefully have enough time and space to foresee and react to hazards in the road environment if need be. Indeed, it is assumed that the main task of driving is to maintain control in order to achieve a safe trip (cf. Fuller, 2007).

In particular, drivers' regulatory actions to adapt to the dynamics of the current circumstance are a means to keep the driving task under control in order to pursue goal-directed behavior. The driving task itself is, with experience, largely automated, fast, and effortless and remains so unless something critical happens (Bellet, Bailly-Asuni, Mayenobe, & Banet, 2009) or unless the driver chooses to deliberately monitor vehicle control (Summala, 1997). This means that if there is a deviation from the anticipated situation and therefore the usual habitual behavior, drivers tend to take action to avoid negative consequences (Saad, 2002; Summala, 2007), shift between the goals, and take further regulatory actions based on the mental representations of the situation in order to maintain control over their vehicle and preferably return to a more typical automated effortless driving style (cf. Brehmer, 1992).

Drivers' performance and the associated behavioral regulation are hypothesized to keep them "within a certain comfort zone", which gives drivers enough time and space for their reactions and is based primarily on the maintenance of learned and automatic safety margins (Summala, 2007, 2005). It is also assumed that drivers have a satisficing performance criterion for a given goal as long as they are within the comfort zone. Thus, drivers do not try to perform the best action possible for the situation, but rather the action that is good enough. In fact, the limited information processing resources available to drivers in dynamic tasks like driving make it essentially impossible for drivers to completely optimize their goal performance. Also, since drivers have multiple goals that can come into conflict, optimizing performance on one goal may have negative effects for one or all of the other goals. This also means that it is more likely that drivers aim for satisficing performance between their competing goals. The upshot of this is that they are satisfied with a good enough performance that exceeds a certain aspiration level (Simon, 1957; Boer, 2000; Sivak, 2002; Summala, 2007, 2005). What exactly constitutes the aspiration level while driving is still a matter of debate however (e.g., Summala, 2007, 2005; Rothengatter, 2002). In any case the criterion does seem to be related to people's goals and situational factors. Näätänen and Summala (1976, as cited in Summala, 2007) predict higher speed and shorter safety margins when external motives such as time goals, maintenance of speed, or feeling of control are prominent while driving. For instance, a former study showed that time pressure can lead drivers to reduce their safety margins (Van der Hulst, Meijman, & Rothengatter, 2001). Therefore, drivers can be said to be satisfied with their performance in terms of safety as long as they reach their destination alive, unharmed and without incident, despite the fact that their performance may not be at an objectively optimum level.

With the above in mind, how do drivers balance multiple goals when they are set a strategic goal which requires that they try to optimize their behavior? The current study aims to investigate this question. To do so, in addition to the presumed main goal of driving safely (cf. Fuller, 2007), we added a secondary goal of saving as much fuel as possible during the trip. We chose fuel saving because it would require drivers to consciously monitor their driving behavior and reducing fuel consumption has become an important goal for driving as seen by the implementation of many eco-driving programs during the last decade (CIECA, 2007). Eco-driving aims to reduce the environmental impact of one's driving style, for instance, by maintaining a steady speed, anticipating traffic flow, and accelerating and decelerating smoothly (CIECA, 2007). By doing so an eco-driving style results in less fuel use and a reduction of CO_2-emissions. However, the smooth driving style required by eco-driving must also be balanced with managing interactions with other road users and road situations in a safe way.

Participants were also required to drive on both a residential and rural road in the current study. The two different road environments were chosen because of naturalistic differences in task demand they place on the drivers. In particular, the results of a study by Harms (1991) suggest that drivers perform better on multiple tasks on rural roads than on urban roads and that drivers' performance is further jeopardized when they have to manage their interactions with other road users at intersections. As such we also presented drivers with several interaction situations in the residential areas.

Another critical condition influencing task demand in driving is available time (Summala, 2007). Drivers have to make decisions and perform them in continuously evolving situations in real time, which requires drivers to relate the timing of their actions to the dynamic changes of the situation. Time constraints therefore leave limited capacity for information processing (Hancock & Caird, 1993) and increase the task demands of the situation and the difficulty of decision making while driving. With this in mind, time pressure was also induced in one of the groups, with the other group serving as a control.

In summary, a fuel saving goal was explicitly set, in addition to a presumed implicit safety goal in order to examine how drivers manage these two goals in different traffic environments, i.e., urban versus rural roads. Also, we specifically created several critical situations that further increased task demands. In addition, we introduced time pressure in half of the sample in order to test how this would influence performance and commitment to the safety and the fuel saving goals. The other half of the sample did not receive any explicit temporal limitations. In order to facilitate the monitoring of fuel consumption, continuous feedback on the amount of fuel available was provided through a display on the dashboard of the simulated vehicle.

We assumed that setting the goal to save as much fuel as possible would motivate drivers to adapt to an eco-driving style. However, we assumed also that drivers in the no-time pressure condition would keep to the fuel saving goal to a greater extent and save more fuel than drivers in the time pressure condition due to the lack of explicit conflict between fuel and time saving. Therefore we expected that the time pressure group would use more fuel, in total as well as for the urban and rural roads separately (hypothesis 1). Moreover, we also hypothesized that the no time pressure group would perform in a fashion more in accordance with the eco-driving style during interaction situations with other road users than the time pressure group (hypothesis 2). Furthermore, we expected that drivers would prioritize safety goals over time and fuel saving ones in situations of high demand. More specifically, we expected that the no time pressure group would neglect the fuel saving goal, and the time pressure group would neglect both the fuel and time saving goals when handling interactions with other road users (hypothesis 3). In relation to the third hypothesis, we expect shorter safety margins (i.e., later pedal responses) from the time pressure group in the interaction situations because of the prominence of the time saving goal. But because the current study made these interactions also safety critical, the expected effect on safety margins would disappear or be reduced due to the prominence of the safety goal. We will also explore whether fuel feedback aids drivers' behavioral adaptation to save fuel.

2. Method

2.1. Participants

Thirty-six first-year students (16 males) at the Psychology Department of the University of Groningen participated in the study in return for course credits. Participants had held a valid B-class driver's license for an average of 36 months (Min= 11, Max= 170). The mean age of participants was 21 years (Min= 19, Max= 32) and their mean lifetime mileage was 21,100 km (Min= 1,800, Max= 75,000).

2.2. Driving simulator

Drivers were tested in an ST Software driving simulator at the Psychology Department of the University of Groningen. The simulator uses a mockup of a VW Golf cabin and 3x42" plasma displays to provide participants with a 210 degree display of the road environment. The road and traffic scene was displayed at 60 Hz refresh rate (see van Winsum & van Wolffelaar, 1993 for further details). Drivers could control the gas pedal, brake pedal, clutch, gears, steering wheel, and the indicators. The behavior of other traffic participants was controlled by means of generic and specific scenario scripts. In this way we ensured that every participant was presented with the same standard traffic situations. The simulator has been proven to be a valid tool for driving behavior research (e.g., Brookhuis & de Waard, 2010).

2.3. Eco-driving

Eriksson (2001) identified acceleration, deceleration, speed, and gear change behaviors as the main indicators of an eco-driving style. Besides these factors, Beusen and colleagues (Beusen, Broekx, Denys, Beckx, Degraeuwe, Gijsbers, … Panis, 2009) included coasting distance, i.e., the distance drivers let the car roll without pressing the gas or brake pedals in their analyses. As such we selected two interaction situations that would require the drivers to perform the aforementioned eco-driving task components; stopping for a traffic light turning red on approach and gap acceptance in a T-intersection with a traffic flow from the right and left. Speed, gear use, and pedal use were included as indicators of an eco-driving style. These dependent variables are further explained in section 2.4.2. Additionally, fuel consumption was measured and recorded for the whole drive, as well as for each section, reflecting the overall performance on the fuel saving goal.

2.4. Procedure and design

The procedure consisted of a test drive and an experimental drive. Before starting the experiment, participants drove a trial route of seven kilometers in a residential area with oncoming traffic in the opposite lane and a speed limit of 50 km/h. During the test drive they practiced several maneuvers that would be required during the experimental drive such as making turns and navigating intersections and traffic lights. The aim was to get participants familiarized with the driving simulator and to detect simulation sickness.

After completing the trial route, all participants then read a text on goal setting. The text included background information stating that the aim of the study was to find out the minimum amount of fuel required to complete the trip. A pilot study found that participants consumed approximately 1 liter of fuel to complete the experimental route when they were asked to drive as they would usually do and around .83 liter of fuel when they were asked to drive in a fuel-efficient manner. Based on this, participants were told that participants in the pilot study consumed around 1 liter of fuel on average to complete the route they were about to drive and that it was possible to reduce fuel consumption by around 17% when an eco-driving style was adopted. Since we did not want the participants to feel that they would not be able to complete the trip due to running out of fuel, participants were told that they had 1.1 liters of fuel at their disposal for the 18 km route, 10% more than the amount of fuel participants in the pilot study used in the usual driving condition. Participants also were prompted to try to save as much fuel as possible. The extra 10% of fuel was excluded from later analyses in order to report the percentage of the fuel saved out of 1 liter of fuel. Participants were also told that the car would stop when they consumed all the fuel in the gas tank.

Next, the time pressure manipulation was introduced to half of the participants, selected at random. Participants in the no time pressure group read that they had no time constraints and they could take as much time as they wished to make the trip. Conversely, participants in the time pressure group were told to imagine that they were late for a meeting. Thus, the no time pressure group was explicitly set the fuel saving goal in addition to the implicit safety goal. The time pressure group had the safety goal, the fuel saving goal, and the goal of meeting temporal limitations; i.e., time saving goal. The time pressure group (TP) and the no time pressure group (NTP) were equivalent on license duration, $t(34) = .33$, $p = .75$ ($M_{TP} = 40.65$ months, $SD_{TP} = 36.20$ months; $M_{NTP} = 37.77$ months, $SD_{NTP} = 12.87$

months), and mileage since licensure, t (34) = .19, p = .85 (M_{TP} = 21,783 km, SD_{TP} = 24,111 km; M_{NTP} = 20,416 km, SD_{NTP} = 19,767 km).

Participants then took part in the experimental drive during which they drove through two villages (urban traffic environments), where the speed limit was 50 km/h, and two sections of rural roads, where the speed limit was 80 km/h. Participants were instructed to keep to the speed limits and obey all of the traffic rules and traffic signs. The drive on the rural roads did not involve any critical events and contained several curves and oncoming traffic in the opposite lane to avoid monotonous driving. The drives through the urban areas included several demanding situations with other vehicles at intersections. It was expected that the safety goal would be more prominent in these high-demand situations and fuel saving and time saving would be less important. The roads were straight and visibility was clear at all the intersections where a critical situation took place. All the necessary traffic signs such as the speed limit, traffic lights, and give right of way were placed appropriately before the relevant intersections to facilitate the drivers' anticipation of the upcoming situations.

To facilitate high performance on the fuel saving goal, feedback on the amount of fuel available was continuously displayed on the screen with a bar graph divided into 20 intervals. Participants were informed that each interval corresponded to 5% of the total available fuel. At the end of the trial they learned the percentage of fuel left in the gas tank. This means that the feedback that was given to the participants about the amount of available fuel through the driving session had a different reference point (a percentage of 1.1 liters) than the amount of fuel saved during the trip reported in the results section (a percentage of 1 liter). Once the experimental drive was over participants answered some manipulation check questions.

Drivers' performance was recorded by the internal camera of the simulator. After the experimental driving session, the recording of the drive was replayed in the simulator and participants were interviewed in order to obtain further in-depth information about their expectations and regulatory actions for each situation. The whole experiment took around 50 to 60 minutes.

2.5. Measures

2.5.1. Driver behavior during critical situations in the road environment

2.5.1.1. Traffic light scenario

The traffic light scenario was activated when the driver was 200 meters away from the intersection where the traffic light was located. The light was timed to ensure that participants initially saw a green light as they were approaching the traffic light, then the green light switched to yellow 3 seconds before the participant would reach the intersection and stayed yellow for 2 seconds. Finally the light turned red a second before the intersection and stayed red for 20 seconds. When the traffic light was red for the participants, traffic from the side roads started to cross the intersection. The average duration of the task from the start of the scenario, 200 meters before the intersection, until switching into fourth gear after crossing the intersection was 51 seconds for the time pressure group and 56 seconds for the no time pressure group.

The measurement of dependent variables for the traffic light scenario was split into two sections: the approach to the traffic light and the drive away from the traffic light once the green signal was redisplayed. The start point of the approach data block was 200 meters before the intersection, because that was the start point of the scenario, with the end point occurring 10 meters before the intersection where the traffic light was located. To prevent data loss, if a participant stopped earlier than 10 meters from the intersection, the end point of the data block was marked as the point where the participant's velocity reached zero. Velocity and speed change (average deceleration and acceleration) were recorded as the speed-related dependent variables; average rpm was recorded as the gear-use-related dependent variable; and maximum and the average extent of brake and gas pedal push were recorded as the pedal-use-related dependent variables during both sections of the traffic light scenario. The variables for pedal push, either gas pedal or brake pedal, indicated the extent to which the pedal was pushed and was measured in terms of a percentage. The maximum pedal push indicates the furthest extent of the pedal push while the average pedal push indicates the extent of pedal push within a selected range of road section, such as while approaching a traffic light. In addition, the gas pedal release distance and brake pedal push distance were recorded as indicators of discrete decisions to take regulatory actions in reaction to the upcoming critical situation. Gas pedal release distance was taken as the distance between the point where the gas pedal was first released and the traffic light. The brake pedal push distance was taken as the distance between the point where the brake pedal was first pushed and the traffic light. Finally, the average amount of fuel used during the approach to the intersection was recorded.

For the drive away behavior, the focus was on gear use to determine the starting and the ending of driving away maneuver. The start point of the data block was the first moment of gear activity while the end point was the moment participants shifted into fourth gear. The fourth gear was chosen because with new cars, such as the one simulated in this experiment, the safe and appropriate gear to obtain fuel-efficiency while driving around 50 km/h is the fourth gear (Kroon, 2006)[1]. Driving in fourth gear was also the general course of action we observed among the participants while in the residential environment. Furthermore, when the velocity graphs were examined reaching fourth gear corresponded to the point where the participants started to maintain a steady velocity. Average fuel consumption from the traffic light until the gear shift into fourth gear was recorded along with the dependent variables related to speed, gear use and pedal use mentioned for the traffic light approach section. Participants who violated the traffic light and those who did not shift up to fourth gear while driving away from the traffic light were excluded, which left 19 participants (10 from the no time pressure group) for the analyses of the traffic light scenario.

2.5.1.2. Gap acceptance scenario

Similar to the traffic light scenario, the approach and drive away behaviors in the gap acceptance task were analyzed separately. Unlike the traffic light scenario, the gap acceptance scenario did not have easily defined start and end points. The scenario within the simulator software started when the participant was 250 meters away from the intersection. However, the appearance of the cars to the participants depended on the speed of the participant and corresponded to different times and distances for each participant. Thus, it was not possible to set specific distances as data markers. Instead, speed regulation was adopted as the criterion. The start marker was the moment drivers took regulatory action by starting to

[1] We controlled the raw data for each participant in order to avoid data loss due to not switching into the fourth gear. In the traffic light scenario two participants and in the gap acceptance scenario four participants were excluded due to our data sampling criterion.

release the gas pedal, while the end marker was when the participants reached a velocity of zero. The duration of the gap acceptance task from the start of the scenario until the participants switched into the fourth gear after crossing the intersection, including the time spent waiting for an appropriate gap, was on average 35 seconds for both the time pressure and the no time pressure groups.

For the drive away from the intersection, the criteria for data markers were the same as in the traffic light scenario, i.e., the start marker was the first gas pedal push and end marker was shifting into fourth gear. Eight participants (5 from the no time pressure group) did not shift into the fourth gear after the intersection, so only the data for the remaining 28 participants (13 from the no time pressure group) was analyzed. The dependent variables for performance while approaching the intersection and while driving away from the intersection were the same as those analyzed in the traffic light scenario.

2.6. Manipulation check

After the experiment, participants were asked several questions about whether they experienced time pressure and if they believed they could have saved more fuel if they had had more time on a 5-point scale (1 “not agree at all”, 5 “totally agree”). Significant differences between the time pressure and no-time pressure groups would therefore indicate that the manipulation to induce time pressure was successful.

2.7. Verbal reports

The aim of the verbal reports was to complement the behavioral data by providing information on the reasoning behind participants’ regulatory actions. Including the type of information drivers reported taking into account when handling the critical situations at the intersections, which goals they stated were prominent during their actions, and how much they used the fuel consumption feedback provided (Saad, 2002). As such, participants were asked several questions for each traffic situation after the video replay of each critical situation was displayed.

The replay of each critical situation was replayed to the participants in two parts. First, the video was stopped as situation was evolving. For instance, in the traffic light situation, the video was stopped before the light turned yellow. Similarly in the gap acceptance situation, the video was stopped when the yield sign was visible but before the cars appeared at the intersection. At this point participants were asked what they had anticipated in that particular situation and what they had thought they should do to manage the situation. Then, the video was started again. At the end of the interaction situation the recording was stopped and participants were asked to describe their behavior and if they had thought of any other behaviors they could have performed. Finally, participants were asked if they explicitly aimed to save fuel and if they monitored the feedback bar while they were approaching the critical situations.

3. Results

3.1. Time Pressure manipulation check

Participants in the time pressure group reported experiencing higher time pressure during the drive than those in the no time pressure group, t (34) = 4.31, p <.001 (M_{NTP} = 1.55, SD_{NTP} = .78; M_{TP} = 2.83, SD_{TP} = .98). Additionally, participants in the time pressure group believed that they could have saved more fuel if they had had more time, t (34) = 3.20, p =.003 (M_{NTP} = 1.61, SD_{NTP} = .97; M_{TP} = 2.94, SD_{TP} = 1.47). The duration of the trip was also different between the groups, with the time pressure group completing the trip in a shorter time, t (34) = -3.23, p = .003 (M_{NTP} = 20.06, SD_{NTP} = 1.57; M_{TP} = 18.47, SD_{TP} = 1.25). These results suggest that the manipulation to induce time pressure was effective.

3.2. Total fuel saved during the trip

In order to test the first hypothesis, we compared participants' performance on the fuel saving goal. As expected, fuel saving was higher among the no time pressure participants than the time pressure participants, F (1, 34) = 8.38, p= .007 (see Figure 1). A similar effect was observed when the fuel consumption on the urban and on the rural roads was analyzed separately. With the no time pressure participants consuming less fuel than the time pressure participants on both the urban, F (1, 34) = 7.88, p= .008, and the rural roads, F (1, 34) = 7.43, p= .010 (see Figure 2). Thus, fuel saving was higher for the no time pressure group for the entire trip and for the different road environments separately.

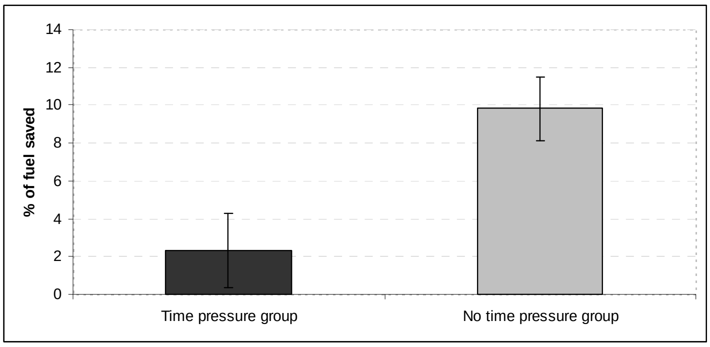

Figure 1 Means and Standard Errors of the Amount of Fuel Saved by the Time Pressure and the No Time Pressure Groups

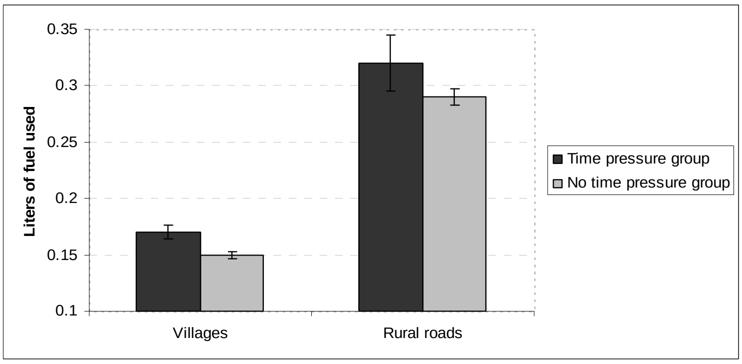

Figure 2 Means and the Standard Errors of the Amount of Fuel Used by the Time Pressure and the No Time Pressure Groups in Different Road Environments

Drivers' verbal reports on the overall trip revealed an interesting finding about the monitoring of the fuel level feedback throughout the experimental drive: the majority of the participants in both groups reported that their driving style was most directed by a fuel saving goal while driving on the rural roads rather than on the urban roads. A particularly common comment was that it was difficult to pay attention to the feedback on the amount of the fuel available and to drive fuel-efficiently while also paying attention to possible interactions with other road users in the urban areas.

3.3. Effects on indicators of an eco-driving style: the traffic light scenario

3.3.1. Behavioral analyses

To test hypothesis 2, first, we examined participants' behavior while approaching the intersection where the traffic light scenario took place. An independent t-test analysis was carried out to compare the performance of the two groups on the main indicators of an eco-driving style mentioned in Section 2.4.2.1. Table 1 shows the means, standard deviations, t-test coefficients, and p-values for the performance variables recorded while approaching the traffic light. The two groups differed mainly on speed-related variables that affect fuel consumption. More specifically, participants in the no time pressure group drove slower, at a lower rpm, and had lower average fuel consumption compared to the time pressure group, although the last result was marginally significant. There was no significant difference between the groups in deceleration or braking.

Based on the third hypothesis, we also expected that the time pressure group would respond later than the no time pressure group only when the time saving goal was prominent. Participants in the time pressure group had a longer gas pedal release distance and brake pedal push distance than the participants in the no time pressure group but this difference was only marginally significant. Considering that the participants in the time pressure group might have released the gas pedal and braked earlier because they were driving at a higher speed, we conducted a univariate ANCOVA with the average velocity as a covariate. In this case, the marginal difference between the groups in terms of gas pedal release distance reached significance, $F(1, 16) = 4.54$, $p = .049$, whereas the difference in brake distance did not $F(1, 16) = 3.36$, $p = .085$. Additionally, the groups were similar on coasting distance, $F(1, 16) = 2.13$, $p = .164$ ($M_{TP} = 22.91$, $SD_{TP} = 17.36$; $M_{NTP} = 16.88$, $SD_{NTP} = 12.20$). The pattern of the results therefore suggests that the performance and regulatory behaviors while approaching the traffic light were in line with participants acting with a safety goal in mind.

Table 1 Means, Standard Deviations, t-values, and p-values for Behavioral Indicators of an Eco-Driving Style while Approaching the Traffic Light for the Time Pressure (TP) and the No Time Pressure (NTP) Groups

	TP	No-TP		
	M (SD)	M (SD)	t	p
Velocity (m/s)	16.01 (1.70) 58 km/h	14.10 (.82) 51 km/h	3.18	.006
Average rpm	1455 (176)	1232 (111)	3.32	.004
Average fuel (lt)	.032 (.010)	.025 (.006)	1.94	.069
Deceleration (m/s^2)	-.95 (.34)	-.76 (.16)	-1.54	ns
Maximum brake push (%)	92.68 (7.56)	96.15 (5.12)	-1.18	ns
Average brake push (%)	12.11 (5.52)	9.90 (2.37)	1.16	ns
Gas pedal release distance (m)	61.61 (12.71)	51.37 (12.03)	1.81	.089
Brake pedal push distance (m)	39.70 (5.72)	34.49 (2.93)	2.05	.056

Note. ns means $p > .10$

Secondly, we examined drivers' behavior while they drove away after the traffic light returned green. Similar to the approach behavior, independent t-test analysis was conducted to compare the groups. Table 2 shows the means, standard deviations, t-test coefficients, and p-values of the performance variables recorded while driving away from the traffic light. In line with the second hypothesis, participants in the no time pressure group drove slower overall, had a more gradual acceleration, a lower gas pedal push, and lower fuel consumption when compared to the time pressure group. We did not observe significant differences between the groups in rpm or gear shift distance.

Table 2 Means, Standard Deviations, t-values, and p-values for Behavioral Indicators of an Eco-Driving Style while Driving Away from the Traffic Light for the Time Pressure (TP) and the No Time Pressure (NTP) Groups

	TP	NTP		
	M (SD)	M (SD)	t	p
Velocity (m/s)	14.32 (2.02) 52 km/h	12.11 (2.02) 44 km/h	2.38	.029
Average rpm	1654 (292)	1480 (219)	1.48	ns
Average fuel (lt)	.060 (.020)	.043 (.009)	2.39	.029
Maximum gas pedal push (%)	60.03 (17.65)	43.72 (13.52)	2.28	.036
Average gas pedal push (%)	31.12 (6.46)	22.99 (3.14)	3.55	.002
Acceleration (m/s^2)	.92 (.37)	.56 (.18)	2.74	.014
Gear shift distance (m)	102.40 (50.06)	115.47 (46.21)	-.590	ns

Note. ns means p > .10

3.3.2. Verbal reports

We analyzed participants' verbal reports following the experimental drive by focusing on two issues: drivers' expectation of the developing situation and the role of their goals and feedback in their regulatory actions. The subsequent analysis of the verbal reports suggest that the participants' decision criteria for regulatory actions during the critical situations were based on the safety margins such as the distance from the traffic light, their approach speed, and the period that the traffic light had already been green, as well as the anticipated consequences of their regulatory actions (e.g., "I wouldn't be able to stop at that speed if I had braked slowly. So I had to brake abruptly.”). All participants expected the light to turn red when they reached the intersection because it had stayed green for a long time already. Despite anticipating that they would have to slow down, only three participants reported releasing the gas pedal when the traffic light was green. The majority of the participants instead reported releasing the gas pedal when the traffic light turned yellow, or in other words when they became sure that they would have to stop. When asked whether they had thought of any alternative reactions, the majority reported that they had not, and that they would probably have reacted in the same way if they encountered the same situation again.

The results in relation to the second and third hypotheses about the effect of the fuel saving goal on the regulatory actions revealed that the majority of the participants (6 in the time pressure group, 7 in the no time pressure group out of 19 for the traffic light scenario) said that their actions were not directed by the fuel saving goal while approaching the traffic light. Also the majority of the participants in both groups reported that they were concerned more with handling the situation safely than with driving fuel-efficiently (e.g., “I was more concerned about a possible accident.”). Indeed, some of them reported forgetting the fuel saving goal (e.g., “I [only] remembered about fuel saving only after braking so rapidly, just before the traffic light.”). Similarly, the majority of the participants reported that they did not check the fuel feedback information while they were approaching the traffic light.

3.4. Effects on indicators of an eco-driving style: the gap acceptance scenario

3.4.1. Behavioral analyses

To test hypothesis 2 for the gap acceptance task, first, independent t-test analyses were conducted to examine eco-driving performance while approaching the intersection. Table 3 shows the means, standard deviations, and t-test values for the two groups' performance as they approached the intersection. Participants in the time pressure group drove faster than those in the no time pressure group. However, the time pressure participants did not have a significantly higher average level of fuel consumption than those in the no time pressure group. The participants in the time pressure group did brake more than those in the no time pressure group, but this was marginally significant. There were also no significant differences between the groups in deceleration or rpm. With respect to the third hypothesis, there were no significant differences between the groups on gas pedal release distance and brake pedal push distance. Interestingly, the mean values for gas pedal release distance for both groups corresponded to the appearance of cars in the intersection. This indicates that participants' initial response to the oncoming cars was releasing the gas pedal regardless of whether they were in a hurry or not.

Table 3 Means, Standard Deviations, t-values, and p-values for Behavioral Indicators of an Eco-Driving Style while Approaching the Gap Acceptance Intersection for the Time Pressure (TP) and the No Time Pressure (NTP) Groups

	TP	NTP		
	M (SD)	M (SD)	t	p
Velocity (m/s)	16.39 (1.39) 59 km/h	14.89 (1.44) 53 km/h	2.80	.001
Average rpm	1021 (116)	1004 (122)	0.39	ns
Average fuel (lt)	.009 (.002)	.008 (.005)	0.83	ns

Deceleration (m/s^2)	-1.50 (.82)	-1.32 (.65)	-0.63	ns
Maximum brake push (%)	87.40 (18.29)	70.66 (29.13)	1.85	.076
Average brake push (%)	18.14 (10.74)	18.17 (15.66)	.995	ns
Gas pedal release distance (m)	100.81 (27.97)	105.80 (28.33)	-0.47	ns
Brake pedal push distance (m)	55.07 (18.33)	49.58 (18.42)	0.79	ns

Note. ns means $p > .10$

Next, we investigated participants' behavior as they drove away after the gap acceptance task. The groups were compared using independent t-test analyses. During the drive away, the two groups significantly differed only on instantaneous fuel use, with the time pressure group participants using more fuel than the no time pressure group participants, $t(26) = 2.15$, $p = .042$ ($M_{TP} = .14$, $SD_{TP} = .05$; $MN_{TP} = .10$, $SD_{NTP} = .04$). There were no significant differences between the groups for any of the other indicators.

3.4.2. Verbal reports

The behavioral data indicated that the majority of the participants released the gas pedal around the same distance. Consistent with this finding, most participants after watching the replay reported that they released the gas pedal as soon as the cars became visible at the intersection. Therefore, the critical factor for the participants was not the yield sign but the vehicles in the intersection. Similarly to the traffic light situation, participants also reported they did not consider any alternative reactions to the developing situation.

Twenty-two participants of the 28 analyzed for the gap acceptance situation reported that they were not thinking of the fuel saving goal while approaching the interaction situation. This is consistent with the third hypothesis and similar to the traffic light scenario, with the majority of the participants reporting that they focused on safe performance (e.g., “I was more worried about crossing the intersection safely.”) rather than the fuel saving goal once they detected that a potential conflict situation was evolving. Furthermore, the majority of the participants reported that they were not paying attention to the fuel use feedback while they were approaching the interaction (e.g., “I was not checking the bar when I was approaching the intersection but I thought that I was consuming fuel when I was waiting to cross.”). Several participants had statements which explicitly indicated attempts to compromise between different goals like “I had to cross the intersection, on the one hand, and had to save fuel, on the other. [So] I had to find a middle way”.

4. Discussion

The current study investigated drivers’ behavioral adaptation when balancing multiple goals under different task loads. Starting from the assumption that all drivers consider the safety goal while driving, we also set fuel saving as a strategic goal to motivate drivers to adopt a fuel-efficient driving style. In addition, time pressure was placed on half of the participants. This resulted in one group which had to only consider the extra goal of fuel saving, and another group which had to consider both the extra fuel and time saving goals. Driving performance was monitored for the complete trip and for specific critical situations. Our main interest was how drivers adapted their behavior to multiple goals in low and high demand situations and which goal was prioritized. We also explored whether feedback on fuel consumption facilitated adaptive behavior for the fuel saving goal.

As expected, the overall fuel saving was higher for the no time pressure group than for the time pressure group. The amount of fuel saved by the no time pressure group (around 10%) was similar to that reported by studies on the average effects of eco-driving training in real world situations (as cited in Barkenbus, 2010). The time pressure group, on the other hand, had a fuel saving of only 2%. The difference in fuel saving between the time pressure groups was also consistent across both the urban and rural settings. Consistent with the first hypothesis, the no time pressure group saved more fuel than the time pressure group in the urban as well as the rural road segments. Thus, we can conclude that overall, the participants in the no time pressure group kept better to the fuel saving goal than the participants in the time pressure group.

For the critical situations we obtained somewhat different results. Consistent with our expectations, we observed differences between the two groups in terms of speed-related indicators of eco-driving such as fuel consumption and rpm, particularly for the traffic light scenario. However, there were no differences in regulatory actions such as speed change related to fuel saving in either group. Therefore, the second hypothesis was only partly supported. We did find differences between the time pressure and no time pressure groups in pedal use, which can also be interpreted as related to speed. The groups were similar in terms of deceleration and acceleration, in both interaction situations. However, participants in the time pressure group released the gas pedal and started braking slightly earlier than the no time pressure group during the traffic light interaction, although this difference was marginally significant. Based on these findings we can conclude that the regulatory behaviors of all participants during the critical situations indicate that, in line with the third hypothesis, drivers' regulatory actions in conflict situations seem to be particularly directed by safety-oriented goals, even when they have to manage several other conflicting goals.

The verbal reports also suggest that the participants varied the importance of the competing goals based on the different road situations and task demands they encountered. As we assumed, safety goals seemed to remain focal throughout the drive. Also participants did report that they tried to adapt their driving style to drive fuel-efficiently mainly when they were driving on the rural roads. However, in the urban areas the safety goal became more prominent because they had to pay attention to the more complex traffic environment. This is consistent with research from Cnossen et al. (2000) who also found that drivers give priority to the goals of driving safely over any additional non-driving goals in high demand situations. In the current study, we found this also to be the case even when the additional goal is driving-related and could be realized by adapting one's driving style.

Furthermore, the results indicate that drivers in the time pressure group saved almost no fuel and completed the trip in a shorter time than the participants in the no time pressure group. This suggests that the former group was strongly motivated by the time saving goal at the cost of the fuel saving goal. This is of note, as we did not use a very strong manipulation to induce time pressure such as setting a specific time limit to complete the trip or using a timer to indicate time running. Instead, we only asked the participants to imagine that they were in a hurry. So, even with a weak induction participants still seemed to give priority to saving time rather than to saving fuel. This is likely to be because saving time can be considered as a natural and immediate goal for drivers in many situations, whereas explicitly aiming to save fuel because of ecological considerations is a relatively new goal for drivers. Therefore, it may take time before drivers can internalize the fuel saving goal, integrate fuel saving as part of the driving task in their mental representations, and learn to assign a high utility to fuel saving goal. However, based on the current findings, we can speculate that fuel saving does not fulfill the aspiration level to compete with other goals of driving such as time saving and therefore may be abandoned easily by drivers as situations change. Additionally, we can reason that fuel saving did not become a decision criterion to guide drivers' actions during negotiations of interactions with other road users such as handling a gap acceptance task, or drivers' performance in demanding road environments such as driving in an ordinary urban area. This result has important implications for eco-driving training and will be discussed below.

The verbal reports also revealed that the use of fuel feedback for behavioral adaptation depended on the situational demands imposed by the road and traffic conditions. For instance, participants reported not paying attention to the fuel saving goal or the feedback during the critical situations or on the urban roads. This suggests that the feedback was ignored when the situational demands were high. However, previous research on eco-driving has shown that drivers do benefit from in-vehicle feedback systems in reducing fuel consumption (e.g., Hallihan et al., 2011; Barkenbus, 2010). The current study therefore complements these findings by specifying certain task conditions that influence drivers' attentiveness to and negligence of fuel feedback systems in demanding situations. Based on drivers' verbal reports, we can also conclude that while the traffic environment made a difference in terms of feedback processing, having a time limitation did not.

Our results could be taken as suggesting that mental workload plays a role in drivers' adaptation of their driving style to meet multiple strategic goals during driving: the majority of the participants reported that they were not acting in order to fulfill the fuel saving goal during demanding situations such as the interaction situations and driving through the urban area. However, in this study we did not explicitly measure mental workload, instead inferred it from verbal reports; therefore, future research should test the role of mental workload more directly.

Another important direction for further research is the replication of our findings in real life. In particular, distance estimation in a driving simulator can be difficult for drivers. However, the dynamics of on-road research make the control of external factors, task demand factors, and the monitoring of goal prioritization more challenging, and potentially risky.

The current results can be seen as having theoretical implications for drivers' possible goal hierarchy, with the priority of different goals changing at the different task levels that are theorized to make up the driving task. For instance, although fuel saving can be a dominant goal at the strategic level, it may be pushed to background at the maneuvering level, especially when the task demands are high and other goals are prioritized (cf. Lindenberg & Steg, 2007). It seems that the deciding factor for which goal is prioritized depends highly on the situation. Future research should study how and which contextual factors influence the prominence of different goals of driving and regulatory actions to prioritize goals within the driving task hierarchy.

In particular, our findings may have important implications for eco-driving training programs. Our current results suggest that eco-driving goals are likely to conflict with other goals such as time saving, which appears to be a much stronger motivating factor. Indeed, a recent study indicated that drivers consistently overestimate the amount of time they could save by increasing their speed, which may help to partly explain why time saving is so strongly valued (Svenson, 2008). Eco-driving campaigns and eco-driving trainings can emphasize this point further in order to convince drivers that an eco-driving style does not have to have a significantly negative impact on travel time. Policy makers in particular have set an aim for a 10% reduction in fuel consumption in the long run by means of fuel-efficient driving style (White Paper, 2001). However, a one-day eco-driving training program targeting experienced drivers resulted in a reduction in fuel consumption of only 5% to 2% one year after the training (af Wåhlberg, 2007; Beusen, et al. 2009). It may be that eco-driving training programs are more effective when a more extensive program is followed in order to make eco-driving a part of drivers habitual, automated driving, and more work on these types of long term training programs should be encouraged. Furthermore, in order to tackle the challenge of managing critical situations, training programs could give a higher emphasis in the training of eco-efficient driving skills in such high demanding situations. However, these critical situations do only make up a small percentage of regular driving, and tend to be safety critical situations of short duration. Therefore, it may be more worthwhile for eco-driving to only concentrate on periods outside of these critical situations where drivers have greater time, and inclination to drive in an eco-friendly manner.

Limitations

In their naturalistic driving environment drivers have various and sometimes even competing goals. However, in the current study we only explicitly focused on three goals: fuel saving, time saving, and safety. Future research could expand the current study by focusing on different types of goals. Furthermore, past research shows that driver's level of familiarity with the route network influence choice of the strategy in time management such as travelling alternative routes or adjusting the time of leave (e.g., Hamed & Abdul-Hussain, 2001), which eventually have consequences for fuel consumption. Such an option was not available in this study, since all participants were required to follow the same route in order to maximize experimental control. However, driver's familiarity with the road network could perhaps be taken into account in future research. Also, replicating the study with a more experienced driver sample could yield more reliable results for the generalizability to the larger driver population.

Verbal reports were used to investigate the subjective experiences of drivers with respect to behavioral regulation which provided great insight to drivers' goal prioritization in regulatory actions. However, this approach does somewhat lack structure. Therefore, based on the current results, a structured instrument could be developed to study more systematically to enrich our knowledge on goal prioritization and decision making processes in drivers' self-regulatory behavior.

Conclusion

The current study showed that drivers were less able to keep to an eco-driving style when the traffic environment is highly demanding, particularly in residential areas and during critical situations. Additionally, time pressure inhibited performance on the goal to drive in a fuel efficient manner. This suggests that eco-driving goals are easily pushed to the background when they conflict with other goals, particularly goals related to safety and time saving.

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CHAPTER 4: To what extent does feedback content affect the effectiveness of feedback?

Making small numbers count: environmental and financial feedback in promoting eco-driving behaviors

Abstract

Eco-driving is considered to be a promising behavioral strategy to reduce the negative impact of road transport. Eco-driving reduces fuel consumption, and thus results in environmental (reduced emissions) and financial (reduced fuel costs) savings. Drivers' perception of the worthiness of eco-driving behaviors may differ depending on whether environmental or financial savings are emphasized. The current study investigated the effects of using either environmental or financial feedback to promote eco-driving. Participants evaluated six scenarios describing different eco-driving behaviors. Participants in experimental groups were either informed about the environmental or financial savings realized by adopting the behaviors. A control group did not receive information on possible savings. Analyses indicated that, unlike commonly assumed, environmental savings are considered more worthwhile than commensurate financial savings. Intentions to adopt eco-driving behaviors were mainly sensitive to the presence of feedback per se, rather than the content of feedback. We discuss the theoretical and practical implications of these findings.

Chapter 4 is based on Dogan, E., Bolderdijk, J.W., & Steg, L. Making small numbers count: environmental and financial feedback in promoting drivers' adoption of eco-driving style (*Manuscript under review*)

1. Introduction

"Did you know that turning off the air-conditioner would save you 0.44 Euro per trip?"
"Did you know that turning off the air-conditioner would save you 0.56 kg CO_2-emissions per trip?"

Imagine you come across these two messages. Which message is more appealing to you? In general, financial feedback is considered to be more effective than environmental feedback because the former is assumed to yield clear individual benefits and thus to be more worthwhile. But would you really consider it is worthwhile to change your behavior for a couple of eurocents? Or would you consider the prospect of saving some CO_2-emissions to be more worth the effort? The current research addresses these questions in relation to eco-driving behaviors.

1.1. The use of feedback for behavioral change

Research suggests that the provision of feedback can effectively promote energy savings and thus reduce greenhouse gas emissions (see Abrahamse, Steg, Vlek, & Rothengatter, 2005; Fischer, 2008, for reviews), also in the traffic domain (e.g., Siero, Boon, Kok, & Siero, 1989; Birrell & Young, 2011; Dogan, Steg, & Delhomme, 2011). However, relatively little is known on how the *content* of feedback influences motivation. As such, it remains unclear how feedback on eco-driving could be best conveyed to enhance effects.

Fuel savings as a result of eco-driving has both environmental and financial benefits. Eco-driving can therefore be promoted by emphasizing the environmental benefits of eco-driving (i.e., reducing CO_2-emissions) as well as by stressing financial benefits (i.e., saving money). Initial campaigns aimed at promoting eco-driving mostly emphasized financial aspects by stressing that eco-driving saves money. In countries like Finland and Sweden, for instance, eco-driving has been introduced as “economical” driving (CIECA, 2007). The assumption behind this strategy seems to be that people consider the financial benefits of eco-driving more worth the effort than the environmental benefits and that drivers will be particularly motivated to adopt eco-driving when they are made aware of the financial (rather than environmental) benefits of doing so (Thøgersen & Crompton, 2009; Bolderdijk, Steg, Geller, Lehman, & Postmes, in press). However, an important issue concerning many pro-environmental behaviors, including eco-driving, is that specific energy-saving behaviors typically result in modest (financial) benefits. For example, turning a car’s engine off during a 10-minute wait saves 0.14 liters of fuel, which amounts to 25 eurocents[1]. An important question, then, is whether people indeed consider the financial benefits of specific eco-driving behaviors to be worth the effort, as widely assumed. And if not, to what extent is environmental feedback considered worthwhile? Thus, does the type of the information conveyed by feedback influence how worthwhile people perceive the outcomes of the behavior, and their willingness to pursue that behavior?

We suspect that, depending on the content of feedback, different types of motivations are activated. In essence, feedback content may induce different decision frames (Tenbrunsel, 1999; Heyman & Ariely, 2004; Vansteenkiste, Simons, Lens et al., 2004; Lindenberg & Steg, 2007). People will consider different aspects of a situation or evaluate the same aspects of a situation differently depending on which decision frame is activated

[1] Financial savings were calculated based on oil price per litre in the Netherlands at the time of the study.

(Lindenberg & Steg, 2007). Following Heyman and Ariely (2004), we propose that depending on the content of feedback (and thus conveying different types of possible rewards), different decision frames are elicited, reflecting the type of market relations people are in. The decision frame activated will in turn influence how worthwhile people consider specific rewards.

Heyman and Ariely (2004) distinguish money and social markets to characterize how level of reward can be related to the effort people are willing to exert in a behavior. In a money market, the amount of effort exerted is determined by reciprocity (Fehr & Falk, 2002). That is, a behavior is perceived to be worth the effort when the expected reward is proportionate to the effort: the lower the financial gain expected, the lower the effort invested. Consequently, small rewards are not sufficient to motivate effortful behaviors. In fact, small rewards can be even counterproductive in motivating effortful behaviors. For instance, underpaid volunteers tended to perform worse than volunteers that were not paid at all (Gneezy & Rustichini, 2000). Thus, financial rewards may not be considered worthwhile when their size does not reciprocate the effort required.

In the social market, conversely, the amount of effort exerted depends mainly on altruistic motives. In other words, people consider behavior to be worth the effort when it benefits the welfare of others and the environment, rather than themselves exclusively. As people are acting out of altruistic, rather than selfish concerns, effort will be maintained regardless of the amount of benefits expected: whether a volunteers' work improves the lives of 10 or 100 children does not alter the inherent satisfaction from volunteering: in both cases, people volunteer out of the desire to do 'good'. So, in a social market, the amount of benefits is less relevant than that in a money market, and behaviors could be still considered worthwhile even though they yield modest benefits.

We argue that financial feedback, by appealing to drivers' monetary concern, may elicit a money market frame. Conversely, environmental feedback, by appealing to altruistic motives, may elicit a social market frame (cf. Heyman & Ariely, 2004). Financial feedback on eco-driving stresses the monetary gains as a consequence of adopting an eco-driving style while environmental feedback stresses non-pecuniary benefits. Hence, the fact that eco-driving behaviors result in small benefits will be particularly problematic for how worthwhile savings are perceived when communicating financial benefits, but less so when communicating environmental benefits.

Eliciting social market relations by using environmental feedback may thus bypass the drawback about the small savings of eco-driving behaviors because the amount of savings would be less relevant in this case. People may perceive that they are doing the right thing for the environment regardless of whether they are saving 1 gram or 1 kg of CO_2-emissions; in both cases their behavior is a positive contribution to environment. Thus, the amount of saving would be less important when communicating environmental benefits, and even small benefits may be perceived to be worthwhile.

The type of the information conveyed by feedback may also influence people's intentions to engage in a behavior (Rothman et al., 2004; Bolderdijk et al., in press). Based on the social market and money market distinction, it is plausible to expect that environmental feedback may be a stronger motivator and yield stronger intentions to adopt behavior than financial feedback because the former is likely to be considered to be more worth the effort.

1.2. Current study

The aim of the current research was to investigate the worthiness and effectiveness of financial and environmental feedback in promoting various types of eco-driving behaviors. We argued that financial feedback would evoke a money market decision frame, and thereby, reciprocity expectations. When motivated by reciprocity, people will evaluate whether the amount of financial benefits are worth the effort needed to adopt the behavior. We expected that environmental feedback would evoke a social market decision frame, and thereby, altruistic motives. In this case, people will think it is worthwhile to adopt eco-driving practices irrespective of the amount of environmental savings to be gained.

Based on this, we first examined whether different types of feedback, focusing on either environmental or financial outcomes (experimental conditions), had a differential effect on how worthwhile eco-driving behaviors were perceived. We hypothesized that drivers would perceive eco-driving behaviors to be more worth the effort when feedback was provided on possible environmental gains rather than financial gains (hypothesis 1). Second, we examined whether presence and type of feedback was effective in influencing intentions to adopt eco-driving behaviors. We hypothesized that intention to adopt eco-driving behaviors would be higher when feedback was provided (experimental conditions) compared to when no feedback was provided (control condition) (hypothesis 2). Furthermore, we expected environmental feedback to evoke stronger intentions to adopt eco-driving behaviors than the financial feedback (hypothesis 3).

2. Method

2.1. Participants, procedure, and design

The study was carried out as part of an online questionnaire study. All participants owned a driver's license and were recruited by an online survey company who approached a representative sample of the Dutch population from their panel. Participants evaluated different eco-driving scenarios (described below), and completed demography questions. Three hundred-five respondents (155 females) participated in the study; one participant did not report his or her gender. The mean age of participants was 43.9 years (SD= 13.63), and the average time since licensure was 23.2 years (SD= 13.63). Respondents drove on average 17,504 kilometers in the year preceding the study (SD= 14,331); 21 participants did not report the mileage driven the year before the study. The average mileage is a bit higher than the Dutch average, which was 13,317 kilometers for 2010 (Statistics Netherlands, 2011).

We presented different eco-driving scenarios to respondents. In each scenario, we described a specific eco-driving behavior. We selected six behaviors that typify an eco-driving style: avoiding idling while waiting for a level crossing, driving below the speed limit on a highway, avoiding overtaking, the use of air-conditioner, the use of a roof-rack, and checking the tire pressure regularly (see Eco-driving Netherlands, 2011). A full description of the scenarios is provided in Appendix A.

The study consisted of two experimental groups, namely an environmental feedback and a financial feedback group, as well as a control group. Respondents were randomly assigned to one of the three conditions, and all participants evaluated the six eco-driving scenarios. Depending on experimental group, participants either read how much money or how much CO_2-emissions could be saved when the indicated fuel-efficient behavior was adopted. Savings were calculated based on the information provided on the websites concerning eco-driving (e.g., The Daily Green, 2011).

Financial savings were calculated based on the price of a liter of oil in the Netherlands at the time the study was conducted. Environmental savings were calculated based on the amount of CO_2-emissions produced for a liter of oil (i.e., 2.3 kg/ liter) (U.S. Environmental Protection Agency, 2005). So, the amount of savings was essentially the same in both conditions and linearly related to fuel consumption. Participants in the control condition did not receive any information on the amount of fuel savings that resulted from the relevant eco-driving behaviors.

2.2. Dependent variables: worth of savings and intention to adopt eco-driving behaviors

For each scenario, participants in the two experimental groups first indicated whether they considered the amount of saving achieved by performing the fuel-efficient behavior to be worth the effort (e.g., The amount of CO_2-emissions (Euros) saved by turning the engine off while waiting is…) on a 6-point scale (1= not at all worth the effort, 6= totally worth the effort). Higher scores indicated higher perceived worthiness of saving. Note that participants in the control condition did not answer the worthiness item, as they did not receive any information on the savings that could be realized by adopting the eco-behaviors.

Second, participants in all three conditions indicated their intention to adopt each of the six eco-driving behaviors (e.g., I would turn the engine off while waiting) on a 6-point scale (1= totally disagree, 6= totally agree). Higher scores indicated a higher intention to adopt the relevant eco-driving behavior.

3. Results

3.1. Effect of Feedback Type on the Worth of savings

In order to test our first hypothesis about the effect of feedback type on how worthwhile the savings were perceived, we conducted a MANOVA with feedback type as a fixed factor and the worthiness of the saving for each scenario as the dependent variable (see left side of Table 1). A clear overall pattern emerged: savings were perceived to be more worth the effort when feedback was provided in terms of environmental (CO_2-emissions) rather than financial units (euros), Hotelling's F (6, 181) = 12.48, $p < .001$, partial $\eta^2 = .29$. Specific analyses revealed that participants rated CO_2-emissions to be more worth the effort than equivalent financial benefits for all the individual eco-driving behaviors, including avoiding idling (F (1, 186) = 13.04, $p < .001$, partial $\eta^2 = .07$), keeping the air-conditioner off (F (1, 186) = 42.44, $p < .001$, partial $\eta^2 = .19$), reducing speed on a highway (F (1, 186) = 9.80, p = 002, partial $\eta^2 = .05$), removing the roof rack (F (1,186) = 39.01, $p < .001$, partial $\eta^2 = .17$), checking the tire pressure regularly (F (1, 186) = 60.76, $p < .001$, partial $\eta^2 = .25$), and avoiding overtaking (F (1, 186) = 25.32, $p < .001$, partial $\eta^2 = .12$).

Table 1. Means and Standard Deviations (in brackets) for Worthiness of Savings and Intention to Adopt Eco-driving Behaviors in the Environmental Feedback, Financial Feedback, and Control Condition

	Worthiness		Intention		
	Environmental feedback	Financial feedback	Environmental feedback	Financial feedback	No feedback
Idling	4.12_a (1.39)	3.38_b (1.35)	4.35_a (1.66)	4.13_a (1.53)	3.37_b (1.82)
Overtaking	3.98_a (1.37)	3.02_b (1.37)	2.93_a (1.72)	2.74_a (1.60)	2.12_b (1.55)
Speed reduction	3.81_a (1.45)	3.17_b (1.42)	2.79_a (1.62)	2.45_a (1.50)	2.04_b (1.49)
Air-co	3.65_a (1.35)	2.43_b (1.26)	2.81_a (1.56)	2.48_a (1.51)	2.61_a (1.76)

Roof rack	4.49_a	3.13_b	4.78_a	4.38_a	4.63_a
	(1.45)	(1.47)	(1.79)	(1.69)	(1.73)
Tire	4.48_a	3.01_b	4.15_a	3.94_a	4.04_a
pressure	(1.26)	(1.29)	(1.71)	(1.36)	(1.50)

Note 1: means with different subscripts for experimental conditions differ at $p < .05$.

3.2. Effects of Feedback Type on Intention to Adopt Eco Driving Behaviors

To test our second and third hypothesis on the effect of presence and type of feedback on the intention to adopt fuel-efficient behavior, we conducted a MANOVA with feedback type as the fixed factor and intention for each scenario as dependent variables (see right side of Table 1). The overall effect of feedback condition (including environmental, financial, and no feedback) on the intention to adopt eco-driving behaviors was significant, Wilk's lambda $F(12, 592) = 3.11$, $p < .001$, partial $\eta^2 = .06$. Specific analyses revealed a significant main effect of feedback type on the intention to adopt three of the six eco-driving behaviors, i.e., intention to avoid idling ($F(2,301) = 9.84$, $p < .001$, partial $\eta^2 = .06$), intention to avoid overtaking ($F(2, 301) = 7.19$, $p = .001$, partial $\eta^2 = .05$), and intention to reduce speed on a highway ($F(2, 301) = 6.05$, $p = .003$, partial $\eta^2 = .04$; see Figure 2). In order to clarify the differences between both experimental groups and the control group, we tested the planned contrasts: 1) comparing the experimental groups to the control group (hypothesis 2) and 2) comparing the environmental and financial groups to each other (hypothesis 3). Contrasts analyses revealed that environmental and financial feedback resulted in higher intention to avoid idling, $F(1, 302) = 18.94$, $p < .001$, avoid overtaking, $F(1, 302) = 13.79$, $p < .001$, and to reduce speed than no feedback, $F(1, 302) = 9.70$, $p < .001$ $p = .002$, than no feedback (control condition). However, we did not find significant differences between the environmental and financial feedback conditions for any of the three behaviors, F (1, 189) = .84, p = .361, F (1, 189) = .58, p= .446, and F (1, 189) =2.28, p=.133, respectively for avoiding idling, avoiding overtaking, and reducing speed. Hence for these behaviors the presence of feedback prompted higher intentions to adopt eco-driving behaviors than no feedback. However, environmental feedback did not appear to result in significantly stronger intentions than financial feedback for any of these behaviors.

Effects of feedback on intentions to adopt the other three eco-driving behaviors, i.e., the intention to keep the air-conditioner off (F (2, 301) = 1.01, p = .364), the intention to remove the roof rack (F (2, 301) = 1.12, p =. 329), and the intention to check tire pressure regularly (F (2, 301) = 0.42, p = .655) were not statistically significant.

Figure 1 shows the scores of the environmental and financial feedback groups relative to the control group. For this purpose, we used the control group as the reference group and subtracted the mean scores of the control group from the scores of environmental feedback group and financial feedback group. The results presented in Figure 1 reveal an interesting trend: for three of the eco-driving behaviors, we found that financial feedback resulted in higher intentions than no feedback at all (see left side of Figure 1), while for the remaining three behaviors, financial feedback resulted in *lower* intentions than no feedback (see right side of Figure 1). However, the contrasts were not statistically significant[2].

[2] We could not establish whether feedback type influenced intention via worthiness as our data do not support an important precondition to establish mediation: the relationship between feedback type (environmental versus financial) and intention was not significant for all behaviors.

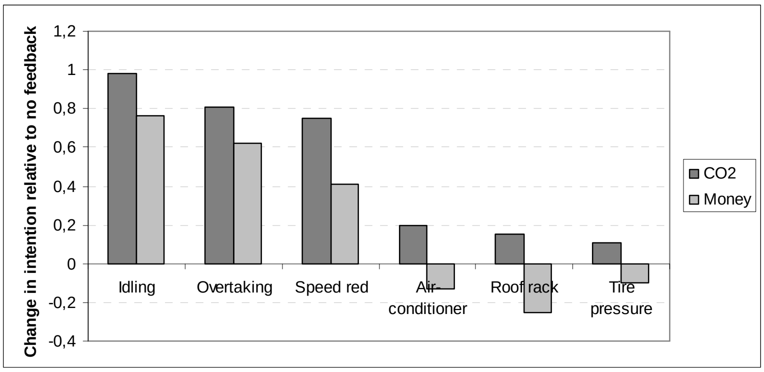

Figure 1. Differences Between Mean Scores of Environmental and Financial Feedback Groups Compared to Control Group on Intention to Adopt Specific Eco-driving Behaviors for Each Scenario

4. Discussion

How can drivers be motivated to adopt eco-driving behaviors, given that energy savings from eco-driving are typically quite modest? In the current study we investigated whether feedback content had a differential effect on how worthwhile drivers perceived eco-driving behaviors to be, and on whether feedback content would affect drivers' intentions to adopt these behaviors. We argued that environmental feedback on eco-driving would elicit a social market decision frame, and decisions would therefore be guided by altruism and thus be less sensitive to the amount of savings to be gained. Financial feedback, on the other hand, would elicit a money market decision frame. Therefore, decisions would be guided by reciprocity and should be sensitive to the amount of savings to be gained.

In support of this reasoning, our results suggest that eco-driving actions were indeed perceived to be more worth the effort when environmental (CO_2-emissions), rather than equivalent financial (fuel costs) consequences were presented (hypothesis 1). This implies that the type of motive elicited by the feedback affects the extent to which people think the behavior is worth investing effort.

However, we did not find that environmental feedback resulted in stronger intentions to adopt eco-driving than financial feedback. If anything, our results indicate that any feedback - at least when promoting behaviors such as avoiding idling, avoiding overtaking, and reducing speed, is more effective than no feedback at all. This finding implies that people's intentions may not be strongly based on whether they perceive a behavior to be worthwhile or not.

We did however observe an interesting trend hinting that in specific cases, financial feedback could prove less effective than no feedback at all. Inspecting Figure 1, one could speculate that financial feedback seems somewhat more effective than no feedback when promoting relatively "effortless" behaviors such as avoiding idling, avoiding overtaking, and reducing speed. Conversely, when promoting more "effortful" behaviors such as tire pressure checks, removing the roof rack, and avoiding the use of air-conditioner, it seems that financial feedback resulted in somewhat *weaker* intentions than no feedback at all. This suggests that the effects of financial feedback depend on the amount of effort required to adopt the relevant eco-driving behaviors (cf. Diekmann & Preisendörfer, 2003). Social-psychological research suggests that any reason, no matter how valid, could be sufficient to prompt compliance to low-effort requests. People are however more wary of a high-effort request, and will only comply when a valid reason is provided (Langer, Blank, & Chanowitz, 1978). Similarly, we suspect that financial savings may, despite that they were considered less worth the effort than environmental savings, still have constituted a valid reason for drivers to adopt low-effort eco-driving behaviors. For the effortful behaviors, on the other hand, financial information is likely to be processed more attentively and may have backfired because small amount of money did not justify the effort of adopting the behavior. Although appealing, we note that our reasoning is speculative and that the abovementioned trend was not significant. Future research should test whether the effect of different types of feedback on intentions to adopt high and low effort behaviors could indeed be verified.

Our findings have important practical implications. We showed that the type of feedback affects the extent to which adoption of eco-driving practices are considered to be worthwhile. Our results indicate that environmental benefits of eco-driving are considered to be more worthwhile than the monetary benefits. This finding challenges the current consensus among policy makers and marketers that possible monetary gains mean more to people than possible environmental gains. These results provide important guidelines to promote eco-driving. Monetary savings of low-gain eco-driving behaviors may eventually be devalued because the amount of savings does not outweigh the effort required to engage in behaviors. Thus, an effective strategy to promote low-gain eco-driving behaviors could be to provide environmental feedback in order to promote the feeling of engaging in a worthwhile action among drivers.

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CHAPTER 5: Summary and general discussion

As the adverse effects of traffic and transport on safety and environmental problems increase, the search for strategies to counteract these effects gains more importance. Changes in driver behavior are needed for effective solutions of these problems, particularly because human behaviors account for a large portion of safety and sustainability problems in traffic. These problems occur partly because drivers may not always be fully aware of the negative consequences of their behaviors. Thus, providing feedback on the consequences of one's behaviors could be an effective strategy to promote self-regulation of safe and sustainable driver behavior (Kuiken & Twisk, 2001; Hatakka et al., 2002). However, as yet, little is known about how feedback should be best conveyed to optimize its effects, and which factors influence the effectiveness of feedback in promoting behavior change.

In the current thesis, I argued that the mere presence of feedback does not always improve driver behavior, and that the effectiveness of feedback depends on a number of cognitive and motivational factors related to the individual, driving context, and the content of feedback. First, feedback that provides no clues about causes of (poor) performance, nor about how performance can be improved (i.e., non-evaluative feedback) may not be effective. Instead, such feedback might induce negative affect and defensive reactions among drivers, particularly when the feedback reveals that one's performance is poorer than anticipated (Chapter 2). Second, drivers may not act upon feedback when other goals than the goal conveyed by feedback are (or need to be) prioritized, or when the traffic situation is too demanding (Chapter 3). Third, different consequences emphasized in feedback may motivate behavior differently (Chapter 4). In three empirical chapters, I examined whether and to what extent these factors influence the effectiveness of feedback on driver behavior. I will first give a summary of the results of each chapter and discuss the theoretical implications of these results. Then, I will elaborate on the practical implications of the studies presented in this thesis.

Non-evaluative feedback may not be an effective strategy to facilitate self-regulatory reactions

‘Evaluative’ feedback can help people form a more accurate view of the outcomes of their behaviors and reveals how they can adjust their behaviors and/or self-evaluations as to realize desirable outcomes. However, ‘non-evaluative’ feedback merely signals whether performance was poor or good, but does not provide reasons for poor or good performance, nor information on how to improve performance. So, such feedback does not clearly reveal which behaviors caused the effects communicated. Consequently, I reasoned that drivers will not change their performance in response to such feedback as they received no cues on how performance can be improved. Besides possibly being ineffective in changing driver behavior, I reasoned that non-evaluative feedback would neither affect drivers’ self-evaluations. Since many drivers have positively biased self-views of skills and abilities (see Sundström, 2008 for a review), non-evaluative feedback may turn out to be *negative* feedback that signals that performance is poorer than the driver expected. Because of this, I argued that non-evaluative feedback will not be effective in promoting self-regulation processes. Instead, I expected that such non-evaluative feedback would generate negative affect and be processed defensively.

I investigated the extent to which drivers self-regulate their performance and/or self-evaluations, using a hazard perception test that aims to assess drivers’ skills to anticipate and react to dangers on the road. Different but equivalent versions of the test were repeated in three successive trials. In addition, I examined whether drivers experienced any discrepancies between their estimated and actual performance. In line with my expectations, I found that participants’ pre-test self-evaluations were rather high, while their actual performance was lower than they expected. This implies that feedback turned out negative for all participants (relative to their self-evaluations), informing them that they performed worse than they anticipated. As expected, participants experienced negative feelings such as dissatisfaction and frustration in response to negative feedback, indicating that they were aware of the discrepancy between their estimated and actual performance. Also, as expected, participants’ actual performance did not improve across trials. Importantly, the initial self-evaluations of performance, which were already positively biased, also remained unchanged across the three trials. So, participants did not adjust their self-evaluations in accordance with the negative feedback, for instance by lowering their performance estimations. In sum, drivers did not act upon the non-evaluative feedback. The results suggest that participants coped with the discrepancy between their expected and actual performance by employing a defensive strategy: they made external attributions for the disappointing test results, in this case by devaluing the validity of the test.

The current findings indicate that, as expected, participants did not change their performance when not provided with cues on how to improve their performance. Also importantly, participants did not change their self-evaluations of performance either, suggesting that they were motivated to protect a positive self-view (e.g., Kunda, 1990; Hepper et al., 2010). So, although holding accurate view of one’s self would be functional for one’s self-regulatory reactions to avoid failure and attain success, participants did not employ this strategy. Instead, negative feedback about one's self triggered negative feelings such as frustration and dissatisfaction, which were not reduced by changing behavior or self-evaluations. Rather, people seemed to employ defensive strategies. More specifically, they questioned the credibility of the test, which enabled them to maintain a positive self-view without adjusting the positively biased evaluation of the self.

The motivation to feel positive about one's self may have reduced the impact of feedback on self-evaluations. Self-enhancement biases are believed to be caused by, among other things, not receiving systematic and sufficient feedback on skills and abilities (e.g., Brown, 1989; Kruger & Dunning, 1999). The current results however suggest that self-enhancement biases also make people impervious to non-evaluative negative feedback, which in turn leads to not acting upon feedback, thereby preserving the biased self-view. As a result, people may not use negative feedback to correct for their self-enhancement bias, as such feedback threatens their positive self-view.

It is worth noting that I did not expect in advance feedback to turn out negative for *all* participants. However, this is exactly what happened: feedback turned out negative relative to self-evaluations for all participants because of the robust, positively biased self-evaluations in all three trials. As a result, the current data does not allow me to draw firm conclusions as to whether drivers did not act upon the feedback because it was negative or because it was not informative enough. Is it the valance (positive-negative), or the evaluative aspect of the feedback that is more determining for drivers' reactions, or is it the combination of the two? Future research is needed to disentangle the effect of the two aspects on the effectiveness of feedback.

Goal prioritization and cognitive load may compel drivers to ignore feedback

Feedback has proven to be effective in changing driving behavior in experimental settings (e.g., Birrell & Young, 2011). However, in real life, drivers constantly face a multitude of distracters and they may experience mental overload, and they may have to balance multiple goals simultaneously. The aim of the second study was to examine how drivers handled feedback when they had to manage other goals than the one that is supported by the feedback. I argued that the presence of multiple goals and demanding traffic situations would inhibit the effectiveness of feedback.

In this study I used an eco-driving task in a driving simulator. I asked drivers to satisfy multiple goals, including an energy saving goal, as well as other goals that are not directly related to eco-driving, namely, safety and time saving. Time saving was varied between the experimental groups (i.e., a time-pressure group and a no time-pressure group). Through an in-car display, all drivers received continuous feedback on fuel consumption that aimed to facilitate the performance on the fuel saving goal. No feedback on the time saving was provided to the time pressure group, nor was feedback on safety goal provided to either group. The results revealed that feedback on fuel consumption resulted in fuel savings, but particularly when drivers did not have to cope with other goals. Feedback on fuel consumption was most effective when other goals did not require much attention, for instance on a low-demand rural road with a calm traffic flow and when time pressure was low. When participants experienced high mental load, for instance because they had to manage interactions with multiple other road users, they saved less fuel, and seemed to prioritize safety. Results from the time pressure group suggest that adding a time saving goal resulted in behaviors that saved time, but also increased fuel consumption, such as higher speed, thereby resulting in a poorer performance on the fuel saving goal. Thus, even though drivers took regulatory actions in line with a particular goal (i.e., fuel saving) and in line with the feedback towards the pursuit of this goal (i.e., feedback on fuel consumption), competing goals and increased task demands compelled drivers to prioritize among goals and perform less well on the goal on which feedback was provided.

These results suggest that feedback may not be effective when drivers (need to) prioritize other goals than the goal for which feedback is provided. The effects of feedback can be inhibited when it is not related to the primary goal of the driver at a given moment or in cases of mental overload where drivers cannot pay full attention to the feedback. These findings have important implications for the self-regulatory actions. Even if external goals, such as saving fuel, may be important to drivers, these goals may not be prioritized when other goals, such as safety and time saving, are present as well.

Results of the current study indicate that the safety goals and fuel saving goals may be in conflict, particularly under high mental load. This finding challenges the assumption that sustainable driver behavior is also safe behavior: safety and sustainability can be in conflict as well (Young, Birrell, & Stanton, 2011). For instance, some participants (Simulator study, Chapter 3) were so keen to drive smoothly that they postponed hitting the brake pedal until it was too late – they crossed the red light. This should however not be interpreted as sustainable driving putting safety at stake. Despite the possible conflicts between safety and sustainability, in many cases sustainable driving is safe as well as it reflects a driving style in which abrupt reactions are avoided and larger safety margins of anticipation are taken. Future research could examine such possible goal conflicts and drivers' strategies to cope with them. Such research would be beneficial especially for eco-driving training programs. Hence, possible conflicts between safe driving and sustainable driving should not undermine the importance and the benefits of eco-driving.

Environmental feedback may motivate drivers to eco-drive to a greater extent than financial feedback

In the final empirical chapter, I examined whether the content of feedback influenced the effectiveness of feedback. I reasoned that using different terms to convey equivalent information would trigger different goals and motives to behave in a particular way, which would in turn lead to perception and evaluation of equivalent information differently (e.g., Lindenberg & Steg, 2007). More concretely, I tested to what extent environmental (CO_2-emissions) or financial feedback (Euros) on the outcomes of specific eco-driving behaviors (fuel savings can be translated to monetary and environmental consequences) was perceived to be worthwhile, and whether this evaluation in turn affected the intentions to adopt the relevant behaviors. Based on a previous study by Heyman and Ariely (2004), I hypothesized that in case of environmental feedback, altruistic motives would be activated and the main concern would be making a positive contribution to environment. This implies that even small savings of CO_2-emissions could be perceived to be worth the effort.

Financial feedback, by inducing financial motives, would only motivate drivers to adopt a behavior if the savings were perceived to outweigh the effort. Since eco-driving behaviors often result in small monetary savings, I expected that participants would not consider the financial savings resulting from specific eco-driving behaviors to be worth the effort.

In this study, I used scenarios describing specific eco-driving behaviors and presented the outcomes of the relevant behaviors either in terms of financial savings or environmental savings. In line with my expectation, results of the study demonstrated that drivers considered the very same eco-driving behaviors more worthwhile when environmental savings rather than financial savings associated with these behaviors were presented. This implies that consequences for the environment’s sake were considered more worthwhile than those for one’s own finances. Drivers’ intentions to adopt these behaviors however did mainly depend on the presence of feedback rather than the type of feedback, with both environmental and financial feedback eliciting higher intentions to adopt eco-driving behaviors than no feedback. However, this was true only for behaviors that required rather low effort. For behaviors that required relatively high effort, on the other hand, the presence or absence of feedback did not significantly affect intentions.

Previous research showed that the satisfaction of acting pro-environmentally (Pelletier, Tuson, Green-Demers, Noels, & Beaton, 1998) and the positive feelings that follow from it (Carter, 2011; Bolderdijk et al., in press) may promote pro-environmental behavior. It is possible that drivers consider the environmental consequences of eco-driving behaviors more worth the effort because acting for the environment gives people the opportunity to feel good about themselves which allows them to maintain a positive self-concept (Bolderdijk et al., in press). Thus, people may not always be motivated by money; conversely, having a positive self-concept can be a stronger motive, and acting pro-environmentally is probably a better way to maintain a positive self-concept than saving money.

The current findings clearly indicate that environmental savings were perceived more worthwhile than financial savings. Nonetheless, differences in the perceived value of outcomes were not reflected in intentions to adopt eco-driving behaviors. This might be related to the fact that people did not think through the feedback thoroughly. Langer and colleagues (Langer, Blank, & Chanowitz, 1978) suggest that people are likely to comply with easy, effortless requests as long as some reason is provided. Thus, it is very likely that when reflecting on their intentions to adopt eco-driving behaviors, drivers did not pay much attention to what type of feedback was communicated, but rather focused on the presence of arguments in favor (i.e., feedback).

Despite that group differences were not significant, I did discover some interesting patterns. For instance, I consistently found that environmental feedback on eco-driving behaviors yielded the highest intentions across all eco-driving scenarios. Interestingly, it seems that financial feedback results in somewhat *weaker* intentions to adopt more effortful eco-driving behaviors (e.g., removing roof rack) than providing no feedback at all. This suggests that financial feedback (contrary to environmental feedback) may even demotivate people to adopt low-gain behaviors (see also Gneezy & Rustichini, 2000; Heyman & Ariely, 2004; Bolderdijk et al., in press).

Practical implications

Overall, the results of the empirical chapters suggest that the motivation to maintain a positive self-concept influences how people act upon feedback. This may account for why people react defensively to negative feedback (Chapter 2), and also for why small environmental rewards that presumably make people feel good are perceived worthwhile (Chapter 4). In both cases, people act in a way that seems to bolster a positive self-concept. The findings reported in the current thesis have important practical implications for how to increase the effectiveness of feedback in promoting drivers' self-regulatory behavior. The results mainly point out that policy makers should keep in mind that besides driving safe and sustainable, drivers are motivated also to maintain positive self-concept, which may determine when and whether feedback will be effective in an important way.

Chapter 2 suggests that negative non-evaluative feedback induces negative feelings and defensive reactions such as disqualifying the feedback to overcome that negativity instead of adjustment of behavior or self-evaluations. Thus, for people to trust and act upon feedback, feedback should be framed in a way that is not seriously threatening one's self and provide clear suggestions on how to improve performance so that it does not elicit defensive reactions. This knowledge may be relevant for many feedback systems that are currently in place. For instance, some online driver training tools, such as hazard perception tests and skill assessment tests (e.g., Theory-Test), rate trainees' responses in comparison to a mean value, or success rate in a driver's licensing exam, or just present a success rate without comparison information. Especially for complex skills like hazard perception, such an approach may elicit further questions among the trainees: did I score poorly because I completely missed a hazard, or because I was late to respond? What exactly was the danger involved? How should I behave in such a situation? Knowing the causes of their poor performance would allow drivers to infer how to take regulatory actions (e.g., “I was late to react to a pedestrian crossing the road. So, I should scan the road ahead better.”). Thus, specific information explaining the current performance and strategies to improve (poor) performance needs to be integrated in the feedback systems for assuring optimum effects and credibility.

Chapter 2 has implications for the use of skill tests, e-learning options, and simulators, which can be useful for the training of skills, provided that information on performance and how to improve it is made available (Vlakveld, 2005 as cited in OECD-ECMT, 2006; Carsten & Jamson, 2011). The results of this thesis suggest that we need to be cautious about how drivers perceive their experience with such training tools: negative feedback in combination with insufficient information on how to change one’s performance may be threatening one’s self-view of skills and abilities and thus lead to defensive reactions such as declaring the tool that produced to feedback invalid (Pronin, Lin, & Ross, 2002). Thus, these concerns should be considered when developing and using training tools.

Results presented in Chapter 3 indicated that drivers drive more energy efficiently when they have the goal to do so and receive feedback on fuel consumption informing them about their performance on their fuel saving goal. However, feedback was particularly effective when no competing goals were prominent, suggesting that saving energy is not always prioritized in the goal hierarchy of the driving task. Among the three goals used in Chapter 3 (fuel saving, time saving, and safety), drivers relinquished the fuel saving goal when mental workload increased, either due to time pressure, or due to interactions with other road users. This suggests that feedback should ideally facilitate multiple goals. Force feedback on the accelerator and brake pedals may for instance serve both sustainability and safety goals. Moreover, feedback needs to be communicated in an easy-to-understand way to facilitate handling multiple goals. An advice for policy makers could be to take into account the requirements of sustainable driving style, such as maintaining a steady speed or anticipation of road conditions, in road design. For instance, the design of roundabouts can facilitate drivers' anticipation of traffic situations and thus decrease situational demands on drivers so that they can take safe and sustainable regulatory actions in a timely fashion. Another possibility would be to reduce speed limits, especially in residential areas, to enable a more steady speed to allow drivers to simultaneously satisfy the safety and fuel efficiency goal (Stemerding & van Beek, 2009). This may also result in a secondary benefit: the number of speed bumps, which increase fuel consumption because they require drivers to slow down and speed up for each bump (Ahn & Rakha, 2009), could be reduced because the average speed would be lower.

Findings of Chapter 4 provide insight into what type of information to emphasize in promotion of eco-driving, although the difference between environmental feedback and financial feedback was significant for perceived worthiness only, and not for behavioral intentions. Marketers of eco-driving campaigns seem to assume that drivers care most about the financial outcomes of saving energy and emphasize mostly the monetary benefits of doing so. The current thesis however indicates that this assumption may not be correct. The low financial benefits of eco-driving behaviors may result in not considering them to be very worthwhile. Emphasizing environmental outcomes could be more effective because it triggers altruistic concerns in which even small contributions to the environment and society are considered to be valuable and make one feel good for acting pro-environmentally (Heyman & Ariely, 2004; Bolderdijk et al., in press). As a result, eco-driving campaigns could benefit more from emphasizing the advantages of eco-driving for the environment rather than solely for one's own finances.

It is important to note that two of the experimental studies presented in the current thesis (Chapters 2 & 3) have been carried out among young drivers, who probably not have extensive driving experience. Increased age and experience have been shown to exert a positive impact on safe driver behavior (Maycock, 2002; OECD-ECMT, 2006), presumably because drivers accumulate mental representations about various traffic situations and their anticipation of road hazards improve (Vlakveld, 2011). Hence, drivers' safety behavior is likely to improve with experience, although experienced drivers are also prone to self-enhancement biases in their skill assessments, even in the presence of feedback (Groeger & Grande, 1996). Whether the results presented in the current thesis, specifically Chapters 2 and 3, could be different if tested among a more experienced driver sample constitutes a direction for future research.

Concluding remarks

The findings reported in this thesis indicate that the presence of extrinsic feedback, as such, is not always sufficient to motivate and facilitate behavior change. The effectiveness of feedback rather depends on drivers' motivations and cognitions. First, when aiming to change behavior through feedback, it is crucial to take into account that feedback should provide clear guidelines of how (poor) performance can be improved, especially when targeting behaviors for which robust self-enhancement biases are prevalent. Second, feedback directed at a specific goal can be effective in facilitating self-regulatory behavior, but particularly so when no other goals are (or need to be) prioritized and when the traffic situations are not too demanding. Hence, the design of road infrastructure could take into account the requirements of safe and sustainable driving in order to facilitate drivers' safe and sustainable regulatory actions. Third, drivers considered environmental outcomes of sustainable driving behavior more worthwhile than equivalent financial outcomes; thus, feedback that appeals to drivers' pro-environmental, rather than financial motives could be even more effective in promoting sustainable driver behavior, especially when the relevant behaviors are associated with relatively small gains.

It is important to be aware of the conditions that enhance and limit the effects of feedback when estimating its potential for promoting safe and sustainable driving, because various individual factors and factors originating from the traffic environment may influence the effectiveness of feedback in an unintended way. Hence, when using feedback to improve driver behavior, policy makers should take into account drivers' motives and cognitive limits. These motives and cognitive limits ultimately drive the effectiveness of feedback.

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Appendices

Appendix 1: Text of the scenarios used in Chapter 4

Avoiding idling

As you approach a level crossing in your car, you hear the bell signaling that a train is approaching. The level crossing will be closed for a minute. If you turn off the engine of your car while you are waiting, you would save **0.018 kg CO_2-emissions / € 0.05**.

Speed reduction

You are driving on a motorway with a 120 km/h speed limit. You still have 100 kilometers to reach your destination. If you drive 100 km/h instead of 120 km/h, you would save **2.40 kg CO_2-emissions/ € 1.70** for this trip.

Overtaking

You are driving on a motorway with a 120 km/h speed limit. You still have to travel 80 kilometers to reach your destination. The cars in front of you drive between 100 km/h and 110 km/h. There are opportunities to safely overtake. If you do not overtake the cars in front of you, you would save **1.92 kg CO_2-emissions/ € 1.35** for this trip.

Air-co

You are travelling by your car on a warm day. You still have 40 kilometers to go. You consider turning on the air conditioner. If you keep the air conditioner off, you would save **0.56 kg of CO_2-emissions / € 0.44** for this trip.

Roof rack

You have a roof rack installed on your car. You will need the roof rack again in a month. You consider keeping the roof rack on your car during this month. If you remove the roof rack now and re-install it when you need it, you would save **1.96 kg CO_2-emissions / € 1.20** during this month.

Tire pressure

You have not checked your tires for some time, and notice your tires are underinflated. If you check the tire pressure of your vehicle regularly on monthly basis from now on, you would save **1.47 kg of CO_2-emissions / € 0.90** over a month.

Nederlandse samenvatting

Veel milieuproblemen (bijvoorbeeld klimaatverandering als gevolg van CO_2-uitstoot door motorvoertuigen) en veiligheidsproblemen (bijvoorbeeld door verkeersongelukken) worden mede veroorzaakt door het rijgedrag van automobilisten (Sabey & Taylor, 1980; Streff, 1991; EC, 2010). Het is daarom van groot belang om te begrijpen hoe veilig en duurzaam rijgedrag kan worden bevorderd. Autogebruikers rijden niet altijd veilig en duurzaam, mede omdat ze zich niet altijd bewust zijn van de negatieve gevolgen van hun rijgedrag. Een belangrijke vraag is dus hoe we autogebruikers bewust kunnen maken van de gevolgen van hun rijgedrag.

Uit onderzoek blijkt dat het geven van feedback over de gevolgen van specifiek rijgedrag een effectieve strategie kan zijn om autogebruikers bewust te maken van de consequenties van hun rijgedrag (bijv. Hatakka, Keskinen, Gregersen, Glad, & Hernetkoski, 2002). Feedback biedt autogebruikers de mogelijkheid om hun gedrag te vergelijken met de doelen die ze hebben of met hun inschattingen van de eigen vaardigheden. Feedback maakt daarbij duidelijk of er een discrepantie is tussen hoe mensen denken dat ze rijden en hoe ze werkelijk rijden (Carver & Scheier, 1998). Hierdoor motiveert feedback autogebruikers tot zelf-regulatie, door bijvoorbeeld het gedrag aan te passen, bepaalde doelen te prioriteren, of de inschattingen van de eigen vaardigheden aan te passen.

Eerder onderzoek laat zien dat feedback in veiliger rijgedrag kan resulteren doordat autogebruikers zich na het krijgen van feedback meer aan verkeersregels houden (bijv. Carsten & Tate, 2005). Feedback kan er ook toe bijdragen dat automobilisten een energiezuinige rijstijl aannemen (Birrell & Young, 2011). Verschillende onderzoeken hebben aangetoond dat feedback een bruikbaar middel is om gedragsverandering te stimuleren. Het is echter nog niet duidelijk hoe de effecten van feedback geoptimaliseerd kunnen worden. In dit proefschrift heb ik onderzocht welke omstandigheden de effectiviteit van feedback op rijgedrag beïnvloeden. Mijn centrale hypothese is dat de effectiviteit van feedback als middel voor gedragsverandering sterk afhankelijk is van motivationele en cognitieve factoren.

Is niet-evaluatieve feedback een effectief middel om zelfregulerende reacties te bevorderen?

Feedback is vooral effectief wanneer het inzicht geeft in de achterliggende oorzaken van (onveilig of milieuonvriendelijk) rijgedrag en daarnaast iets zegt over de manier waarop dit rijgedrag kan worden verbeterd (bijv. Brown, 1989; Kruger & Dunning, 1999). In sommige gevallen geeft feedback echter alleen inzicht in de vraag of rijgedrag goed of slecht is, zonder dat er informatie wordt gegeven over hoe de rijprestaties kunnen worden verbeterd. Wat is het effect van dit soort niet-evaluatieve feedback? Aangezien niet-evaluatieve feedback geen inzicht geeft over hoe prestaties verbeterd kunnen worden, veronderstelde ik dat het de rijprestatie niet zou verbeteren. Ik verwachtte dat dit type feedback ook niet zou leiden tot een verandering van zelf-evaluaties, omdat automobilisten over het algemeen hun eigen prestaties overschatten (Sundström, 2008). Daardoor zal niet-evaluatieve feedback vaak betekenen dat men negatieve feedback krijgt: de feedback geeft weer dat men slechter presteert dan men had verwacht. Omdat mensen streven naar een positief zelfbeeld, zal men dit soort negatieve feedback, dat een bedreiging vormt voor het zelfbeeld, naast zich neerleggen. Op basis van deze redenatie veronderstelde ik in Hoofdstuk 2 dat niet-evaluatieve feedback niet tot aanpassing van gedrag en zelf-evaluaties zou leiden. In plaats daarvan verwachtte ik dat niet-evaluatieve feedback een negatief gevoel zou veroorzaken en een defensieve houding zou oproepen.

Ik heb mijn hypothesen getest aan de hand van een risicoperceptietest, die meet hoe goed men anticipeert op verkeersrisico's. Deelnemers vulden achtereenvolgens drie keer een verschillende versie van de risicoperceptietest in. Voorafgaande aan elke test gaven deelnemers aan hoe goed ze dachten te presteren op de test. Na elke test liet ik de helft van de deelnemers weten hoe goed of slecht ze werkelijk scoorden op de test (niet-evaluatieve feedback), terwijl de andere deelnemers geen feedback kregen (controlegroep). Na de test gaven de alle deelnemers aan hoe ze zich voelden over hun testscore. Uit de resultaten bleek dat alle deelnemers voorafgaande aan de test een te positief beeld hadden van hun prestatie; ze verwachtten allemaal dat ze beter zouden presteren dan ze in werkelijkheid deden. Dit betekent dat iedereen negatieve feedback kreeg. Zelfs nadat deelnemers feedback ontvingen, bleven ze zichzelf nog steeds overschatten in de volgende testronden. Ook hun werkelijke prestatie op de risicoperceptietest veranderde niet in de volgende ronden. Hieruit blijkt dat, in overeenstemming met de verwachting, deelnemers hun gedrag en zelf-evaluaties niet aanpassen in overeenstemming met de feedback. De negatieve niet-evaluatieve feedback veroorzaakte wel negatieve gevoelens zoals frustratie en ontevredenheid. Deelnemers reageerden op deze negatieve gevoelens door een defensieve houding aan te nemen, in dit geval door de betrouwbaarheid van de feedback en de geloofwaardigheid van de test in twijfel te trekken.

Deze resultaten suggereren dat het behouden van een positief zelfbeeld belangrijk is voor deelnemers. In plaats van dat deelnemers hun prestaties verbeterden of hun zelf-evaluaties aanpasten na het krijgen van negatieve feedback, schreven deelnemers hun slechte prestatie toe aan de (in hun ogen) slechte kwaliteit van de test. Hierdoor waren zij in staat een positief (maar in dit geval incorrect) beeld van hun vaardigheden te behouden. Dit suggereert dat de motivatie om je positief te voelen over jezelf de effecten van feedback kan ondermijnen. Eerder onderzoek suggereert dat een vertekend zelfbeeld het gevolg is van onsystematische en onvoldoende feedback op vaardigheden en capaciteiten (bijvoorbeeld Brown, 1989; Kruger & Dunning, 1999). De resultaten van dit onderzoek suggereren echter dat een vertekend zelfbeeld ertoe kan leiden dat de betrouwbaarheid van niet-evaluatieve negatieve feedback in twijfel wordt getrokken, waardoor feedback niet leidt tot veranderingen in gedrag of zelfbeeld, en het onrealistisch positieve zelfbeeld in stand blijft.

Het effect van feedback in situaties waarin meerdere doelen saillant zijn

Automobilisten streven op één moment vaak meerdere doelen na, wat kan leiden tot mentale overbelasting. In Hoofdstuk 3 onderzocht ik in welke mate feedback effectief kan zijn in situaties waarin automobilisten meerdere doelen nastreven, alsmede in mentaal belastende verkeerssituaties. Ik veronderstelde dat de aanwezigheid van meerdere doelen en mentaal belastende verkeerssituaties zou leiden tot het prioriteren van doelen, waardoor er mogelijk geen prioriteit wordt gegeven aan het doel waarop feedback wordt gegeven. Dit kan de effectiviteit van feedback verminderen.

Ik testte deze hypothese in een onderzoek in de rijsimulator, waarin deelnemers werd gevraagd een energiezuinige rijstijl te hanteren. Ik verhoogde de mentale belasting bij deelnemers door het stellen van meerdere doelen (namelijk brandstof besparen, tijd besparen en veilig rijden) en door mentaal belastende verkeerssituaties te creëren (bijvoorbeeld door interacties met andere automobilisten). Alle deelnemers ontvingen feedback over hun brandstofverbruik. De resultaten van het onderzoek lieten zien dat deze feedback over brandstofverbruik vooral effectief was wanneer autogebruikers zich niet hoefden te concentreren op concurrerende doelen terwijl ze aan het rijden waren. Zodra deelnemers te maken hadden met veeleisende interacties met andere automobilisten waren ze vooral gericht op veiligheid en bespaarden ze minder brandstof. Het geven van een extra doel tijdens de rijtaak (in dit geval tijd besparen) resulteerde in rijden met een hoge snelheid en snelle acceleraties, waardoor men tijd bespaarde maar ook het brandstofverbruik toenam. Feedback over brandstofverbruik was dus minder effectief als men ook de aandacht moest richten op andere doelen, die prioriteit kregen boven brandstofbesparingen.

Deze resultaten wijzen erop dat mensen cognitieve beperkingen hebben en moeite hebben met het balanceren van meerdere doelen tegelijkertijd, vooral als zij een hoge mentale belasting ervaren. Dit impliceert dat feedback op een begrijpelijke manier gecommuniceerd dient te worden, en het beste op momenten kan worden aangeboden waarop automobilisten er ontvankelijk voor zijn. Deze bevindingen hebben daarnaast implicaties voor milieuvriendelijk rijden. Vaak wordt aangenomen dat veilig en milieuvriendelijk rijgedrag op dezelfde gedragingen neerkomen. Echter, de huidige bevindingen geven aan dat er ook een conflict kan bestaan tussen veilig en milieuvriendelijk rijgedrag (Young, Birrell, & Stanton, 2011). Het remmen op de motor om brandstof te besparen betekent bijvoorbeeld dat de remlichten niet gaan branden, waardoor achteropkomend verkeer minder gemakkelijk kan anticiperen op het gedrag van de voorligger. Het is belangrijk om inzicht te krijgen in mogelijke conflicten tussen milieuvriendelijk en veilig rijgedrag en om strategieën te ontwikkelen die deze conflicten kunnen verminderen.

Mensen hecht meer waarde aan kleine positieve effecten op het milieu dan aan kleine financiële besparingen

In hoofdstuk 4 heb ik onderzocht in welke mate de effecten van feedback afhangen van de inhoud van feedback. Ik veronderstelde dat, afhankelijk van de inhoud van feedback, verschillende gevolgen van gedrag saillant worden gemaakt, welke vervolgens verschillende motieven activeren om al dan niet te reageren op de feedback (Lindenberg & Steg, 2007).

Veel reclame- en overheidscampagnes gaan er van uit dat mensen vooral bereid zijn om milieuvriendelijk te handelen wanneer de financiële voordelen worden benadrukt, in plaats van positieve effecten op het milieu (Thøgersen & Crompton, 2009). Echter, veel milieuvriendelijke handelingen, zoals een milieuvriendelijke rijstijl, leveren zeer kleine financiële voordelen op, waardoor de financiële baten in kwestie mogelijk niet de moeite waard worden gevonden. Op basis van een onderzoek van Heyman en Ariely (2004) verwachtte ik dat feedback over de milieueffecten van een milieuvriendelijke rijstijl (verminderde CO_2-uitstoot) effectief zou kunnen zijn, omdat dit type feedback altruïstische motieven oproept. In dit geval is het belangrijkste motief om een positieve bijdrage aan het milieu te leveren, en kunnen zelfs kleine besparingen van CO_2-uitstoot de moeite waard worden gevonden. Aan de andere kant verwachtte ik dat feedback over financiële effecten (verminderde brandstofkosten) vooral motiverend zijn als de opbrengsten opwegen tegen de moeite die het gewenste gedrag kost, wat vaak niet het geval is bij een milieuvriendelijke rijstijl. Mijn hypothese was dus dat de voordelen van een milieuvriendelijke rijstijl voor het milieu (verminderde CO_2-uitstoot) meer de moeite waard zou worden gevonden dan financiële voordelen van dit gedrag (verminderde brandstofkosten). Het is zelfs mogelijk dat het benadrukken van positieve milieugevolgen in feedback tot een grotere verandering in intenties leidt dan het benadrukken van de financiële gevolgen.

Ik heb een scenario-onderzoek uitgevoerd om na te gaan of het type feedback invloed heeft op de mate waarin men milieuvriendelijk rijden de moeite waard vindt, en op intenties tot milieuvriendelijk rijden. Deelnemers beoordeelden zes verschillende typen milieuvriendelijk rijgedrag. Deelnemers in de eerste experimentele conditie ontvingen feedback over de financiële besparingen van de verschillende typen milieuvriendelijk rijgedrag. Deelnemers in de tweede experimentele conditie ontvingen feedback over de milieubesparingen (CO_2-uitstoot) van deze gedragingen. De grootte van de besparingen was gelijk in beide experimentele condities, het enige verschil was de gebruikte eenheid van de besparingen. Een aanvullende controlegroep ontving geen feedback. Een vergelijking van de resultaten in de twee experimentele condities leert dat milieubesparingen inderdaad bij alle gedragingen als meer de moeite waard werden gezien dan financiële besparingen. De intentie van autogebruikers om deze gedragingen uit te voeren hing echter voornamelijk af van de aanwezigheid van feedback en niet van het type feedback. Deelnemers die feedback over milieugevolgen of over financiële gevolgen kregen hadden een sterkere intentie om een milieuvriendelijke rijstijl aan te nemen dan deelnemers die dan geen feedback ontvingen. Echter, dit verschil was alleen significant bij gedragingen die weinig moeite kosten (zoals de auto niet stationair laten draaien, niet inhalen, snelheid verminderen). Voor gedrag dat relatief veel moeite kost (bijvoorbeeld bandenspanning controleren, een imperial van het autodak verwijderen en geen gebruik maken van de air-conditioning) had feedback geen significante invloed op intenties.

Recent onderzoek suggereert dat wanneer mensen milieuvriendelijk handelen dit een ‘boost’ kan geven aan een positief zelfbeeld (Bolderdijk et al., 2012). Mogelijk vindt men de milieuvoordelen van het nieuwe rijden meer de moeite waard omdat milieuvriendelijk gedrag je een goed gevoel kan geven over jezelf, en leidt tot een positief zelfbeeld. Omgekeerd kunnen financiële consequenties de indruk wekken dat men alleen milieuvriendelijk gedrag vertoont om egoïstische redenen, wat kan worden gezien als moreel verwerpelijk (Kretzman, 1992). Mensen worden dus niet enkel gedreven door geld. Het hebben van een positief zelfbeeld kan zelfs een sterker motief zijn voor milieuvriendelijk gedrag, en handelen uit milieuoverwegingen is waarschijnlijk een betere manier om een positief zelfbeeld te krijgen dan geld besparen.

Deze resultaten laten zien dat automobilisten het soms meer de moeite waard vinden om het milieu te sparen dan om geld te besparen. Maar waarom leidt feedback over de milieugevolgen van gedrag niet tot sterkere intenties om milieuvriendelijk te rijden? Mogelijk dachten de deelnemers niet goed na over de implicaties van de feedback: wanneer het gevraagde gedrag gemakkelijk is om te doen (bijvoorbeeld de auto stationair laten draaien bij een spoorwegovergang), kan elke (zelfs oppervlakkige) reden genoeg zijn om het gedrag te vertonen (Langer, Blank, & Chanowitz, 1978). Het is daarom mogelijk dat intenties vooral waren gebaseerd op de aanwezigheid van feedback en niet op het type feedback dat werd gegeven.

Praktische implicaties

In dit proefschrift werd de invloed van motivationele en cognitieve factoren op de effecten van feedback onderzocht. De uitkomsten van dit onderzoek hebben belangrijke praktische implicaties voor het stimuleren van veilig en duurzaam (rij)gedrag middels feedback. Beleidsmakers moeten er rekening mee houden dat automobilisten niet alleen gemotiveerd zijn om geld te verdienen, of accurate inschattingen te maken van hun eigen kunnen, maar ook om een positief zelfbeeld te behouden. Daarnaast moet men zich realiseren dat mensen, en dus ook automobilisten, een beperkte cognitieve capaciteit hebben die bepaalt of ze aandacht (kunnen) besteden aan feedback of niet.

De resultaten die in dit proefschrift beschreven worden hebben belangrijke implicaties voor methoden die worden gebruikt om rijvaardigheden te trainen. De resultaten in Hoofdstuk 2 suggereren dat het gebruik van niet-evaluatieve feedback, waarbij geen duidelijke informatie wordt gegeven over de oorzaken van (negatieve) prestaties en manieren om de prestaties te verbeteren, vaak niet effectief is. Dit soort feedback kan leiden tot negatieve reacties, omdat veel autogebruikers een te positief beeld hebben van hun eigen vaardigheden. In plaats van veranderingen in prestaties of zelf-evaluaties kan niet-evaluatieve feedback een onaangenaam gevoel geven en ervoor zorgen dat mensen de feedback in twijfel trekken. Om te zorgen dat feedback positieve effecten heeft is het daarom belangrijk dat zowel duidelijke informatie wordt gegeven over de oorzaken van een goede of slechte prestatie, als tips om deze prestatie te verbeteren als dat nodig is.

De resultaten van Hoofdstuk 3 laten zien dat specifieke feedback over één bepaald doel vooral effectief is als er geen andere doelen actief zijn en geprioriteerd worden, en de situatie waarin de autogebruiker zich bevindt niet te complex is. Dit betekent dat het belangrijk is om feedback zo eenvoudig en duidelijk mogelijk te maken, zodat autogebruikers ook in complexe situaties waarin verschillende doelen actief zijn in staat zijn om de feedback te verwerken. Deze resultaten kunnen ook gebruikt worden bij de aanleg van wegen: in complexe situaties, zoals bij rotondes of kruispunten, is het voor autogebruikers moeilijk om op hun eigen veiligheid te letten en tegelijkertijd feedback over bijvoorbeeld milieuvriendelijk rijden te verwerken. Bij de aanleg van infrastructuur in dit soort complexe situaties zou men kunnen proberen om milieuvriendelijk rijden te faciliteren middels het wegontwerp, zodat autogebruikers hun aandacht niet hoeven te verdelen tussen bijvoorbeeld veilig en milieuvriendelijk rijden.

De resultaten in Hoofdstuk 4 geven inzicht in welke type informatie benadrukt moet worden bij het stimuleren van milieuvriendelijk rijgedrag (‘het nieuwe rijden’). In tegenstelling tot de focus van veel reclamecampagnes is geld niet altijd het belangrijkste motief voor mensen om een duurzame rijstijl aan te nemen, vooral niet als het gaat om gedrag dat weinig financiële winst oplevert. Kleine milieuwinsten worden als waardevoller ervaren dan kleine financiële winsten. Deze informatie kan door beleidsmakers en reclamemakers worden gebruikt om milieuvriendelijk rijgedrag te stimuleren. Door de positieve milieu-effecten van een milieuvriendelijke rijstijl te promoten worden altruïstische motieven geactiveerd. Handelen in overeenstemming met deze boodschap kan een persoon een goed gevoel geven waardoor zelfs kleine besparingen de moeite waard worden. Dus in plaats van het benadrukken van financiële opbrengsten van het nieuwe rijden, kunnen reclamecampagnes zich ook richten op de positieve effecten van het nieuwe rijden op het milieu.

Slotopmerkingen

De resultaten in dit proefschrift wijzen erop dat het aanbieden van feedback niet altijd leidt tot gedragsverandering. De effectiviteit van feedback hangt af van de motivaties en cognities van automobilisten. Het is ten eerste belangrijk dat feedback inzichtelijk maakt hoe (slechte) prestaties kunnen worden verbeterd, vooral wanneer feedback wordt gegeven over gedragingen waarover automobilisten een vertekend positief zelfbeeld hebben. Ten tweede, specifieke feedback kan zelfregulatie bevorderen, maar vooral als er geen sprake is van belangrijkere conflicterende doelen en als de verkeerssituatie niet te veeleisend is. De inrichting van het wegennet moet dus worden afgestemd op de voorwaarden van veilig en duurzaam rijgedrag om zo veilige en duurzame zelfregulatie van autogebruikers te bevorderen. Ten derde bleek dat men de milieueffecten van duurzaam rijgedrag meer de moeite waard vond dan de financiële effecten. Feedback die appelleert aan milieuvriendelijke in plaats van financiële motieven kan dus mogelijk effectiever zijn in het bevorderen van duurzaam rijgedrag, vooral als het gedrag waarover feedback wordt gegeven geassocieerd wordt met relatief kleine opbrengsten.

Als feedback wordt gebruikt ter bevordering van duurzaam en veilig rijgedrag is het belangrijk te letten op de condities die de effecten van feedback verzwakken en versterken. Uit dit onderzoek blijkt dat zowel individuele factoren als factoren in de verkeerssituatie de effecten van feedback kunnen ondermijnen. Bij het gebruik van feedback ter verbetering van het rijgedrag moeten beleidsmakers dus rekening houden met de motieven en cognitieve beperkingen van autogebruikers.

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